GLOBAL EDITION

Supply Chain Management

Strategy, Planning, and Operation

FIFTH EDITION

Sunil Chopra • Peter Meindl

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Fifth Edition

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Kellogg School of Management

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Dedication

I would like to thank my colleagues at Kellogg for all that I have learned from them about logistics and supply chain management. I am grateful for the love and encouragement my parents, Krishan and Pushpa, and sisters, Sudha and Swati, have always provided during every endeavor in my life. I thank my children, Ravi and Rajiv, for the joy they have brought me. Finally, none of this would have been possible without the constant love, caring, and support of my wife, Maria Cristina.

—Sunil Chopra

I would like to thank three mentors—Sunil Chopra, Hau Lee, and Gerry Lieberman—who have taught me a great deal. Thank you also to my parents and sister for their love, and to my sons, Jamie and Eric, for making me smile and teaching me what life is truly all about. Most important, I thank my wife, Sarah, who makes life wonderful and whom I love with all of my heart.

—Pete Meindl

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Sunil Chopra is the IBM Distinguished Professor of Operations Management and Information Systems at the Kellogg School of Management. He has served as the interim dean and senior associate dean for curriculum and teaching, and the codirector of the MMM program, a joint dual-degree program between the Kellogg School of Management and the McCormick School of Engineering at Northwestern University. He has a Ph.D. in operations research from SUNY at Stony Brook. Prior to joining Kellogg, he taught at New York University and spent a year at IBM Research.

Professor Chopra's research and teaching interests are in supply chain and logistics management, operations management, and the design of telecommunication networks. He has won several teaching awards at the MBA and Executive programs of Kellogg. He has authored more than 40 papers and two books.

He has been a department editor for *Management Science* and an associate editor for *Manufacturing & Service Operations Management*, *Operations Research,* and *Decision Sciences Journal*. His recent research has focused on understanding supply chain risk and devising effective risk mitigation strategies. He has also consulted for several firms in the area of supply chain and operations management.

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The first edition of this book won the prestigious Book of the Year award in 2002 from the Institute of Industrial Engineers.

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Part II Designing the Supply Chain Network

Part III Planning and Coordinating Demand and Supply in a Supply Chain

PREFACE

This book is targeted toward an academic as well as a practitioner audience. On the academic side, it should be appropriate for M.B.A. students, engineering master's students, and senior undergraduate students interested in supply chain management and logistics. It should also serve as a suitable reference for both concepts as well as methodology for practitioners in consulting and industry.

NEW TO THIS EDITION

The fifth edition has focused on building on the changes that were incorporated in the fourth edition. We have also added changes based on specific reviewer feedback that we believe significantly improve the book and its use by faculty and students.

- We have added several new mini-cases throughout the book. New cases appear in Chapters 3, 5, 6, 12, and 14. Information in other cases has been updated to be current.
- For numerical examples discussed in the book, we have spreadsheets that students can use to understand the concept. The spreadsheets provide the details of the example discussed, but are live which allows the student to try different what-if analyses. These spreadsheets are available at www.pearsonglobaleditons.com/chopra.
- In Chapter 3, we have added a section on financial metrics and ratios and linked these to the different supply chain drivers and metrics. This chapter allows a faculty member to position the supply chain management as it directly impacts the financial performance of the firm. We have also added a supporting mini-case with which students can dig into Walmart's financials in detail.
- We have enhanced Chapter 6, which focuses on designing global supply chains. In particular, we have included a detailed example in Section 6.6 that looks at the onshoring/offshoring decision as a real option in the context of uncertainty.
- Supply chain coordination (Chapter 17 in the fourth edition) is now part of the module on "Planning and Coordinating Demand and Supply in the Supply Chain." Based on reviewer feedback, we decided it was appropriate to include the collaboration and coordination discussions with the forecasting and sales and operations planning discussions.
- In Chapter 7, we have enhanced the discussions on forecast errors and selecting the best smoothing constant.
- In Chapter 8, we have enhanced the discussions on identifying the aggregate unit and then disaggregating the aggregate plan.
- In Chapter 9, we now have a spreadsheet that allows students to work through the entire sales and operations planning process for the example presented. Spreadsheets are available that allow students to build every table shown in Chapters 7–9.
- In Chapter 11, we have added numerical examples supporting the entire discussion on the rationale for quantity discounts. Supporting spreadsheets are provided for students.
- In Chapter 12, we added numerical examples supporting the value of postponement discussion and a mini-case investigating a decision to potentially postpone packaging.
- In Chapter 13, we have also enhanced and highlighted the discussion on tailored postponement.
- In Chapter 14, we have enhanced the quantitative examples which support the qualitative discussion on the design of transportation networks. Students will also have live spreadsheets available to use with these examples.
- In Chapter 15, we have enhanced the discussion on risk sharing and supply chain contracts. Students will also have live spreadsheets with which they can evaluate different risk-sharing options. The chapter also contains an enhanced discussion of tailored sourcing when designing a supplier portfolio.

- A new Chapter 18 focuses on sustainability and the supply chain.
- We have added current examples throughout the book with a particular focus on bringing in more global examples.

The book has grown from a course on supply chain management taught to second-year M.B.A. students at the Kellogg School of Management at Northwestern University. The goal of this class was to cover not only high-level supply chain strategy and concepts, but also to give students a solid understanding of the analytical tools necessary to solve supply chain problems. With this class goal in mind, our objective was to create a book that would develop an understanding of the following key areas and their interrelationships: the strategic role of a supply chain, the key strategic drivers of supply chain performance, and analytic methodologies for supply chain analysis.

Our first objective in this book is for the reader to learn the strategic importance of good supply chain design, planning, and operation for every firm. The reader will be able to understand how good supply chain management can be a competitive advantage, whereas weaknesses in the supply chain can hurt the performance of a firm.

Within the strategic framework, we identify facilities, inventory, transportation, information, sourcing, and pricing as the key drivers of supply chain performance. Our second goal in the book is to convey how these drivers may be used on a conceptual and practical level during supply chain design, planning, and operation to improve performance. We have included a case on Seven-Eleven Japan that can be used to illustrate how the company uses various drivers to improve supply chain performance. For each driver of supply chain performance, our goal is to provide readers with practical managerial levers and concepts that may be used to improve supply chain performance.

Utilizing these managerial levers requires knowledge of analytic methodologies for supply chain analysis. Our third goal is to give the reader an understanding of these methodologies. Every methodological discussion is illustrated with its application in Excel. In this discussion, we also stress the managerial context in which the methodology is used and the managerial levers for improvement that it supports.

FOR INSTRUCTORS

Instructor's Resource Center

REGISTER. REDEEM. LOGIN. www.pearsonglobaleditions.com/chopra, instructors can access a variety of print, media, and presentation resources that are available with this text in downloadable, digital format.

NEED HELP? Our dedicated Technical Support team is ready to assist instructors with questions about the media supplements that accompany this text. Visit http://247.pearsoned.com/ for answers to frequently asked questions.

INSTRUCTOR'S SOLUTIONS MANUAL This manual contains sample syllabi, chapter lecture notes, and solutions to all the end-of-chapter questions. The solution spreadsheets are provided in Microsoft Excel.

TEST ITEM FILE The file contains true/false questions, multiple-choice questions, and essay/problem questions.

POWERPOINT SLIDES These slides provide the instructor with individual lecture outlines to accompany the text. The slides include many of the figures and tables from the text.

FOR STUDENTS

The following material is available to students at www.pearsonglobaleditions.com/chopra:

- Spreadsheets for numerical examples discussed in the book. These provide the details of the example discussed, but are live and allow the student to try different what-if analyses.
- Spreadsheets that allow students to build every table shown in Chapters 7–9.

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1

Understanding the Supply Chain

LEARNING OBJECTIVES

After reading this chapter, you will be able to

1. Discuss the goal of a supply chain and explain the impact of supply chain decisions on the success of a firm.
2. Identify the three key supply chain decision phases and explain the significance of each one.
3. Describe the cycle and push/pull views of a supply chain.
4. Classify the supply chain macro processes in a firm.

In this chapter, we provide a conceptual understanding of what a supply chain is and the various issues that need to be considered when designing, planning, or operating a supply chain. We discuss the significance of supply chain decisions and supply chain performance for the success of a firm. We also provide several examples from different industries to emphasize the variety of supply chain issues that companies need to consider at the strategic, planning, and operational levels.

1.1 WHAT IS A SUPPLY CHAIN?

A *supply chain* consists of all parties involved, directly or indirectly, in fulfilling a customer request. The supply chain includes not only the manufacturer and suppliers, but also transporters, warehouses, retailers, and even customers themselves. Within each organization, such as a manufacturer, the supply chain includes all functions involved in receiving and filling a customer request. These functions include, but are not limited to, new product development, marketing, operations, distribution, finance, and customer service.

Consider a customer walking into a Wal-Mart store to purchase detergent. The supply chain begins with the customer and his or her need for detergent. The next stage of this supply chain is the Wal-Mart retail store that the customer visits. Wal-Mart stocks its shelves using inventory that may have been supplied from a finished-goods warehouse or a distributor using trucks supplied by a third party. The distributor in turn is stocked by the manufacturer (say, Procter & Gamble [P&G] in this case). The P&G manufacturing plant receives raw material from a variety of suppliers, who may themselves have been supplied by lower-tier suppliers. For example, packaging material may come from Pactiv Corporation (formerly Tenneco Packaging) while Pactiv receives raw materials to manufacture the packaging from other suppliers. This supply chain is illustrated in Figure 1-1, with the arrows corresponding to the direction of physical product flow.

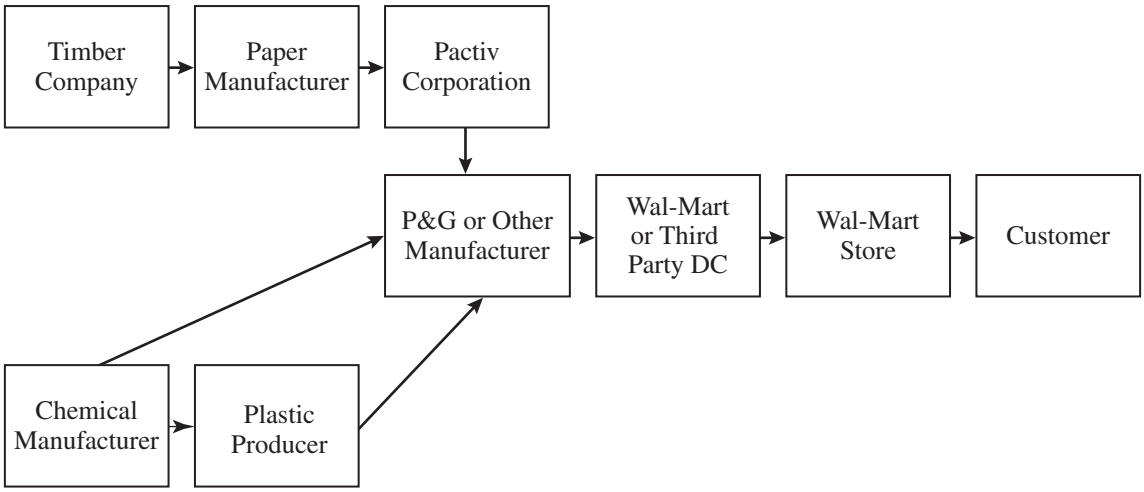

FIGURE 1-1 Stages of a Detergent Supply Chain

A supply chain is dynamic and involves the constant flow of information, product, and funds between different stages. In our example, Wal-Mart provides the product, as well as pricing and availability information, to the customer. The customer transfers funds to Wal-Mart. Wal-Mart conveys point-of-sales data as well as replenishment orders to the warehouse or distributor, who transfers the replenishment order via trucks back to the store. Wal-Mart transfers funds to the distributor after the replenishment. The distributor also provides pricing information and sends delivery schedules to Wal-Mart. Wal-Mart may send back packaging material to be recycled. Similar information, material, and fund flows take place across the entire supply chain.

In another example, when a customer makes a purchase online from Dell Computer, the supply chain includes, among others, the customer, Dell's Web site, the Dell assembly plant, and all of Dell's suppliers and their suppliers. The Web site provides the customer with information regarding pricing, product variety, and product availability. Having made a product choice, the customer enters the order information and pays for the product. The customer may later return to the Web site to check the status of the order. Stages further up the supply chain use customer order information to fill the request. That process involves an additional flow of information, product, and funds among various stages of the supply chain.

These examples illustrate that the customer is an integral part of the supply chain. In fact, the primary purpose of any supply chain is to satisfy customer needs and, in the process, generate profit for itself. The term *supply chain* conjures up images of product or supply moving from suppliers to manufacturers to distributors to retailers to customers along a chain. This is certainly part of the supply chain, but it is also important to visualize information, funds, and product flows along both directions of this chain. The term *supply chain* may also imply that only one player is involved at each stage. In reality, a manufacturer may receive material from several suppliers and then supply several distributors. Thus, most *supply chains* are actually networks. It may be more accurate to use the term *supply network* or *supply web* to describe the structure of most supply chains, as shown in Figure 1-2.

A typical supply chain may involve a variety of stages, including the following:

- Customers
- Retailers
- Wholesalers/distributors
- Manufacturers
- Component/raw material suppliers

Each stage in a supply chain is connected through the flow of products, information, and funds. These flows often occur in both directions and may be managed by one of the stages or an intermediary.

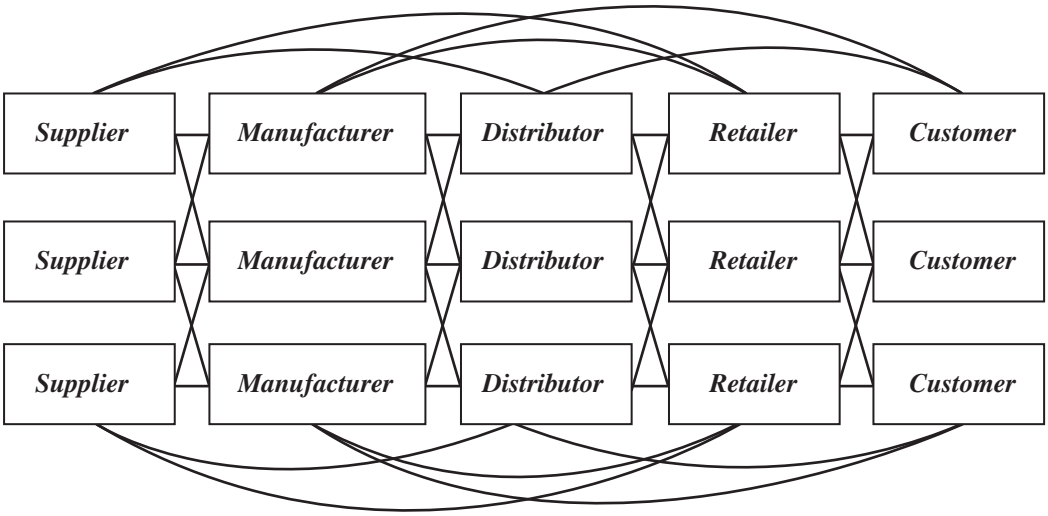

FIGURE 1-2 Supply Chain Stages

Each stage in Figure 1-2 need not be present in a supply chain. As discussed in Chapter 4, the appropriate design of the supply chain depends on both the customer's needs and the roles played by the stages involved. For example, Dell has two supply chain structures that it uses to serve its customers. For its corporate clients and also some individuals who want a customized personal computer (PC), Dell builds to order; that is, a customer order initiates manufacturing at Dell. For these customers, Dell does not have a separate retailer, distributor, or wholesaler in the supply chain. Since 2007, Dell has also sold its PCs through Wal-Mart in the United States and the GOME Group, China's largest electronics retailer. Both Wal-Mart and the GOME Group carry Dell machines in inventory. This supply chain thus contains an extra stage (the retailer) compared to the direct sales model also used by Dell. In the case of other retail stores, the supply chain may also contain a wholesaler or distributor between the store and the manufacturer.

1.2 THE OBJECTIVE OF A SUPPLY CHAIN

The objective of every supply chain should be to maximize the overall value generated. The *value* (also known as *supply chain surplus*) a supply chain generates is the difference between what the value of the final product is to the customer and the costs the supply chain incurs in filling the customer's request.

$$\textit{Supply Chain Surplus} = \textit{Customer Value} - \textit{Supply Chain Cost}$$

The value of the final product may vary for each customer and can be estimated by the maximum amount the customer is willing to pay for it. The difference between the value of the product and its price remains with the customer as *consumer surplus*. The rest of the supply chain surplus becomes *supply chain profitability*, the difference between the revenue generated from the customer and the overall cost across the supply chain. For example, a customer purchasing a wireless router from Best Buy pays $60, which represents the revenue the supply chain receives. Customers who purchase the router clearly value it at or above $60. Thus, part of the supply chain surplus is left with the customer as consumer surplus. The rest stays with the supply chain as profit. Best Buy and other stages of the supply chain incur costs to convey information, produce components, store them, transport them, transfer funds, and so on. The difference between the $60 that the customer paid and the sum of all costs incurred by the supply chain to produce and distribute the router represents the supply chain profitability. Supply chain profitability is the total profit to be shared across all supply chain stages and intermediaries. The higher the supply chain profitability, the more successful is the supply chain.

For most profit-making supply chains, the supply chain surplus will be strongly correlated with profits. Supply chain success should be measured in terms of supply chain profitability and not in terms of the profits at an individual stage. (In subsequent chapters, we see that a focus on profitability at individual stages may lead to a reduction in overall supply chain profits.) A focus on growing the supply chain surplus pushes all members of the supply chain toward growing the size of the overall pie.

Having defined the success of a supply chain in terms of supply chain profitability, the next logical step is to look for sources of value, revenue, and cost. For any supply chain, there is only one source of revenue: the customer. The value obtained by a customer purchasing detergent at Wal-Mart depends upon several factors, including the functionality of the detergent, how far the customer has to travel to Wal-Mart, and the likelihood of finding the detergent in stock. The customer is the only one providing positive cash flow for the Wal-Mart supply chain. All other cash flows are simply fund exchanges that occur within the supply chain, given that different stages have different owners. When Wal-Mart pays its supplier, it is taking a portion of the funds the customer provides and passing that money on to the supplier. All flows of information, product, or funds generate costs within the supply chain. Thus, the appropriate management of these flows is a key to supply chain success. Effective *supply chain management* involves the management of supply chain assets and product, information, and fund flows to maximize total supply chain surplus. A growth in supply chain surplus increases the size of the total pie, allowing contributing members of the supply chain to benefit.

In this book, we have a strong focus on analyzing all supply chain decisions in terms of their impact on the supply chain surplus. These decisions and their impact can vary for a wide variety of reasons. For instance, consider the difference in the supply chain structure for fast-moving consumer goods observed in the United States and India. U.S. distributors play a much smaller role in this supply chain compared to their Indian counterparts. We argue that the difference in supply chain structure can be explained by the impact a distributor has on the supply chain surplus in the two countries.

Retailing in the United States is largely consolidated, with large chains buying consumer goods from most manufacturers. This consolidation gives retailers sufficient scale that the introduction of an intermediary such as a distributor does little to reduce costs and may actually increase costs because of an additional transaction. In contrast, India has millions of small retail outlets. The small size of Indian retail outlets limits the amount of inventory they can hold, thus requiring frequent replenishment—an order can be compared with the weekly grocery shopping for a family in the United States. The only way for a manufacturer to keep transportation costs low is to bring full truckloads of product close to the market and then distribute locally using "milk runs" with smaller vehicles. The presence of an intermediary who can receive a full truckload shipment, break bulk, and then make smaller deliveries to the retailers is crucial if transportation costs are to be kept low. Most Indian distributors are one-stop shops, stocking everything from cooking oil to soaps and detergents made by a variety of manufacturers. Besides the convenience provided by one-stop shopping, distributors in India are also able to reduce transportation costs for outbound delivery to the retailer by aggregating products across multiple manufacturers during the delivery runs. Distributors in India also handle collections, because their cost of collection is significantly lower than that of each manufacturer collecting from retailers on its own would be. Thus, the important role of distributors in India can be explained by the growth in supply chain surplus that results from their presence. The supply chain surplus argument implies that as retailing in India begins to consolidate, the role of distributors will diminish.

1.3 THE IMPORTANCE OF SUPPLY CHAIN DECISIONS

There is a close connection between the design and management of supply chain flows (product, information, and funds) and the success of a supply chain. Wal-Mart, Amazon, and Seven-Eleven Japan are examples of companies that have built their success on superior design, planning, and

operation of their supply chain. In contrast, the failure of many online businesses such as Webvan can be attributed to weaknesses in their supply chain design and planning. The rise and subsequent fall of the bookstore chain Borders illustrates how a failure to adapt its supply chain to a changing environment and customer expectations hurt its performance. Dell Computer is another example of a company that had to revise its supply chain design in response to changing technology and customer needs. We discuss these examples later in this section.

Wal-Mart has been a leader at using supply chain design, planning, and operation to achieve success. From its beginning, the company invested heavily in transportation and information infrastructure to facilitate the effective flow of goods and information. Wal-Mart designed its supply chain with clusters of stores around distribution centers to facilitate frequent replenishment at its retail stores in a cost-effective manner. Frequent replenishment allows stores to match supply and demand more effectively than the competition. Wal-Mart has been a leader in sharing information and collaborating with suppliers to bring down costs and improve product availability. The results are impressive. In its 2010 annual report, the company reported a net income of more than $14.3 billion on revenues of about $408 billion. These are dramatic results for a company that reached annual sales of only $1 billion in 1980. The growth in sales represents an annual compounded growth rate of more than 20 percent.

Seven-Eleven Japan is another example of a company that has used excellent supply chain design, planning, and operation to drive growth and profitability. It has used a very responsive replenishment system along with an outstanding information system to ensure that products are available at each of its convenience stores to match customer needs. Its responsiveness allows it to change the merchandising mix at each store by time of day to precisely match customer demand. As a result, the company has grown from sales of 1 billion yen in 1974 to almost 3 trillion yen in 2009 with profits in 2009 totaling 164 billion yen.

The failure of many online businesses such as Webvan and Kozmo can be attributed to their inability to design appropriate supply chains or manage supply chain flows effectively. Webvan designed a supply chain with large warehouses in several major cities in the United States, from which groceries were delivered to customers' homes. This supply chain design could not compete with traditional supermarket supply chains in terms of cost. Traditional supermarket chains bring product to a supermarket close to the consumer using full truckloads, resulting in very low transportation costs. They turn their inventory relatively fast and let the customer perform most of the picking activity in the store. In contrast, Webvan turned its inventory marginally faster than supermarkets but incurred much higher transportation costs for home delivery and high labor costs to pick customer orders. The result was a company that folded in 2001 within two years of a very successful initial public offering.

As the experience of Borders illustrates, a failure to adapt supply chains to a changing environment can significantly hurt performance. Borders, along with Barnes & Noble, dominated the selling of books and music in the 1990s by implementing the superstore concept. Compared to small local bookstores that dominated the industry prior to that, Borders was able to offer greater variety (about 100,000 titles at superstores relative to fewer than 10,000 titles at a local bookstore) to customers at a lower cost by aggregating operations in large stores. This allowed the company to achieve higher inventory turns than local bookstores with lower operating costs per dollar of sales. In 2004, Borders achieved sales of almost $4 billion with profits of $132 million. Its model, however, was already under attack with the growth of Amazon, which offered much greater variety than Borders at lower cost by selling online and stocking its inventories in a few distribution centers. Borders inability to adapt its supply chain to compete with Amazon led to a rapid decline. By 2009, sales had dropped to $2.8 billion and the company lost $109 million that year.

Dell is another example of a company that enjoyed tremendous success based on its supply chain design, planning, and operation but then had to adapt its supply chain in response to shifts in technology and customer expectations. Between 1993 and 2006, Dell experienced unprecedented growth of both revenue and profits by structuring a supply chain

Key Point

Supply chain design, planning, and operation decisions play a significant role in the success or failure of a firm. To stay competitive, supply chains must adapt to changing technology and customer expectations.

that provided customers with customized PCs quickly and at reasonable cost. By 2006, Dell had a net income of more than $3.5 billion on revenues of just over $56 billion. This success was based on two key supply chain features that supported rapid, low-cost customization. The first was Dell's decision to sell directly to the end customer, bypassing distributors and retailers. The second key aspect of Dell's supply chain was the centralization of manufacturing and inventories in a few locations where final assembly was postponed until the customer order arrived. As a result, Dell was able to provide a large variety of PC configurations while keeping low levels of component inventories.

In spite of this tremendous success, the changing marketplace presented some new challenges for Dell. Whereas Dell's supply chain was well suited for highly customized PCs, the market shifted to lower levels of customization. Given the growing power of hardware, customers were satisfied with a few model types. Dell reacted by adjusting its supply chain with regard to both direct selling and building to order. The company started selling its PCs through retail chains such as Wal-Mart in the United States and GOME in China. It also outsourced a large fraction of its assembly to low-cost locations, effectively building to stock rather than to customer order. Unlike Borders, Dell is making a significant effort to adapt its supply chain to changing times. It remains to be seen whether these changes will improve Dell's performance.

In the next section, we categorize supply chain decision phases based on the frequency with which they are made and the time frame they take into account.

1.4 DECISION PHASES IN A SUPPLY CHAIN

Successful supply chain management requires many decisions relating to the flow of information, product, and funds. Each decision should be made to raise the supply chain surplus. These decisions fall into three categories or phases, depending on the frequency of each decision and the time frame during which a decision phase has an impact. As a result, each category of decisions must consider uncertainty over the decision horizon.

1. ***Supply Chain Strategy or Design:*** During this phase, a company decides how to structure the supply chain over the next several years. It decides what the chain's configuration will be, how resources will be allocated, and what processes each stage will perform. Strategic decisions made by companies include whether to outsource or perform a supply chain function in-house, the location and capacities of production and warehousing facilities, the products to be manufactured or stored at various locations, the modes of transportation to be made available along different shipping legs, and the type of information system to be utilized. PepsiCo Inc.'s decision in 2009 to purchase two of its largest bottlers is a supply chain design or strategic decision. A firm must ensure that the supply chain configuration supports its strategic objectives and increases the supply chain surplus during this phase. As the PepsiCo CEO announced in a news release on August 4, "while the existing model has served the system very well, the fully integrated beverage business will enable us to bring innovative products and packages to market faster, streamline our manufacturing and distribution systems and react more quickly to

changes in the marketplace." Supply chain design decisions are typically made for the long term (a matter of years) and are expensive to alter on short notice. Consequently, when companies make these decisions, they must take into account uncertainty in anticipated market conditions over the next few years.

2. ***Supply Chain Planning:*** For decisions made during this phase, the time frame considered is a quarter to a year. Therefore, the supply chain's configuration determined in the strategic phase is fixed. This configuration establishes constraints within which planning must be done. The goal of planning is to maximize the supply chain surplus that can be generated over the planning horizon given the constraints established during the strategic or design phase. Companies start the planning phase with a forecast for the coming year (or a comparable time frame) of demand and other factors such as costs and prices in different markets. Planning includes making decisions regarding which markets will be supplied from which locations, the subcontracting of manufacturing, the inventory policies to be followed, and the timing and size of marketing and price promotions. For example, steel giant ArcelorMittal's decisions regarding markets supplied by a production facility and target production quantities at each location are classified as planning decisions. Planning establishes parameters within which a supply chain will function over a specified period of time. In the planning phase, companies must include uncertainty in demand, exchange rates, and competition over this time horizon in their decisions. Given a shorter time frame and better forecasts than in the design phase, companies in the planning phase try to incorporate any flexibility built into the supply chain in the design phase and exploit it to optimize performance. As a result of the planning phase, companies define a set of operating policies that govern short-term operations.

3. ***Supply Chain Operation:*** The time horizon here is weekly or daily. During this phase, companies make decisions regarding individual customer orders. At the operational level, supply chain configuration is considered fixed, and planning policies are already defined. The goal of supply chain operations is to handle incoming customer orders in the best possible manner. During this phase, firms allocate inventory or production to individual orders, set a date that an order is to be filled, generate pick lists at a warehouse, allocate an order to a particular shipping mode and shipment, set delivery schedules of trucks, and place replenishment orders. Because operational decisions are being made in the short term (minutes, hours, or days), there is less uncertainty about demand information. Given the constraints established by the configuration and planning policies, the goal during the operation phase is to exploit the reduction of uncertainty and optimize performance.

The design, planning, and operation of a supply chain have a strong impact on overall profitability and success. It is fair to state that a large part of the success of firms such as Wal-Mart and Seven-Eleven Japan can be attributed to their effective supply chain design, planning, and operation.

In later chapters, we develop concepts and present methodologies that can be used at each of the three decision phases described earlier. Most of our discussion addresses the supply chain design and planning phases.

Key Point

Supply chain decision phases may be categorized as design, planning, or operational, depending on the time frame during which the decisions made apply. Design decisions constrain or enable good planning, which in turn constrains or enables effective operation.

1.5 PROCESS VIEWS OF A SUPPLY CHAIN

A supply chain is a sequence of processes and flows that take place within and between different stages and combine to fill a customer need for a product. There are two ways to view the processes performed in a supply chain.

1. ***Cycle View:*** The processes in a supply chain are divided into a series of cycles, each performed at the interface between two successive stages of a supply chain.
2. ***Push/Pull View:*** The processes in a supply chain are divided into two categories depending on whether they are executed in response to a customer order or in anticipation of customer orders. *Pull* processes are initiated by a customer order, whereas *push* processes are initiated and performed in anticipation of customer orders.

Cycle View of Supply Chain Processes

Given the five stages of a supply chain as shown in Figure 1-2, all supply chain processes can be broken down into the following four process cycles, as shown in Figure 1-3:

- Customer order cycle
- Replenishment cycle
- Manufacturing cycle
- Procurement cycle

Each cycle occurs at the interface between two successive stages of the supply chain. Not every supply chain will have all four cycles clearly separated. For example, a grocery supply chain in which a retailer stocks finished-goods inventories and places replenishment orders with a distributor is likely to have all four cycles separated. Dell, in contrast, bypasses the retailer and distributor when it sells directly to customers.

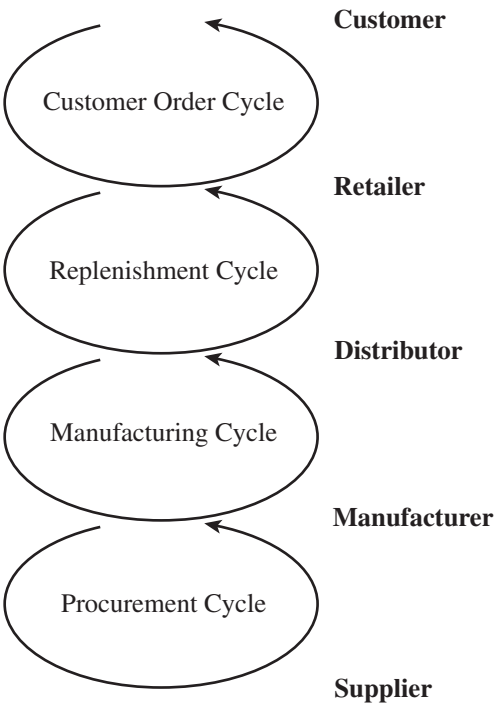

FIGURE 1-3 Supply Chain Process Cycles

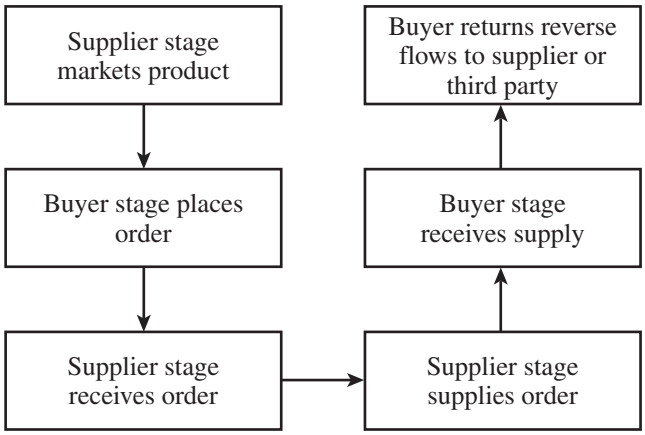

FIGURE 1-4 Subprocesses in Each Supply Chain Process Cycle

Each cycle consists of six subprocesses as shown in Figure 1-4. Each cycle starts with the supplier marketing the product to customers. A buyer then places an order that is received by the supplier. The supplier supplies the order, which is received by the buyer. The buyer may return some of the product or other recycled material to the supplier or a third party. The cycle of activities then begins all over again.

Depending on the transaction in question, the subprocesses in Figure 1-4 can be applied to the appropriate cycle. When customers shop online at Amazon, they are part of the customer order cycle—with the customer as the buyer and Amazon as the supplier. In contrast, when Amazon orders books from a distributor to replenish its inventory, it is part of the replenishment cycle—with Amazon as the buyer and the distributor as the supplier.

Within each cycle, the goal of the buyer is to ensure product availability and to achieve economies of scale in ordering. The supplier attempts to forecast customer orders and reduce the cost of receiving the order. The supplier then works to fill the order on time and improve efficiency and accuracy of the order fulfillment process. The buyer then works to reduce the cost of the receiving process. Reverse flows are managed to reduce cost and meet environmental objectives.

Even though each cycle has the same basic subprocesses, there are a few important differences among the cycles. In the customer order cycle, demand is external to the supply chain and thus uncertain. In all other cycles, order placement is uncertain but can be projected based on policies followed by the particular supply chain stage. For example, in the procurement cycle, a tire supplier to an automotive manufacturer can predict tire demand precisely once the production schedule at the manufacturer is known. The second difference across cycles relates to the scale of an order. Whereas a customer buys a single car, the dealer orders multiple cars at a time from the manufacturer, and the manufacturer, in turn, orders an even larger quantity of tires from the supplier. As we move from the customer to the supplier, the number of individual orders declines and the size of each order increases. Thus, sharing of information and operating policies across supply chain stages becomes more important as we move further from the end customer.

A cycle view of the supply chain is useful when considering operational decisions because it clearly specifies the roles of each member of the supply chain. The detailed process description of a supply chain in the cycle view forces a supply chain designer to consider the infrastructure required to support these processes. The cycle view is useful, for example, when setting up information systems to support supply chain operations.

Key Point

A cycle view of the supply chain clearly defines the processes involved and the owners of each process. This view is useful when considering operational decisions because it specifies the roles and responsibilities of each member of the supply chain and the desired outcome for each process.

Push/Pull View of Supply Chain Processes

All processes in a supply chain fall into one of two categories depending on the timing of their execution relative to end customer demand. With pull processes, execution is initiated in response to a customer order. With push processes, execution is initiated in anticipation of customer orders based on a forecast. Pull processes may also be referred to as *reactive processes* because they react to customer demand. Push processes may also be referred to as *speculative processes* because they respond to speculated (or forecasted) rather than actual demand. The *push/pull boundary* in a supply chain separates push processes from pull processes as shown in Figure 1-5. Push processes operate in an uncertain environment because customer demand is not yet known. Pull processes operate in an environment in which customer demand is known. They are, however, often constrained by inventory and capacity decisions that were made in the push phase.

Let us compare a make-to-stock environment like that of L. L. Bean and a build-to-order environment like that of Dell to compare the push/pull view and the cycle view.

L. L. Bean executes all processes in the customer order cycle *after* the customer order arrives. All processes that are part of the customer order cycle are thus pull processes. Order fulfillment takes place from product in inventory that is built up in anticipation of customer orders. The goal of the replenishment cycle is to ensure product availability when a customer order arrives. All processes in the replenishment cycle are performed in anticipation of demand and are thus push processes. The same holds true for processes in the manufacturing and procurement cycles. In fact, raw material such as fabric is often purchased six to nine months before customer demand is expected. Manufacturing itself begins three to six months before the point of sale. The processes in the L. L. Bean supply chain break up into pull and push processes, as shown in Figure 1-6.

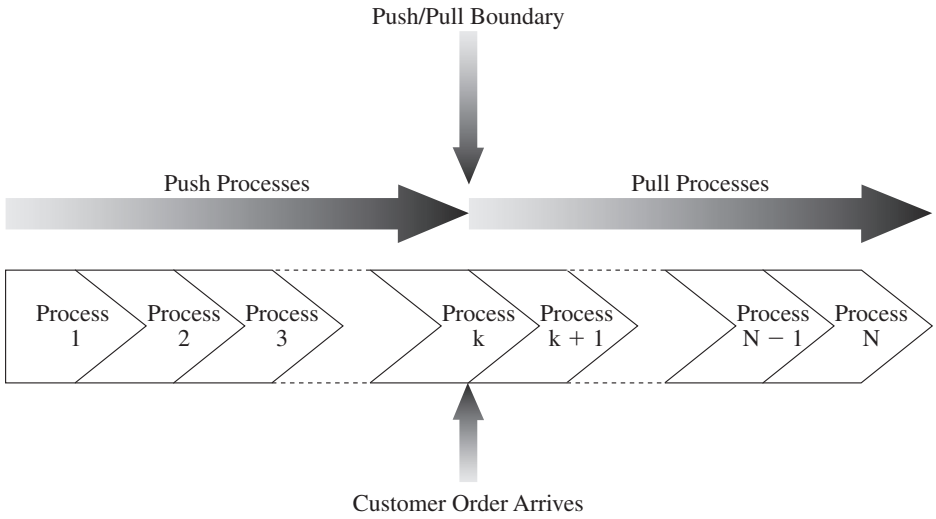

FIGURE 1-5 Push/Pull View of the Supply Chain

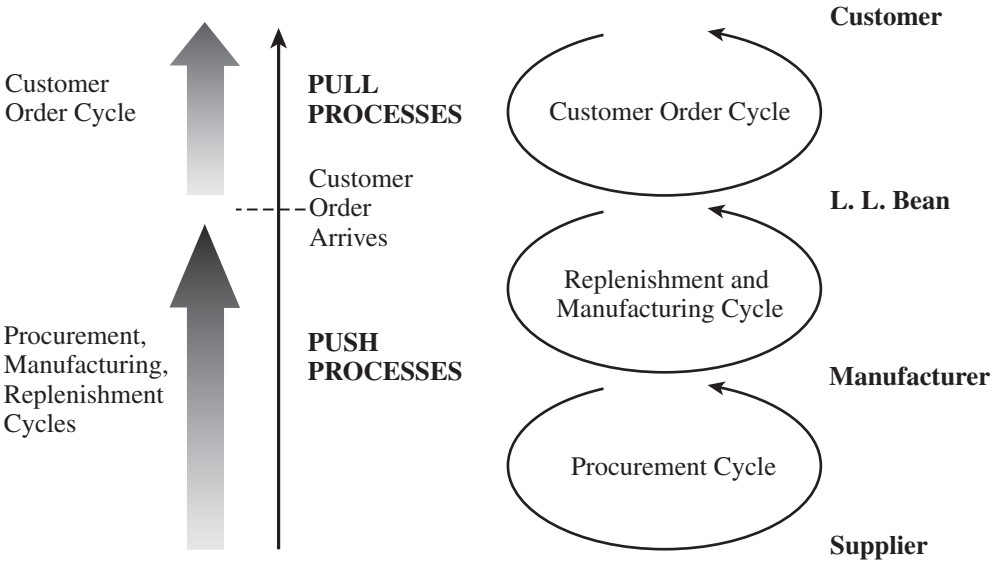

FIGURE 1-6 Push/Pull Processes for the L. L. Bean Supply Chain

For the PCs it sells through Wal-Mart, Dell's order cycles and its push/pull boundary look like that of L. L. Bean with Wal-Mart as the retailer instead of L. L. Bean and Dell as the manufacturer. The situation is different when Dell builds customized computers to order for its customers. In this case, the arrival of a customer order triggers production of the product. The manufacturing cycle is thus part of the customer order fulfillment process in the customer order cycle. There are effectively only two cycles in the Dell supply chain for customized PCs: (1) a customer order and manufacturing cycle and (2) a procurement cycle, as shown in Figure 1-7.

All processes in the customer order and manufacturing cycle at Dell are thus classified as pull processes because they are initiated by customer order arrival. Dell, however, does not place component orders in response to a customer order. Inventory is replenished in anticipation

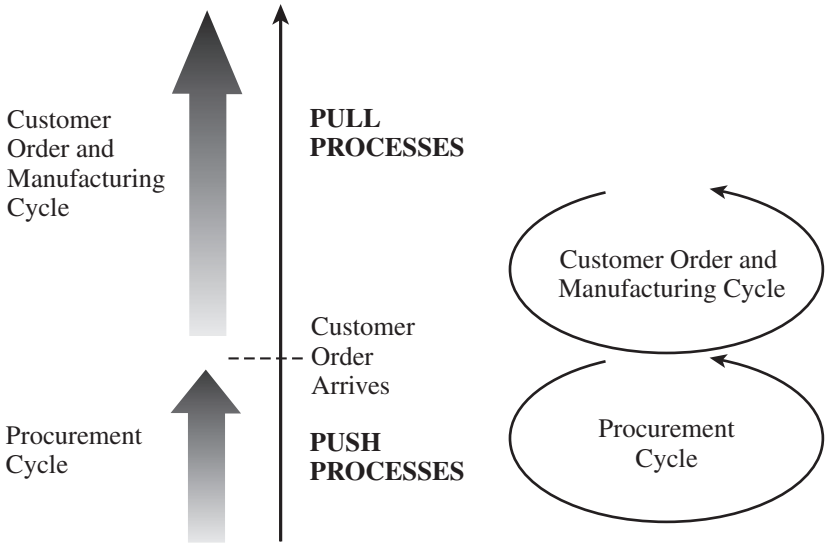

FIGURE 1-7 Push/Pull Processes for Dell Supply Chain for Customized PCs

Key Point

A push/pull view of the supply chain categorizes processes based on whether they are initiated in response to a customer order (pull) or in anticipation of a customer order (push). This view is useful when considering strategic decisions relating to supply chain design.

of customer demand. All processes in the procurement cycle for Dell are thus classified as push processes, because they are in response to a forecast. For build-to-order PCs, the processes in the Dell supply chain break up into pull and push processes as shown in Figure 1-7.

A push/pull view of the supply chain is very useful when considering strategic decisions relating to supply chain design. The goal is to identify an appropriate push/pull boundary such that the supply chain can match supply and demand effectively.

The paint industry provides another excellent example of the gains from suitably adjusting the push/pull boundary. The manufacture of paint requires production of the base, mixing of suitable colors, and packing. Until the 1980s, all these processes were performed in large factories, and paint cans were shipped to stores. These qualified as push processes, as they were performed to a forecast in anticipation of customer demand. Given the uncertainty of demand, the paint supply chain had great difficulty matching supply and demand. In the 1990s, paint supply chains were restructured such that mixing of colors was done at retail stores after customers placed their orders. In other words, color mixing was shifted from the push to the pull phase of the supply chain even though base preparation and packing of cans were still performed in the push phase. The result is that customers are always able to get the color of their choice, while total paint inventories across the supply chain have declined.

Supply Chain Macro Processes in a Firm

All supply chain processes discussed in the two process views and throughout this book can be classified into the following three macro processes, as shown in Figure 1-8:

1. ***Customer Relationship Management (CRM):*** all processes that focus on the interface between the firm and its customers
2. ***Internal Supply Chain Management (ISCM):*** all processes that are internal to the firm
3. ***Supplier Relationship Management (SRM):*** all processes that focus on the interface between the firm and its suppliers

FIGURE 1-8 Supply Chain Macro Processes

Key Point

Within a firm, all supply chain activities belong to one of three macro processes: CRM, ISCM, and SRM. Integration among the three macro processes is crucial for successful supply chain management.

These three macro processes manage the flow of information, product, and funds required to generate, receive, and fulfill a customer request. The CRM macro process aims to generate customer demand and facilitate the placement and tracking of orders. It includes processes such as marketing, pricing, sales, order management, and call center management. At an industrial distributor such as W.W. Grainger, CRM processes include the preparation of catalogs and other marketing materials, management of the Web site, and management of the call center that takes orders and provides service. The ISCM macro process aims to fulfill demand generated by the CRM process in a timely manner and at the lowest possible cost. ISCM processes include the planning of internal production and storage capacity, preparation of demand and supply plans, and fulfillment of actual orders. At W.W. Grainger, ISCM processes include planning for the location and size of warehouses; deciding which products to carry at each warehouse; preparing inventory management policies; and picking, packing, and shipping actual orders. The SRM macro process aims to arrange for and manage supply sources for various goods and services. SRM processes include the evaluation and selection of suppliers, negotiation of supply terms, and communication regarding new products and orders with suppliers. At W.W. Grainger, SRM processes include the selection of suppliers for various products, negotiation of pricing and delivery terms with suppliers, sharing of demand and supply plans with suppliers, and the placement of replenishment orders.

Observe that all three macro processes are aimed at serving the same customer. For a supply chain to be successful, it is crucial that the three macro processes are well integrated. The importance of this integration is discussed in Chapters 10 and 17. The organizational structure of the firm has a strong influence on the success or failure of the integration effort. In many firms, marketing is in charge of the CRM macro process, manufacturing handles the ISCM macro process, and purchasing oversees the SRM macro process—with little communication among them. It is not unusual for marketing and manufacturing to have different forecasts when making their plans. This lack of integration hurts the supply chain's ability to match supply and demand effectively, leading to dissatisfied customers and high costs. Thus, firms should structure a supply chain organization that mirrors the macro processes and ensures good communication and coordination among the owners of processes that interact with one another.

1.6 EXAMPLES OF SUPPLY CHAINS

In this section, we consider several supply chains and raise questions that must be answered during their design, planning, and operation phases. In later chapters, we discuss concepts and present methodologies that can be used to answer these questions.

Gateway and Apple: Two Different Journeys into Retailing

Gateway was founded in 1985 as a direct sales manufacturer of PCs with no retail footprint. In 1996, Gateway was one of the first PC manufacturers to start selling PCs online. After many years of selling its PCs without a retail infrastructure, Gateway introduced an aggressive strategy of opening Gateway retail stores throughout the United States in the late 1990s. Its stores carried no finished-goods inventory and were primarily focused on helping customers select the right configuration to purchase. All PCs were manufactured to order and shipped to the customer from one of the assembly plants.

Initially, investors rewarded Gateway for this strategy and raised the stock price to more than $80 per share in late 1999. However, this success did not last. By November 2002, Gateway shares had dropped to less than $4, and Gateway was losing a significant amount of money. By April 2004, Gateway had closed all its retail outlets and reduced the number of configurations offered to customers. In August 2007, Gateway was purchased by Taiwan's Acer for a price of $710 million. By 2010, Gateway computers were sold through more than 20 different retail outlets including Best Buy and Costco. As you can imagine, this was quite a transition for the company to experience.

In contrast, Apple has enjoyed tremendous success since it opened its first retail store in 2001. By 2010, Apple had more than 300 stores worldwide, and retail sales represented about 15 percent of the company's total net sales. Unlike Gateway, Apple has always carried product inventory at its stores. Given its product designs, Apple has relatively little variety that it carries in its stores. Each of its stores has a relatively high level of sales with its Regent Street store in London reaching sales of 2,000 pounds per square foot in 2009. In the 2010 annual report, Apple listed retail sales totaling almost $10 billion, a growth of 47 percent relative to the previous year.

The following questions highlight supply chain decisions that have a bearing on the difference between Apple's and Gateway's performance:

1. Why did Gateway choose not to carry any finished-product inventory at its retail stores? Why did Apple choose to carry inventory at its stores?
2. Should a firm with an investment in retail stores carry any finished-goods inventory? What are the characteristics of products that are most suitable to be carried in finished-goods inventory? What characterizes products that are best manufactured to order?
3. How does product variety affect the level of inventory a retail store must carry?
4. Is a direct selling supply chain without retail stores always less expensive than a supply chain with retail stores?
5. What factors explain the success of Apple retail and the failure of Gateway country stores?

Zara: Apparel Manufacturing and Retail

Zara is a chain of fashion stores owned by Inditex, Spain's largest apparel manufacturer and retailer. In 2009, Inditex reported sales of about 11 billion euros from more than 4,700 retail outlets in about 76 countries. In an industry in which customer demand is fickle, Zara has grown rapidly with a strategy to be highly responsive to changing trends with affordable prices. Whereas design-to-sales cycle times in the apparel industry have traditionally averaged more than six months, Zara has achieved cycle times of four to six weeks. This speed allows Zara to introduce new designs every week and to change 75 percent of its merchandise display every three to four weeks. Thus, Zara's products on display match customer preferences much more closely than the competition. The result is that Zara sells most of its products at full price and has about half the markdowns in its stores compared to the competition.

Zara manufactures its apparel using a combination of flexible and quick sources in Europe (mostly Portugal and Spain) and low-cost sources in Asia. This contrasts with most apparel manufacturers, who have moved most of their manufacturing to Asia. About 40 percent of the manufacturing capacity is owned by Inditex, with the rest outsourced. Products with highly uncertain demand are sourced out of Europe, whereas products that are more predictable are sourced from its Asian locations. More than 40 percent of its finished-goods purchases and most of its in-house production occur after the sales season starts. This compares with less than 20 percent production after the start of a sales season for a typical retailer. This responsiveness and the postponement of decisions until after trends are known allow Zara to reduce inventories and forecast error. Zara has also invested heavily in information technology to ensure that the latest sales data are available to drive replenishment and production decisions.

In 2009, Inditex distributed to stores all over the world from eight distribution centers located in Spain. The group claimed an average delivery time of 24 hours for European stores and up to a maximum of 48 hours for stores in America or Asia from the time the order was

received in the distribution center (DC) to the time it was delivered to the stores. Shipments from the DCs to stores were made several times a week. This allowed store inventory to closely match customer demand.

The following questions raise supply chain issues that are central to Zara's strategy and success:

1. What advantage does Zara gain against the competition by having a very responsive supply chain?
2. Why has Inditex chosen to have both in-house manufacturing and outsourced manufacturing? Why has Inditex maintained manufacturing capacity in Europe even though manufacturing in Asia is much cheaper?
3. Why does Zara source products with uncertain demand from local manufacturers and products with predictable demand from Asian manufacturers?
4. What advantage does Zara gain from replenishing its stores multiple times a week compared to a less frequent schedule? How does the frequency of replenishment affect the design of its distribution system?
5. Do you think Zara's responsive replenishment infrastructure is better suited for online sales or retail sales?

W.W. Grainger and McMaster-Carr: MRO Suppliers

W.W. Grainger and McMaster-Carr sell maintenance, repair, and operations (MRO) products. Both companies have catalogs and Web pages through which orders can be placed. W.W. Grainger also has several hundred stores throughout the United States. Customers can walk into a store, call in an order, or place it via the Web. W.W. Grainger orders are either shipped to the customer or picked up by the customer at one of its stores. McMaster-Carr, on the other hand, ships almost all its orders (though a few customers near its DCs do pick up their own orders). W.W. Grainger has nine DCs that both replenish stores and fill customer orders. McMaster has five DCs from which all orders are filled. Neither McMaster nor W.W. Grainger manufactures any product. They primarily serve the role of a distributor or retailer. Their success is largely linked to their supply chain management ability.

Both firms offer several hundred thousand products to their customers. Grainger stocks about 200,000 stock-keeping units (SKU), whereas McMaster carries about 500,000. Grainger also provides many other products that it does not stock direct from its suppliers. Both firms face the following strategic and operational issues:

1. How many DCs should be built and where should they be located?
2. How should product stocking be managed at the DCs? Should all DCs carry all products?
3. What products should be carried in inventory and what products should be left with the supplier to be shipped directly in response to a customer order?
4. What products should W.W. Grainger carry at a store?
5. How should markets be allocated to DCs in terms of order fulfillment? What should be done if an order cannot be completely filled from a DC? Should there be specified backup locations? How should they be selected?
6. How should replenishment of inventory be managed at the various stocking locations?
7. How should Web orders be handled relative to the existing business? Is it better to integrate the Web business with the existing business or to set up separate distribution?
8. What transportation modes should be used for order fulfillment and stock replenishment?

Toyota: A Global Auto Manufacturer

Toyota Motor Corporation is Japan's top auto manufacturer and has experienced significant growth in global sales over the past two decades. A key issue facing Toyota is the design of its global production and distribution network. Part of Toyota's global strategy is to open factories in every market it serves. Toyota must decide what the production capability of each of the

factories will be, as this has a significant impact on the desired distribution system. At one extreme, each plant can be equipped only for local production. At the other extreme, each plant is capable of supplying every market. Prior to 1996, Toyota used specialized local factories for each market. After the Asian financial crisis in 1996/1997, Toyota redesigned its plants so that it could also export to markets that remain strong when the local market weakens. Toyota calls this strategy "global complementation."

Whether to be global or local is also an issue for Toyota's parts plants and product design. Should parts plants be built for local production or should there be few parts plants globally that supply multiple assembly plants? Toyota has worked hard to increase commonality in parts used around the globe. While this helped the company lower costs and improve parts availability, common parts caused significant difficulty when one of the parts had to be recalled. In 2009, Toyota had to recall about 12 million cars using common parts across North America, Europe and Asia causing significant damage to the brand as well as the finances.

Any global manufacturer like Toyota must address the following questions regarding the configuration and capability of the supply chain:

1. Where should the plants be located and what degree of flexibility should be built into each? What capacity should each plant have?
2. Should plants be able to produce for all markets or only specific contingency markets?
3. How should markets be allocated to plants and how frequently should this allocation be revised?
4. What kind of flexibility should be built into the distribution system?
5. How should this flexible investment be valued?
6. What actions may be taken during product design to facilitate this flexibility?

Amazon and Independent Merchants

Amazon is consistently rated as the top e-commerce company in the world. It has achieved this impressive performance thanks to its supply chain and warehouses across the UK. At the heart of the company's business is the trust customers have in its ability to deliver their orders on time with very few errors. In order to maintain high satisfaction ratings, the company consistently adopts innovative supply chain and warehouse management techniques. Furthermore, in its bid to remain the largest retailer online, Amazon offers other businesses the opportunity to develop sales through its Amazon Fulfillment Centers, whereby Amazon manages their inventories and shipments. This service is available for large corporations as well as smaller companies selling less than 40 items per month. The service is not limited to Amazon's Web site. Merchants selling through their own Web sites can benefit from Amazon's facilities. This was the case until recently for Borders. Books sold by Borders via its Web site were in fact stocked and shipped from Amazon's warehouses. The deal came to an end when Borders liquidated its assets.

Amazon's know-how resides in warehouse management but also, since the beginning of its operations back in 1995, on its IT infrastructure. Jeff Bezos is known for being detail driven and always wanted his systems to be able to produce accurate reports immediately. These systems are now available for merchants and allow them to enter a global supply chain at a minimum cost.

Amazon not only picks and packs for merchants but also handles dispatches and returns. In addition, Amazon customer representatives manage customer service questions, enabling merchants to concentrate on marketing or product development. Merchants have the ability to increase sales without investing in new capacity.

Several questions arise concerning how Amazon is structured and the product categories it continues to add:

1. Why did Amazon decide to allow other merchants to use its supply chain expertise?
2. What advantages do merchants have when partnering with Amazon?
3. Should Amazon stock every product it sells?

4. What advantage can bricks-and-mortar players derive from setting up an online channel? How should they use the two channels to gain a maximum advantage?
5. What advantages or disadvantages do large book retailers gain by letting Amazon manage their supply chain?
6. For which products does the online channel offer the greatest advantage relative to retail stores? What characterizes these products?

1.7 SUMMARY OF LEARNING OBJECTIVES

1. ***Discuss the goal of a supply chain and explain the impact of supply chain decisions on the success of a firm.*** The goal of a supply chain should be to maximize overall supply chain surplus. Supply chain surplus is the difference between the value generated for the customer and the total cost incurred across all stages of the supply chain. A focus on the supply chain surplus grows the size of the overall pie for all members of the supply chain. Supply chain decisions have a large impact on the success or failure of each firm because they significantly influence both the revenue generated and the cost incurred. Successful supply chains manage flows of product, information, and funds to provide a high level of product availability to the customer while keeping costs low.

2. ***Identify the three key supply chain decision phases and explain the significance of each one.*** Supply chain decisions may be characterized as strategic (design), planning, or operational, depending on the time period during which they apply. Strategic decisions relate to supply chain configuration. These decisions have a long-term impact lasting several years. Planning decisions cover a period of a few months to a year and include decisions such as production plans, subcontracting, and promotions over that period. Operational decisions span from minutes to days and include sequencing production and filling specific orders. Strategic decisions define the constraints for planning decisions, and planning decisions define the constraints for operational decisions.

3. ***Describe the cycle and push/pull views of a supply chain.*** A cycle view of a supply chain divides processes into cycles, each performed at the interface between two successive stages of a supply chain. Each cycle starts with an order placed by one stage of the supply chain and ends when the order is received from the supplier stage. A push/pull view of a supply chain characterizes processes based on their timing relative to that of a customer order. Pull processes are performed in response to a customer order, whereas push processes are performed in anticipation of customer orders.

4. ***Classify the supply chain macro processes in a firm.*** All supply chain processes can be classified into three macro processes based on whether they are at the customer or supplier interface or are internal to the firm. The CRM macro process consists of all processes at the interface between the firm and the customer that work to generate, receive, and track customer orders. The ISCM macro process consists of all supply chain processes that are internal to the firm and work to plan for and fulfill customer orders. The SRM macro process consists of all supply chain processes at the interface between the firm and its suppliers that work to evaluate and select suppliers and then source goods and services from them.

Discussion Questions

1. Consider the purchase of a can of soda at a convenience store. Describe the various stages in the supply chain and the different flows involved.
2. Why should a firm such as Dell take into account total supply chain profitability when making decisions?
3. What are some strategic, planning, and operational decisions that must be made by an apparel retailer such as The Gap?
4. Consider the supply chain involved when a customer purchases a book at a bookstore. Identify the cycles in this supply chain and the location of the push/pull boundary.
5. Consider the supply chain involved when a customer orders a book from Amazon. Identify the push/pull boundary and two processes each in the push and pull phases.
6. In what way do supply chain flows affect the success or failure of a firm such as Amazon? List two supply chain decisions that have a significant impact on supply chain profitability.

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