Supply Chain Management

Strategy, Planning, and Operation

SEVENTH EDITION

Sunil Chopra

Seventh Edition
Global Edition

Supply Chain Management

Strategy, Planning, and Operation

Sunil Chopra
Kellogg School of Management

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Dedication

I would like to thank my colleagues at Kellogg for all I have learned from them about logistics and supply chain management. I thank Peter Meindl for his collaboration during earlier editions of this book. I am grateful for the love and encouragement that 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

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SUNIL CHOPRA

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 PhD 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, combinatorial optimization, 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 50 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*. He has also consulted for several firms in the area of supply chain and operations management.

CONTENTS

PREFACE

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

NEW TO THIS EDITION

The seventh edition has focused on changes that enhance students' ability to sharpen their critical thinking and data analytics skills as they study with the book. All concepts discussed in the book are linked to strategic decision making in a supply chain, and all quantitative ideas are illustrated using spreadsheets that can be implemented in practice. Some specific changes in the seventh edition include:

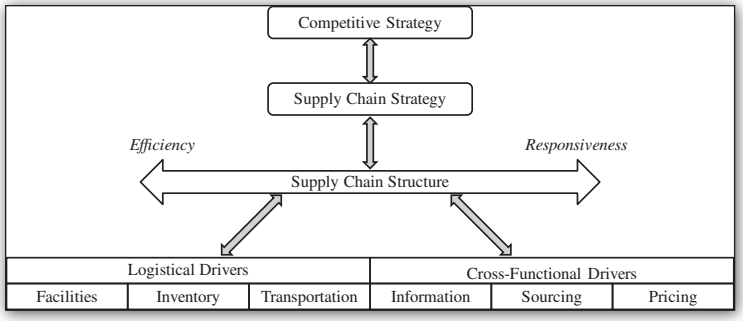
- The link between supply chain decisions and the financial performance of a firm is developed in detail in Chapter 3.
- The concepts underlying the design of distribution networks are illustrated in the context of omni-channel retailing in Chapter 4. The evolution of retailing is used throughout the book to illustrate the link between supply chain concepts and strategic decision making in a supply chain.
- Each section of each chapter in the book is associated with a clearly identified learning objective that is summarized at the end of the section.
- We have added new mini-cases in Chapters 5, 8, and 15. Information in other cases has been updated to be current.
- New exercises have been added in several chapters.
- For all numerical examples discussed in the book, we have developed spreadsheets that students can use to understand the concept at a deeper level. These spreadsheets are referred to in the book and allow the student to try different "what-if" analyses. These spreadsheets are available at *http://www.pearsonglobaleditions.com* along with basic guidance on how they may be created and used.
- We have continued to add current examples throughout the book, with a particular focus on bringing in more global examples.

SOLVING TEACHING AND LEARNING CHALLENGES

To be successful, supply chain practitioners must be able to formulate effective supply chain strategy and be able to solve any resulting supply chain problems using the available analytical tools. In a supply chain class this creates the challenge of teaching students to think strategically while supporting their decisions with robust quantitative analysis. This book is designed to help faculty and students overcome this challenge through its conceptual and pedagogical structure. Conceptually, the book aims to 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
- Analytic methodologies for supply chain analysis

To illustrate the strategic importance of good supply chain management, we provide many current examples to show how companies have succeeded through effective supply chain management or failed because of weak supply chain management. Our strategic framework, the use of Excel-based models to explain analytic methodologies, and several mini-cases to help students internalize the link between the analytic methodologies and strategic decision making provide pedagogical support for faculty using the book.



A Consistent Strategic Framework

Within the strategic framework, we identify facilities, inventory, transportation, information, sourcing, and pricing as the key drivers of supply chain performance. The book is structured to dig deeper into each driver to understand its role in the success of a supply chain, its interaction with other drivers, analytic methodologies to support decisions related to the driver, and managerial levers related to the driver that help improve supply chain performance.

Every analytic methodology is illustrated with its application in Excel. Students have access to the associated Excel file along with instructions to construct and use the file. The Excel files help students deepen their understanding of the link between the analytic models and the strategic decisions they support.

Mini Cases

Most chapters have mini cases that can be used by faculty to ensure that students can apply the concepts and methodologies in the context of strategic decision making for a business.

DEVELOPING CAREER SKILLS

Skills learned in this book will be of great use no matter what path students choose to follow. The book is developed with the premise that good strategic decisions cannot be made without access to relevant analytics, and all analytics should be designed to support decision making. As a result, students will develop critical thinking, the ability to formulate and analyze problems, and support their recommendations with analytics that uses data literacy and computing skills.

	A	B	C	D	E	F	G	H	I	J
1	***Inputs - Costs, Capacities, Demands***									
2		*Demand Region*								
		Production and Transportation Cost per 1,000,000 Units					Fixed	Low	Fixed	High
3	*Supply Region*	N. America	S. America	Europe	Asia	Africa	Cost ($)	Capacity	Cost ($)	Capacity
4	N. America	81	92	101	130	115	6,000	10	9,000	20
5	S. America	117	77	108	98	100	4,500	10	6,750	20
6	Europe	102	105	95	119	111	6,500	10	9,750	20
7	Asia	115	125	90	59	74	4,100	10	6,150	20
8	Africa	142	100	103	105	71	4,000	10	6,000	20
9	*Demand*	12	8	14	16	7				
10										
11	***Decision Variables***									
12		*Demand Region - Production Allocation (Million Units)*					Plants	Plants		
13	*Supply Region*	N. America	S. America	Europe	Asia	Africa	(1=open)	(1=open)		
14	N. America	0	0	0	0	0	0	0		
15	S. America	0	0	0	0	0	0	0		
16	Europe	0	0	0	0	0	0	0		
17	Asia	0	0	0	0	0	0	0		
18	Africa	0	0	0	0	0	0	0		
19										
20	***Constraints***									
21	*Supply Region*	*Excess Capacity*								
22	N. America	0								
23	S. America	0								
24	Europe	0								
25	Asia	0								
26	Africa	0								
27		N. America	S. America	Europe	Asia	Africa				
28	*Unmet Demand*	12	8	14	16	7				
29										
30	***Objective Function***									
31	***Cost =***	$ -								

Cell	Cell Formula	Equation	Copied to
B28	=B9 - SUM(B14:B18)	5.1	C28:F28
B22	=G14*H4 + H14*J4 - SUM(B14:F14)	5.2	B23:B26
B31	=SUMPRODUCT(B14:F18,B4:F8) + SUMPRODUCT(G14:G18,G4:G8) + SUMPRODUCT(H14:H18,I4:I8)	Objective Function	—

Excel Based Models

- Every chapter in the book pushes students to think critically in order to define and solve supply chain problems. For example, Chapter 4 develops a framework for distribution networks and then pushes students to think about how retailing may evolve in the future as consumer preferences and technology change. The first part of the chapter teaches frameworks and concepts related to the design of distribution networks. The last part of the chapter then pushes the students to analyze retailing by applying the knowledge they have gained in order to decide how retailers need to change in order to succeed in the 21st century.
- All the analytics in the book are developed through the use of Microsoft Excel. This helps students develop data literacy, computing skills, and the knowledge of how to apply information technology to support decision making. The analytics that are developed in these chapters in turn support the framework laid out in Chapter 4. Whereas Chapter 4 helps students to think conceptually about why certain retailing models have succeeded for selling jewelry while others have failed, the succeeding chapters help students quantify financial metrics for different retail networks. As a result, students learn how to use data and models to improve strategic decision making.

TABLE OF CONTENTS OVERVIEW

Part 1	**Building a Strategic Framework to Analyze Supply Chains**	
	Ch. 1: Understanding the Supply Chain	Introduces the supply chain, the managerial objective, and key decisions
	Ch. 2: Achieving Strategic Fit in a Supply Chain	Discusses the need to align strategy with supply chain capabilities
	Ch. 3: Supply Chain Drivers and Metrics	Defines key drivers of supply chain performance and associated performance metrics
Part 2	**Designing the Supply Chain Network**	
	Ch. 4: Designing Distribution Networks and Applications to Omni-Channel Retailing	Introduces framework for designing distribution networks with an application to omni-channel retailing
	Ch. 5: Network Design in the Supply Chain	Presents analytic models that support network design
	Ch. 6: Designing Global Supply Chain Networks	Discusses risks in global supply chains and analytic methodologies that incorporate uncertainty in network design
Part 3	**Planning and Coordinating Demand and Supply in a Supply Chain**	
	Ch. 7: Demand Forecasting in a Supply Chain	Introduces techniques for demand forecasting and measuring forecast error
	Ch. 8: Aggregate Planning in a Supply Chain	Introduces methodologies to plan supply to meet seasonal demand
	Ch. 9: Sales and Operations Planning in a Supply Chain	Discusses how optimally managing both demand and supply can grow supply chain profits
	Ch. 10: Coordination in a Supply Chain	Discusses obstacles to coordination and managerial levers that help improve coordination in a supply chain
Part 4	**Planning and Managing Inventories in a Supply Chain**	
	Ch. 11: Managing Economies of Scale in a Supply Chain – Cycle Inventory	Introduces methodologies to obtain optimal batch sizes and discusses managerial levers that help reduce cycle inventory without hurting costs
	Ch. 12: Managing Uncertainty in a Supply Chain – Safety Inventory	Introduces methodologies to obtain safety inventory and discusses managerial levers that help reduce safety inventory without hurting product availability
	Ch. 13: Linking Product Availability to Profits	Discusses managerial levers that help increase profits in a supply chain
Part 5	**Designing and Planning Transportation Networks**	
	Ch. 14: Transportation in a Supply Chain	Discusses options and tradeoffs when designing a transportation network
Part 6	**Managing Cross Functional Drivers in a Supply Chain**	
	Ch. 15: Sourcing Decisions in a Supply Chain	Introduces the concept of total cost in the context of sourcing and discusses the benefits of sharing risk and reward in a supply chain
	Ch. 16: Pricing and Revenue Management in a Supply Chain	Discusses how differential pricing can help increase profits in a supply chain
	Ch. 17: Sustainability and the Supply Chain	Discusses the challenge to sustainability posed by the tragedy of the commons and the role of incentives and regulation for improved sustainability
Part 7	**Online Chapter**	
	Ch. A: Information Technology in a Supply Chain	Introduces a framework for the role of information technology in a supply chain

INSTRUCTOR TEACHING RESOURCES

At the Instructor Resource Center, *http://www.pearsonglobaleditions.com*, instructors can easily register to gain access to a variety of instructor resources available with this text in downloadable format. If assistance is needed, our dedicated technical support team is ready to help with the media supplements that accompany this text. Visit *https://support.pearson.com/getsupport* for answers to frequently asked questions and toll-free user support phone numbers.

This program comes with the following teaching resources.

Supplements available to instructors at *www.pearsonglobaleditions.com*	Features of the Supplement
Instructor's Solution Manual developed by the author	• Case Teaching Notes and Worksheets • Spreadsheets for all quantitative examples • Discussion questions • Example figures • Additional exercises • Solutions to all questions and problems in the book
Test Bank authored by Geoff Willis of the University of Central Oklahoma	2000 multiple-choice, true/false, short- answer, and graphing questions with these annotations: • Correct answer • Difficulty level (1 for straight recall, 2 for some analysis, 3 for complex analysis) • Learning outcome reference • Topic covered • AACSB learning standard (Analytical Thinking; Information Technology; Application of Knowledge)
TestGen® Computerized Test Bank	TestGen allows instructors to: • Customize, save, and generate classroom tests • Edit, add, or delete questions from the Test Item Files • Analyze test results • Organize a database of tests and student results.
PowerPoint Presentations authored by Jeff Heyl of the Lincoln University	Slides include all the graphs, tables, and equations in the textbook.

For Students

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

- 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 5 through 16.
- Online chapter: Chapter A: Information Technology in a Supply Chain.
- Technical Note: Routing and Scheduling in Transportation. This note is also bundled with the Instructor's Manual available on *www.pearsonglobaleditions.com.*

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CHAPTER

1

Understanding the Supply Chain

LEARNING OBJECTIVES

After reading this chapter, you will be able to

1.1 Discuss the goal of a supply chain and explain the impact of supply chain decisions on the success of a firm.

1.2 Define the three key supply chain decision phases and explain the significance of each one.

1.3 Describe the cycle and push/pull views along with the macro processes of a supply chain.

1.4 Identify important issues and decisions to be addressed in a supply chain.

1.5 Develop skills that employers have identified as critical to success in the workplace.

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

WHAT IS A SUPPLY CHAIN?

1.1 *Discuss the goal of a supply chain and explain the impact of supply chain decisions on the success of a firm.*

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 Toyota dealership to purchase a new car. The supply chain begins with the customer and his or her need for a car. The next stage of this supply chain is the dealer that the customer visits. The dealer has several cars in inventory that may have been supplied from the assembly plant using trucks from a third party. The assembly plant, in turn,

gets various modules such as electronics and powertrain from a variety of Tier 1 suppliers. Each Tier 1 supplier receives material from several Tier 2 suppliers. For example, the electronics supplier receives cameras from the camera supplier and the dashboard display from another supplier. Each of these suppliers receives raw materials from lower tier suppliers. This supply chain is illustrated in Figure 1-1, with the arrows corresponding to the direction of physical product flow.

A supply chain is dynamic and involves the constant flow of information, product, and funds among different stages. In our example, the dealer provides the product, as well as pricing and availability information, to the customer. The customer transfers funds to the dealer. The dealer conveys sales data and replenishment orders to the assembly plant, which sends cars back to the dealer on a truck. The dealer transfers funds to the auto manufacturer after the replenishment. The manufacturer also provides pricing information and sends delivery schedules to each dealer. Similar information, material, and fund flows take place across the entire supply chain.

In another example, when a customer makes a purchase online from Amazon, the supply chain includes, among others, the customer, Amazon's website, the Amazon warehouse, the carrier who delivers packages to customers, and all of Amazon's suppliers and their suppliers. The website provides the customer with information regarding pricing, product variety, and product availability. After making a product choice, the customer enters the order information and pays for the product. The product is then picked and shipped from an Amazon warehouse. As its inventory diminishes, the warehouse places replenishment orders with suppliers.

A typical supply chain may involve a variety of stages including customers, retailers, wholesalers, distributors, manufacturers, and suppliers. Even though the term supply chain may imply that only one player is involved at each stage, most supply chains are actually networks where each stage receives product from several suppliers and sends output to several customers. It may be more accurate to use the term supply network or supply web to describe the structure of most supply chains.

A critical point to keep in mind is that the customer is an integral part of any 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 functioning of a supply chain involves three key flows – information, product, and funds - as illustrated in Figure 1-2. The goal when designing a supply chain is to structure the three flows in a way that meets customer needs in a cost effective manner. For example, Apple serves its customers in a variety of ways depending upon their needs. Customers

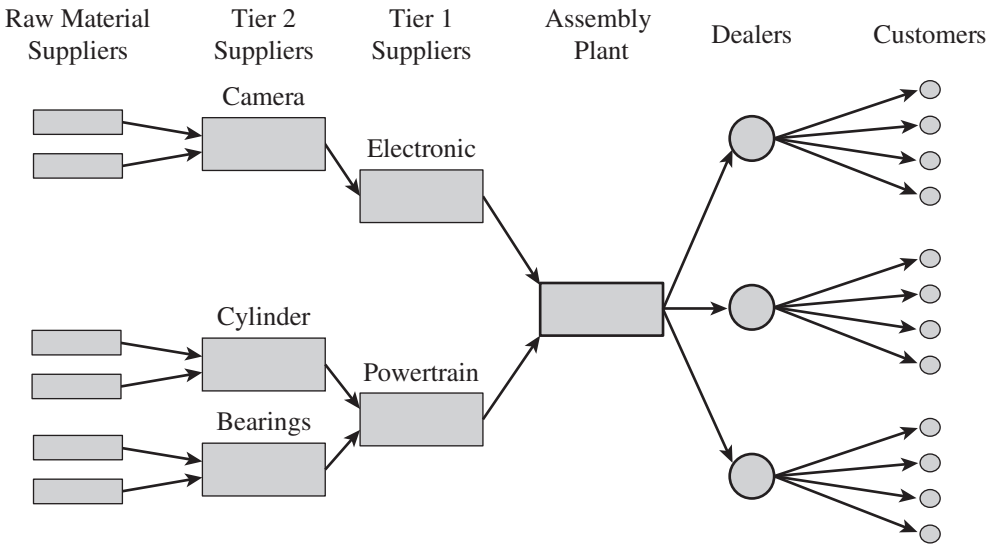

Figure 1-1 Stages of an Automotive Supply Chain

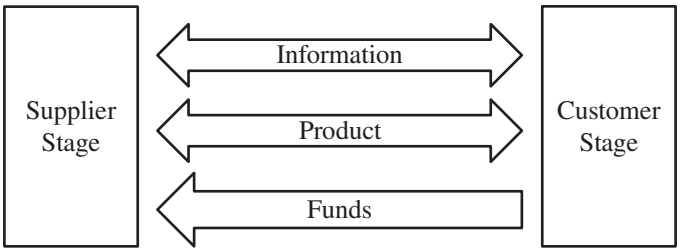

Figure 1-2 The Three Flows in a Supply Chain

can walk into an Apple store (or a third party store) or go online to purchase a product. Standard products are stocked at the stores and customers can leave the store with their phone or computer after paying the appropriate funds. Orders placed online can either be delivered at home or be picked up at an Apple store. The time taken for home delivery depends on whether the product is stocked by Apple at its warehouse or not. Personalized and custom-configured items take longer because they are not stocked at the warehouse but produced after the customer order arrives. Observe that Apple changes the flow of information, product, and funds based on the customer needs and product characteristics. The goal of this book is to develop concepts and methodologies that can be used to design supply chains that effectively meet customer needs while generating supply chain profits.

THE OBJECTIVE OF A SUPPLY CHAIN

The objective of every supply chain should be to maximize the net value generated. The net value a supply chain generates is the difference between what the value of the final product is to the customer and the costs the entire supply chain incurs in filling the customer's request. We will refer to this difference as the *supply chain surplus*.

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

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, the $60 that a customer pays Best Buy for a wireless router 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 costs incurred across all stages by the supply chain to produce and distribute the router represents the supply chain profitability: the total profit to be shared across all supply chain stages and intermediaries. The higher the supply chain profitability, the more successful 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 surplus 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 surplus.) 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 surplus, 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 a car at a Toyota dealership depends on several factors, including the functionality and features of the car, the variety of options available, and the service offered by the dealer. The customer is the only one providing positive cash flow for the Toyota supply chain. All other cash flows are simply fund exchanges that occur within the supply chain, given that different stages have different owners. When the dealer pays Toyota, it is taking a portion of the funds the customer provides and passing that money on to Toyota. 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 grow the 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 that is observed in the United States and India. U.S. distributors play a much smaller role in this supply chain compared with 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 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—a retail 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 that 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 what it would cost each manufacturer to collect from retailers. 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.

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. Amazon, Seven-Eleven Japan, and Walmart 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.

Seven-Eleven Japan is an 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 when and where customers need them. Its responsiveness allows the company to change the merchandise mix at each store by time of day to precisely match customer demand. As a result, the company has grown total store sales from 1 billion yen in 1974 to almost 2.7 trillion yen in 2016, with profits in 2016 totaling 304 billion yen.

Walmart has been a leader at using supply chain design, planning, and operation to achieve success with its brick-and-mortar stores. From its beginning, the company invested heavily in transportation and information infrastructure to facilitate the effective flow of goods and information. Walmart 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. Walmart 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 2016 annual report, the company reported a net income of about $14.7 billion on revenues of about $482 billion. Despite its success with large Walmart stores, the company has had some difficulty being successful with small format stores as well as the online channel where they offer an expanded assortment. Over the years the company has realized that the supply chain structure that is effective for the brick-and-mortar channel requires modification to be effective for the online channel. Similarly, the supply chain that is very effective for large format stores is not so effective for small format stores.

The failure of many online businesses, such as Webvan and Kozmo, can be attributed to their inability to design appropriate supply chains or manage information, product, and fund flows effectively. In the late 1990s, 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 store close to the consumer using full truckloads, resulting in very low transportation costs. They turn their inventory relatively quickly 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, as well as high labor costs to pick customer orders. As a result, Webvan failed in its efforts to compete with supermarkets on price. The company 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 with 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 and 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. The company declared bankruptcy in 2010.

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 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 Walmart 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.

SUMMARY OF LEARNING OBJECTIVE 1

The goal of a supply chain should be to grow 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 increases 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.

1.2 *Define the three key supply chain decision phases and explain the significance of each one.*

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 on the structure of the supply chain for 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 used. Hyundai Motor's decision to build a second manufacturing plant in India in 2008 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. The two Hyundai plants have allowed the firm to cost effectively serve the growing Indian market and also use its Indian plants to serve global demand for small cars. In 2015, Hyundai was the second largest automobile manufacturer and the largest automobile exporter in India. 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 following 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, Hyundai's decisions regarding markets supplied by its two Indian plants and target production quantities at each plant are classified as planning decisions. 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 by which 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 Seven-Eleven Japan and Walmart 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.

SUMMARY OF LEARNING OBJECTIVE 2

Supply chain decisions may be characterized as strategic (design), planning, or operational, depending on the time horizon over which they apply. Strategic decisions relate to supply chain configuration. These decisions have a long-term impact that lasts for several years. Strategic decisions define the constraints for planning decisions, and planning decisions define the constraints for operational decisions. Planning decisions cover a period of a few months to a year and include decisions regarding production plans, subcontracting, and promotions over that period. Operational decisions span from minutes to days and include sequencing production and filling specific orders.

1.3 *Describe the cycle and push/pull views along with the macro processes of a supply chain.*

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 the 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 1-3, all supply chain processes can be broken down into the following four process cycles:

- 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 servers directly to customers.

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

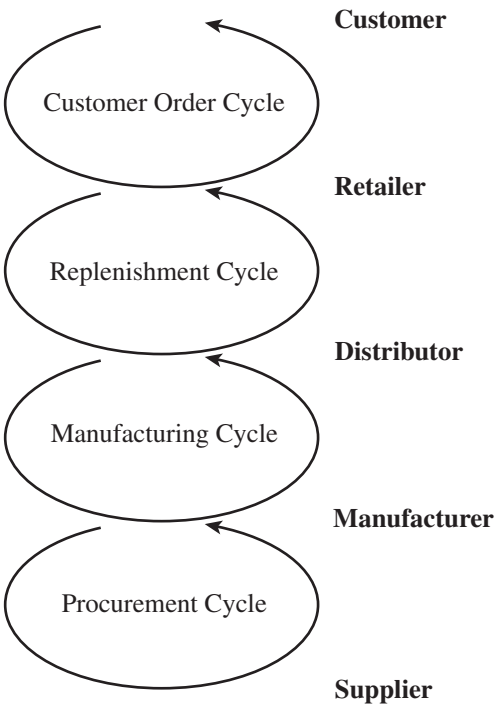

Figure 1-3 Supply Chain Process Cycles

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 again. The subprocesses in Figure 1-4 can be linked to the source, make, deliver, and return processes in the supply chain operations reference (SCOR) model. The SCOR model provides a description of supply chain processes, a framework for relationships between these processes, and a set of metrics to measure process performance. The description of the supply chain in the SCOR model is similar to the cycle view of supply chains discussed in this section.

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 publisher to replenish its inventory, it is part of the replenishment cycle—with Amazon as the buyer and the publisher as the supplier.

Within each cycle, the goal of the buyer is to ensure product availability for its customers and to achieve economies of scale in ordering. The supplier attempts to forecast buyer 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 is 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. A customer buys a single car, but 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.

The detailed process description of a supply chain in the cycle view is useful when considering operational decisions because it clearly specifies the roles of each member of the supply chain. The cycle view is used by enterprise resource planning (ERP) systems to support supply chain operations.

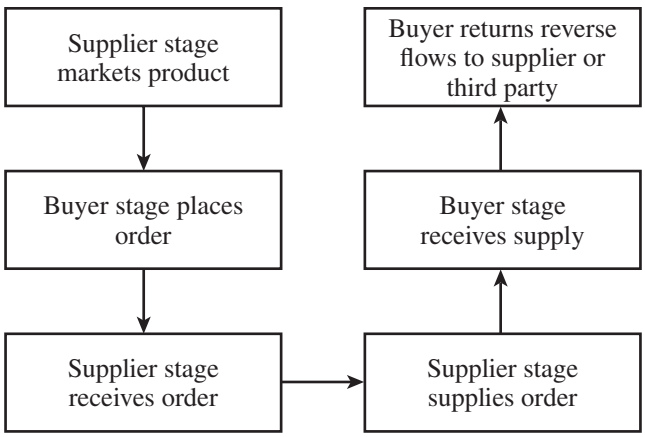

Figure 1-4 Subprocesses in Each Supply Chain Process Cycle

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 a predictable environment where 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 Ethan Allen 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.

Ethan Allen makes customized furniture, such as sofas and chairs, for which customers select the fabric and finish. 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 Ethan Allen supply chain for customized furniture: (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 Ethan Allen are classified as pull processes because they are initiated by customer order arrival. The company, however, does not place raw material orders in response to a customer order. Raw material inventory is

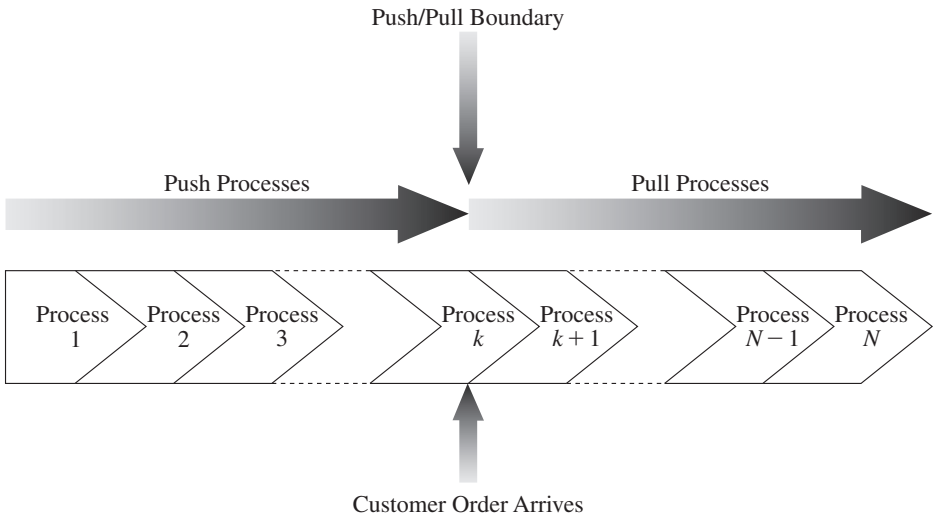

Figure 1-5 Push/Pull View of the Supply Chain

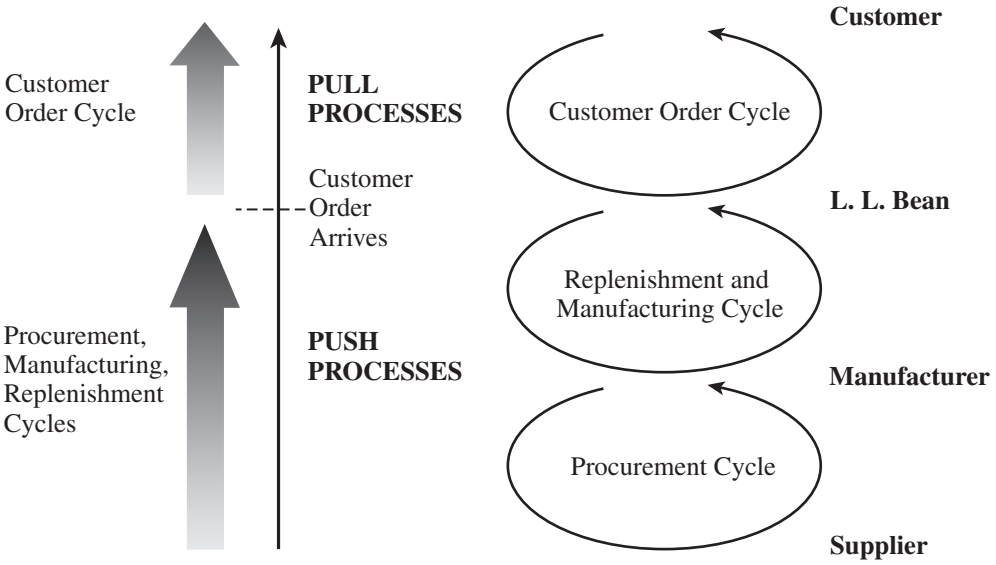

Figure 1-6 Push/Pull Processes for the L. L. Bean Supply Chain

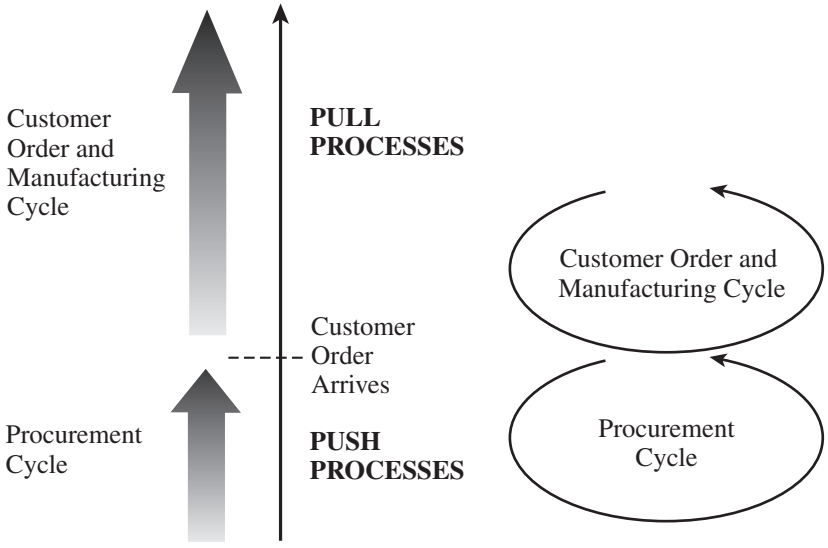

Figure 1-7 Push/Pull Processes for Ethan Allen Supply Chain for Customized Furniture

replenished in anticipation of customer demand. All processes in the procurement cycle for Ethan Allen are thus classified as push processes, because they are in response to a forecast.

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 an 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, though, the paint

supply chain had great difficulty matching supply and demand. In the 1990s, paint supply chains were restructured so 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, whereas 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 at 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 at the interface between the firm and its suppliers

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 website, 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 and receipt 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 9 and 10. 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

Figure 1-8 Supply Chain Macro Processes

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.

SUMMARY OF LEARNING OBJECTIVE 3

The cycle view 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. All supply chain processes within a firm can be classified into three macro processes: CRM, ISCM, and SRM. 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. Integration among the three macro processes is crucial for successful supply chain management.

EXAMPLES OF SUPPLY CHAINS

1.4 *Identify important issues and decisions to be addressed in a supply chain.*

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, however, 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 showrooms 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 $710 million. By 2010, Gateway computers were sold through more than 20 different retail outlets, including Best Buy and Costco. As one 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 2016, Apple had more than 460 stores worldwide, with sales of over $20 billion. Unlike Gateway, Apple has always carried product inventory at its stores. Given its product designs, Apple carries relatively little variety in its stores. In 2014, Apple retail stores had an average revenue per square foot of $4,799, the highest among all retailers.

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. What are the characteristics of products that are most suitable to be carried in finished-goods inventory at a retail store? 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 2015, Inditex reported sales of about 21 billion euros from more than 7,000 retail outlets in about 88 countries. In an industry where 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 do those of 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 with 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, along with 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 2012, Inditex distributed to stores all over the world from eight distribution centers located in Spain. The group claimed an average delivery time of 24 to 36 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 with a less frequent schedule?
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 website. 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 (although 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 both 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 from inventory along with many other products that are drop shipped from 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?

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. Before 1996, Toyota used specialized local factories for each market. After the Asian financial crisis in 1996–97, Toyota redesigned its plants so 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 a few parts plants globally that supply multiple assembly plants? Toyota has worked hard to increase commonality in parts used around the globe. Although this has 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 to 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 for specific contingency markets?

3. How should markets be allocated to plants and how frequently should this allocation be revised?
4. How should the investment in flexibility be valued?

Amazon: Online Sales

Amazon sells books, music, and many other items over the Internet and is one of the pioneers of online consumer sales. Amazon, based in Seattle, started by filling all orders using books purchased from a distributor in response to customer orders. As it grew, the company added warehouses, allowing it to react more quickly to customer orders. By 2015, Amazon had over 100 locations in the United States and another 100 in the rest of the world. It used the U.S. Postal Service and other package carriers, such as UPS and FedEx, to send products to customers. Outbound shipping-related costs at Amazon in 2015 were over $10 billion.

Amazon has continued to expand the set of products that it sells online. Besides books and music, Amazon has added many product categories such as toys, apparel, electronics, jewelry, industrial supplies, grocery items, and shoes. In 2009, one of its largest acquisitions was Zappos, a leader in online shoe sales. This acquisition added a great deal of product variety: According to the Amazon annual report, this required creating 121,000 product descriptions and uploading more than 2.2 million images to the website. In 2010, another interesting acquisition by Amazon was diapers.com. Unlike Zappos, this acquisition added little variety but considerable shipping volumes.

In 2016, Amazon opened its first physical bookstore with plans to open more. By the end of 2016 there were reports that Amazon planned to open small brick-and-mortar stores that would sell produce, milk, meats and other perishable items. Several questions arise concerning how Amazon is structured and the product categories it continues to add:

1. Why is Amazon building more warehouses as it grows? How many warehouses should it have, and where should they be located?
2. Should Amazon stock every product it sells?
3. What advantage can online players derive from setting up a brick-and-mortar location? How should they use the two channels to gain maximum advantage?
4. What advantages and disadvantages does the online channel enjoy in the sale of shoes and diapers relative to a retail store?
5. For what products does the online channel offer the greater advantage relative to retail stores? What characterizes these products?

Macy's and W.W. Grainger: Omni-Channel Retailing

After selling for decades from its department stores, Macy's made a big push into omni-channel retailing, allowing customers to have a seamless experience between shopping online or at a store. Customers could browse online and then experience the product at a store or order online after seeing a product at the store. Omni-channel is not just about ordering, however; it is also about fulfillment. Orders placed on any channel could access Macy's entire assortment. By 2012, Macy's had equipped 292 Macy's stores to fulfill online orders or orders from other stores that were sold out of a particular item. If customers desired, orders placed online could be picked up at select stores and items purchased online could be returned to stores. By 2015, this approach was presenting some challenges.

Macy's approach of using stores to fulfill online orders is similar to what W. W. Grainger practiced until about 2001. At that time, about 50 percent of the units and 30 percent of sales dollars were shipped to customers from Grainger stores. In 2001, Grainger embarked on a network redesign where the fulfillment of online orders was shifted from stores to DCs. The goal was to take advantage of picking and transportation efficiencies by aggregating online order fulfillment from DCs.