

Case Studies of Postponement in the Supply Chain

by

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Abstract

The thesis addresses the growing trend in business to offer a wide variety of products while maintaining customer order fulfillment expectations. This trend is happening at the same time the US is losing manufacturing jobs to overseas labor markets, namely China, India, and Central America. While it may not be possible for the US to compete with these countries on the basis of labor costs or even quality in manufacturing, it can compete in the area of faster delivery times and product-service interaction which must inherently take place onshore. Postponement is a strategy that allows businesses to take advantage of the offshore capacity and labor for manufacturing in addition to local finishing centers for final assembly, packaging, and distribution.

Postponement is widely used in the automotive, apparel, and consumer electronics industries. Many companies produce products that are candidates for postponement but are unlikely to undergo the implementation changes necessary to support it. This thesis highlights some of the leading companies who are pioneers of postponement and includes case studies of additional companies who have followed their lead. They have seen the tangible benefits of lower inventory costs, quicker response time, better forecasts, and more variety as well as the intangible benefits of better customer service and the coordination and integration of manufacturing, sales, and marketing functions.

The assortment and range of case studies suggest that postponement is used across a breadth of industries and not only profitable as a business strategy but also as a means for creating local jobs because of the inherent product-customer interaction.

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Chapter 1

Introduction

America is witnessing a fundamental change in consumer behavior. Following the shift from mass markets to what Jonathan Byrnes [13] refers to as “the age of precision markets,” consumers are demanding a wide variety of products customized to meet their specific needs. To satisfy the increased demand for more variety and highly customized products, companies will have to change their supply chain in an effort to lower costs and maintain the economies of scale of a mass market environment while creating economies of scope through a wide range of product offerings. Popular methods for reducing costs include increasing labor productivity through automation, strategic sourcing of production processes, and implementing design for manufacturing initiatives. These initiatives can cut production and inventory cost while giving a company more flexibility to maintain or improve customer service levels.

This thesis will look at another method for reducing costs, known as postponement, or delayed differentiation, through case study analysis. The case studies provide insight into strategic motivations for postponement as well as the costs and benefits that result. The outcome is an analysis of performance measures and product or process characteristics which can be used to determine a product’s candidacy for postponement. Further analysis comments on the potential of postponement to become not only an optimal strategy in manufacturing but also a source of local job creation.

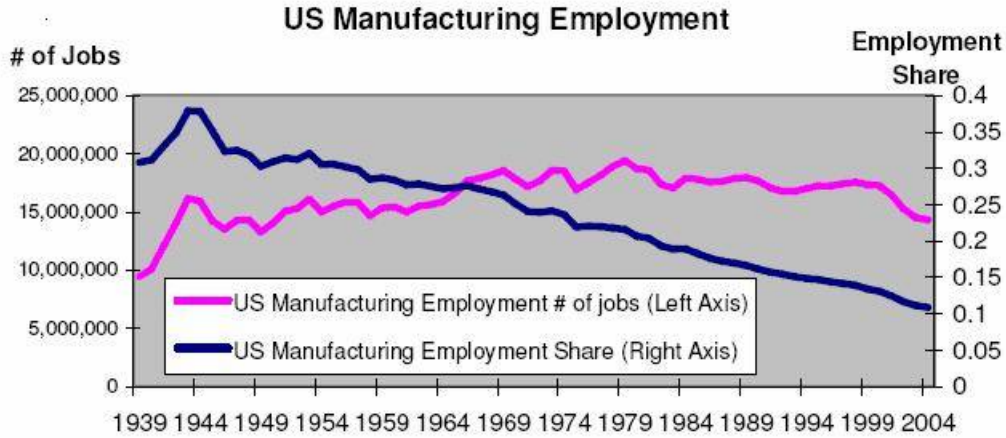


Figure 1-1: US Manufacturing Employment (1939-2004) [32]

1.1 Motivation for Postponement Research

In addition to the push towards more innovative and efficient supply chains, companies are looking everywhere for ways to reduce costs and create competitive advantage in emerging markets. The automation of tasks is a common solution in companies where jobs are rule based, involve pattern recognition, or require problem solving under time constraints [22]. In addition to automation, outsourcing low-skilled jobs overseas is another way to save on labor and capital. The latter, however, is a source of political debate. Manufacturing has been the hardest hit sector of employment in terms of job moving overseas. According to the National Association of Manufacturers, the US lost nearly 3 million manufacturing jobs between July 2000 and November 2003 [2]. This is due to intense global competition, the rising cost of production, a decrease in exports, and a decline in the skilled-labor pool [2]. Figure 1-1 shows the decline in absolute manufacturing jobs and the percentage of manufacturing jobs in total US employment from 1939-2004. According to the National Bureau of Labor and Statistics, these jobs include, but are not limited to, apparel and textile manufacturing; sectors for which the cost of labor is traditionally cheaper through offshoring. [Note: For the purpose of this thesis, the term “offshoring” will mean outsourcing of production processes offshore.]

Wallace and Stahl [47] propose that the US cannot continue to compete in the

areas of labor costs or quality because overseas manufacturing is cheaper and comparable in quality. The US does, however, have a comparative advantage in providing better service levels in the form of faster shipments and more on-time deliveries. According to a 2006 Business Week article, “Speed is emerging as the ultimate competitive weapon...The pace is picking up across such industries as retailing, consumer goods, software, electronics, autos, and medical devices” [16]. Postponement, or delayed customization, is a way to achieve these benefits. Recognizing that offshoring is unavoidable, postponement offers a way to accentuate the positive effects of value creation in emerging markets while reserving part of the value creation for final assembly where local labor is needed to finish and distribute the product.

Different service options can also become points of differentiation around the product and are inherently postponed. The jobs that are required to create value through personal services by nature require a physical presence or interaction with the customer. These jobs include maintenance, repair, diagnostics, and home product delivery. By coupling services with products and postponing the final customization of value-added features and services, postponement may help alleviate the pressure felt by the US in terms of manufacturing jobs moving offshore.

Chapter 2

Defining Postponement

The term postponement refers to delayed decision-making about a product. It is beneficial to delay commitment to product-specific characteristics as late as possible in order to avoid a mismatch between orders and inventory on hand. The length of delay is specific to a product but the common strategic motivation is to gain better information about customer demand by waiting to customize a product for a particular market or customer. At the point of postponement a standardized module or platform starts to acquire customer or market specific characteristics. Figure 2-1 shows the spectrum of opportunities for postponement that extends from procurement to distribution.

Postponement enables forecasters to make better predictions about end product demand over time since the standard module is built-to-forecast and the finished product is built to a better forecast or even built-to-order. Lee and Whang [20] observe that the shorter the time horizon over which predictions are made, the more

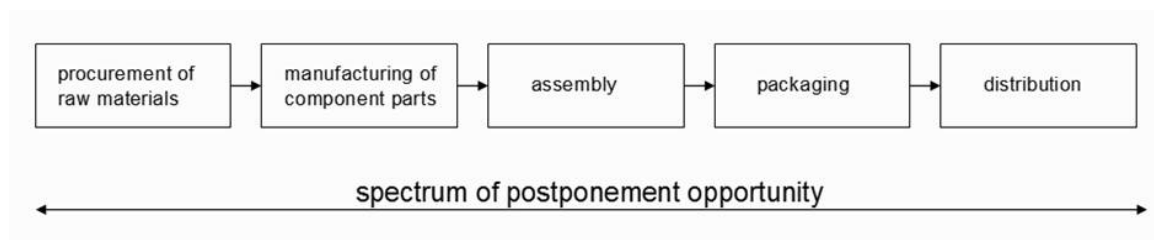


Figure 2-1: Possible points of differentiation in the supply chain

accurate the forecast. The benefits are better end product forecasts and the ability to respond quickly to demand signals by holding unfinished goods in inventory awaiting final assembly or customization. Postponement also creates opportunities to lower inventory costs due to risk pooling because goods are kept in unfinished or component form and can be used to assemble more than one type of finished good. The monetary value of an unfinished good is less because it is not committed to becoming a finished product and lacks the added value gained in final assembly.

Postponement can take on many forms for a variety of products. The point of postponement can occur as early as the design phase and as late as packaging and distribution. Many of the case studies described in this thesis concentrate on postponement at the manufacturing stage. This has arguably the most potential for cost savings in inventory due to risk pooling. Other points of differentiation can occur in the assembly, labeling, packaging, or distribution phases. Some postponement can even occur after the point of sale in the form of service offerings. Choosing the right place to set a postponement point is a function of product and market characteristics which will be discussed in this thesis. While many companies are taking advantage of postponement it is still an underutilized strategy across manufacturing. Costs and benefits are sometimes hard to quantify. However, successful case studies can help identify savings as well as highlight challenges in implementation.

2.1 A specific example

Consider a common case of postponement involving a fast food restaurant. Burger King started a trend with the “have it your way” marketing jingle as a way of advertising the value of getting a customized sandwich - fast! This strategy ensured the customer that each order would be made individually at the time of purchase - not taken from a batch of pre-made products. In a restaurant, ingredients are ordered in aggregate because it is not known what the final customer orders will be. Ingredients that are common to all sandwiches, like buns and lettuce, are ordered based on a total forecast of sales for each type of sandwich. Having a bun and lettuce ready

and waiting for final assembly is the “platform” for the sandwich. The rest of the ingredients, like cheese, meat, and pickles, are components that are specific to each end product. If more of one type of sandwich is ordered or less of another, the total number of buns is not affected by this deviation in demand, however, the amount of cheese would be. It is much less costly to throw out a piece of cheese and use the platform for another order than to throw out an entire sandwich.

At Burger King, inventory is managed at the aggregate level. There are four choices of meat and three different types of bun. In addition to buns and meat, there is the choice of cheese, bacon, lettuce, tomato, pickles and onion. In total Burger King can produce 768 different sandwiches as show in Table 2.1. They know that it is costly to try and predict individual customer’s preferences so they aggregate orders into common platforms which consist of a bun, patty (chicken, beef, fish, or veggie) and lettuce, reducing the options from 768 to 128. Once common components are paired together in a platform the number of options reduces dramatically because variety is determined by multiplying the number of options together. Once the platform is specified by a customer the rest of the sandwich is made-to-order.

Table 2.1: Sandwich options at Burger King

Component	Nuumber of Options
patty	4
buns	3
cheese	2
bacon	2
lettuce	2
tomato	2
onion	2
pickle	2
Total Combinations	768

This strategy works well for restaurants like Subway and small lunch counter establishments, but is not suited for places like McDonalds where customers expect their sandwich ready when they arrive. Customers usually do not custom order sandwiches at McDonalds which is why they can produce orders quickly from a batch

of pre-made sandwiches made according to a forecast of daily orders.

This example illustrates how postponement through platform design and stocking individual components instead of finished goods is able to mitigate the risk associated with producing a wide variety of products. This concept can be applied to more than just food. Examples of products which can benefit from postponement include consumer appliances, automobiles, apparel, and even airplanes. These products have one or more of the following characteristics: high degree of forecast uncertainty, modularity, and high inventory carrying costs.

2.2 Postponement in operation

Operational postponement can be applied in one of two ways - manufacturing and assembly postponement and logistical postponement. Manufacturing and assembly postponement involves the engineering of a product as a module or platform which can take on several different features thereby increasing the variety of end products. The point of postponement can occur as early as the design phase. The intermediate product is stored in inventory and awaits customization. The value added through assembly or manufacturing may be performed at a finishing facility or at a warehouse just before shipping. Manufacturing and assembly postponement involve decisions made while the product is in production. Engineers seek to design a product as a module or platform which can accept different attachments or features in order to transform the appearance and or function to increase product variety. This concept was referred to as a “vanilla box” by Swaminathan and Tayur [42] because the generic platform is one without any customized value and is therefore the common denominator among a family of different products. In a report on the fundamentals of product modularity, Tung and Ulrich [45] defined five levels of manufacturing and assembly postponement:

1. component-swapping modularity - A variety of components are designed to fit into a standardized port. Example: car tires, radios, vacuum cleaner attachments.

2. component-sharing modularity - A component is standardized to fit into a variety of different platforms. Example: batteries, power sources, plugs, microprocessors.
3. fabricate-to-fit modularity - The finished product is a specific quantity from a batch of bulk product tailored to customized dimensions. Example: bulk goods, plastic sheeting used between layers of glass, clothing, electric cable wires.
4. bus modularity - The platform serves as a vehicle which can accept one or more different varieties of components. Example: computers, cars.
5. sectional modularity - Any arbitrary combination of components connected at their interfaces. Example: Legos, construction pipe, tubing, scaffolding.

Each type of postponement describes a different way products can be designed to be customized without knowing final demand. With component-swapping and component-sharing modularity companies have to adopt standards across products and even across industries so that integral components, like batteries, can fit into a variety of different products. Having a vanilla box allows production to take place without knowing specific volume requirements for different stock keeping units (SKUs). Production can begin even without a customer order in place. The vanilla boxes are produced to a forecast and held in inventory until demand is realized closer in both time and location to the point of sale. Black and Decker provides one of the earliest examples of production and assembly postponement involving component and bus modularity. This case is explained in the literature review in chapter four.

Logistical postponement takes into account all other types of postponement involving logistical decisions like packaging, labeling, and distribution. Packaging and labeling postponement traditionally applies to small consumer goods products like razors, batteries, compact disks, film, and snack foods. Large retailers like Wal-Mart and Target require different configurations of packages to accommodate their customer demand and shelf space capacity and to differentiate commodity products. Gillette is well known for their packaging postponement operations. In 1996 Gillette

decided to outsource the packaging of their health and beauty items to Sonoco. Bulk quantities of products are sent to Sonoco to await final packaging. Once orders are received appropriate packaging configurations are assembled and shipped to retailers.

Manufacturers spend a significant amount of capital and labor trying to satisfy the variability in demand for different configurations for their retailers. According to Polaroid spokesman George Fotheringham [15], \$1-2 million is spent annually on labor and materials to reconfigure orders of film. However, companies like Gillette, that focus on their core competency, innovating and manufacturing razors and razor blades, push the risk onto their packaging supplier. Sonoco assumes the risk of forecasting for the different retailers which allows Gillette to produce to an aggregate forecast. The benefits for Gillette included a reduction in order fulfillment time from six weeks to one, a 15 percent decrease in packaging inventory, a 10 percent improvement in inventory accuracy, and a 15 percent reduction in packaging costs [37]. Not only does this save Gillette from mis-matching demand and configurations, it allows them to focus on engineering, design, and manufacturing of new products instead of packaging. Gillette “avoided plant expansion...[has a] focused factory workforce...[and is] winning favor with retailers by being so responsive” [37].

Another example of logistical postponement is the postponement of decisions made about the product during its distribution lead time (from finished product to customer delivery). Whirlpool, a popular manufacturer of household appliances, provides a good example. Customers of Whirlpool include retailers like Sears and Home Depot. Holding inventory of large appliances such as refrigerators and washing machines at local stores is costly because of the high product value and the space taken up in a back storage room. For this reason Whirlpool will send finished goods to a central distribution center and ship directly to the home once a customer order is placed. This method saves the retailer in inventory cost and eliminates additional transportation cost by bypassing the retailer. In addition, it reduces the risk that is inherit in sending a dedicated number of products to individual stores and having to transship orders between retailers.

Chapter 3

Benefits and Costs of Postponement

Postponement has the potential to lower the total delivered cost of a product. However, postponement does come with its own costs to implement and maintain. The benefits outweigh the costs when postponement is implemented correctly for the right type of product. For products with certain characteristics postponement allows companies to offer more variety, improve forecast accuracy, reduce inventories, and improve customer service levels. With these benefits come the costs of implementation and manufacturing. Below are explanations of the benefits and costs that are typically seen when postponement is introduced into a supply chain.

3.1 More variety

Having variety allows for a closer match between customer preferences and offered products leading to increased sales and (sometimes) increased prices [8]. The build-to-order strategy pioneered by Dell shows how manufacturing a product according to customer specifications is one way to offer a large variety in a cost effective way. Dell offers enough options for their Dimension 4600C desktop to build over 100 million different computers using combinations of the components listed in Table 3.1.

Just like Burger King, Dell does not stock each of the 100 million varieties. Instead,

Table 3.1: Component List and Options for Dell 4600C [39]

Parts	Options
Intel Pentium 4	5
Operating Systems	5
Productivity Software	6
Memory	8
Hard Drive	4
Floppy/Storage Device	4
CD/DVD Drive	6
CD/DVD Software	4
Storage Devices and Media	2
Keyboards	3
Mouse	4
Monitor	9
Total Combinations	100 million

they wait for customers to place an order before they build a machine. They have perfected this strategy so well that they are able to shape demand and produce popular combinations to forecast. Dell can offer discounts on combinations that are popular because of economies of scale and can carefully encourage customers to choose components that are in-stock using discounts. This strategy allows them to offer a quick turnaround and ensures that customers will not have to wait more than a week for a new product.

Customers have grown to expect more options while at the same time companies are developing new technologies which allow for greater product variety. Figure 3-1 shows the number of varieties of consumable goods in grocery stores [38].

These numbers suggests an exponential growth in the number of product varieties available over time. However, time, cost, and capital limit the amount of variety a company can offer. At the same time, consumers can only process so much variety without information overload and search time constraints. When people are saturated with choice, they settle for products they are comfortable with and disregard 75 percent of other options [38]. Figure 3-2 shows a system dynamic loop measuring different factors that affect the number of product variety offerings. There are seven loops in the figure. The reinforcing loops (denoted by a positive arrow) show factors

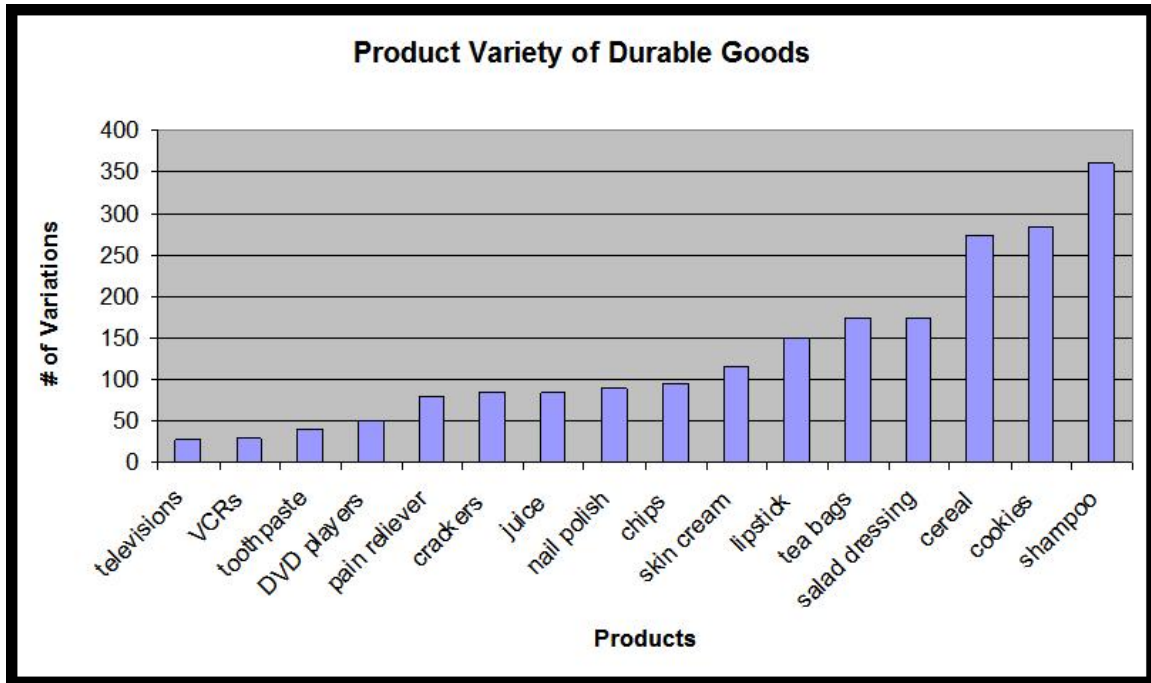


Figure 3-1: Product Variety of Durable Goods [38]

which increase the growth of product variety. The balancing loops (denoted by a negative arrow) show factors which inhibit the growth of variety. Loop one is a reinforcing loop that shows how variety grows because of the need to satisfy individual customers' needs. The more customers see that their needs can be met, the greater their satisfaction in finding a unique product. This can force their expectations to be greater which narrows down markets even further. Loop two is a balancing loop that shows how a company reacts when it has captured most or all of the market, suppressing the need for innovation and excess product variety. Loop three is a reinforcing loop that shows what happens when there are multiple firms competing for market share. As a company's customer base increases it continues to innovate and offer more variety as a competitive advantage. Loop four is a reinforcing loop that shows the effect of technology on product variety. Loop five is a balancing loop that suggests that customers will become saturated with information and buy the product which offers them the best value given their search costs (time and information processing). "As the number of choices keeps growing, negative aspects of having a multitude of options begin to appear...the negatives escalate until we

become overloaded” [38]. When too much variety exists, companies must tradeoff between offering variety and holding inventory. Loop six is a balancing loop which shows how high variety is traditionally associated with higher unit costs. When the unit cost increases, the customer’s willingness to pay for that variety goes down unless the extra cost adds value to the customer, which is the goal of customization. Similarly, in loop seven, as production lead time increases, customer service levels drop and customers are less willing to wait for variety without some compensation in terms of added value.

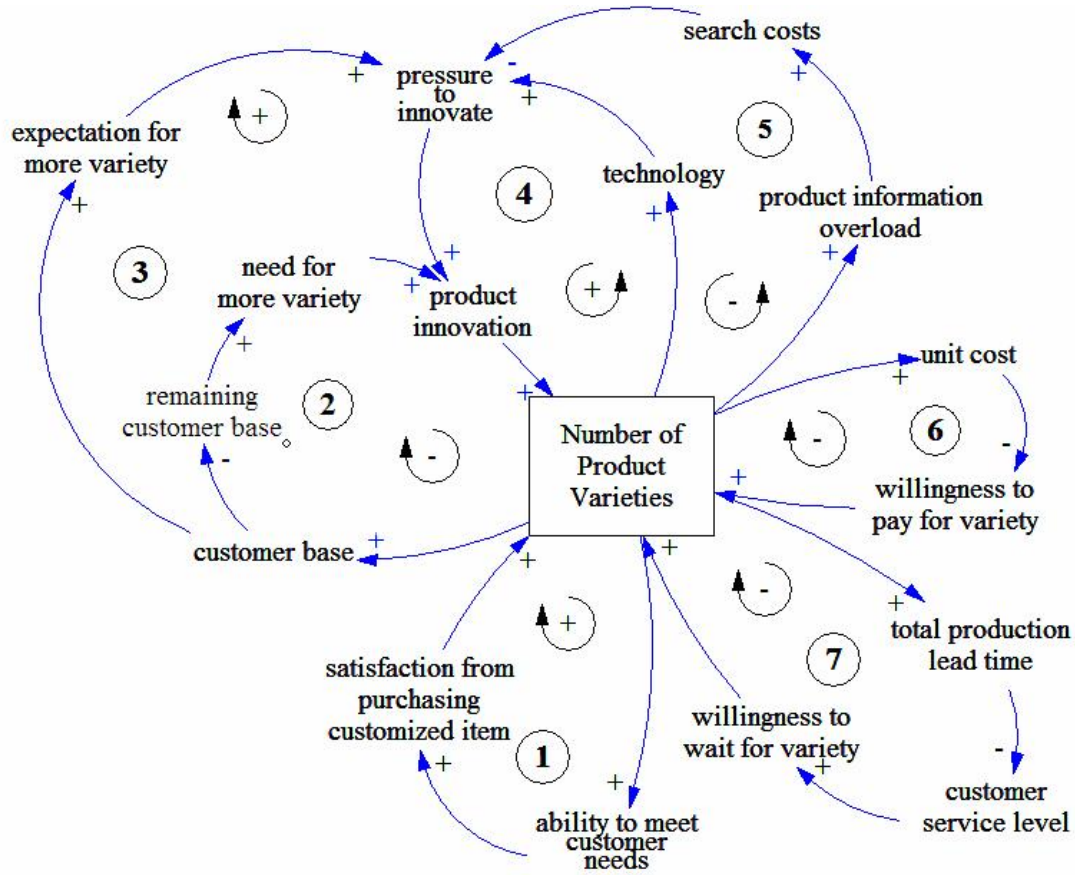


Figure 3-2: Systems dynamic loop showing product variety proliferation

Loops six and seven are opportunities where postponement can change the direction of the loops from balancing to reinforcing negating the traditional trade-off that exists between higher costs and variety with poorer levels of service [47]. Postponement allows for more variety through standardization and holding intermediate product inventory and better customer service though relocating final assembly closer

to the customer.

3.2 Inventory reduction

Reduction in inventory under a fixed level of service is another benefit of postponement. When companies increase variety they increase the number of SKUs they must maintain which translates into higher inventory costs. Each SKU is subject to different forecasts and therefore require different levels of safety stock. Safety stock buffers against sudden increases in demand. Holding safety stock ensures better customer service but is also expensive because of inventory holding costs. In a study of the effect of product variety on production-inventory systems, Benjaafar and Kim [8] found that inventory levels increased linearly with variety. They also found that cost was most sensitive to demand variability, capacity constraints, and set-up costs (assuming a fixed cost to switch the production line between products). This highlights the risk associated with having too much variety for products, especially those with high demand variability. Companies can mitigate this risk by standardizing parts, holding more work in process (WIP) inventory, and postponing customization.

3.3 Better forecast accuracy

Delaying the final customization of a product until more information is available allows forecasters to make better predictions of finished product demand. In order to delay customization, however, it is necessary to define what features or components make a product unique. Figure 3-3 shows how postponement reduces the variability of end product demand and saves on total inventory cost.

Using Figure 3-3, suppose that coffee mugs come in five different colors. The demand for each color is an independent random variable normally distributed with mean μ_i and standard deviation σ_i where $i = 1...5$ for each of the different colors and $\sigma_i = \sigma_{ij}$ and $\mu_i = \mu_{ij}$ for all i and j . Total demand for mugs is $N(\sum \mu_i, \sqrt{\sum \sigma_i^2})$. The standard deviation for the demand of white mugs, $\sqrt{\sum \sigma_i^2}$, is less than the sum

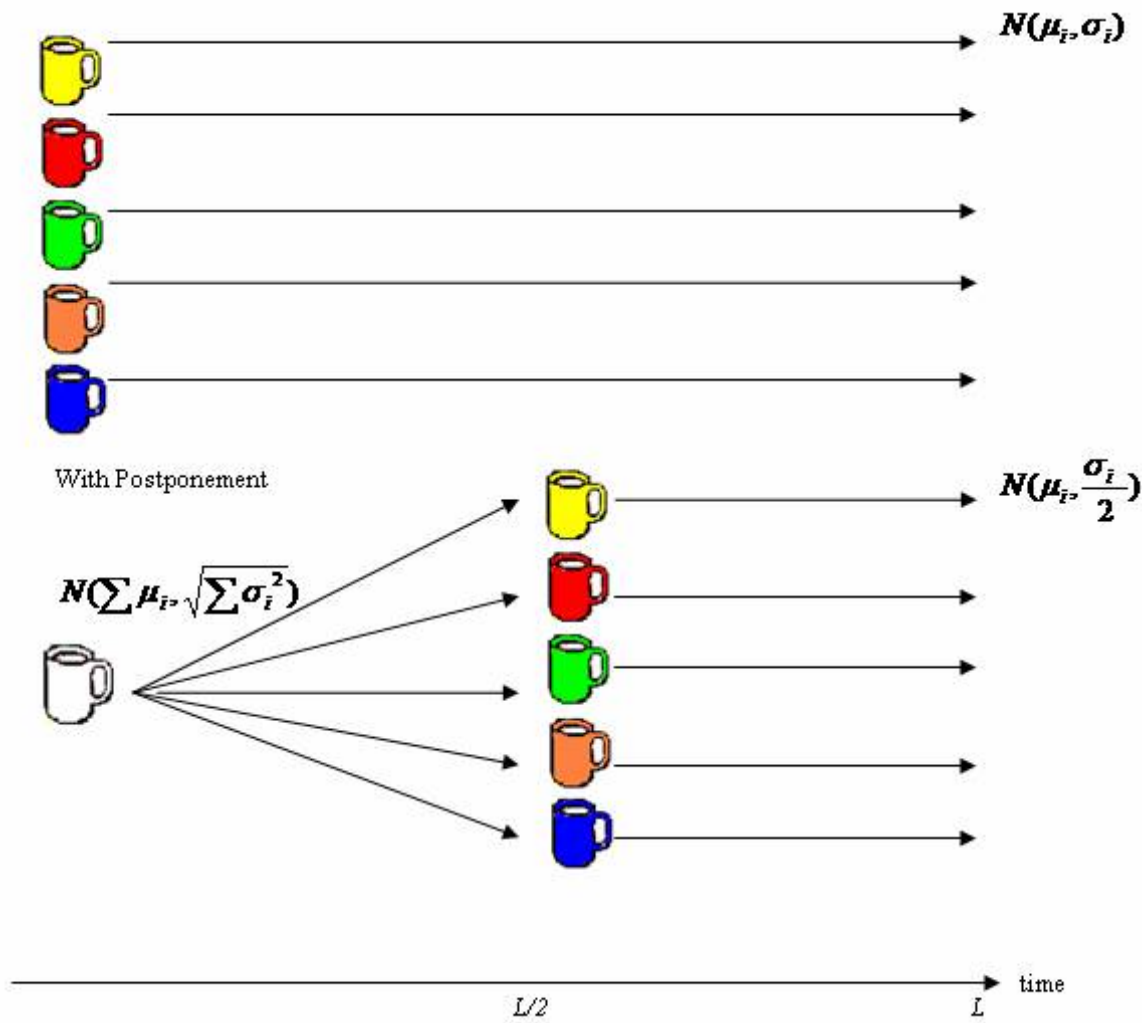


Figure 3-3: Demand accuracy of postponed and non-postponed operations over time

of the standard deviations of the individual demand, $\sum \sqrt{\sigma_i^2}$, which explains why aggregate forecasts are less volatile. Additionally, forecasts generally improve over time therefore, $\sigma_{i,T} > \sigma_{i,t}$ where $T > t$ and $\sigma_{i,t}$ is the standard deviation in demand of mug i at time t . In this example, assume information about demand gained in the period up until time $L/2$ reduced the standard deviation of demand for each individual mug by half. Also, assume that at time $L/2$ the finishing time is equal to the customer's willingness to wait. The producer is then forced to start painting the mugs at time $L/2$ to meet the customer demand on time. The variability of demand for mug color is more accurate at this point than it was at the start of the manufacturing process. It makes sense, then, to produce $\sum \mu_i$ or 5μ uncolored mugs at time zero and then paint them at time $L/2$ assuming there are no additional switching costs incurred in this two-stage model.

3.4 Inventory cost reduction

The amount of variety also affects inventory levels and hence, cost. The appropriate inventory level for a single SKU during a period of time consists of stocking the expected demand plus safety stock. Safety stock acts as a buffer to avoid stock-outs. Holding more safety stock improves customer service levels, but it comes at a cost. There are many formulas and practices for determining safety stock, however, this simple "fixed safety factor" approach assumes demand is normally distributed and is commonly used to determine the appropriate level of safety stock, ss_i , given a certain level of customer service [41],

$$ss_i = k\sigma_i \tag{3.1}$$

In equation 3.1 k is the safety stock factor which is based on a given level of service desired by the producer and σ_i is the standard deviation of the errors of forecasts over a given period of time. The amount of inventory, h_i , to have at the beginning of an order cycle for a single SKU is given by



Figure 3-4: FGI under postponed and non-postponed operations

$$h_i = \mu_i + ss_i \quad (3.2)$$

Assuming that all colors of mugs have the same mean, μ , and standard deviation, σ , of forecast errors, total inventory, H , is a function of the number of varieties, n ,

$$H = n(\mu + ss) \quad (3.3)$$

Without postponement, inventory cost increases exponentially, not linearly, with n . However, as mentioned above, if orders are aggregated and produced in unfinished form, the total overall variation decreases. For example, assume each mug has the same mean forecast, $\mu_i = 50$ and standard deviation or forecast error, $\sigma_i = 2$ for all i . The company wants to maintain a customer service level of 98 percent which equates to a safety factor of $k = 2.05$. A comparison of the amount of inventory required to satisfy the variability in demand at the beginning of the production cycle with and without postponement as variety increases is shown in Figure 3-4.

Not only is the amount of inventory less under postponement, the cost to hold a single SKU is also lower because the product is unfinished. There is still the cost of stocking components for the finishing process (paint) but it is less expensive to keep the mug in an uncommitted state and hold the paint in component form.

3.5 Logistics cost reduction

This simple case of postponement illustrates delayed customization involving painting the exterior of a pre-produced standardized good, a coffee mug. Many examples of postponement exist where points of differentiation occur as early as the design phase and as late as product labeling and packaging. A modular product design offers more opportunities for outsourcing non-core processes, like packaging and distribution, to third parties. This can happen both on shore or off shore depending on the location and distance of the end customer. In either case, the manufacturer can save money by shipping products in bulk instead of in packaged form which usually adds extra weight and volume.

3.6 Improved customer service levels

Customer service levels are defined in terms of lead time - how long it takes an order to arrive, and item fill rate - how often orders are filled from inventory on hand. Providing customers with orders quickly can be the result of improvements in manufacturing processes or by repositioning inventory closer to the customer. Customer willingness to wait is a key factor when assessing a product for postponement and determining the location of the postponement point within the supply chain. If customers are willing to wait a long time for a product then there is no benefit from expediting orders or sourcing components or processes closer to the customer even if they can be done cheaper overseas. On the other hand, if customers are only willing to wait, for example, one week, then the supply chain must be structured so that the finishing lead time and delivery time is less than or equal to one week. This

breakpoint between initial and finishing lead times is called the decoupling point and separates production into two stages. The length of time for the first stage is not visible to the customer and therefore all options for achieving lower manufacturing costs can be exhausted. The second stage of the supply chain (from intermediate product to delivery) must be structured in a way that offers the customer the highest level of service without sacrificing cost.

3.7 Increased product development cost

Another cost of postponement is the cost of design. If a product does not already have a modular design but meets all of the necessary market characteristics then it is worth researching the cost of redesigning the product for postponement. The benefit of a modular design is the flexibility it creates for other products within a family. However, there is a balance between too much modularity and its effect on product variety. As one case points out in chapter five, the risk of too much modularity is a lack of differentiation between products. In addition, the cost to switch manufacturing operations between varieties is sometimes responsible for reducing economies of scale that could otherwise result. In terms of cost, product redesign can take engineers months translating into increased research and development costs.

3.8 Increased manufacturing cost

There is a considerable amount of financial investment and commitment required to reconstruct the supply chain to support postponement. Manufacturing cost per unit may increase due to a restructuring of the production process into two or more stages. There should be dedicated areas for postponed activities in a warehouse and easy access to loading docks [25]. If all manufacturing is not done in-house (which is more likely than not) implementation may require additional facilities to support final assembly and distribution. This also requires more labor at a higher skill level to complete kitting, final assembly, and packaging as opposed to the lower skilled labor

required for loading, storing, and sorting [25].

3.9 Macroeconomic implications

Globalization, lower labor costs, technology, inventory costs, and customer willingness to wait must be considered when deciding whether to outsource different operations and where. Sending manufacturing jobs overseas may lead to high unemployment in the US if it is not offset by the creation of new domestic jobs. Postponement offers a unique lever by which a company can enjoy the benefits of lower labor costs without sacrificing the level of service it promises to customers. While routine and low skilled labor can be acquired offshore to produce commodity products, there is a need for a local labor presence for final assembly, delivery, sale, and service. The types of jobs postponement will create and the type of skills that are likely to be outsourced is the basis for this research. Examining different companies which use postponement can help predict the impact that postponement will have on reversing the trend of sending employment offshore.

Chapter 4

Literature Review

Sources date the idea of postponement as far back as the 1920s and the first use of postponement as a manufacturing strategy as early as the 1950s [34]. Early mention of postponement suggested that costs due to risk and uncertainty were a function of variety and that an efficient means of producing a product is to “postpone changes in form and identity to the latest point in the marketing flow [and] postpone changes in inventory location to the latest point in time” [6]. In 1965, Louis Bucklin recognized that little had been done in the area of postponement despite its tremendous potential for cost savings. He defined total cost as the sum of inventory holding cost and delivery cost, both of which are a function of delivery time. He argued that “a speculative inventory will appear at each point in a distribution channel whenever its costs are less than the net savings to both buyer and seller from postponement” [11]. In other words, postponement is not cost effective when there is sufficient information about demand to produce finished goods in mass and store them in inventory. For some products it makes sense to postpone the finishing process by introducing a finishing cost and increasing the delivery time because the product is not readily available from stock.

A shift in mindset was needed before the idea of postponement could catch on. Joseph Pine [35] traces the conception of manufacturing in the US from early manufacturing (pre-industrialization) to mass customization. Early manufacturing is characterized by highly skilled workers producing unique goods often one order at a time

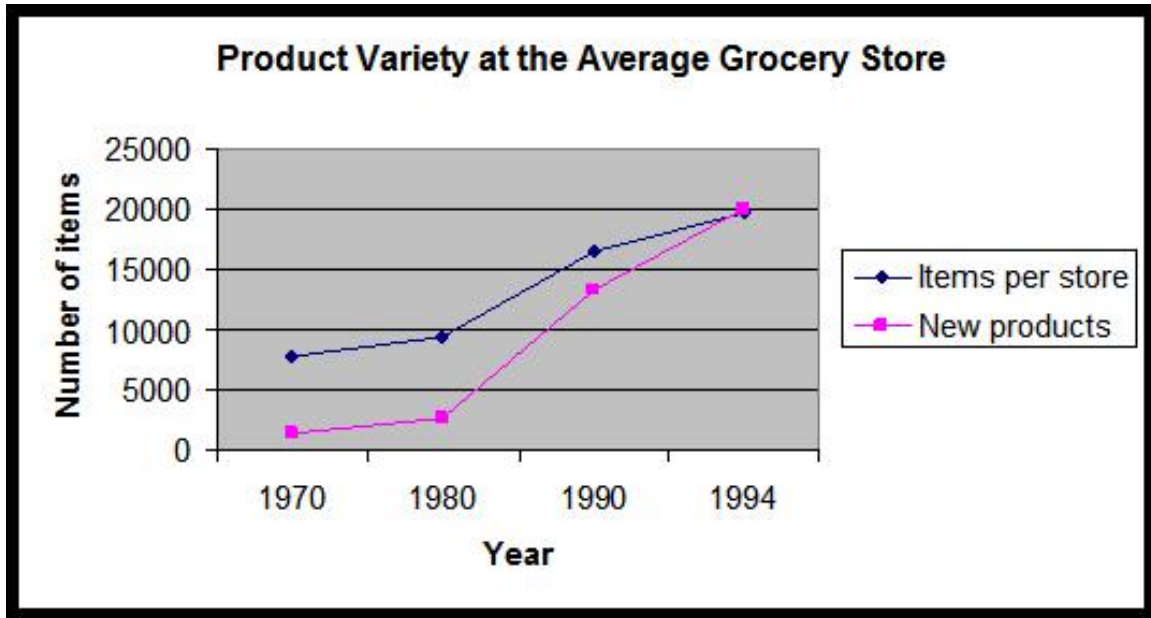


Figure 4-1: Growth of product variety and new products over time [28]

where economies of scale do not exist. Major innovations and technology lead to the gradual transition of agriculture jobs to manufacturing jobs during second half of the nineteenth century. The concept of mass production was introduced in the early 1900s with the start of the industrial revolution. Mass production took the technology and infrastructure of a manufacturing plant and turned it into an efficient assembly line where man was replaced with machine and products were pushed into the markets forcing customers to buy what was produced. Economies of scale and lower labor costs made products abundant and affordable. Mass customization introduced the possibility of using customer preferences as inputs into the manufacturing process thereby replacing the “pushing” of products into the market with the “pulling” of information to make customized products for the consumer. As a result, America saw a change in the variety of products. Instead of a black Ford Model-T customers can now choose between make, model, color, and performance capabilities for their car.

In the 1980s niche markets were replacing the mass markets and expectation for variety increased. “In the last twenty years, the number of different items on supermarket shelves has exploded, allowing manufacturers and retailers to reach the

ever-finer granularities of consumer desires” [35]. Figure 4-1 shows this increase in variety and new product introductions in supermarkets between 1970-1994 [28]. The two curves indicate that even as the number of new products continues to rise, the number of items per store is reaching a plateau. Stores cannot even offer the number of products that exist in the market.

Zinn and Bowersox [50] classified postponement into five distinct types; labeling, packaging, assembly, manufacturing, and time. Labeling postponement assumes that products are standardized until they receive a label distinguishing them by brand. Packaging postponement is best suited for products in which variation is determined by package size. Paint, chemicals, medicine, razors, and many food items sold in bulk are good candidates for packaging postponement.

Assembly postponement is applied to products in which variety is based on cosmetic features like cars, iPods, t-shirts, and printers. Hewlett-Packard (HP) provides an excellent example of assembly postponement. Printers designed for different global markets are inherently the same product except for country specific power supply modules, power cord plugs, and instruction manuals. HP makes a two types of printers in Vancouver: a US version and a generic version that is customized once it reaches a distribution center in Europe, Asia, or the Pacific based on country specific orders [20]. One benefit is decreased transportation cost because printers are shipped in bulk and are considered "vanilla" until they receive the value-added accessories like language manual and power supply.

Manufacturing postponement is an extension of assembly postponement. The difference lies in the degree of final assembly that takes place at the distribution or finishing center. According to Zinn and Bowersox [50], manufacturing postponement occurs when parts are shipped to the finishing center from more than one supplier. Manufacturing postponement has the greatest potential for cost savings in inventory because the value of the product increases through the addition of each successive component. Manufacturing postponement usually results in higher production costs. The increase is due to the capital cost of switching machinery between different types of variety and shipping them to different finishing facilities.

Table 4.1: Potential Utilization of Postponements [50]

Postponement Type	Potentially Interested Firms
Labeling	Several brand names
	High unit value products
	High product sales fluctuations
Packaging	Variability in package size
	High unit value products
	High product sales fluctuations
Assembly	Selling products with several versions
	High volume incurred by packaging
	High unit value products
Manufacturing	High product sales fluctuations
	High proportion of ubiquitous material
	High unit value products
Time	High product sales fluctuations
	High unit value products
	Large number of distribution warehouses

Time postponement occurs when finished products are shipped to centralized warehouses closer to the customer than the manufacturing location. The motivation is to increase customer service levels by decreasing customer lead time and to respond quickly to orders by placing inventories closer to the customer without committing to an individual order.

The final outcome of their research is a framework which serves to assist managers in determining what type of postponement is best for a given product or supply chain structure. Table 4.1 shows a list of the postponement types and the firms which would benefit from implementing each type of postponement.

Swaminathan and Lee [42] go further and identify the factors which influence the costs and benefits of postponement as market factors, process factors, and product factors. Market factors refer to characteristics of demand and uncertainty. Process factors refer to characteristics of operating policy within the firm as well as the external supply chain, such as managerial support and the location of and relationship with suppliers. Product factors refer to the design and characteristics of an individual product such as integral versus modular and inventory carrying cost. They

also highlight enablers of postponement such as process standardization, process re-sequencing (redesigning the assembly process to move value-added processes closer to the customer), and component standardization. Redesigning products with these characteristics makes postponement possible and reduces the risk to the manufacturer by eliminating redundant processes and designing products to be modular and component interfaces to have standard ports for easy assembly.

Alvin Lehnerd and Marc Meyer [21] offer a detailed look at the benefit of engineering products to be platforms for a family of different products. The authors define two terms which are the basis for postponement.

1. product platform - a set of common components, modules, or parts from which a stream of derivative products can be efficiently created or launched
2. product family - a set of products that share common technology and address a related set of market applications

These are both concepts that Black and Decker (BD) considered when they started to redesign their line of power tools. In the 1970s BD replaced customized parts with standardized components, interfaces, and connections in order to pool the part inventory and save on component inventory costs. Components included common screws, gears, and the motors which powered 122 different power tools. At a cost of \$17 million over three years, BD was able to fully integrate its supply chain, reduce scrap rate from six percent to one percent, reduce failure rate from 11 percent to less than five percent, and reduce the selling price by half while still maintaining a 50 percent margin. BD was also able to reduce the number of suppliers and push its competition out of the market. This is one of the first cases of postponement using product platform design [35].

Product platforms are also common in automotive and aircraft design. Examples of the use of product platforms extend far beyond those we use and consume on a daily basis. In 2005 the US military tested the JSF-35, the next generation joint-service strike fighter. This common platform is tailored to meet the demands of the US Air Force, Navy, Marines, and the British Royal Air Force. The common platform

helps minimize spare parts inventory across the military and streamlines maintenance tasks.

Lee, Billington, and Carter [20] discuss Hewlett-Packard's strategy when it created a single platform for its DeskJet Plus, Deskwriter, Deskwriter Appletalk, and the DeskJet 500 series. A major source of variability for HP was the final shipping destination. HP ships its DeskJet Plus printers to North America, Europe, Asia, and the South Pacific. Each one requires a different power supply module and language manual [20]. Under the "DC-localization" initiative printers are shipped from the manufacturing center in Vancouver and arrive at a local distribution center (DC) without language manuals or power supply modules. The DC supplies the remaining country specific features and packages the printers for final sale. This allows HP to pool the risk of stocking inventory by destination. Taking the process a step further, HP realized that Vancouver was close enough to the US where it could act as the local DC and hence two different types of printers are produced; US and non-US versions. This example illustrates how postponement is used in multiple ways for a single product. The designers at HP had to create a printer with a generic power supply port which is a form of assembly/production postponement. The local DCs had the job of assembling a final product complete with instruction manual, power supply, and the appropriate packaging material.

Robert Stahl and Thomas Wallace [47] propose a framework for implementing postponement by classifying products according to two factors; product complexity - the number of product varieties, and speed - the time from customer order to delivery. This results in four levels of differentiation as shown in Figure 4-2.

Companies in each of the four quadrants have different challenges when adopting a postponement strategy. For example, a company in quadrant B produces a product that has very little variety but takes a long time to produce and deliver to the customer. Wallace and Stahl suggest that a company in this quadrant focus on speed by reducing the lead time from suppliers and expedite the delivery to the customer. They can accomplish this by implementing lean manufacturing initiatives, improving the work flow, and reexamining the location of their suppliers in terms of distance

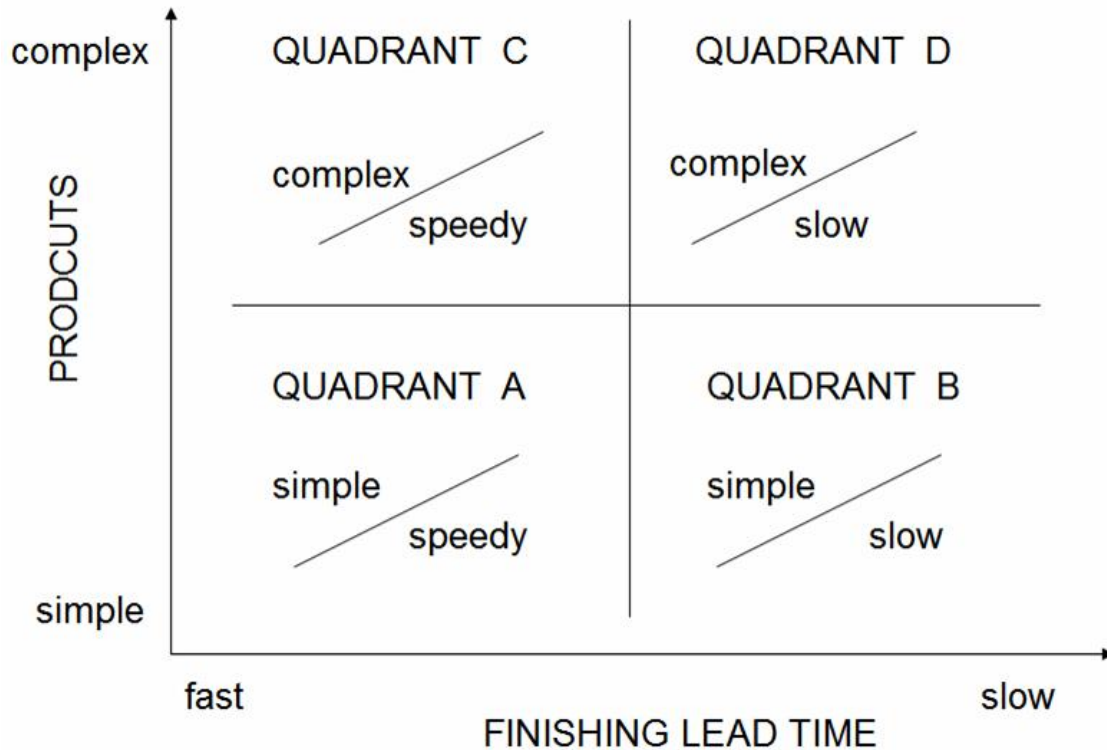


Figure 4-2: Complexity v. Speed Matrix [47]

to the customer [47]. This dilemma illustrates the trade-off between cost and service level. One way to take advantage of distant suppliers and still achieve fast delivery is to decouple the production process and hold inventory of intermediate product locally. It is important to note that “not all of the manufacturing process needs to be highly speedy, only the part where the options are added” [47].

Employment in both manufacturing and services may increase as more and more companies explore postponement because of the localization of final processes and services. Political debate surrounding the question of US employment and offshoring makes this an important area of research. Factors that are affecting the offshoring of jobs include the increased use of the internet and real time information, availability of low-cost labor, standardization of business practices, commoditization of services and products, and automation [14]. On the other hand, jobs that are not susceptible to offshoring or automation are those that require a physical presence.

The use of postponement determines the extent to which the displacement of manufacturing jobs will be offset by the creation of a new domestic market for jobs

Table 4.2: Services offered by logistics providers (1994 and 2005) [25]

Services Offered	1994(%)	2005(%)
Manufacturing	2	11
Assembly	69	74
Packaging	17	74

that require proximity to the customer. Postponement can combine the benefits of mass production by taking advantage of offshore economies of scale for manufacturing yet still provide domestic jobs for final assembly and/or providing service.

A major sector of the service industry in the US is the distribution of products. “The implementation of postponement facilitates outsourcing to third parties” [27]. Third party logistics providers (3PLs) like UPS, DHL, FedEx, and others are increasing their offerings to provide additional services for customers. Menlo Logistics offers an example of the increased services provided by logistics providers. In 2002, Efficient Networks, an electronics provider, started outsourcing not only distribution, but final assembly to Menlo. Menlo accepts product in basic form and configures and assembles to order based on end-customer needs [9]. They also perform quality checks, handle reverse logistics, and perform maintenance on returned products [9]. This shows how some manufacturing which was done in Asia is being decoupled from the process and brought back to the US in order to decrease lead time and increase service levels. Table 4 shows the increase in services offered by 3PLs in 1994 and 2005.

The motivation for this research is to determine which companies are using postponement and categorize the type of products that are ideal candidates for postponement. Because postponement is a widely known, yet underutilized, strategy it is important to understand strategic motivations and operational consequences that can help aid in future research.

Chapter 5

Postponement Everywhere

The following case studies give detailed information about several companies that have adopted postponement in some capacity. It is worth understanding the motivations and risks that they incurred in order to understand how companies can determine whether their product is a candidate for postponement. Each case provides background on the company and product that is postponed, a description of the supply chain before and after postponement was adopted, the decoupling point between intermediate product and finished good, costs and benefits, and discusses how the supply chain is structured to take advantage of offshore manufacturing and local final assembly.

5.1 General Motors

The auto industry is a prime candidate for postponement for many reasons. First, a car is defined as a modular system of components. This creates opportunity for commonality by producing a platform and adding modular subassemblies customized according to the make and model and ultimately the end user of the vehicle. Second, individually customized vehicles have high forecast variability. As this case points out there are far too many varieties to accurately forecast each combination and there is typically disagreement on the forecast within the different divisions of a company [44]. Third, cars depreciate as soon as they are driven off the lot. New models come out

each year which feature new technologies and capabilities. Lastly is high inventory holding cost. It is much riskier to hold a finished vehicle on the showroom floor than to have a partly finished good waiting for final customization because of the high forecast variability for end products and high product obsolescence cost. General Motors (GM) offers a unique look into customization during manufacturing and after the point of sale.

As of 2004, GM produced 68 different models in North America. There are over 200 facilities constituting 52 percent of their revenues. There are over 600 million combinations when all the different component variations and customer specific preferences (color, interior options) are considered. “Of course we don’t produce all of those” but the options are there, and that is what the customer wants explains Jeffrey Tew of GM’s Research and Development Center [44]. Forecasting becomes difficult when there are this many combinations to consider. Different divisions within GM use different methods of forecasting further complicating the problem. “Excess inventory on the field is evidence of that” [44]. Searching for a way to create variety and mass customize beyond the idea of platforms, GM looked at software configuration, entertainment, and aesthetic features as a different way to use postponement.

From a software standpoint, each of the systems within a vehicle can also be considered a unique central processing unit (CPU) made up of several electronic control units (ECUs). These include safety systems, engine, and transmission controls. In the 1990s there were only one or two ECUs in a vehicle. Now there are as many as 30-35 per vehicle because software is becoming increasingly essential in automobiles for voice recognition, global positioning systems, and entertainment [40].

Before postponement, GM experienced the effects of product variety proliferation and high inventory costs of stocking ECUs for individual models. The ECUs came to GM in finished form with all of the software pre-loaded. Each part was assigned to a specific vehicle but they all looked the same on the outside. Suppliers charged GM a premium for custom software installation which not only raised the price but also created problems with repair and maintenance [40]. GM decided that they would assume the responsibility for software configuration and postpone the installation

until the latest possible point in the assembly process.

In order to accomplish this, GM had to redesign both the assembly process and the ECU hardware. In the mid-1990s GM achieved the capability to install custom software for individual orders towards the end of the vehicle assembly process. The ECU now comes from suppliers to GM in a generic form. The hardware is a common platform which can receive customized software in just 81 seconds [44]. GM dealers also had to acquire the capability for flash programming for individual cars at the point of sale as well as after-market upgrades [40].

After realizing that software could be postponed, GM looked at other systems that could be delayed until purchase. They recognized the emergence of the accessory market for vehicles as another way to differentiate and increase revenues. Post-sale “accessorization” of vehicles is a \$28 billion industry and OEMs are “slow to pick up on it.” Entertainment systems have become far more sophisticated over the years and offer key differential options on a vehicle. “[Customers] place a high utility on the entertainment system” [44]. Because of the plug-and-play capability, entertainment systems can be uploaded into the vehicle at the dealer. Another key differentiator is the wheel set. Dealers are very involved in putting specialized wheels on a car to make it more desirable. This was not a high-emphasis item before 2000.

Through the use of the internet, GM introduced an on-line purchasing website. “It is allowing us to provide the customer with a hands-on involvement” [44]. Customers can log on to GMbuypower.com and point and click their way to the car of their dreams. GM offers a 99 percent guarantee that they will deliver the vehicle within one day of the projected delivery day to a dealer close to the customer. Five years ago this would not have been possible. The OEM did not have a way of knowing when the vehicle would be finished because the build sequence “wasn’t structured for speed, it was structured for low cost shipping” [44].

As of 2004, about 18 percent of the cars in assembly at GM were custom made and 82 percent were made-to-stock for dealers and showrooms. The goal is to move to 60-80 percent custom orders but the shift is happening in different markets at different rates. In China, for example, the rate of technology use among the population is very

high and customers are more apt to order a custom-made vehicle.

In addition, all of this information decreases the variability in demand and provides more accurate forecasts for auto OEMs. GM is experiencing the benefits of postponement through delayed software configuration and customization. In a study to estimate the benefits of postponement, GM, along with MIT and Stanford University, developed a cost model which projected inventory cost savings to be 10-15 percent [40]. Other benefits included maintenance cost savings due to the highly communized ECU hardware and having GM software engineers solve repair issues instead of sending parts back to suppliers. GM's main goal, however, is to create a more flexible supply chain that can handle higher throughput and is more responsive to immediate demand. Tew recognizes that the most flexible manufacturer can handle up to six platforms at a given time, as is the case at the Nissan plant in Canton, MS. GM plants can only handle two platforms at one time.

GM has taken advantage of the benefits of both postponement and outsourcing. The subassemblies are outsourced to suppliers with the comparative advantage of quality and expertise. Leaving some of the customer-specific features to be customized by the OEM, the dealer, and the customer gives flexibility to the supply chain ensuring that customers get exactly what they want. As the auto industry transitions to a predominately build-to-order manufacturing system their suppliers will have to commit to the increased demand for customized features instead of aggregate orders for common parts. More local jobs are needed to provide the after-sale customization and the repair and maintenance of the new software.

5.2 Honda

Postponement in the form of platform design has been a standard in the automotive industry since the early 1990s when GM and Volkswagen (VW) both introduced their platform strategy in an effort cut development time as well as design, engineering, and manufacturing costs. VW reduced the number of platforms from 14 to just four in eight years and increased platform use among its models from 70 percent in

1996 to near 100 by 2001 [48]. As what seemed like the winners in the automotive race to get the most productivity per platform, GM and VW quickly found out that convincing their customers that they made unique automobiles was the more difficult challenge. Buyers of GM products called their line of automobiles “cookie-cutter look-alikes” forcing them to reconsider platform engineering and focus on component standardization, as in the postponement of the ECUs. Instead of “platforms” they renamed the concept to “architectures” to reflect the “application of architectural standards to a family of vehicles.” VW similarly adopted “modules” to describe a set of components that share a common platform [48].

The story of GM and VW is a lesson to other manufacturers in the auto industry. Not wanting to take the risk of creating too much variety from too few platforms, Honda decided to implement flexible manufacturing in the mid 1990s. Flexible manufacturing at Honda is composed of three elements; programmable robots to aid in standardized assembly, an increase in offline or outsourced subassembly, and one-size-fits-all conveyer belts [46]. Honda took flexible one step further and implemented the New Manufacturing System in September 2000. This was the first attempt at a truly global automobile designed from a single platform with the flexibility to meet multi-market demand.

In 1994 Honda was faced with the problem of designing a single car for its world-wide market. The traditional Honda Accord was criticized by consumers in both the US and Japan. US customers complained that the car was too small while Japanese complained that it lagged behind in stylistic features. In 1996 Honda decided to increase the size of the Accord. Sales increased by 12 percent in the US making the Accord a best seller among mid-size cars and more than half of Honda sales in the US. But, the new model failed miserably in Japan and Honda realized that it would need two different designs for the same model for each of the two distinct markets. Engineers started searching for other options because of the extremely high cost of adding variety at the vehicle model level [29].

By 1998 Honda had figured out a way to satisfy demand in all three of their largest markets; US, Japan, and Europe. The answer lies in the design of the chassis, the

platform or skeleton of an automobile. Honda engineer Yozi Kami is responsible for redesigning the chassis so that the height, width, and length can be adjusted based on market preference. This was the first attempt at creating a global car by introducing flexibility into the platform. Now, instead of multiple platforms for each Accord, only a single platform was needed. At first this idea extended to just the Accord but would later be used to develop a truly robust chassis that could transcend across multiple models [29].

In terms of design, the gas tank was moved to the rear of the car and the wheels were connected with brackets that can be moved closer or farther apart based on the specific final dimensions of the car. In terms of specialty, the brackets that connect the adjustable frame to the wheel set are unique to the type of Accord.

Honda spent only \$600 million on the project compared with \$2.8 billion spent by Ford to redesign the Taurus [29]. After the new platform was introduced the US Accord was 4 in. wider, 6 in. longer, and 1 in. higher than the Japanese Accord and it quickly became competitive with the Taurus in the market for family-size cars. The new design allowed Honda to create three distinct Accords from a single platform at 20 percent less than it cost to produce Accords four years prior. This resulted in a savings of \$1200 per vehicle, \$1000 of which is passed on to the customer [29].

Since 1997, Honda has improved the design of the Civic chassis to be used in a three and five-door hatchback edition for European and Japanese markets respectively, the four-door sedan (US) and the Honda Stream, a new compact minivan with three-row seating and room for seven passengers. The flexibility of the chassis allows it to take on the following dimensions:

Table 5.1: Dimension Specification for Civic Models [49]

Dimension (in.)	3/5 Door Hatchback	4 Door Sedan	Stream Minivan
Wheelbase	106	103.6	107
Length	169	175	179
Height	59	58	63

Honda has not only seen savings as a result of their new design, they also struck

gold first in the race for a global car. Honda has plans to use the same Accord platform in their luxury, SUV, and minivan models. Other auto manufacturers are also experimenting with platforms that will fit more than one make or model. GM hopes to build all of its vehicles out of only seven different platforms. Toyota and Ford are also following suit. But this is just the beginning. Car manufacturers are moving towards industry standardization and the availability of a car that is composed of parts and assemblies that come from many different car manufacturers.

In terms of employment, having the capability to send any vehicle off the line means that more facilitates in localized markets can satisfy demand without reliance on other plants. This saves on transportation costs by eliminating the transshipment between plants. By 2001 Honda increased its local production by opening plants in Malaysia, Thailand, and India. Their US plant in East Liberty, OH was the first to produce an SUV and minivan off of a single production line and, since 2001, is capable of producing nearly every vehicle in their market. As a result, employment increased by 20,000 in 2001 and 75 percent of Honda vehicles produced in the US were sold locally [4].

5.3 Embraer

The commercial aircraft production at Embraer provides an example of production and assembly postponement in the airline industry. The motivation for postponement was to focus on “optimizing cash flow” by creating a flexible supply chain that can provide the right airplane to the right airline company [23]. In other words, the goal is to give customers the ability to change their decision regarding customizable features, or to cancel an order completely, by designing the aircraft to accept these changes as late in production as possible.

In response to the changing dynamics within the aircraft industry Embraer differentiates its new family of regional jets based on the number of seats. In 2005 Embraer’s goal was to create an optimal size jet for the 70-110 seat market. The new family of regional jets, the Embraer 170, 175, 190 and 195, focuses on a high degree

of parts commonality as all four jets have exactly the same cockpit and fly-by-wire systems.

Embraer decided to implement postponement in order to make its supply chain more flexible and able to respond quickly to changes in demand. This was evident when a customer, US Air, had to cancel an order for six ERJ 170 aircraft because of financial constraints in October 2004. With the majority of the production complete it was too costly to go back and change any of the customized features and reconfigure it for another airline. Embraer developed a strategy for postponing as much of the high-value features, like engine type, software, radar devices, and interior specifications as possible. Not only did it save on costs, the flexibility to change order specifications became an attractive alternative to backing out of an order or having to pay for costly reconfigurations.

The example involving US Air is common throughout the industry. “Customers are hurting under oil prices and other constraints which is why they are changing their order in a short period of time, shorter than our capability to react...We must review the shape [of the supply chain] in order to synchronize and reduce the gap between supply and demand” [23].

The current supply chain at Embraer is structured to allow for two postponement points throughout the production cycle as illustrated in Figure 5-1. The first point occurs roughly one year before delivery to the customer where the platform is differentiated based on product family (170 versus 190 family of aircraft). Six to eight months later it will assume the configurations, engine, software and hardware which distinguish it as a 170 versus a 175 or 190 versus a 195 aircraft. After this point the customer specific features such as seating arrangements, galley configurations, and tail art are added.

Embraer still builds-to-order because of the high cost to hold a finished airplane in inventory. The white tail concept (analogous to a “vanilla box”) allows the production processes to begin and run in parallel with some of the steps that usually take a long time to complete such as certification for safety, avionics, and entertainment systems. Total lead time for production is usually 24-36 months because of the long

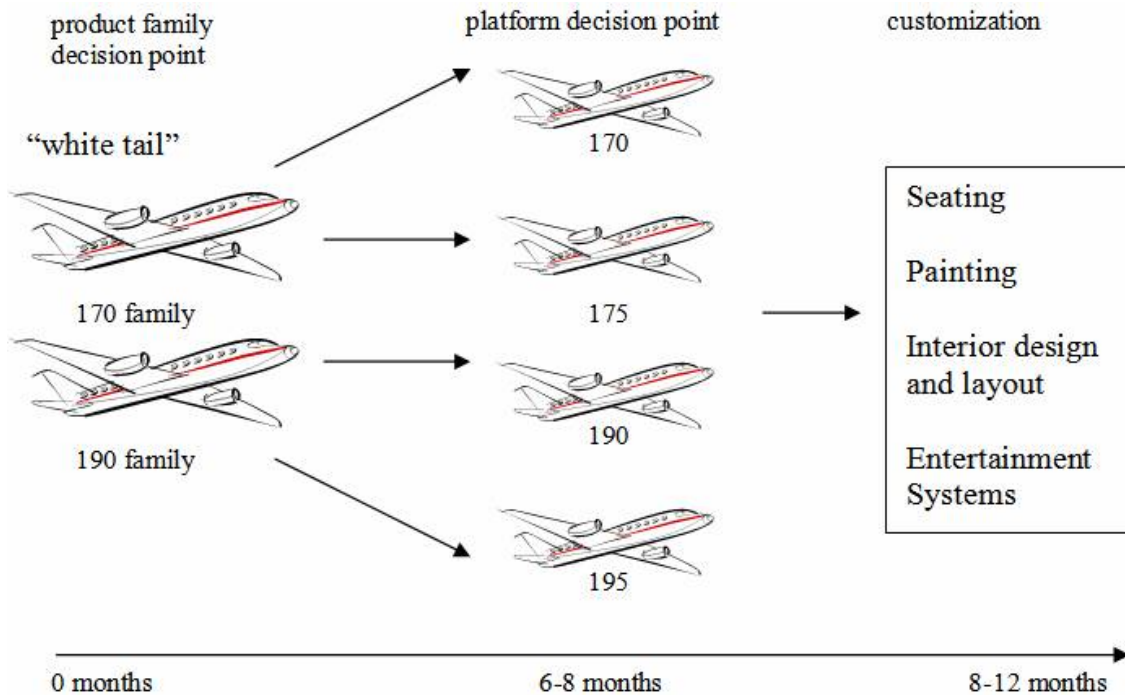


Figure 5-1: Lead time break down of value added components and features

lead time for suppliers. Production begins 12 months before delivery and the order is considered 90 percent “frozen” or unchanging. However, some customers change their mind within the final month of production.

Embraer is committed to developing the idea of postponement further within the company. Any flexibility that can be gained through delaying the customization makes Embraer jets more attractive to a customer facing the uncertainties of the aircraft industry. Engine, avionics, interior and galley layout are some of the hardest subassemblies to change and also have the highest value. The white tail concept allows Embraer to have flexible production in its new family of 170/190 aircraft. They do hold some inventory of semi-finished aircraft that await orders from larger companies in the corporate jet market because the orders are more predictable.

Embraer represents a company that is practicing postponement and is not seeing huge savings in inventory. Instead they redesigned their process to accommodate the addition of components based on value to the customer and degree of customization. Better service levels and customer satisfaction give Embraer a competitive advantage

in a very competitive market.

5.4 Dade Behring

This case study was written in conjunction with Mike McCormick, Director, Global Supply Chain Planning, Instruments at Dade Behring [24].

Dade Behring (DB) is an industry leader in clinical diagnostic equipment and reagents. Their customers include over 25,000 hospitals and reference laboratories which require instruments that analyze human fluids such as blood and urine. They have global operations in more than 34 countries and currently deliver products in six main areas: Chemistry, Immunochemistry, Hemostasis, Plasma Protein, Microbiology, and Infectious Disease Diagnostics [1].

DB diagnostic instruments are high value with a retail price ranging from \$20,000 to over \$200,000. Demand forecasting is a challenge due to long buying cycles ranging anywhere from six months to two years. Forecasts are generally compiled from sales representatives' predictions. Because of the high cost of the products, the decision making process and financial constraints of the customers, it is somewhat difficult to know when products will be ordered. Additionally, instruments were designed/configured to local country power requirements which exasperated the forecasting impact. As a result, DB was plagued with less than optimum service levels for some instruments and higher than planned inventories for others. All of these conditions were catalysts for a postponement strategy, which became even more important as a result of an industry-wide European directive.

The first postponement strategy involved designing flexible power capability into the Dimension Chemistry/Immunochemistry analyzers that Dade Behring designed and produced. Originally Dimension was offered in either a 110 V or 220 V power version. To optimally manage inventories of these instruments, DB collaborated with an external supplier to replace the power supply module with a universal power supply. During the redesign phase engineers were able to develop the universal module at a lower cost because of advanced technology which was previously unavailable. The

cost to produce the universal module was actually less expensive than supplying two different versions.

Then, a second postponement strategy was put into place due to the European IVDD initiative. In 1998, the In Vitro Diagnostics Directive (IVDD) was published as the third of three European directives which required medical and diagnostic equipment to come packaged with local language manuals and labeling. The regulation gave 17 countries the right to specify the national language that would come available with each instrument for which they contracted. In total 12 different language manuals were eventually required. The instrument manuals are approximately 350 pages (+/-) in length and therefore it did not make sense to create a single manual with all 12 languages included nor package 12 different manuals with each instrument. DB initiated the switch to language specific packaging in the industry through the postponement of packaging materials at distribution centers and flexible language capability within the operating software. This is a straight forward process accomplished by marrying a language specific accessory box to the instrument during the shipment process.

Shortly after achieving successful packaging operations, DB initiated another postponement strategy in their Chemistry product line. This next strategy was to redesign the product so that it could be configured-to-order at the end of the assembly process. There are currently four variations of the Dimension Chemistry/Immunochemistry Analyzer Series. Dimension is offered as RxL Max Basic and RxL Max HM (heterogeneous model), or as an Xpand Plus Basic and Xpand Plus HM. Through a carefully designed manufacturing process, Dade Behring is able to manufacture to a specific model as soon as that specific model is shipped to fill a customer order.

This strategy involved the redesign of the manufacturing process so that the analyzer could be configured-to-order at the end of the assembly process. This meant that all of the commonalities between the two different variations of each model would be combined into an intermediate product that would be produced to a forecast, stored as intermediate inventory, and configured-to-order once an order was received.

The redesign phase took a team of engineers six months to make changes and

train workers on the assembly line. The supply chain became vastly more efficient and service levels increased dramatically. Figure 1 is a representation of the supply chain after postponement.

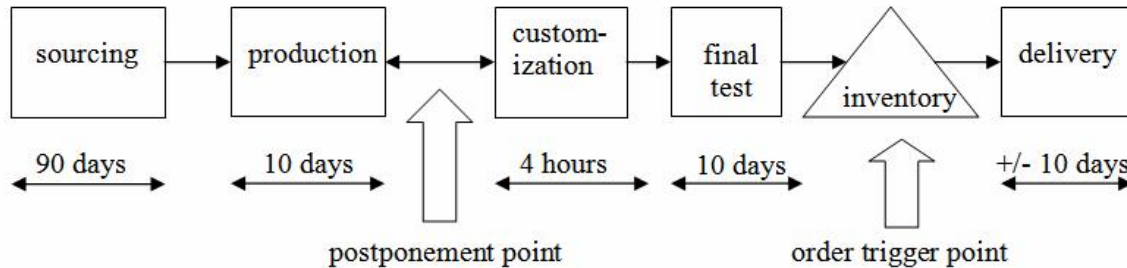


Figure 5-2: Dade Behring supply chain

At the point of postponement, an intermediate instrument is held in inventory awaiting a customer order. This allows DB to reduce customer lead time from roughly 20 days to four hours plus test and delivery time. In the testing stage the equipment must go through a standard process in which multiple cycles of different testing scenarios take place. Before delivery, the equipment is placed in buffer inventory waiting for shipment. The shipment of an instrument is a trigger for the replacement of that configuration in buffer inventory.

Customer service levels improved and inventory was significantly reduced by eliminating the need to store high value finished goods. Inventory across the supply chain was reduced through a 50 percent reduction in “buffer” or safety stock. Service levels went from oscillating between 70-100 percent to greater than 98 percent. Once DB was able to improve service time to customers they started looking at their distribution centers and found opportunities to improve distribution strategies, given the improved flow of instruments through the manufacturing process. Because the opportunity cost of a lost sale in this industry is very high, distribution centers would store finished goods as a way to mitigate the risk of instrument shipment delays. However, when service levels improved, DB found that they could eliminate 50 percent of their global buffer inventory by eliminating the stocking of instruments in distribution centers in Asia and Canada, and reducing inventory levels in Latin America. Their

primary instrument warehouses in the US and Europe service their global instrument distribution needs. The make-to-order and inventory management strategy provides DB with a decisive advantage in the industry.

This is a classic example of the benefits of the successful implementation of postponement. Because of this success, DB was able to continue developing postponement in other lines of instruments. Today, more than 85 percent of instrument production at DB involves some form of postponement compared to less than five percent five years ago. By redesigning the Dimension instruments to be easily adaptable for configuration, DB realized that the product could also be easily de-configured back to the intermediate stage to support the secondary market for instruments.

Finally, DB decided to look into reagents which are sold along with instruments for diagnostic purposes. Each reagent is very unique to the end customer and also requires compliance to the IVD Directive in Europe requiring language specific labeling and package inserts. DB is exploring various strategies to help manage this increasingly complex language issue. This is a potential area of opportunity for DB to focus its future postponement operations.

Getting companies to implement a postponement strategy sometimes requires outside forces to jumpstart the process, especially in a non-competitive industry. Some companies are unwilling to make the transition because of the implementation cost of switching warehouse and distribution centers to more of an assembly and packaging center. With this comes the cost of more skilled labor and the reorganization of warehouse space to provide an area dedicated to performing value-added services [25].

5.5 Reebok

As a licensed supplier for the NBA and NHL and principle supplier for the NFL, Reebok knows the difficulties that come with satisfying the demand of a very “fair weather” crowd. When teams do well more team apparel is demanded. This may or may not be the result of a specific player’s performance. The demand for a player specific jersey is inherently more volatile than for a given team. Meeting customer

requirements within a short period of time is a major challenge in the sporting goods industry.

According to the Sporting Goods Manufacturers Association (SGMA), the sporting goods industry witnessed \$55 billion in sales in 2004 with \$38.8 billion in apparel - up \$1.8 billion from 2003 [3]. This includes jackets, shirts, jerseys, and hats customized with team logos and players' numbers emblazoned on the front. Jim Keane, vice president and CFO of Reebok says hats are its most "stable" item [5]. Sales of t-shirts and jerseys, however, are not as predictable because Reebok does not know which teams will be "hot" at the beginning of the season. Demand for jerseys averages 30,000 per week or 1.5 million each year [33]. The different choices of team name, player name, color scheme, and size makes it extremely difficult to predict demand of an individual item during the pre-season.

The idea of postponement in this industry is not new. Images of silk-screen companies working overtime minutes after an NCAA basketball championship game or game seven of the World Series illustrates the idea of postponement. These manufacturers know that it is better to wait until there is certainty about the outcome of a game before producing apparel with the losing team's name on it. As a result they keep white or blank shirts on hand ready for printing. At this point in the supply chain it would not make sense to put in an order for finished shirts from scratch to an overseas manufacturer (even if it costs less to make the shirt). The long lead time would mean missing the increase in sales generated within two weeks after a big win [33]. This can be anything from an important mid-season upset, a new player entering the roster, players becoming "hot", or the end of season championships.

Reebok recognized this as an opportunity to restructure the supply chain to cater to both stable items - finished apparel that is produced to a forecast much earlier in the season, and customized apparel. The difference in the lead time for both of these items is significant. Retailers expect lead time to be 3-12 weeks for the stable items and as little as one week for the "hot" items [33].

Reebok outsources the cutting and sewing of fabric to contract manufacturers in Central America. Some of the jerseys sent to Reebok are finished meaning that

there is a customized team and player name already on the garment. Other jerseys, called “team finished” jerseys are sent with everything but a player’s name. These go straight to a distribution center that Reebok owns and operates in Indianapolis. The blank or team finished jerseys help satisfy two different types of demand. The first is for the hot players or players who sign with a team late in the pre-season and the second is for the players who have a small, but somewhat predictable demand.

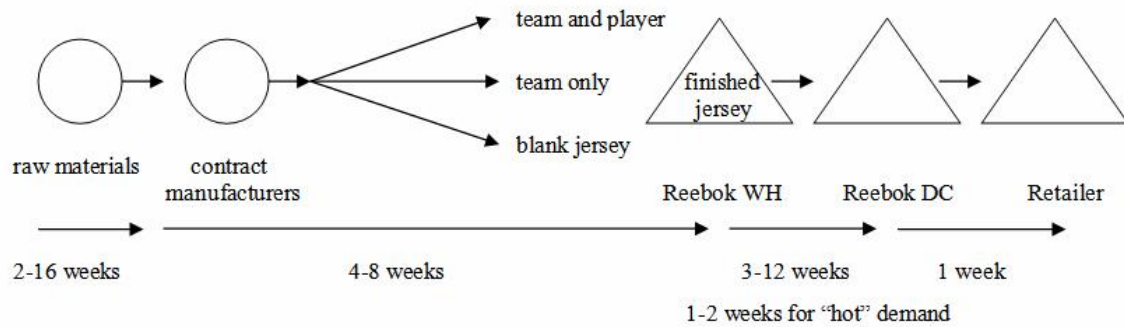


Figure 5-3: Reebok Supply Chain [33]

According to Figure 5-3 the blank jerseys arrive in the US and are ready for screen printing and embroidering. The Reebok finishing facility is the second largest of its kind in the US [33]. The decision to have a separate facility in the US is a result of the end customer’s unwillingness to wait. Fans expect to find the jersey they are looking for in a store. There is a chance they will be less likely to want one if they have to wait weeks to get it - especially when an NFL team only plays 16 games per season. At a price of \$25 for a long-sleeve t-shirt or \$250 for an authentic jersey, the cost of lost sales is greater than the cost to ship, unpack, finish and reship a jersey from a local finishing center.

Reebok provides a standard case of postponement based on customer willingness to wait. The fact that a spike in sales will occur within two weeks following a significant event means that goods must be available to send to retailers immediately. Reebok has carefully structured its supply chain to handle the different types of items based on customer demand patterns. There are two distinct phases between the time an order is placed and when it arrives at a retail store. Manufacturing the blank jerseys requires low-skilled labor that can be outsourced. In this case the manufacturing is

offshore in Central America. According to Keane it is not just the cost of labor that dictates the location. Quotas, duties, treaties, human rights regulation and distance all play a factor in the decision [5]. Keane also looks deeper at the supply chain; getting raw materials to their suppliers. If there is no fabric to sew, there will be no jerseys so sourcing of raw materials suppliers is also an issue of time and distance.

Reebok is a classic example of two-stage production with postponement. They are able to take advantage of lower labor costs for the production of blank jerseys and optimize service levels by sourcing the final assembly in the US. This also creates local jobs in the areas of textile and silk-screen printing.

5.6 Polaroid

The name Polaroid is synonymous with instant photography. Their product line includes digital cameras, printers, specialty identification and medical imaging devices, and of course, film. Film is considered a consumable product bought in bulk or customized packaged configurations which creates high variability for end products. The company's most popular instant color film is the 600/SX which is one of two SKUs used in 50-60 different photo imaging devices. Polaroid's customers include the major mass retailers; Wal-Mart, Target, K-Mart and drug stores; Walgreens, CVS, and Rite-Aid. Each has different packaging and security tagging requirements. "In the past five years we have been fully engaged in postponing to the greatest extent possible" said George Fotheringham, part of Polaroid's sales and operations planning group [15].

Film is a very seasonal product with the greatest demand occurring during the holiday and summer months. The variability of the different configurations of packages increases as the film reaches the end of the supply chain because of the different channels and different promotional activities that Polaroid participates in. "Given the capacity and variability it would be too expensive to offer the underlying volume of film so we build lots of 'core' film [not knowing] what kind of configuration it will take" explained Peter Spinney, Polaroid's director of logistics for the Americas [15].

Prior to postponement Polaroid film had a total lead time (from production to retail delivery) of four to six weeks. Within the US there was a network of workshops in Boston, MA that were committed to film configurations far in advance of shipment to the retailers. They have since consolidated their operations into a single facility in Norton, MA where generic product is brought in from their European manufacturing plant. At that point the facility holds approximately two weeks of inventory and configurations are made according to a short term forecast. Polaroid cannot make-to-order configurations of film “because our order patterns are usually a one-day turn around we stock to a forecast” [15]. The relocation of the distribution center at Norton has not affected the total production lead time of four to six weeks. The difference now is that three of those weeks are spent shipping the bulk film from Europe to the US where before it was manufactured and packaged locally. By keeping bulk inventory at the local level Polaroid’s customers do not experience the three weeks that are tied up in shipping overseas.

The European plant was chosen as the central manufacturing center because of available capacity. “We had very expensive film plants and we only had sufficient demand to support one and when we did the financial assessment we found that there was a greater financial savings but there was also a real estate recovery that was far greater for our US location than it would have been for Europe” [15].

Bulk film is considered a pack of 10 frames and is assembled into a “white box” which is not a shippable configuration. The white box is “the lowest common denominator” of one of 50-60 different packaging configurations i.e. 1, 3, 5, 10, or 20-packs of film. A simple configuration could be a packaged white box complete with graphics and security tags or any one of several multi-pack configurations. Once the bulk items are received, better information about the demand is known and there is less variability for each of the different configurations which are packaged and held in inventory.

In addition to the packaging of film, Polaroid looked at similar strategies with its other products. Polaroid cameras are manufactured in the Asia but all receive the same packaging in terms of color scheme, graphics, and model numbers. Only one

fourth of the products sent to Europe must receive additional language customization. The biggest challenge was to standardize the security tags for all customers. Each customer requires one of two different security tags - another level of customization and source of variability. Instead of postponing the addition of the security tags, Polaroid decided that it was worth the extra five cents per tag to include both. In this case Polaroid eliminated postponement all together using a strategy called “risk pooling.” Because the tags were so cheap it made sense to include both rather than incur the cost of retagging.

Polaroid has seen a positive return on investment since the postponement initiative was introduced. The costs included bringing unique equipment from the local manufacturing plant in the US and the outsourced workshops in Boston to a single facility in Norton. “Over the years we have added some technology but it was probably less than \$1 million worth of investment” [15]. Before postponement it used to cost nearly twice that amount in annual reconfiguration costs. “We didn’t realize that we were tearing down previously packaged product losing the labor and packaging associated with reconfiguring.” There was no change in inventory levels “it was more of inventory avoidance as opposed to an absolute reduction” [15]. “The really big benefit that we saw was we have very high customer fulfillment metrics now” [15]. Before, Polaroid was able to provide their film on time 70-80 percent of the time. That has since improved to 90 percent. Spinney estimates that the improvement was roughly 75 percent due to postponement efforts within the company.

Because of all the consolidation, Polaroid has seen an absolute decline in employment since postponement. However, there are a proportion of jobs that remained in the US which deal specifically with customization at the finishing center in Norton. “Because there are so many moving parts and our product is in a significant decline because of the digital era, our employment has reduced dramatically” [15]. Approximately 1,500-2,000 jobs were lost but not specifically sent offshore. “We used to have a very large manufacturing and film plant in the US, now we no longer have that. The remaining operations are nowhere near the numbers we employed making cameras. The film machines are highly automated customized equipment with ma-

chine operators and the cameras [require] a high level of automation and semi-skilled work” [15].

The bottom line is that the digital era has shifted demand away from film and into the camera and digital imaging equipment. What does remain in the film production line is highly automated equipment which has the potential to be located offshore. The same applies to camera manufacturing. “It was our demand patterns that dropped dramatically and we had to make a decision to drop plants. The number of jobs that we have in the postponement area are a fraction of the higher skilled, higher paid jobs that were eliminated due to demand” [15]. In other words, a fraction of the jobs that remained were associated with the postponement initiative indicating the need for a local physical presence of highly skilled workers.

When looking at the future of postponement at Polaroid, both Fotheringham and Spinney agreed that they have streamlined operations to the fullest extent possible and continue to focus on providing “what the customer wants.” Polaroid experimented with different kitting and coloring options for their cameras, however, they quickly realized that it was not worth the investment. Polaroid continues to look at Kodak and Gillette as a benchmark for further postponement research.

5.7 Bic

“Bic is making a significant move towards postponement because it is a competitive advantage” said Jim O’Brien, Director of Operations for consumer products at Bic [31]. There is a strong push towards using postponement as a way to differentiate product and react to the increasing pressure from customers to have products delivered quicker. This is adding to the complexity of operations and forcing large retailers and manufacturers to realize that “[they] are going to have to get really good at postponement in order to have that as a competitive advantage.”

The Bic product line includes lighters, razors, and stationary products. The customer is the biggest driver of postponement because they are not willing to wait for a consumable product like a razor or a pen and will buy another brand if a particular

one is out of stock. Therefore, any reduction in safety stock will result in lower sales. In order to remain competitive, Bic decided to postpone the packaging of its materials in order to improve order fill rates and keep inventory as low as possible without sacrificing service levels. As a result of customer demand, production lead time for most stationary products has been compressed to between six and eight weeks. Since packaging typically takes more time than production it offered the most potential for process redesign.

Before postponement there was an attempt to do all the customization and packaging at a single manufacturing point. “The early postponement strategy involved a lot of production to fast moving SKUs...it became fairly obvious that the customization and packaging was the choke point in the factory” [31].

There was a realization within the company that savings could be made by delaying this step even further by moving packaging and customization to localization centers in different countries. Bic currently operates manufacturing plants in the US, Europe, South America, and Asia with local distribution centers in Cerritos, CA and Charlotte, NC. The customization is done locally for all of North and South America while in Europe there is some consolidation of manufacturing and customization. This process involves the transfer of product from a bulk package to a customized package based on customer demand for personalized orders, promotional activities, and seasonal packaging.

The biggest benefit has been an overall simplification of the manufacturing process and the removal of bottlenecks in the facility. Designing the appropriate packaging to have the right density and protection in transit is difficult because the savings must exceed the cost to tear down and repackage the items. The bulk products are brought to the point of distribution, then torn down from their original package and repackaged into the appropriate lot sizes based on customer demand.

Since postponement, Bic has seen a growth in volume 10-15 percent each year over the past five years. They have shifted into more of a customized product industry with half of their products made-to-order (for promotional and personalized orders) and half made-to-stock. They have seen a trend where this ratio is expected to increase 20

percent each year in favor of make-to-order. Their suppliers are under a tighter time constraint when it comes to designing and approving the artwork for the customized packaging within the six to eight week lead time. With the initiation of several other initiatives at Bic, isolating the savings in cost specifically due to postponement is nearly impossible.

As mentioned earlier, Bic transitioned to postponement in order to respond to customer requirements for faster service and a differentiated product. They are not interested in postponing in their assembly process because their products “do not lend themselves to modular format” [31]. This case highlights the ability to practice postponement without an inherently modular product where the cost savings are primarily due to packaging postponement decisions. Local distribution centers in California and North Carolina emphasize the need for local storage of intermediate goods awaiting customization to support faster delivery times. This adds to the argument for the increased need for local employment to satisfy the growing expectation for faster service times.

5.8 McGraw-Hill

Buying text books that each cost between \$80-100 is a large investment over the course of a student’s collegiate experience. It is even more frustrating to buy a text book and only read parts of it, or worse, never open it at all. McGraw-Hill, one of several large publishers of educational text books recognized this problem as an opportunity and decided to start offering custom text publishing. The motive was very straight forward according to Ginny Moffat who runs the custom publishing for McGraw-Hill’s higher education division. “It started when professors started realizing that they did not cover everything in the text.” There are professors who do not feel like the right text book exists for their course. Instead of creating a course around a text book, professors want to create a text book to complement their course. From a financial perspective custom publishing is a way to deliver text books in an efficient and cost effective way so that students do not pay more for less, professors will be satisfied

with the content, and both can still have a book delivered in the same amount of time.

Custom publishing essentially follows the Dell model. The platform in this case is white paper and ink. The components consist of over 130,000 chapters, lab reports, cases, and readings available in an online database. Most of the content comes from traditional full-text McGraw-Hill books. All the customer has to do is log onto a website and select the chapters, articles, or cases that make up the text they wish to publish. An added feature is the ability to upload any personal or professional documents to include in the text. Anything that comes from another publisher requires permission which seems to be the only obstacle for customers as well as McGraw-Hill. However, the process is relatively easy and is even allowed between other text book publishers.

“Custom publishing has evolved dramatically over the past 15 years” [26]. The biggest evolution was the internet. Before the internet sales representatives carried around catalogues with samples of different offerings. Now, customers are able to see all the options through the internet. The advent of custom color publishing, however, has created some headaches. There has yet to be “efficient cost effective short run color printing...and we don’t see it in the foreseeable future” [26]. Traditional black and white printing experiences economies of scale when large orders are produced. With custom color printing economies of scale do not exist. This is because the entire color text has to be printed even if only a portion of the book is needed. Manual labor is required to physically separate the chapters and assemble them into a finished book. For McGraw-Hill, the cost of holding the remaining unwanted chapters in inventory is too high to justify and the unused pages are thrown out or recycled. The customer is still charged for an entire book even if selected chapters are used whereas the black and white printing is priced per chapter.

Another advantage of customizing text online is the increased attractiveness of e-books. “We can deliver an e-book in full color [and] we don’t have to print it, bind it, or ship it.” In 2005 over 200 custom books were available as e-books but this only represents a fraction of total sales. McGraw-Hill has approximately 60,000 hits per

year on their website by professors alone. Of that number 4,000-5,000 customers will build a text book based on what they see online. About 1,500 more customers do not find what they are looking for and create their projects with a sales representative. The minimum order requirement for black and white or e-books is just 10 copies. The cost of a customized text book can range from \$20 to over \$100 based on the amount of information and color used.

While the savings have come in the form of more succinct texts and less waste and printing costs, the increase in savings for their suppliers came from the cost of the manual labor required to sort and assemble the customized color texts. McGraw-Hill outsources their printing to approximately a dozen companies who specialize in either black and white or color printing.

McGraw-Hill did not experience a rise in sales specifically due to custom text offerings except in the color custom business. “Customization sales are growing at about double the growth rate of traditional books. But it isn’t typically new business, it’s just people realizing they can customize rather than order a traditional full text.” This fact is causing customization in text book publishing to be the standard, not a luxury. “If you want the business, you better be able to offer it in the format the customer wants be that color, custom, black and white, or an e-book” [26].

Looking forward McGraw-Hill is constantly trying to increase the offerings and services to their customers. They are now trying to decide how to address the inevitable demand for customized media and other technologies. “It has been an evolutionary process so we continue to try to address what the market wants and how we create that” [26].

5.9 Imation

Imation is a world leader in the removable data storage device industry. Their commercial product line includes CDs, DVDs, floppy disks, cassettes, data cartridges, and USB flash devices. They also specialize in high-end tape storage devices which are used by banks and financial institutions to store data, financial records, and insur-

ance information. Imation serves all the major office supply retailers such as Office Depot, Office Maxx, Staples, and Best Buy as well as consumer product retailers like Wal-Mart and Target.

Imation is a prime case study for postponement because it uses this strategy in multiple ways to maximize efficiency and flexibility throughout the supply chain. In 2001 data storage devices were becoming a commodity and Imation started looking for ways to differentiate within their supply chain. Additionally, the industry was plagued with long lead times, price erosion, and short product life cycles of three months or less. With an average total product lead time (from production to distribution) of 100 days, the company knew it needed to find ways to streamline its operations. Gillette's packaging strategy became the model from which Imation built its own postponement strategy. In addition to packaging, Imation realized that there was also value added in customizing products for some of its smaller customers. Therefore, they also looked into ways to postpone within the assembly process for both their high and low-end products [30].

Imation's supply chain is very decentralized with the main headquarters located in Oakdale, MN. Before postponement was implemented suppliers in Asia would manufacture the devices, a process that took anywhere from 30-45 days depending on the time of the month. The products were packaged at the point of manufacturing, placed in inventory, and shipped direct to customers. This process usually took between 40-50 days bringing total product lead time to 100 days. It was the realization of long product lead time coupled with short life cycles and price erosion that lead Imation to consider alternative methods for manufacturing and distributing their products.

Several changes were made to facilitate the transition to postponement. Imation began using suppliers in India instead of Asia despite the longer transit time to the US. "It was capacity along with cost and they [India] were also evolving the speed of their operations so that they could get the higher margins" [30]. This is a signal that shows how offshore manufacturers are beginning to compete for US manufacturing jobs by trying to offer faster turnaround - a source of competitive advantage for local

producers.

Part of the difficulty in choosing and keeping suppliers also had to do with taking away the value added step from the suppliers and requiring them to change the product design. “They like to be involved in the value added part because they probably generate more value for themselves...The second issue is that you need to get them to redesign the product and the way it is going to get shipped to you in more of a bulk pack. Otherwise you end up putting a lot more added cost into your product that you end up throwing away” [30].

The next step was to identify the postponement points for their wide variety of products. The solution was to have two distinct postponement points for the low-end commodity products. Imation saw that there was value added by offering the customization of disks and CDs for smaller customers such as private companies and universities who custom order media and data storage devices with a logo printed on them. Therefore, they created a secondary manufacturing plant in Oakdale where logo printing takes place.

The second postponement point occurs at the point of packaging. Products are shipped in bulk to a packaging center in Kansas City, MO where different size packages are assembled-to-order. By having two postponement points Imation has been able to delay adding value at several steps until more information about customer demand is known. The result has been less obsolescence, lower inventory costs, and the creation of new domestic job opportunities.

Manufacturing for all of the high-end products (tape libraries and large data storage devices) takes place in the US because of the location to the customer and an unwillingness to wait for manufacturing offshore. Imation holds inventory of these high margin items but adds labels and initializes the tapes for a specific customer order. In this case it is the customer which drives the location of the business as well as the level of inventory.

Before implementing postponement, strategists at Imation built a model to help quantify the benefits and costs associated with changing their operations. Expenses for the company came in three areas: faster shipping methods, obsolescence, and

increased inventory cost as a result of price erosion. “The model looks at all the components and says, ‘based on this type of price erosion and life cycle, this is the amount of postponement you should do.’ The supply chain team and finance can plug those figures in and then we do a calculation and say ‘ok, based on these criteria, this is the best solution for us.’ We are trying to minimize the total delivered cost instead of the total unit cost” [30]. As a result, manufacturing cost increased and there was resistance from suppliers because Imation wanted to assume more responsibility for the value-added process, or customization.

Getting management support was difficult because they would see cost increases in manufacturing. However, realizing that they minimized total delivered cost, Imation saw their inventory turns double and transportation costs offset by the ability to ship products to the US in bulk instead of in packaged form. In addition, market share for products that are not postponed is anywhere from 10-15 percent as opposed to 80-90 percent for those that are postponed.

In further developing their postponement strategy, Imation uses caution because some products do not require postponement activities in order to be profitable. It is a combination of market price and life cycle changes that dictate whether or not postponement is a viable option [30]. Using the model is helpful to understand the extent to which Imation should postpone. “It’s not a fixed number. We look at all these variables and our number will fluctuate. We are less likely to postpone items at the launch of a new product” [30]. Postponement assumes certain characteristics about demand and market factors. At product introduction some deficiencies of the product may not be visible until the maturity phase. Decisions on sourcing are not final until the market reacts to competition and suppliers are strategically chosen based on customer willingness to wait.

Imation highlights the benefits that come from postponing at various stages in a product’s total lead time. The case emphasizes that increased costs in manufacturing are inevitable and the importance of minimizing total product cost instead of unit cost. It also points out the importance of timing when implementing postponement. Allowing a product to reach maturity may prove to be a better overall approach in

order to determine whether demand characteristics even support such a move.

5.10 Solutia

Solutia is a chemical company specializing in films, glass, chemicals, nylons and fibers. Established as an independent company in 1997, Solutia has grown into a \$3 billion company with over 9,000 employees with 35 manufacturing sites in over 30 countries. Corporate headquarters is located in St. Louis where Wing Kwang works as the world-wide product manager for the laminated glazing interlayer business. This product, more commonly referred to as PVB (polyvinyl butyral) is a special adhesive film that is put between layers of glass in order to prevent shards from separating upon impact. Glass products which require this interlayer are car windshields and windows on high-rise buildings and store fronts.

PVB is manufactured in rolls, much like a roll of toilet paper. Variability comes from the width of these rolls as well as the color or tint. Bulk rolls of 200-500m are sent to a finishing center in Singapore where customized rolls are cut according to aggregated demand forecasts. “We essentially make it into a spiral role. All the specifications are different. Some of them have a tint and all have different width sizes” [19].

PVB is used in industrial, retail, and sky-rise windows, wood coatings, ceramics, automobile windows, and other adhesives. Solutia customers include American, European, and Asia-Pacific car manufacturers. American and European customers tend to be more stable with the dimensions and demand for PBV, however, the Asia-Pacific region has more inherent variability because they are constantly changing the specifications for their automobiles. For this reason, and the fact that Asia represents their second highest market share, Singapore was chosen as the location for the finishing center.

At the finishing center bulk rolls are received and then cut into different dimensions. The width is defined as the measurement from the dash board to the roof of the car. Each make of car generally has different specifications making each width

of PVB a different SKU. There is a salvage value for a roll that is unused because it can be melted and formed back into bulk PVB. However, Solutia tries to avoid this as much as possible because of the high cost to reconfigure.

Because of the unstable demand from Asia and the cost of recycling, Solutia created the Flexible Inventory Program by consolidating several different SKUs. For example, a customer requiring a roll of width 83cm will receive one that is 85cm but still be charged the 83cm price. They are able to do this because the cost to supply a roll that is slightly larger is offset by the cost to recycle and reconstruct a roll in a new dimension. By creating rolls in increments of 5-10cm they are able to aggregate demand, reduce the number of orders that are sent back, and improve customer service levels. Total lead time was reduced from two months in an essentially make-to-order environment to one week plus shipment time.

Solutia provides a simple case of product postponement and risk pooling. The two-stage production process allows finishing operations to occur close to their main market and eliminates inventory at the manufacturing site. By providing a standard list of dimensions instead of cut-to-fit customization, they were able to eliminate waste and push risk onto the customers. It is one more example of a need for local jobs to provide this final level of customization.

5.11 Xilinx

Xilinx is a semi-conductor manufacturer with headquarters in San Jose, CA. The semi-conductor industry is very volatile due to the wide variety of products and short product life cycle. Semi-conductors manufacturers are suppliers to OEMs in the telecom, small electronics, and aerospace industries. However, they have a supply chain of their own which requires assembling and configuring wafers of silicon into programmable dies which later become integrated circuits. Their position in this multi-echelon supply chain makes forecasting for specific end product demand costly, impractical, and very inaccurate. In addition, semi-conductor manufacturing is quickly becoming a commoditized process. Comparative intellectual and techno-

logical benefits that leaders in this industry were accustomed to are now becoming less of a competitive advantage. The focus has shifted from intellectual advantage to supply chain efficiency as a means of differentiation [10].

The life cycle for an integrated circuit is anywhere from six months to two years. During that time new technology will make existing products obsolete. Having long manufacturing lead times cripples a company's ability to quickly respond to these changes as well as changes in customer specific orders. Having a generic product and creating a postponement point separating a die with generic qualities and one with a specific logic configuration allows them to respond quickly and offer flexibility to their customers.

Xilinx began with a combination of both process and product postponement. Product postponement was implemented by redesigning the dies to a certain range of parameters for the different characteristics. For example, there are four major sources of variety in an integrated circuit; speed, number of logic gates, package types, and voltage. Customers can specify generic capabilities and can customize the chip to their specific specifications after the fabrication stage.

"Product postponement is very suitable for programmable devices because a near-infinite number of varieties can be created from a few thousand physical-product permutations" [20]. The amount of variety makes postponement very beneficial. Xilinx can manufacture 200 different dies that can proliferate into over 4,000 different end product combinations. That makes the ratio of generic dies to end products roughly 1:20 [17].

The manufacturing process is broken up into two stages. Suppose a certain generic die, A, can be configured to take on 20 different configurations, $\{A_1, A_2, A_3, \dots, A_{20}\}$. When a customer requests the specifications, they only need to specify the generic die. Once it is pulled from "A" inventory, it is customized to a certain degree depending on customer order specifications. This specification can take place at Xilinx for high volume orders or it can be delayed even further so that the point of customization occurs at the customer. Approximately 20 percent fall into the high volume category and the remaining 80 percent are left for customization at the customer.

The final customization is a matter of programming the software within the chip. By eliminating this process from the front end (manufacturing) process, Xilinx cut manufacturing lead time from three months to three weeks. Manufacturing usually takes place in Taiwan or Japan and then product sits in inventory at Xilinx awaiting testing. Testing facilities are located in Korea, Taiwan, and Japan. According to Jiang, this step was not always outsourced overseas. Assembly and testing first took place in San Jose until Xilinx started to take advantage of cheaper labor and the educational capital found in Ireland and, most recently, Asia in 2004 [17].

While postponement has reduced inventory and helped Xilinx meet customer requirements with more accuracy and on-time deliveries, it is just the beginning. Jiang forecasts that postponement within the semiconductor industry will extend far beyond customer configuration capabilities. He believes that companies such as Comcast, will be able to change the logic of a given circuit from a remote location taking the responsibility away from the customer completely.

Chapter 6

A summary of case studies and analysis

The case studies presented in this thesis come from a wide variety of industries. Each company was successful in implementing postponement for similar reasons but have seen a wide variety of results. The most common strategic motivations for starting postponement were to improve service level and to reduce inventory holding cost as a result of an increase in product variety.

Postponement strategies start with the goal of minimizing one metric and often result in improvements in other areas. Figure 6.1 shows a list of the primary drivers of postponement for each company and the primary resulting benefits.

Another key factor in successful implementation is product modularity. Black and Decker took advantage of common housings for power supplies in order to streamline the assembly process. Custom text books and electronics are also cases of the use of module assembly. If a product is not inherently modular, a successful postponement strategy requires a redesign of the product or a rethinking of product definition. In the cases of small consumables, the end product is not a razor blade or a disk, but rather a finished configured package destined for a particular retail outlet. Dade Behring realized that they had to reengineer their RxL diagnostic equipment line to take advantage of product postponement using a common platform. Honda did the same when they created a flexible chassis.

Table 6.1: Primary drivers and benefits of postponement

Company	Primary Driver(s) of Postponement	Primary Benefits
GM	inventory cost product variety	service levels inventory reduction maintenance costs
Honda	product variety	manufacturing cost reduction
Embraer	reconfiguration costs	service levels
Dade Behring	inaccurate forecasts inventory cost	inventory reduction service levels lead time reduction
Reebok	inventory cost	lead time reduction
Polaroid	reconfiguration costs	service levels lead time reduction reconfiguration costs
Bic	inventory cost long lead times	service levels sales volume increase
McGraw-Hill	product variety	more accurate forecasts
Imation	long lead times price erosion short product life cycles	lead time reduction more accurate forecasts
Solutia	reconfiguration costs	reconfiguration costs service levels
Xilinx	product variety short product life cycles	service levels

The relationship between forecast variability and the decision between a make-to-stock or a build-to-order strategy is also a commonality among the cases. Products with stable demand stand to gain little from a postponement strategy because there is little benefit for delaying production when sales are committed. On the other hand, products with high variability gain from postponement because there is no commitment to final configuration until the order is placed. Lantis eyewear is a case of a mis-used postponement strategy. When the company realized that postponement would hedge against the variability in demand they started postponing the addition of security tags, UPC labels, and pricing for all product lines to each of their different customers. However, the backlog at the postponement point prevented them from shipping anything on time. After an assessment of the operations and needs of their customers they stopped postponing the items to their top eight customers because the demand was predictable and because of high turnover. For the more volatile items, postponement proved to be a cost-effective solution. The optimal strategy with the appropriate product/postponement mix reduced lead time by 50 percent to less than 24 hours for their larger accounts and to within five days for their second-tier customers [25].

A company should determine the location of variability when deciding to implement postponement. Variability can be caused by product variety, reliability of customer orders, seasonality, trends, promotional activities, or it can be a result of the supply chain itself. Variability is often inflated up stream in a supply chain, otherwise known as the bullwhip effect. If the variability is caused by product variety then assembly postponement with intermediate product inventory is needed. If variability is caused by market characteristics such as location, retail or national standards, or language, then a packaging postponement strategy is needed. If variability is caused by the distribution of finished products to end customers, then logistics postponement which uses a centralized warehouse is needed.

Perhaps one of the more valuable metrics for determining a product's postponement potential is the customer's willingness to wait. This is somewhat difficult to measure because it is not only different among products, it is also dynamic and unique

to the customer. Willingness to wait can depend on market expectations but it is also dependant on the reason customers purchase an item. As a general statement, consumers buying commodity products tend to have low willingness to wait because of the many options and availability of similar products. However, “In some situations, customers do not favor the speed of delivery and are even willing to sacrifice benefits such as short waiting time for more options” [27]. In other words, the more customized and specific a product, such as a personal computer or custom designed clothing, the more the customer is willing to wait. In the former case the postponement point will occur further downstream in the supply chain while in the latter it will occur further upstream.

Finally, there is no single strategy for determining postponement potential that extends across all industries. The decision must be made at the product level according to specific metrics measuring demand, inventory costs, turnover, and lead time constraints. Different companies are better able to transition to a postponement strategy if their product is modular and they can see the benefits in total delivered cost instead of total unit cost. A truly robust framework of this nature is not possible without accurate and adequate data of product characteristics and data quantifying the costs and benefits of both successful and unsuccessful attempts at postponement. Companies looking to start a postponement strategy will most likely use a benchmark company, like Dell (assembly postponement), HP (labeling/distribution postponement) or Gillette (packaging postponement) to help determine what factors facilitate postponement within the production process. Studying more cases to create a framework is the next step in determining any product’s postponement potential.

Chapter 7

The future of postponement

7.1 Services and postponement

Service employment has exceeded manufacturing since the 1970s [32]. The innovation of product-service interaction looks at delivering a solution to a problem rather than just a product. Once the product is purchased the value of additional service is applied creating another postponement point past the point of sale. Customers will pay for different “packages” of products and services depending on the amount of service that they want.

In Figure 7-1, the different circles represent processes within a simple supply chain. Points of differentiation as well as opportunities for outsourcing can occur at each of the six steps. Services as an additional means for differentiation are inherently postponed until the customer chooses which options best meet their needs. Adding

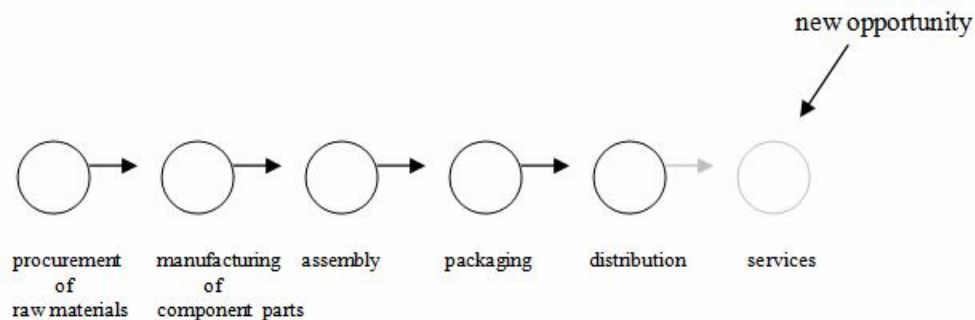


Figure 7-1: Creation of new postponement opportunity in services

services can be an additional way to add value to a product which simultaneously can increase a customer's willingness to wait.

Some services reflect the need of a person to perform a physical activity i.e. maintenance, delivery, diagnostic, and support activities. Others can be done by the consumer if they possess the tools, knowledge, and time to complete the service. Services around an automobile include warranty options, maintenance services, oil changes, and tune-ups. All of these functions are necessary hassles of car ownership and people are willing to pay to have them done by someone (or something) else. By coupling service options with a product and creating a unique product-service bundle, the consumer is no longer buying a car they are buying a function; in this case, mobility.

ChemStation of Dayton, OH is a case of product-service bundling. ChemStation provides companies with soap for industrial purposes such as cleaning factory floors and equipment. However, ChemStation customers do not purchase soap, they purchase the ultimate "soap service." Instead of just delivering the product ChemStation custom blends the right formula, monitors their soap usage and storage levels, and replenishes it according to usage. This eliminates the need for in-house personnel to concern themselves with monitoring soap levels. "They only know - and care - that the soap works and is always there when they need it" [36]. Because there are different service options, there is also a new level of product variety created for the consumer.

Just as goods are customized to form services, services customized to form experiences will be the new economic offering in the US according to Pine and Gilmer [36]. "Experiences" are the new frontier for business opportunity because they reflect a new customer need - the need to group services and products in a theatrical and entertaining way which engages the senses. Experiences can be looked at as another form of postponement because products and services have been commoditized and customization does not happen until the customer is engaged in the experience. Since no two people can have the same experience, experiences allow the amount of variety available to customers to be infinite as shown in Figure 7-2.

Experiences, like services, are inherently interactive. Engaging the senses re-

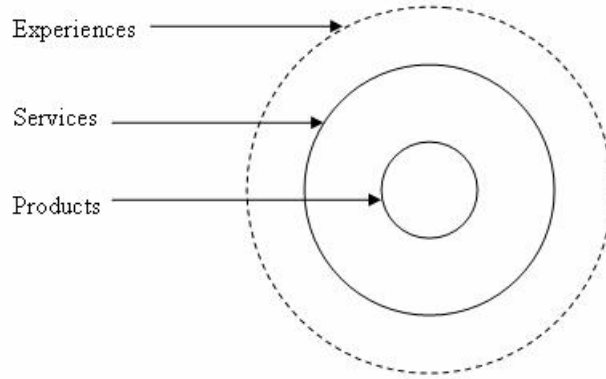


Figure 7-2: Boundaries of variety for different economic offerings

quires a physical proximity to the products and services that create the experience. More opportunities for employment in experience are created every time an industry transitions into the business of offering people an experience rather than a product. Examples of experts in the “experience economy” are theme parks, casinos, movie theaters, restaurants, shopping malls, and Starbucks. Anywhere people are willing to pay extra for an otherwise commodity product, like a souvenir, means that they value the unique experience that comes with it. This economic offering has the potential to add jobs to the economy because it is very hard to stage an experience from China.

7.2 Postponement and outsourcing

Postponement offers a way for the US to capitalize on its comparative advantage of providing quick response. Separating a production cycle into core vs. non-core processes helps companies make the decision when it comes to strategic sourcing of overseas suppliers and manufacturers. When assessing a product for postponement companies should also consider the following characteristics; customer willingness to wait, product modularity, demand variability, product variety, and service requirements. Of these characteristics, modularity, demand variability, and product variety are product-specific. Customer willingness to wait is a market characteristic which describes the immediacy of a customer’s needs. It is the most significant characteristic when determining the structure of the supply chain because it sets limits on

the length of finishing lead time. Products for which customers are not willing to wait are commodities or products in a competitive market where there are lots of options for a customer to get what he/she wants based on quality and availability. On the other hand, customers are willing to wait more for a good that is customized to meet their needs. This allows manufacturers some flexibility when determining the length of finishing time. If the customer sets a willingness to wait limit, one way the manufacturer can buy more time is by adding more customization.

Knowing the finishing time, a company now has constraints for sourcing. Reebok understood that silk-screen printing could be cheaper in Central America where the blank jerseys are made. However, the cost of lost sales and sacrifice in customer service they would incur from the longer lead time was more than the cost of operating the finishing facility in the US.

According to Amy Swotinsky, Director of Product Marketing for Optiant, companies feel pressure to offshore for three main reasons [43]. The first is to reduce the cost of goods sold. This is usually directly associated with low cost labor. Dr. David Anderson, author of *Build-to-Order and Mass Customization*, suggests that instead of only looking at labor cost, companies should evaluate labor productivity [7]. The wage rate in a foreign country may be lower than the US, but paying more workers less money does not always equate to lower overall cost of labor.

The second reason companies are outsourcing operations overseas is to expand their market influence and take advantage of an increase in capacity. Many times the hidden costs to open operations in a foreign country are not overcome by the increase in sales generated in the new market. Mike Kilgore of CHAINalytics cites a lack of understanding of “activity based costing” as a common flaw in outsourcing decision making. “There is often a fairly crude analysis of inventory impact...Total delivered cost is constantly changing” and companies need a dynamic cost model in order to continuously evaluate those changes [18].

The third reason for outsourcing is to gain access to local markets. This move is designed to place products in markets where the potential for profit outweighs the complexity that is added to the supply chain. More and more companies are

offshoring portions of their supply chains simply because other companies are doing it according to Jay Burkholder, Director of Product Management at Opitiant [12]. In these cases inefficiencies may exist where the complexity of offshoring does not fix problems, it only makes them worse. Trying to optimize an inefficient supply chain will often result in higher costs because companies fail to look at the total cost to produce a good. Anderson highlights the dangers of adding complexity into a system of mass customization,

Creating great distances in supply chains slows down the flow of parts and products in addition to eliminating the benefit of any flow in plants at either since everything has to be batched and shipped. This problem might have not been noticed in the mass production era of large batched forecasted production but will become the ‘weakest link in the chain’ for quick response [7].

As a solution he suggests that “local production for local consumption” is the most efficient means of combining postponement and offshoring. This involves build-to-order and mass customization strategies designed to mass produce standard products to a forecast and then ship them to their local markets where they are finished according to updated forecasts or specific customer demand signals.

There are two ways to accomplish local production for local consumption. US companies can source the manufacturing overseas and bring the product back on shore for localization. This eliminates US manufacturing jobs while keeping labor associated with the finishing process and service interaction. The other option is for US companies to manufacture intermediate products and send them out to the local markets for final assembly and customization. This option keeps manufacturing and R&D onshore but eliminates the work of final packaging and assembly. The choice is made based on the location of the final customer. In either case, however, there will always be a need for local services in order to maintain the products at the customer level.

The left side of Table 7.2 lists the benefits of postponement alongside the risks assumed by sourcing offshore. Some of these costs can be mitigated by a successful

Table 7.1: Offshoring costs and postponement benefits

Offshoring Costs	Postponement Benefits
increased lead time	increased customer satisfaction
increased transportation cost	reduced transportation cost
longer pipeline	reduced inventory cost
loss of control	improved order fill rate
increased overhead	better forecast accuracy
loss of intellectual property	risk minimization
increased complexity	

postponement strategy. For example, because offshoring assumes a longer lead time postponement can help by using a two-stage production process to facilitate quick response. Similarly, the increased transportation cost can be mitigated by postponing weight or volume-added processes until the product reaches the final destination. All of these processes involve differentiating “flexible v. planned production” and “core v. non-core processes.” Typical products for outsourcing include the non-core products or processes which require labor intensive manufacturing and have a relatively predictable aggregated demand. Products typical for onshore production include those with high intellectual property, short lead times, and unpredictable demand.

Imation provides an example where postponement and outsourcing are combined in a cost effective manner. Imation outsources the non-core process of manufacturing the basic products - CDs, disks, and small data storage devices to India. They are shipped to the US and packaged by a local third party logistics provider. Imation’s core competency is coordinating the operations and providing a brand name label. Imation was able to transition their operations to take advantage of offshore labor costs while at the same time provide quick response for their local market through postponement.

Chapter 8

Conclusion

As companies start embracing postponement and realizing the benefits of mass customization there will be a transformation in the way consumers do their shopping. Fewer people will need to visit a store when online shopping becomes the fastest way to get a customized product. Product variety will also continue to increase based on new technology and customer expectations.

Finally, more jobs are being created at the local distribution level where customization takes place and labor is required to provide service close to the customer. While postponement is a new concept for some companies it is now the standard for those who have seen its benefits. Postponement has proven itself as a valuable strategy for addressing the inevitable uncertainty of customer demand. Mike Kilgore of CHAINalytics estimates that “80 percent of companies are doing postponement at some level and 80 percent of those are just getting their feet wet” [18]. The biggest inhibitor he sees is overcoming the cultural manufacturing mentality that prohibits marketing and sales from effectively analyzing the trade-offs of postponement. In the future, it will no longer be a question of whether postponement is the right strategy, but rather how the supply chain will change in order to take advantage of cost saving strategies like postponement, the attractiveness of offshore employment, and the impact that will have on customer satisfaction.

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