Designing and Managing the Supply Chain: Concepts, Strategies, and Case Studies

Fourth Edition

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To our children, Sara and Yuval, who have the patience and humor to survive our work together

D.S.L., E.S.L.

To my family, for their support and encouragement

P.K.

DAVID SIMCHI-LEVI is a Professor of Engineering Systems at MIT and serves as the Director of the MIT Data Science Lab. He is considered one of the premier thought leaders in supply chain management and business analytics. His Ph.D. students have accepted faculty positions in leading academic institutes including U. of California Berkeley, Carnegie Mellon U., Columbia U., Duke U., Georgia Tech, Harvard U., U. of Illinois Urbana-Champaign, U. of Michigan, Purdue U., and Virginia Tech. Professor Simchi-Levi is the current Editor-in-Chief of *Management Science*, one of the two flagship journals of INFORMS. He served as the Editor-in-Chief for *Operations Research* (2006–2012), the other flagship journal of INFORMS and for *Naval Research Logistics* (2003–2005). He is an INFORMS Fellow, MSOM Distinguished Fellow, and was awarded the prestigious 2020 INFORMS Impact Prize for playing a leading role in developing and disseminating a new highly impactful paradigm for the identification and mitigation of risks in global supply chains. He is the recipient of the 2020 INFORMS Koopman Award given to an outstanding publication in military operations research; Ford Motor Company 2015 Engineering Excellence Award; 2014 INFORMS Daniel H. Wagner Prize for Excellence in Operations Research Practice; 2014 INFORMS Revenue Management and Pricing Section Practice Award; and 2009 INFORMS Revenue Management and Pricing Section Prize. He was the co-founder of LogicTools, which provided software solutions and professional services for supply chain optimization. LogicTools became part of IBM in 2009. In 2012, he co-founded OPS Rules, an operations analytics consulting company. The company became part of Accenture in 2016. In 2014, he co-founded Opalytics, a cloud analytics platform company focusing on operations and supply chain intelligence. The company became part of the Accenture Applied Intelligence in 2018.

PHILIP KAMINSKY is the Earl J. Isaac Professor in the Science and Analysis of Decision Making in the Department of Industrial Engineering and Operations Research at UC Berkeley. He served as Executive Associate Dean and Associate Dean for Students in the UC Berkeley College of Engineering, and before that, faculty director of the Sutardja Center for Entrepreneurship and Technology, director of the Initiative for Research in Biopharmaceutical Operations, and department chair of the Industrial Engineering and Operations Research Department. He currently serves as the Focused Issue Editor for *IISE Transactions Scheduling and Logistics*. His research focuses on the analysis and development of robust and efficient tools and techniques for design, operation, and risk management in logistics systems and supply chains.

EDITH SIMCHI-LEVI is startup adviser and investor in New York City. She was the co-founder and Vice President of Operations of LogicTools, which became part of IBM in 2009 and Opalytics, which was acquired by Accenture in 2018. She has extensive experience in software development and has engaged in numerous projects in logistics and supply chain management. She received her B.S. in Mathematics and Computer Science from Tel-Aviv University.

When the first edition of this book appeared, in August 1999, it stood out from the explosion of publications on supply chain management. Although a few books were published and many articles appeared in academic, trade, and popular magazines, most of these publications were either too technical—and therefore inaccessible to practitioners and students—or lacked the breadth and depth that the topic deserves. Certainly, it was difficult to find a book appropriate for teaching supply chain management to business or engineering students. *Designing and Managing the Supply Chain* solved that problem!

Since that time, this has been the most influential supply chain management book. With a combination of analytical concepts, case studies, and examples, the book has helped numerous executives, graduate, and undergraduate students grasp the practice and science of supply chain management. This was the first book that covered a comprehensive breadth of supply chain topics in depth, and addressed the major challenges in this area. It was written by experts from academia and industry who have been researching, consulting, and developing software for supply chain management for many years.

The book continues to be an important contribution and major milestone for the supply chain community. The fourth edition continues in this direction in important ways by adding new chapters on timely topics including supply chain risk management, supply chain flexibility, and sustainable supply chains.

This book includes many classic and new case studies, numerous examples, and in-depth analyses of the critical technical issues involved in inventory management, network design, risk, and strategic partnering, to name a few. It is therefore an ideal textbook for classes on supply chain management at the undergraduate, Master's, and M.B.A. levels. Since each chapter is self-contained, instructors can pick the chapters they want to use depending on the length of the class and its requirements.

I want to compliment the authors for having written such an outstanding textbook for the supply chain community.

Hau L. Lee
Kleiner Perkins, Mayfield, Sequoia Capital Professor
Director, Stanford Global Supply Chain Forum
Stanford University

The original edition of this book, published in 1999, grew out of a number of supply chain management courses and executive education programs we taught at Northwestern University, as well as numerous consulting projects and supply chain decision-support systems we developed at LogicTools, a company we founded in 1995, which became part of IBM in 2009.

Since the publication of the first edition, we have continued teaching executive and regular courses, both at Massachusetts Institute of Technology and at the University of California, Berkeley, and have continued to develop a variety of supply chain decision support tools. These courses have spawned many innovative and effective supply chain education concepts. The focus in these programs has always been on presenting, in an easily accessible manner, recently developed state-of-the-art models and solution methods important in the design, control, and operation of supply chains. Similarly, the consulting projects and decision-support systems developed by LogicTools have focused on applying these advanced techniques to solve specific problems faced by our clients.

These developments led to the release of two subsequent editions, in 2002 and 2007, where we continued to add new approaches, models, and techniques and, in particular, introduced and emphasized frameworks for supply chain integration. We are pleased to note that these revisions were successful; we received a tremendous response from adopters, students, executives, and consultants.

As interest in supply chain management increased both in industry and academia, many businesses have adopted strategies such as just-in-time, lean manufacturing, offshoring, and frequent deliveries to retail outlets. These much-touted strategies may have allowed companies to cut cost but dramatically increased supply chain risk. This was demonstrated in a powerful way during events such as the global financial turmoil in 2008, the 2011 tsunami in Japan and flood in Thailand and the world-wide COVID-19 pandemic in 2020.

In response to some of these developments, David Simchi-Levi published in 2011, the business book *Operations Rules: Delivering Customer Value through Flexible Operations*, where he offers a set of scientific and empirically based rules that management can follow to achieve a quantum leap in operational performance. The book identifies the crucial elements in a company's success: the link between the value it

provides and supply chain strategies; flexibility, an important capability that allows the firm to innovate its supply chain strategy; and effective sustainability and risk mitigation strategies. The fourth edition of *Designing and Managing the Supply Chain* now includes new chapters that provide in-depth coverage of these important topics.

Finally, recent technology trends such as digitization, advanced analytics, in particular, machine learning and artificial intelligence, and automation are changing the way companies manage businesses, from demand planning and promotional decisions, all the way to financial planning. In this space, we have benefited both from academic research as well as numerous development and implementations of digital solutions from Ops Rules and Opalytics, two companies we founded that became part of Accenture in 2016 and 2018, respectively. In recognition of these developments, the fourth edition includes material based on work that we have done individually and collectively in the area of business analytics.

The book is written to serve as

- A textbook for M.B.A.-level logistics and supply chain management courses.
- A textbook for B.S. and M.S. industrial engineering courses on logistics and supply chain management.
- A reference for teachers, consultants, and practitioners involved in any one of the processes that make up the supply chain.

The emphasis is on a format that is accessible to executives and practitioners, as well as students interested in careers in related industries. For that reason, almost every chapter starts with a case study that raises a few supply chain issues; issues discussed in the chapter. Similarly, every chapter ends with a case-study that motivates an in-depth discussion of the material covered in the chapter.

Of course, supply chain management is a very broad area, and it would be impossible for a single book to cover all of the relevant areas in-depth. Indeed, there is considerable disagreement in academia and industry about exactly what these relevant areas are. Nevertheless, we have attempted to provide a broad introduction to many critical facets of supply chain management. Although many essential supply chain management issues are interrelated, we have strived wherever possible to make each chapter as self-contained as possible, so that the reader can refer directly to chapters covering topics of interest.

The book includes four interrelated parts.

Part I (Chapters 2–5) is focused on *fundamentals* and covers topics such as inventory management, logistics network planning, supply contracts, the Bullwhip Effect, and the value of information in the supply chain.

Part II (Chapters 6–11) covers *coordination and integration* and is focused on topics such as Push–Pull strategies, distribution strategies, strategic alliances such as Vendor Managed Inventory, procurement and outsourcing strategies, product design, and the interface between product design and supply chain strategies and supply chain flexibility.

Part III (Chapters 12–15) is all about *strategy,* from the coordination of customer value proposition and supply chain strategy to risk management, sustainability, and corporate social responsibility, all the way to smart pricing.

Part IV (Chapters 16–17) is focused on *technology* including business processes such as Sales and Operations planning, information technology for supply chains, decision-support systems, and technology standards associated with infrastructure, architecture, the Internet of Things (IoT), RFID, and Blockchain.

Each chapter utilizes numerous case studies and examples, and mathematical and technical sections can be skipped without loss of continuity.

The fourth edition of the book represents a substantial revision. Indeed, while we kept the same structure and philosophy as in the previous editions, we have included new chapters:

- Chapter 11 Supply chain flexibility;
- Chapter 13 Supply chain risk management;
- Chapter 14 Sustainable supply chains.

Existing chapters have been completely revised to introduce new concepts such as the link between customer value and supply chain strategies (Chapter 12); business analytics and smart pricing (Chapter 15); and new technologies such as IoT, Blockchain, and their impact on supply chains (Chapter 17).

Some of the new material in the fourth edition is based on recent work by David Simchi-Levi.

- Chapters 11–14 borrow extensively from Simchi-Levi, D., *Operations Rules: Delivering Customer Value through Flexible Operations*. MIT Press, 2011.
- Chapter 13 also borrows heavily from Simchi-Levi, D.; W. Schmidt; and Y. Wei, "From Superstorms to Factory Fires: Managing Unpredictable Supply Chain Disruptions." *Harvard Business Review,* January–February 2014, pp. 96–101.
- Chapter 15 is, in part, based on the paper by Simchi-Levi, D., "The New Frontier of Price Optimization." *Sloan Management Review,* Fall 2017, pp. 22–26, as well as the paper by Simchi-Levi, D; and M.X. Wu, "Powering Retailers Digitization Through Analytics and Automation." Special issue of *International Journal of Production Research,* dedicated to 55 Best Scholars in Production Research for the 55th Volume Anniversary of *IJPR,* Volume 56, (2018) Issue 1–2, pp. 809–816.
- Chapter 15 is also based on the paper by Johnson, K.; A.B.H. Lee; and D. Simchi-Levi, "Analytics for an Online Retailer: Demand Forecasting and Price Optimization." *Manufacturing and Service Operations Management,* Volume 18, No. 1 (2016), pp. 69–85.

The spreadsheets used in the third edition to assist learning topics such as supply contracts (Chapter 4), the bidding game (Chapter 9) and the new Nissan case (Chapter 13), are now on the book's website through Connect.

Selected Harvard and Stanford cases in the fourth edition are available in a Case Supplement at the end of the text. This supplement is also available separately through McGraw Hill's Create system at http://create.mhhe.com.

It is our pleasure to acknowledge all those who helped us with the four editions of this manuscript. First, we would like to thank Dr. Myron Feinstein, former director of supply chain strategy development at Unilever, New York City, who read through and commented on various chapters of the first edition. Similarly, we are indebted to the instructors who reviewed the manuscript of the first edition, Professors Michael Ball (University of Maryland), Wendell Gilland (University of North Carolina, Chapel Hill), Eric Johnson (Dartmouth College), Douglas Morrice (The University of Texas, Austin), Michael Pangburn (Pennsylvania State University), Powell Robinson (Texas A&M University), William Tallon (Northern Illinois University), and Rachel Yang (University of Illinois, Urbana-Champaign).

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We also are indebted to those who reviewed the second edition in preparation for the third edition: Kyle Cattani (University of South Carolina, Chapel Hill), Zhi-Long Chen (University of Maryland), Deborah F. Cook (Virginia Technical University), Sriam Dasu (University of California, Los Angeles), Mark Ferguson (Georgia Technical University), Manoj K. Malhotra (University of South Carolina, Columbia), Charles Petersen (Northern Illinois University), and Young K. Son (Baruch College). The third edition has greatly benefited from their comments.

The third and fourth editions benefited from comments by Professor Chung-Lun Li (The Hong Kong Polytechnic University) and Professor Victor Martinez de Albeniz (IESE, Spain).

We are grateful to our colleagues at Massachusetts Institute of Technology; University of California, Berkeley; Amazon; LogicTools; IBM; Ops Rules; Opalytics; and Accenture who have provided us with opportunities to interact with some of the brightest minds in our field and to learn from their research and development.

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Fierce competition in today's global markets, the introduction of products with shorter life cycles, increased risk (for example weather, pandemic, cyber) and the heightened expectations of customers have forced business enterprises to invest in, and focus attention on, their supply chains. This, together with new technology trends, (for example Artificial Intelligence, Internet of Things, RFID and blockchain technologies, and more generally, digitization, advanced analytics, and automation), has motivated the continuous evolution of the supply chain and of the techniques to manage it effectively.

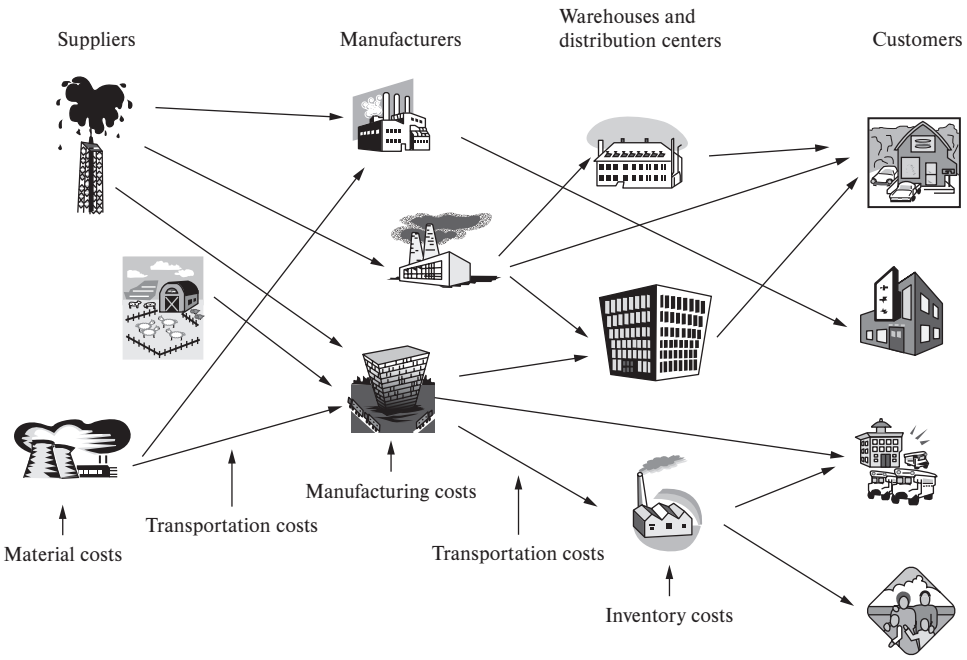
In a typical supply chain, raw materials are procured and items are produced at one or more factories, shipped to warehouses for intermediate storage, and then shipped to retailers or customers. Consequently, to reduce cost and improve service levels, effective supply chain strategies must consider the interactions at the various levels in the supply chain. The supply chain, which is also referred to as the *logistics network,* consists of suppliers, manufacturing centers, warehouses, distribution centers, and retail outlets, as well as raw materials, work-in-process inventory, and finished products that flow between the facilities (see Figure 1-1).

In this book, we present and explain concepts, insights, practical tools, and decision support systems important for the effective management of the supply chain. But what exactly is *supply chain management*? We define it as follows:

> Supply chain management is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize systemwide costs while satisfying service level requirements.

This definition leads to several observations. First, supply chain management takes into consideration every facility that has an impact on cost and plays a role in making the product conform to customer requirements: from supplier and manufacturing facilities through warehouses and distribution centers to retailers and stores. Indeed, in some supply chain analyses, it is necessary to account for the suppliers' suppliers and the customers' customers because they have an impact on supply chain performance.

Second, the objective of supply chain management is to be efficient and cost-effective across the entire system taking into account customer service and value requirements; total systemwide costs, from transportation and distribution to inventories of raw materials,



work in process, and finished goods, are to be minimized. Thus, the emphasis is not on simply minimizing transportation cost or reducing inventories but, rather, on taking a *systems approach* to supply chain management.

Finally, because supply chain management revolves around efficient integration of suppliers, manufacturers, warehouses, and stores, it encompasses the firm's activities at many levels, from the strategic level through the tactical to the operational level.

What about logistics management, or value chain management, or demand chain management? Various companies, consultants, and academics have developed a variety of terms and concepts to stress what they believe are the salient issues in supply chain management. Although many of these concepts are useful and insightful, for the purposes of this text, we will use supply chain management as the generic name for the set of concepts, approaches, strategies, and ideas that we are discussing.

What makes supply chain management difficult? Although we will discuss a variety of reasons throughout this text, they can all be related to some or all of the following observations:

1. **Supply chain strategies cannot be determined in isolation. They are directly affected by another chain that most organizations have, the *development chain*** that includes the set of activities associated with new product introduction. Similarly, decisions regarding the development chain, such as product design and introduction, are affected by the characteristics of the supply chain. Thus, these two chains (i.e., the supply chain and development chain) must be integrated to improve business performance.
2. **It is challenging to design and operate a supply chain so that total systemwide costs are minimized, and systemwide service levels are maintained.** Indeed, it is frequently difficult to operate *a single facility* so that costs are minimized and service level is maintained. The difficulty increases exponentially when an entire

system is being considered. The process of finding the best *systemwide* strategy is known as *global optimization*.

3. **Uncertainty and risk are inherent in every supply chain;** customer demand can never be forecast accurately, travel times will never be certain, and machines and vehicles will break down. Similarly, recent industry trends, including outsourcing, offshoring, and lean manufacturing that focus on reducing supply chain costs, significantly increase the level of risk in the supply chain. Thus, supply chains need to be designed and managed to eliminate as much uncertainty and risk as possible as well as deal effectively with the uncertainty and risk that remain.
4. **One-size-fits-all strategy is not appropriate.** Indeed, different customer segments, channels, or products may require different supply chain strategies. This drives the need for **supply chain segmentation,** that is, the need for multiple supply chains within the same firm, each of which may focus on delivering a different customer value proposition. Unfortunately, segmentation can lead to increased complexity and loss of the ability to benefit from economies of scale.

In the next four sections, we discuss these issues in more detail.

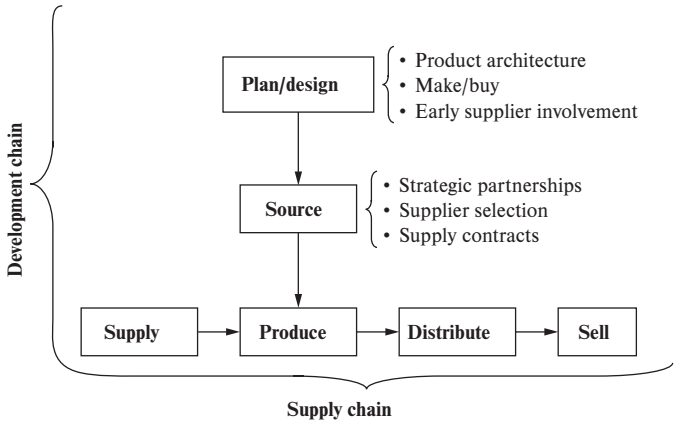
The *development chain* is the set of activities and processes associated with new product introduction. It includes the product design phase, the associated capabilities and knowledge that need to be developed internally, sourcing decisions, and production plans. Specifically, the development chain includes decisions such as product architecture, what to make internally and what to buy from outside suppliers (i.e., make/buy decisions, supplier selection, early supplier involvement, and strategic partnerships).

The development and supply chains intersect at the production point, as illustrated in Figure 1-2. It is clear that the characteristics of and decisions made in the development chain will have an impact on the supply chain. Similarly, it is intuitively clear that the characteristics of the supply chain must have an impact on product design strategy and hence on the development chain.

Hewlett Packard was one of the first firms to recognize the intersection of the development and supply chains. A case in point is the Inkjet printer introduction, where decisions about product architecture were made by considering not only labor and material cost, but also total supply chain cost throughout the product life cycle. More recently, HP has focused on making decisions such as what design activities to outsource and the corresponding organizational structures needed to manage the outsource design process by considering the characteristics of both the development chain and supply chain.

Unfortunately, in most organizations, different managers are responsible for the different activities that are part of these chains. Typically, the VP of Engineering is responsible for the development chain, the VP of Manufacturing for the production portion of the chains, and the VP of supply chain or logistics for the fulfillment of customer demand. Unless carefully addressed, the typical impact of this organizational structure is a misalignment of product design and supply chain strategies.

To make matters worse, in many organizations, additional chains intersect with both the development and supply chains. These may include the reverse logistics chain (i.e., the chain associated with returns of products or components, as well as the spare-parts chain).



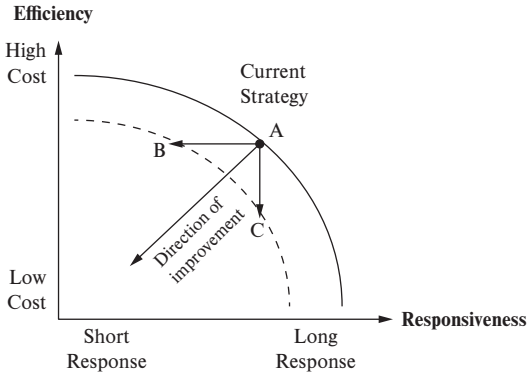
In this book, we explore the various characteristics of each of these supply chains in order to better understand the impact of these on product and supply chains strategies. We illustrate how these characteristics lead to the development of frameworks to assist in matching products with strategies.

What makes finding the best systemwide, or globally optimal, integrated solution so difficult? A variety of factors make this a challenging problem:

1. **The supply chain is a complex network** of facilities dispersed over a large geography, and in many cases, all over the globe. The following example illustrates a network that is fairly typical of today's global companies.

Intel Corporation, whose main competitor is Samsung Electronics, is one of the world's largest semiconductor chip manufacturers. Currently, the company has 11 fabrication facilities and five assembly/test factories spread across North America, Asia, Europe, and the Middle East, for a total of seven countries. These manufacturing facilities are supported by about 30 global distribution centers that ship around 1 million units per day to global customers. In addition to semiconductor chips, the company offers a variety of products from wireless controllers to software solutions. Since this industry is highly competitive, Intel recognized that its supply chain is central to its success and has focused on a variety of initiatives including shorter lead time; more cost-effective performance; and increase environmental sustainability. All of these objectives need to be achieved at the same time that their product mix and volume has increased dramatically.[1]

2. **Supply chain trade-offs are not easy to optimize.** Supply chain strategies affect multiple measures of performance such as cost, time, and service levels. Unfortunately, these are conflicting measures as is illustrated in Figure 1-3 where you can see the solid curve represents the trade-offs between efficiency and responsiveness. Efficiency refers to cost while responsiveness refers to speed, or time to serve customers. This curve, sometimes referred to as the efficient frontier, represents a range of possible strategies, each with a corresponding cost (efficiency) and response time (responsiveness). Indeed, a high-efficiency level (i.e., a low-cost supply chain strategy) typically increases time to serve customers and does not



emphasize a high level of service. Alternatively, a highly responsive strategy increases cost but reduces customer response time. The challenge is to find the appropriate trade-offs between the various measures and as we will see later on, this is a daunting challenge.

Of course, trade-offs between efficiency and responsiveness are not the only ones. Flexibility versus cost; cost versus exposure to risk; inventory versus service levels; and quality versus price are all examples of trade-offs that need to be made. Each of these trade-offs entails a figure similar to Figure 1-3. Supply chain innovation is about improving performance despite these trade-offs. To illustrate this idea, look at Figure 1-3 again and assume that your current strategy is the one corresponding to point A on the top efficient frontier curve. This strategy of course invests in a specific trade-off between efficiency and responsiveness.

Imagine now that you can devise a new strategy that, somehow, pushes the efficient frontier downwards. If this is possible, then for the same level of efficiency, you can improve the response time, see point B. Similarly, for the same level of responsiveness, one can reduce the operational cost, see point C, that is, improve operations efficiency. More importantly, there is a range of strategies between B and C where the firm improves both efficiency and responsiveness. The challenge, of course, is to identify such strategies.

3. **Different facilities in the supply chain frequently have *different, conflicting, objectives*.** For instance, suppliers typically want manufacturers to commit themselves to purchasing large quantities in stable volumes with flexible delivery dates. Unfortunately, although most manufacturers would like to implement long production runs, they need to be flexible to their customers' needs and changing demands. Thus, the suppliers' goals are in direct conflict with the manufacturers' desire for flexibility. Indeed, since production decisions are typically made without precise information about customer demand, the ability of manufacturers to match supply and demand depends largely on their ability to change supply volume as information about demand arrives. Similarly, the manufacturers' objective of making large production batches typically conflicts with the objective of distribution centers to reduce inventory. To make matters worse, this latter objective of reducing inventory levels typically implies an increase in transportation costs.
4. **The supply chain is a dynamic system** that evolves over time. Indeed, not only do customer demand and supplier capabilities change over time, but supply chain relationships also evolve over time. For example, as customers' power increases,

there is increased pressure placed on manufacturers and suppliers to produce an enormous variety of high-quality products and, ultimately, to produce customized products.

5. **System variations over time** are also an important consideration. Even when demand is known precisely (e.g., because of contractual agreements), the planning process needs to account for demand and cost parameters varying over time due to the impact of seasonal fluctuations, trends, advertising and promotions, competitors' pricing strategies, and so forth. These time-varying demand and cost parameters make it difficult to determine the most effective supply chain strategy, the one that minimizes systemwide costs and conforms to customer requirements.

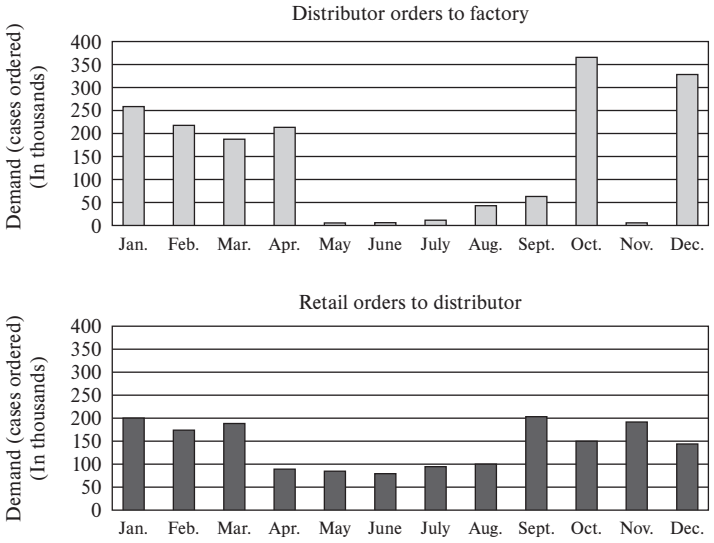
Of course, global optimization also implies that it is not only important to optimize across supply chain facilities, but also across processes of the development chain and supply chain. That is, it is important to identify processes and strategies that optimize, or alternatively, synchronize, both chains simultaneously.

Global optimization is made even more difficult because supply chains need to be designed for, and operated in, uncertain environments, thus creating sometimes enormous risks to the organization. A variety of factors contribute to this:

1. **Matching supply and demand** is a major challenge:
   - **a.** In 2002, Cisco announced a $2.25 billion inventory write-off due to a downturn in the telecommunication industry.[2]
   - **b.** In April 2014, Walmart acknowledged that the company lost $3 billion in 2014 sales due to problems stocking desired items, even as inventory costs grew faster than sales revenues.[3]
   - **c.** Circuit protection product manufacturer **Littelfuse** reported its second-quarter results before the market opened on July 31, 2019. Revenue and adjusted earnings tumbled as trade tensions, a weak automotive market, and bloated channel inventories posed major challenges. High inventories will be a problem for the rest of the year, likely killing any chance of a significant rebound in the second half.[4]

   Obviously, this difficulty stems from the fact that months before demand is realized, manufacturers have to commit themselves to specific production levels. These advance commitments imply huge financial and supply risks.

2. **Inventory and back-order levels fluctuate considerably across the supply chain,** even when customer demand for specific products does not vary greatly. To illustrate this issue, consider Figure 1-4, which suggests that in a typical supply chain, distributor orders to the factory fluctuate far more than the underlying retailer demand.
3. **Forecasting doesn't solve the problem.** Indeed, we will argue that the first principle of forecasting is that "forecasts are always wrong." Thus, it is impossible to predict the precise demand for a specific item, even with the most advanced forecasting techniques.
4. **Demand is not the only source of uncertainty.** Delivery lead times, manufacturing yields, transportation times, and component availability can also have significant supply chain impact.



5. **Trends such as lean manufacturing, outsourcing, and offshoring that focus on cost reduction increase risks significantly.** For example, consider an automotive manufacturer whose parts suppliers are in Canada and Mexico. With little uncertainty in transportation and a stable supply schedule, parts can be delivered to assembly plants "just-in-time" based on fixed production schedules. However, in the event of an unforeseen disaster, such as the September 11 terrorist attacks, COVID-19 pandemic, port strikes and weather-related calamities adherence to this type of strategy could result in a shutdown of the production lines due to lack of parts.

   Similarly, outsourcing and offshoring imply that the supply chains are more geographically diverse and as a result, natural and man-made disasters can have a tremendous impact.

- On March 11, 2011, a 9.0-magnitude earthquake, among the five most powerful on record, struck off the coast of Japan. Tsunami waves in excess of 40 meters high traveled up to 10 kilometers inland and three nuclear reactors at Fukushima Daiichi experienced Level 7 meltdowns. The impact of this combined disaster was devastating, with over 25,000 people dead, missing, or injured. The event was not just a humanitarian crisis, but also a heavy blow to the Japanese economy—125,000 buildings were damaged and economic costs were expected to exceed $200 billion. In the weeks following the disaster, approximately 80 percent of Japanese automotive plants suspended production and Mitsubishi UFJ Morgan Stanley Securities estimated utilization at other plants were below 10 percent, see Nissan case study, Chapter 13 of this book.
- On August 29, 2005, Hurricane Katrina devastated New Orleans and the Gulf coast. Procter and Gamble (P&G) coffee manufacturing, with brands such as Folgers that get over half of their supply from sites in New Orleans, was severely impacted by the hurricane. Six months later, there were, as a P&G executive told The New York Times, "still holes on the shelves" where P&G's brands should be.[5]
- A 2002, West Coast port strike shut down ports from Seattle to San Diego. Economists estimate that this strike cost the economy up to $1 billion a day, as stores could not be stocked, fruits and vegetables rotted, and factories were shut down due to lack of parts.[6]
- Fabric shipments from India were delayed in the wake of the January 26, 2001, earthquake in the Indian state of Gujarat, impacting many U.S. apparel manufacturers.[7]

Of course, uncertainty and risk cannot be eliminated. However, we will explore a variety of examples that illustrate how product design, network modeling, information technology, procurement and inventory strategies are used to reduce uncertainty or minimize its impact. Similarly, we will introduce a new way to identify hidden risk in the supply chain, referred to as the Risk Exposure Index,[8] and explore a variety of examples that illustrate how capacity redundancy, supply chain flexibility, and speed in sensing and responding are used to reduce or mitigate risks.

Consider Zara, the large Spanish clothing company known for fashion, stylish designs, as well as product diversity. Since 1974, when Mr. Amancio Ortega Gaona, Zara's chairman, opened his first store, the objective was not only to compete on price but, even more importantly, to provide customers with the trendy fashion products they like. This required building a business model quite different from its competitors, such as the Gap Inc., one of the world's largest specialty retailers.

While retailers such as Gap reduce cost by outsourcing manufacturing mostly to the Far East, Zara owns its entire supply chain, from manufacturing through distribution centers to retail outlets. Because of the focus on fashionable, trendy products, for which demand is highly uncertain, Zara procures capacity from its fabric suppliers, not committing necessarily to a specific color or print until there is a clear picture on consumers preference. Retail stores provide direct feedback to the company headquarters through its IT infrastructure, allowing designers to identify trends, new designs and styles.

Using this strategy, Zara is able to reduce time to market for new styles down to three to 4 weeks, significantly shorter than the competition. In comparison, Gap's focus on low-cost manufacturing in the Far East implies a long pipeline, typically loaded with inventory, hence diminishing its ability to frequently introduce new products to the market.

The stories of Zara and Gap communicate a powerful message. Firms operating in the same space but providing different **customer value propositions** need different operations and supply chain strategies. Indeed, Gap's focus on competitive pricing demands an operations strategy dedicated to efficiency; that is, a strategy where the primary goal is reducing operational costs. By contrast, Zara's value proposition, which provides customers with trendy fashion products, requires an operations strategy focused on speed and hence a vertically integrated supply chain dedicated to responsiveness.

Dell, to name another example, outperformed the competition by over 3,000 percent in terms of shareholder growth over the 8-year period from 1988 to 1996.[9] Dell's success over this period can be attributed to its virtual integration, a strategy that blurs the traditional boundaries between suppliers, manufacturers, and end users. Dell's decision to sell computers built from components produced by other manufacturers relieved the firm of the burden of owning assets, doing research and development, and managing a large workforce. At the same time, its direct sales model allows consumers to configure their computer and as a result, the customer value proposition is focused entirely on customer experience. This value proposition requires Dell to design a supply chain strategy that fully customizes an order with a short response time.

Dell's struggle in the late 2000s was in part due to a change in the PC market: growth in this market had shifted from online to retail and from developed to developing countries where consumers were not used to, or not comfortable with, buying online. As we shall see (Chapter 12), such a shift entails rethinking supply chain strategies, since the customer value proposition when selling direct is different than the one associated with the retail channel. Indeed, the retail channel implies a focus on price and this requires an efficient supply chain strategy. Thus, the introduction of the retail

channel required the development of multiple supply chain strategies, one focusing on responsiveness and a second focusing on efficiency.

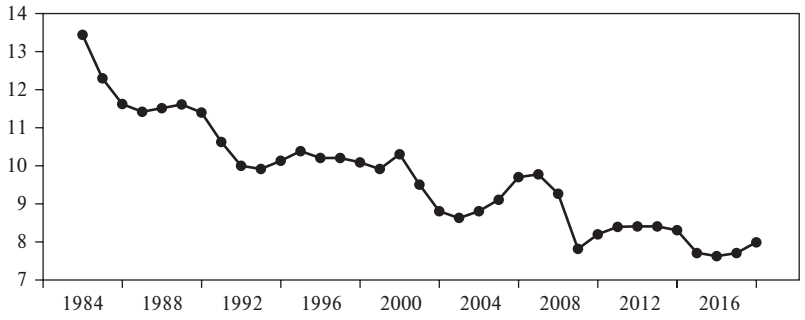
The Dell story illustrates an important lesson for supply chain executives: a one-size-fits-all supply chain strategy is not appropriate. The variety of product characteristics, customers and channels may require the implementation of a segmented supply chain strategy. The challenge, of course, is to identify the appropriate number of segments: too many segments increase supply chain complexity, while a single segment implies a strategy that is effective only on average, but not tailored to deal with the different customer value requirements, product characteristics and channel challenges.

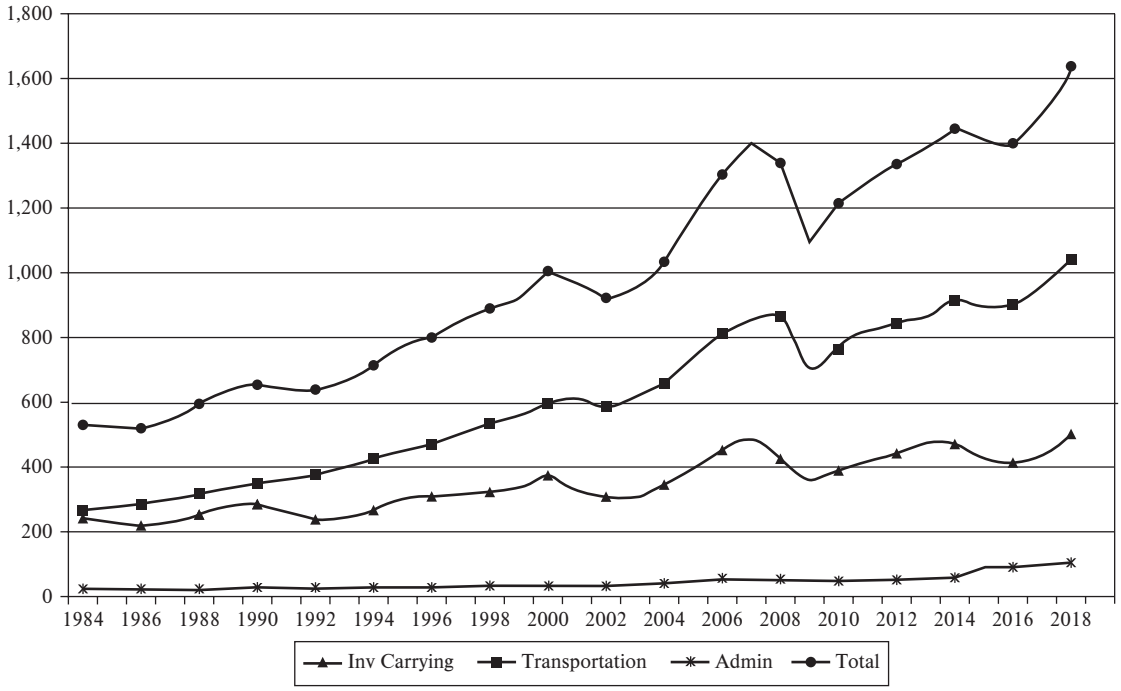
In the 1980s, companies discovered new manufacturing technologies and strategies that allowed them to reduce costs and better compete in different markets. Strategies such as just-in-time manufacturing, *kanban*, lean manufacturing, total quality management, and others became very popular, and vast amounts of resources were invested in implementing these strategies. In the 1990s, however, it has become clear that many companies have reduced manufacturing costs as much as is practically possible. Many of these companies are discovering that effective supply chain management is the next step they need to take in order to increase profit and market share.

Indeed, logistics and supply chain costs play an important role in the U.S. economy: the annual State of Logistics Report, which is sponsored by the Council of Supply Chain Management Professionals, first published in 1989, provides an accounting of the nation's total logistics bill and tracks trends in transportation costs, inventory-carrying costs, and total logistics costs. As you can see from Figure 1-5, the U.S. logistics costs were over 12 percent of GDP in the early 1980s, steadily decreasing until 2003. The absolute numbers are quite staggering: for 1998, the amount was $884 billion, while in 2005, it was $1.18 trillion. This $1.18 trillion represents an increase of $156 billion over 2004, which is even more striking if one considers that while the U.S. economy slowed down in 2005, logistics costs increased by about 15 percent. This increase was driven, according to the State of Logistics report, by "high fuel costs, truck driver and rail capacity shortages, offshoring and outsourcing, and the costs of security."

In 2008 and 2009 Logistics costs, both as a percentage of the U.S. GDP and in absolute values, went down, from $1.4 trillion in 2007 to $1.34 trillion in 2008 all the way to $1.10 trillion in 2009. This is of course related to the 2008 financial crisis. However, following the crisis, logistics costs have increased steadily and in 2018, it was $1.63 trillion.

It is also interesting to understand the magnitude of the various cost components that constitute the U.S. logistics costs. This data is presented in Figure 1-6 (taken





again from the State of Logistics Report) where you can see that transportation cost is by far the largest cost component; inventory cost is slightly higher than half of the transport costs. Both costs have steadily increased in the last few years except for 2009 where both inventory and transportation costs showed a slight decrease.

Unfortunately, this huge investment typically includes many unnecessary cost components due to redundant stock, inefficient transportation strategies, and other wasteful practices in the supply chain. For instance, experts believe that the grocery industry, a notoriously low margin industry, can save about $30 billion, or 10 percent of its annual operating cost, by using more effective supply chain strategies.[10]

To illustrate this issue, consider the following two examples:

1. It takes a typical box of cereal more than three months to get from the factory to a supermarket.
2. It takes a typical new car, on average, 15 days to travel from the factory to the dealership. This lead time should be compared with the actual travel time, which is no more than four to 5 days.

Thus, in the 1990s, many companies focused on strategies to reduce their costs as well as those of their supply chain partners.

Procter & Gamble estimates that it saved retail customers $65 million in a recent 18-month supply chain initiative. "According to Procter & Gamble, the essence of its approach lies in manufacturers and suppliers working closely together . . . jointly creating business plans to eliminate the source of wasteful practices across the entire supply chain."[11]

As the example suggests, an important building block in an effective supply chain strategy is *strategic partnerships* between suppliers and buyers, partnerships that can help both parties reduce their costs.

Indeed, manufacturers such as P&G and Kimberly-Clark, and giant retailers like Walmart have used strategic partnering as an important element in their business strategies. Firms such as 3M, Eastman Kodak, Dow Chemical, Time Warner, and General Motors turned over large portions of their logistics operations to third-party logistics providers.

At the same time, many supply chain partners engage in *information sharing* so that manufacturers are able to use retailers' up-to-date sales data to better predict demand and reduce lead times. This information sharing also allows manufacturers to control the variability in supply chains (known as the bullwhip effect, see Chapter 5), and by doing that reduce inventory and smooth out production.

Among the first companies to utilize real-time information was Milliken and Company, a textile and chemicals company. Milliken worked with several clothing suppliers and major department stores, all of which agreed to use POS data from the department stores to "synchronize" their ordering and manufacturing plans. The lead time from order receipt at Milliken's textile plants to final clothing receipt at the department stores was reduced from 18 weeks to 3 weeks.[12]

The huge pressure during the 1990s to reduce costs and increase profits pushed many industrial manufacturers towards *outsourcing*; firms considered outsourcing everything from the procurement function to production and manufacturing. Indeed, in the mid-90s, there was a significant increase in purchasing volume as a percentage of the typical firm's total sales. Similarly, between 1998 and 2000, outsourcing in the electronic industry has increased from 15 percent of all components to 40 percent.[13]

In the late 1990s and the early 2000s, the *Internet* and the related *e-business models* led to expectations that many supply chain problems would be solved merely by using these new technologies and business models. E-business strategies were supposed to reduce cost, increase service level, and increase flexibility and, of course, increase profits, albeit sometime in the future. In reality, these expectations frequently were not met, as many e-businesses failed. In many cases, the downfall of some of the highest profile Internet businesses can be attributed to their logistics strategies.

Furniture.com, launched in January 1999, offered thousands of products from many furniture makers, although only few brand names. The company had $22 million in sales in the first nine months of 2000 and one million visitors a month to its website. Its downfall in November of 2000 was due to logistics details, and, in particular, inefficient delivery processes. Initially, Furniture.com used carriers to ship its products from a central warehouse to the customers. Since transportation costs were too high, the firm formed an alliance with six regional distributors. Unfortunately, these relationships were hard to maintain and left many problems unsolved, including handling of repairs and returns.

Of course, in many cases, the Internet introduced new channels and helped to enable the direct-to-consumer business model. These new channels required many companies to learn new skills and added complexity to existing supply chains.

According to the Stern Stewart EVA 1000 database, Dell Computers outperformed the competition by over 3,000 percent in terms of shareholder growth over the 8-year period from 1988 to 1996. Dell's success over this period can be attributed to its virtual integration, a strategy that blurs the traditional boundaries between suppliers, manufacturers, and end-users. Dell's decision to sell computers built from components produced by other manufacturers relieved the firm of the burdens of owning assets, doing research and development, and managing a large workforce. At the same time, Dell model of direct sales to consumers and production to order virtually eliminated finished goods inventory. These business decisions allowed Dell to grow much faster than its competition and maintain only 8 days of inventory.

Surprisingly, in the mid-2000s, the dot-com companies, like Dell, started to sell their products through retail outlets and at the same time, many traditional retailers (e.g., Walmart) established their own virtual stores. This necessitates the development of a supply chain segmentation strategy, since as we saw earlier, different channel may focus on a different customer value proposition and hence may require different supply chain strategies.

This development also raised the need, in the late 2000s and early 2010, to integrate the various channels, the so-called **omnichannel strategy.** In such a strategy, the focus is on enhancing customer experience independently of which channel the customer is using. Indeed, today's consumers will typically search products both at physical stores and online, in particular using mobile devices and will take advantage of social media recommendations. Thus, in an omnichannel strategy, a customer ordering online may have multiple ways to receive delivery: from the store close by; from the retailer's DC; from the manufacturer's DC; or by picking up the product at the store, where the product is reserved for the customer. This implies that in an omnichannel strategy, inventory is shared across all channels, taking advantage of the **risk pooling effect,** and thereby reducing cost and increasing service level, see Chapter 2.

All of these developments have motivated, primarily in the last 2–5 years, some companies to digitize their supply chain. **Supply chain digitization** is about taking advantage of digitization, advanced analytics, and automation. Digitization refers to the establishment of a dedicated master data that aggregates information from across the entire supply chain. Advanced analytics is focused on the integration of three levels of analytics—statistics (the diagnostic analytic level), machine learning (prediction), and optimization (prescription) in order to improve supply chain planning. One way to think about the three levels is that the focus is on understanding customers' or suppliers' behavior (statistics); predicting future behavior (machine learning); and improving decision making (optimization). Finally, automation is about integrating data and analytics to modify or improve supply chain processes.

The benefits reported in a recent industry survey include not only cost reduction, increase in revenue, and increase in profit, but also improved customer experience and the creation of a stronger more trusted brand.[14] The same study reports that most of the early adopters of supply chain digitization have focused on two areas: demand forecasting and end-to-end visibility.

In parallel to these developments, many industries have recognized that trends such as outsourcing, offshoring, lean manufacturing, and just-in-time manufacturing that focus on reducing manufacturing and supply chain costs, significantly increase the level of risk in the supply chain. As a result, in the past several years, progressive firms have started to focus on strategies that find the right balance between cost reduction and risk management.

A number of approaches have been applied by companies to manage risk in their supply chains:

- Building redundancy into the supply chain so that if one portion fails (e.g., a fire at a warehouse or a closed port), the supply chain can still satisfy demand.
- Using real-time information to better sense and respond to disruptive events.
- Incorporating flexibility into supply contracts to better match supply and demand and deal with risk.
- Improving supply chain processes by including risk assessment measures.

Of course, many of these approaches rely heavily on technology that provides visibility as well as ability to assess supplier's performance. Similarly, inventory planning systems are now used to better position inventory in the supply chain, and to help firms better understand the impact of product design alternatives on supply chain costs and risks, thus facilitating the integration of the development chain and the supply chain.

United Technologies Corp. (UTC) continuously measure and evaluate suppliers' performance using third-party vendor software. The software not only relies on historical delivery data but also on external financial data on each supplier to create supplier risk alerts. UTC complements the supplier performance and risk alert system with teams that help tier 1 suppliers improve their supply chain and reduce risks with their own suppliers. According to UTC, these initiatives significantly increased inventory turns and reduce cost of nonquality (unplanned overtime, scrap, etc.).[15]

To summarize, the urgency to address supply chain challenges has not diminished over the years. Indeed, recent business trends imply that managing supply chain has become even more challenging. These business trends include: (i) global supply chains with long lead times; (ii) rising and shifting customer expectations; (iii) increase in labor cost in developing countries; (iv) increase in logistics costs, see Figure 1-6; (v) increase in supply chain risks and supply and demand volatility; (vi) increase in the importance of supply chain sustainability; and (vii) the increased importance of the e-commerce channel, due to COVID-19, typically implies a higher supply chain cost. Throughout this text, we demonstrate how new technology and supply chain strategies can help companies deal with these challenges.

The preceding section describes a number of supply chain management success stories: P&G, Walmart, UTC, and others. They suggest that in some industries, supply chain management is perhaps the single most important factor determining the success of the firm. Indeed, in the computer and printer industries, where most manufacturers use the same suppliers and identical technologies, companies compete on cost and service levels, the two key elements in our definition of supply chain management.

The examples also raise an important question. If these firms have improved supply chain performance by focusing on strategic partnering, information sharing, and technology, or by applying risk mitigation strategies, what inhibits other firms from adopting the same techniques to improve their supply chain performance?

The earlier discussion suggests that the answer involves three critical abilities that successful firms must possess:

- The ability to match supply chain strategies with product characteristics. Indeed, it is clear that the supply chain strategy for products and industries where the

technology changes frequently, the so-called fast-clock-speed products, must be fundamentally different than that of slow-clock-speed products. Similarly, product design strategy and its relationship with supply chain characteristics depend on product clock speed. Thus, the intersection of the development chain and the supply chain has an impact on both product design and supply chain strategy.

- The ability to replace traditional supply chain strategies, in which each facility or party in the chain makes decisions with little regard to their impact on other supply chain partners, by those that yield a *globally optimized* supply chain.
- The ability to effectively manage uncertainty and risk. As observed earlier, initiatives such as outsourcing and offshoring and manufacturing strategies such as lean and just-in-time have significantly increased the level of risk for the enterprise. This is complemented by the significant increase in the level of demand uncertainty. Indeed, in high-tech industries, product life cycles are becoming shorter and shorter. In particular, many computer and printer models have life cycles of only a few months, so the manufacturer may have only one order or production opportunity. Unfortunately, since these are new products, no historical data are available that allow the manufacturer to accurately predict customer demand. At the same time, the proliferation of products in these industries makes it increasingly difficult to predict demand for a specific model. Finally, significant price declines in these industries are common, reducing the product value during its life cycle.[16]

A Korean manufacturer of electrical products such as industrial relays is facing a service level of about 70 percent; that is, only about 70 percent of all orders are delivered on time. On the other hand, inventory keeps piling up, mostly of products that are not in demand. The manufacturer's inventory turnover ratio, defined as the ratio of the annual flow to average inventory at the manufacturer's main warehouse, is about four. However, in the electronics industry, leading companies turn inventory over about nine times a year. If the Korean manufacturer can increase its inventory turns to this level, it will be able to significantly reduce inventory levels. The manufacturer is, thus, searching for new strategies that will increase service levels over the next 3 years to about 99 percent and, at the same time, significantly decrease inventory levels and cost.

Just a few years ago, most analysts would have said that these two objectives, improved service and reducing inventory levels, could not be achieved at the same time. Indeed, traditional inventory theory tells us that to increase service level, the firm must increase inventory and therefore cost. Surprisingly, recent developments in information and communications technologies, together with a better understanding of supply chain strategies, have led to innovative approaches that allow the firm to improve both objectives simultaneously. Throughout the rest of this book, we endeavor to present these approaches and strategies in detail. We will focus on demonstrating why certain strategies are adopted, what the trade-offs are between different strategies, and how specific strategies are implemented in practice.

In this section, we introduce some of the supply chain management issues that we discuss in much more detail throughout the remaining chapters. These issues span a large spectrum of a firm's activities, from the strategic through the tactical to the operational level:

- The *strategic level* deals with decisions that have a long-lasting effect on the firm. This includes decisions regarding product design, what to make internally and what to outsource, supplier selection, and strategic partnering as well as decisions on the number, location, and capacity of warehouses and manufacturing plants, and the flow of material through the logistics network.
- The *tactical level* includes decisions that are typically updated anywhere between once every quarter and once every year. These include purchasing and production decisions, inventory policies, and transportation strategies, including the frequency with which customers are visited.
- The *operational level* refers to day-to-day decisions such as scheduling, lead time quotations, routing, and truck loading.

Below we introduce and discuss some of the key issues, questions, and trade-offs associated with different decisions.

Distribution Network Configuration Consider several plants manufacturing products serving a set of geographically dispersed retailers. The current set of warehouses is deemed inappropriate, and management wants to reorganize or redesign the distribution network. This may be due, for example, to changing demand patterns or the termination of a leasing contract for a number of existing warehouses. In addition, changing demand patterns may require a change in plant production levels, a selection of new suppliers, and a new flow pattern of goods throughout the distribution network. How should management select a set of warehouse locations and capacities, determine production levels for each product at each plant, and set transportation flows between facilities, either from plant to warehouse or warehouse to retailer, in such a way as to minimize total production, inventory, and transportation costs and satisfy service level requirements? This is a complex optimization problem, and advanced analytics and technology are required to find a solution.

Inventory Control Consider a retailer that maintains an inventory of a particular product. Since customer demand changes over time, the retailer can use only historical data to predict demand. The retailer's objective is to decide at what point to reorder a new batch of the product, and how much to order so as to minimize inventory ordering and holding costs. More fundamentally, why should the retailer hold inventory in the first place? Is it due to uncertainty in customer demand, uncertainty in the supply process, or some other reasons? If it is due to uncertainty in customer demand, is there anything that can be done to reduce it? What is the impact of the forecasting tool used to predict customer demand? Should the retailer orders more than, less than, or exactly the demand forecast? And, finally, what inventory turnover ratio should be used? Does it change from industry to industry?

Supply Chain Flexibility Flexibility can be a powerful tool to gain competitive advantage, reduce cost, and improve responsiveness. Indeed, at the heart of established business strategies such as Toyota's lean manufacturing or Dell's Direct-to-Consumer, or the more recent success story of Pepsi Bottling Group (PBG), see Chapter 11, is a flexible operation designed to match the firm's business model and customer value proposition. So, what exactly is flexibility? In this book, we define flexibility as the ability to respond to change without increasing operational and supply chain costs and with little or no delay in response time. By change, we refer to change in demand volume and mix, commodity prices, labor costs, exchange rates, technology, equipment availability, or indeed any change

in market conditions or the production and logistics environment. How can the firm achieve flexibility? We classify the different strategies that have been applied to achieve flexibility into three categories: System Design, Process Design, and Product Design. System Design is about achieving flexibility through manufacturing or distribution strategy or through capacity redundancy. Process Design refers to flexible workforce, lean manufacturing, organization & management structure, and procurement strategies such as flexible contracts, dual sourcing, and outsourcing. Finally, Product Design is focused on modular product architecture, standard components and interface, postponement strategies, and component substitution all allow the firm to achieve flexibility.

Production Sourcing In many industries, there is a need to carefully balance transportation and manufacturing costs. In particular, reducing production costs typically implies that each manufacturing facility is responsible for a small set of products so that large batches are produced, hence reducing production costs. Unfortunately, this may lead to a higher transportation cost. Similarly, reducing transportation costs typically implies that each facility is flexible and has the ability to produce most or all products, but this leads to small batches and hence increases production costs. Finding the right balance between the two cost components is difficult but needs to be done monthly or quarterly.

Supply Contracts In traditional supply chain strategies, each party in the chain focuses on its own profit and hence makes decisions with little regard to their impact on other supply chain partners. Relationships between suppliers and buyers are established by means of supply contracts that specify pricing and volume discounts, delivery lead times, quality, returns, and so forth. The question, of course, is whether supply contracts can also be used to replace the traditional supply chain strategy with one that optimizes the entire supply chain performance? In particular, what is the impact of volume discount and revenue sharing contracts on supply chain performance? Are there pricing strategies that can be applied by suppliers to provide incentives for buyers to order more products while at the same time increase the supplier profit?

Distribution Strategies An important challenge faced by many organizations is how much should they centralize (or decentralize) their distribution system. What is the impact of each strategy on inventory levels and transportation costs? What about the impact on service levels? And finally, when should products be transported by air from centralized locations to the various demand points? These questions are not only important for a single firm determining its distribution strategy, but also for competing retailers that need to decide how much they collaborate with each other. For example, should competing dealers be selling the same brand share inventory? If so, what is their competitive advantage?

Supply Chain Integration and Strategic Partnering As observed earlier, designing and implementing a globally optimal supply chain is quite difficult because of its dynamics and the conflicting objectives employed by different facilities and partners. Nevertheless, the Dell, Walmart, and P&G success stories demonstrate not only that an integrated, globally optimal supply chain is possible, but that it can have a huge impact on the company's performance and market share. Of course, one can argue that these three examples are associated with companies that are among the biggest companies in their respective industries; these companies can implement technologies and strategies that very few others can afford. However, in today's competitive markets, most companies have no choice; they are forced to integrate their supply chain and engage

in strategic partnering. This pressure stems from both their customers and their supply chain partners. How can integration be achieved successfully? Clearly, information sharing and operational planning are the keys to a successfully integrated supply chain. But what information should be shared? How should it be used? How does information affect the design and operation of the supply chain? What level of integration is needed within the organization and with external partners? Finally, what types of partnerships can be implemented, and which type should be implemented for a given situation?

Outsourcing and Offshoring Strategies Rethinking your supply chain strategy not only involves coordinating the different activities in the supply chain, but also deciding what to make internally and what to buy from outside sources. How can a firm identify what manufacturing activities lie in its set of core competencies, and thus should be completed internally, and what product and components should be purchased from outside suppliers, because these manufacturing activities are not core competencies? Is there any relationship between the answer to that question and product architecture? What are the risks associated with outsourcing and how can these risks be minimized? When you do outsource, how can you ensure a timely supply of products? And, when should the firm keep dual sources for the same component? Finally, even if the firm decides not to outsource activities, when does it make sense to move facilities to the Far East? What is the impact of offshoring on inventory levels and the cost of capital? What are the risks?

Product Design Effective design plays several critical roles in the supply chain. Most obviously, certain product designs may increase inventory holding or transportation costs relative to other designs, whereas other designs may facilitate a shorter manufacturing lead time. Unfortunately, product redesign is often expensive. When is it worthwhile to redesign products so as to reduce logistics costs or supply chain lead times? Is it possible to leverage product design to compensate for uncertainty in customer demand? Can one quantify the amount of savings resulting from such a strategy? What changes should be made in the supply chain in order to take advantage of the new product design? Finally, new concepts such as mass customization are increasingly popular. What role does supply chain management play in the successful implementation of these concepts?

Information Technology and Decision-Support Systems Information technology is a critical enabler of effective supply chain management. Indeed, much of the current interest in supply chain management is motivated by the opportunities that appeared due to the abundance of data and the savings that can be achieved by sophisticated analysis of these data. The primary issue in supply chain management is not whether data can be received, but what data should be transferred; that is, which data are significant for supply chain management and which data can safely be ignored? How frequently should data be transferred and analyzed? What is the impact of the Internet? What is the role of electronic commerce? What infrastructure is required both internally and between supply chain partners? Finally, since information technology and decision-support systems are both available, can these technologies be viewed as the main tools used to achieve competitive advantage in the market? If they can, then what is preventing others from using the same technology?

Customer Value Customer value is the measure of a company's contribution to its customer, based on the entire range of products, services, and intangibles that

constitute the company's offerings. In recent years, this measure has superseded measures such as quality and customer satisfaction. Obviously, effective supply chain management is critical if a firm wishes to fulfill customer needs and provide value. But how is customer value measured? Equally important, what is the relationship between the customer value proposition and the supply chain strategy? What should the firm do when different customer segments, products, or channels are associated with different customer values? What is the relationship between product price and brand name in the conventional world and in the online world?

Smart Pricing Revenue management strategies have been applied successfully in industries such as airlines, hotels, and rental cars. In recent years, a number of manufacturers, retailers, and carriers have applied a variation of these techniques to improve supply chain performance. In this case, the firm integrates pricing and inventory (or available capacity) to influence market demand and improve the bottom line. How is this done? What is the role of machine learning and optimization techniques in improving business performance? Can "smart" pricing strategies be used to improve supply chain performance? What is the impact of rebate strategies on the supply chain?

Sustainability In the last few years, pressured by governments, customers, and trading partners, some senior managers have started focusing on corporate social responsibility, in particular as it relates to the impact of their supply chain on the environment. Of course, corporate social responsibility is not only about the "green" supply chain, it also encompasses the range of decisions that provide social and environmental benefits. Unfortunately, most senior managers consider corporate social responsibility a form of charity, philanthropy, or mere compliance with regulations, but nothing is further from the truth. In an economy with an overabundance of supply and where many products are viewed as interchangeable commodities, corporate social responsibility offers an opportunity for new revenue streams, additional efficiencies, and unique branding.

Each of these issues and strategies is discussed in great detail in the remaining chapters. As you will see, the focus in each case is on either the development chain or the supply chain and on achieving a *globally optimized* supply chain or managing risk and uncertainty in the supply chain, or both. A summary is provided in Table 1-1.

	Chain	Global Optimization	Managing Risk and Uncertainty
Distribution network configuration	Supply	Y	
Inventory control	Supply		Y
Production sourcing	Supply	Y	
Supply contracts	Both	Y	Y
Distribution strategies	Supply	Y	
Strategic partnering	Development	Y	
Outsourcing and offshoring	Development	Y	
Product design	Development		Y
Information technology	Supply	Y	Y
Customer value	Both	Y	Y
Smart pricing	Supply	Y	

For many reasons, interest in logistics and supply chain management has grown explosively in the last few years. This interest has led many companies to analyze their supply chains. In the 1990s and early 2000s, this was done based on experience and intuition; very few analytical models or design tools were used in this process. However, in the last several decades, various technologies and tools have been developed and deployed to assist with the management of the supply chain.

In parallel, the academic community has developed various "laws-of-physics," or supply chain rules, that are always true, independent of geography, culture, or products. The origin of all the rules in this book is scientific; they are either based on mathematical or empirical approaches. By mathematical, we refer to rules derived from detailed mathematical models. Examples include principles that govern the relationships between variability and supply chain performance; inventory and service level; flexibility and cost; or between information, lead time, and variability.

The empirical approach devises rules based on carefully conducted research that observes the strategy and performance of various companies. Such rules are also universal but like any empirical research, and unlike their mathematical counterparts, they need to be considered in the context of the origin of the data. Examples include principles that provide a deep understanding of the relationship between channel characteristics, product attributes, customer value, and supply chain strategy.

The book describes many of these "laws-of-physics" and complements them with best practice, based on the authors' supply chain experience. We intend this book to be useful both as a textbook for MBA-level logistics and supply chain courses and as a reference for teachers, consultants, and managers involved in any one of the processes that make up the supply chain. Each chapter includes case studies, numerous examples, and discussion questions. In addition, each chapter is mostly self-contained, and mathematical and technical sections can be skipped without loss of continuity. Therefore, we believe the book is accessible to anyone with an interest in some of the many aspects of supply chain management. For example, manufacturing executives focusing on flexible strategies to increase service level without increasing cost, supply chain executives looking to identify hidden risk in their supply chain, transportation managers deciding which modes of transportation to use, inventory control managers wanting to ensure smooth production with as little inventory as possible, purchasing/supply managers designing contracts with their company's suppliers and clients, and logistics managers in charge of their company's supply chains can all benefit from the contents of this book.

The book includes chapters covering the following topics:

- Inventory management.
- Logistics network planning.
- Supply contracts for strategic as well as commodity components.
- The value of information and the effective use of information in the supply chain.
- Supply chain integration.
- Centralized and decentralized distribution strategies.
- Strategic alliances.
- Outsourcing, offshoring, and procurement strategies.
- Supply chain management and product design.
- Supply chain flexibility.
- Customer value.

- Supply chain risk management.
- Sustainable supply chain.
- Revenue management and pricing strategies.
- Information technology and business processes.
- Technical standards and their impact on the supply chain.

Finally, a series of spreadsheets is included with the book. These spreadsheets help illustrate various examples and provide data for some of the questions. This includes:

- Chapter 2: Steelworks data as well as the Swimsuit demand and inventory model.
- Chapter 4: Supply contracts.
- Chapter 9: The bidding game.
- Chapter 13: Nissan case study data.

They are available on the book's website through Connect.

DISCUSSION QUESTIONS

1. Consider the supply chain for a domestic automobile.
   a. What are the components of the supply chain for the automobile?
   b. What are the different firms involved in the supply chain?
   c. What are the objectives of these firms?
   d. Provide examples of conflicting objectives in this supply chain.
   e. What are the risks that rare or unexpected events pose to this supply chain?
2. Consider a consumer mortgage offered by a bank.
   a. What are the components of the supply chain for the mortgage?
   b. Is there more than one firm involved in the supply chain? What are the objectives of the firm or firms?
   c. What are the similarities between product and service supply chains? What are the differences?
3. What is an example of a supply chain that has evolved over time?
4. A vertically integrated company is a company that owns, manages, and operates all its business functions. A horizontally integrated company is a corporation consisting of a number of companies, each of which is acting independently. The corporation provides branding, direction, and general strategy. Compare and contrast the supply chain strategies of the two types of companies.
5. If a firm is completely vertically integrated, is effective supply chain management still important?
6. Consider the supply chain for canned peaches sold by a major food processing company. What are the sources of uncertainty in this supply chain?
7. Consider a firm redesigning its logistics network. What are the advantages of having a small number of centrally located warehouses? What are the advantages of having a larger number of warehouses closer to the end customers?
8. Consider a firm selecting a supplier of transportation services? What are the advantages of using a truckload carrier? A package delivery firm such as UPS?
9. What are the advantages of a firm of high inventory levels? What are the disadvantages? What are the advantages of low inventory levels? The disadvantages?
10. What are some ways that redundancy can be built into a supply chain? What are the advantages and disadvantages of building redundancy into the supply chain?
11. Consider Figure 1-6. What are the reasons for the increase in transportation costs? Inventory costs? Does one affect the other? How?

CASE

Meditech Surgical[1]

Three years after Meditech was spun off from its parent company, Meditech captured a majority of the endoscopic surgical instrument market. Its primary competitor, National Medical Corporation, had practically invented the $800 million market just over a decade ago. But Meditech competed aggressively, developing new, innovative instruments and selling them through a first-class sales force. The combination paid off, and Meditech had become a phenomenal success in a short period of time. Despite the success, Dan Franklin, manager of Customer Service and Distribution, was concerned about growing customer dissatisfaction. Meditech had recently introduced several new products that were central to the entire Meditech product line. New product introductions, which were critical to Meditech's strategy of rapid product development, needed to be introduced flawlessly to protect Meditech's reputation and sales of other products. But Meditech consistently failed to keep up with demand during the flood of initial orders. Production capacity became strained as customers waited over 6 weeks to have their orders delivered. Poor delivery service, which is fatal in the health care industry, was jeopardizing Meditech's reputation.

Endoscopic surgical techniques fall under a class of surgical procedures described as minimally invasive. Minimally invasive surgery, as opposed to traditional open surgery, requires only small incisions to perform an operation. As a result, procedures using endoscopic techniques often provide substantial benefits for the patient both physically and financially. The procedures often shorten patient recovery, which can translate into reduced surgical expenses overall. Despite the benefits and the multidecade history of endoscopic technology, the procedures have only become popular in the last 10 years. Only 3 years ago, the market for endoscopic surgical instruments was expected to double its size in 5 years. Growth beyond 5 years also looked promising. Largo Healthcare Company, Meditech's parent company, decided to spin Meditech off as an independent company focused solely on producing and selling endoscopic surgical instruments. Largo management hoped that the new company would prosper without the distractions of other Largo businesses and capture market share of endoscopic instruments as quickly as possible.

Since its inception just over 6 years ago, Meditech has produced innovative, low-cost products. New products were brought to the market quickly and pushed by an aggressive sales force. Old products were updated with innovative features and presented to the market as new products. Consequently, the competition between Meditech and National Medical centered on the continuous development and introduction of new products by both companies. A dozen or more new products would typically be introduced by Meditech in any given year.

While the development strategies were similar, the sales strategies differed dramatically. National Medical concentrated on selling to surgeons. Meditech's sales force concentrated on selling to hospitals material managers as well as to surgeons. Material managers tended to be more concerned with cost and delivery performance. The surgeons, on the other hand, focused on product features. As the pressures increased on health care costs, the importance of the material manager's purchasing position also increased. Meditech was well positioned to take advantage of this important shift.

The success of Meditech's strategy quickly became evident. Within 6 years, Meditech had captured the leading share in the endoscopic surgical instrument market. This was no small feat by any market's standards, but with surgical instruments, this was especially impressive. Market share changes in the professional health care industry tended to take place gradually. Surgeons and doctors often held onto preferred manufacturers. Hospitals frequently used group purchasing organizations (GPOs) that took advantage of extended contracts with suppliers. The process of "converting" a hospital to a new supplier often took months of negotiation and convincing.

Most endoscopic surgical instruments are small enough to fit into the palm of a surgeon's hand. They are mechanical in nature, typically having several intricate mechanisms to provide the required functionality. Materials used to produce the instruments include plastic injection–molded parts, metal blades, springs, and so forth. In all cases of use, surgeons use the instrument for one operation and then immediately dispose of it. Instruments are never resterilized and reused for another patient. All in all, the Meditech product line consists of over 200 separate end-products.

Meditech distributes all its goods from a central warehouse, using two primary channels—domestic dealers and international affiliates—to distribute its products from the central warehouse to end-customers (i.e., hospitals). The first channel, for domestic sales only, uses domestic distributors, or dealers, to ship to hospitals. The dealers order and receive products from multiple manufacturers, including Meditech, typically stocking hundreds of different products. Stocked products range from commodity items, such as surgical gloves and aspirin, to endoscopic surgical instruments. By using dealers to supply products, hospitals do not need to order directly from manufacturers for their diverse needs. Additionally, since dealers maintain regional warehouses all over the United States, the distance between dealer warehouses and most hospitals tends to be quite small. The short distance permits frequent replenishments of hospital inventories; in some cases, trucks from dealers drop off supplies once or twice per day. Hospitals enjoy the frequent replenishments, which reduce hospital inventory and, consequently, reduce material costs.

The regional dealer warehouses act as independent entities, autonomously determining when to order new supplies and how much to order. Therefore, while Meditech only uses four or five major distribution companies, it still receives orders from, and ships to, hundreds of regional, individually run warehouses. Each warehouse in turn ships to about a dozen or more hospitals, resulting in thousands of hospitals that receive Meditech products.

The distribution channel for international sales uses Largo Healthcare's international affiliates. International affiliates are wholly owned subsidiaries of Largo Healthcare residing outside of the United States. As with domestic dealers, affiliates distribute to hospitals in their regional area. However, in contrast with domestic dealers, which may locate within just a few miles of customer hospitals, an affiliate ships product throughout an entire country. From Meditech's point of view, affiliates' orders essentially look no different than dealers'—international affiliates submit orders to Meditech and Meditech fills them with available products.

The production processes to manufacture endoscopic instruments are composed of three major steps: assembling of component parts into individual or "bulk" instruments, packaging one or more bulk instruments into a packaged good, and sterilizing the packaged goods. Each of these steps is described below.

The assembly process is manually intensive. Component parts arrive into the assembly area from suppliers following a brief inspection by Quality Assurance (QA). The parts are placed into inventory until ready for use by one of several assembly lines. Each assembly line is run by a team of cross-trained production workers who can produce any of several instruments within a product family. Line changeovers within a family are quick and inexpensive, merely requiring a warning from the production team leader and a supply of the appropriate component parts. The typical cycle time for assembly of a batch of instruments—the time required to schedule assembly of a batch of instruments and then actually assemble them, assuming that component parts are available in component parts inventory—is on the order of 2 weeks. Leadtime for component parts is on the order of 2–16 weeks. Assembled instruments are moved from the assembly area into bulk instrument inventory, where they wait to be packaged.

The packaging process makes use of several large packaging machines. The machines direct bulk instruments into plastic containers and then adhere a flexible sheet of material over the top of the container. The entire plastic container is then placed into a finished cardboard container and shipped immediately to the sterilizer. Capacity at the packaging area has not restricted output.

The sterilization process uses a large Cobalt radiation sterilizer. After batches of packaged instruments (cardboard container, plastic container, and instruments) are placed into the sterilizer, the sterilizer is turned on for about an hour. The radiation penetrates cardboard and plastic to destroy any potentially harmful contaminants. The sterilizer can sterilize as much product as will fit inside its four walls. Capacity limitations have not been a problem thus far. Sterilized instruments are immediately moved into finished goods inventory.

The entire operations organization reports up through the vice president of Operations, Kenneth Strangler (see Figure 1-6 for an organization chart for Operations). Functions immediately reporting to Strangler include several plant managers (one for each of Meditech's four manufacturing facilities), a director of supplier management, and a director of planning, distribution, and customer service. Other vice presidents (not shown) exist for marketing and sales, product development, and finance. All vice presidents report to the highest officer in the company, the president of Meditech. The plant managers in the organization have responsibility for production personnel, engineering technicians, quality assurance, support services, and material supply for their respective facilities. Reporting directly to the plant managers are several business units. Each business unit has full responsibility either for the assembly of a particular product family or, in the case of packaging and sterilization, for an entire production process. The most important job of each assembly business unit is to meet the production schedule every week. Meeting the schedule ensures a constant supply of bulk instruments to the packaging/sterilization process. The process of determining assembly and packaging/sterilization schedules will be discussed below.

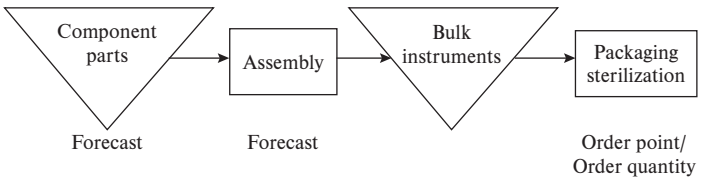
Also reporting to the vice president of Operations are Supplier Management and Planning, Distribution, and Customer Service. Supplier Management works on relationships with suppliers, including establishing purchasing contracts and finding new suppliers if necessary. The Planning, Distribution, and Customer Service department does everything it can to ensure that customers receive products when needed. The positions within the Customer Service department include the manager of Customer Service and Distribution, Dan Franklin; the manager of Central Planning; the manager of Inventory; and a manager of Logistics. Customer Service deals with everything from occasional customer complaints to establishing strategies to improve delivery service to customers. Customer Service representatives work with dealers and affiliates to keep them updated on product delivery schedules and problems. Often this responsibility places the Customer Service representative in direct contact with hospital personnel.

While Customer Service handles issues concerning the movement of product out of finished goods inventory, Central Planning ensures that adequate finished goods are available to meet incoming orders. They develop monthly production plans that are used by the business units to determine weekly and daily schedules.

Charles Stout, the Inventory manager, determines the finished goods inventory policy and establishes parts and bulk inventory guidelines for the business units. When a mandate to reduce inventory is passed on from higher levels of management, the Inventory manager must determine where inventory can be reduced and then begin enforcing those reductions. Through recent efforts, Stout had successfully eliminated several million dollars of obsolete and slow-moving inventory.

The production planning and scheduling process is broken down into two parts: planning, based on monthly forecasts, of assembly and component parts orders and daily scheduling of packaging and sterilization based on finished goods inventory levels. During the fourth quarter of each fiscal year, the marketing and finance organizations determine an annual forecast. The annual forecast is then broken down proportionately, based on the number of weeks in the month, into monthly forecasts. As the year progresses, the Central Planners work with the Marketing organization to make forecast adjustments according to market trends and events. At the beginning of each month, the month's forecasts are adjusted and agreed upon by the Marketingorganization and the Central Planners.

The planning of assembly for a particular instrument begins with the monthly demand forecasts. Based on the month's forecast, the Central Planners determine the amount of product that needs to be transferred from bulk inventory into finished goods inventory to



"meet" the expected demand. This amount, termed the finished goods "transfer requirement," is determined by subtracting the current finished goods inventory level from (1) the demand forecast for the month plus (2) the required safety stock. (The current safety stock policy is to maintain 3 weeks' worth of demand).

The transfer requirements, once completed for all 200-plus product codes, are passed throughout the organization for approval. This process typically takes place one to 2 weeks into the current month. While not actually used to schedule assembly or to alter the packaging and sterilization processes, the transfer requirements provide an estimate of the required overall production for the month. Any problems in being able to deliver to the plan can then be identified and resolved.

Assembly schedules and replenishment orders for parts are based on the monthly demand forecasts and current inventory levels. By mid-month, the completed monthly plans, which contain the monthly forecasts, are sent to the assembly business units. A planner in the business unit plugs the forecasts into a Materials Requirement Planning (MRP) system, which determines weekly production schedules and component parts orders for each finished product. The MRP system determines assembly schedules and parts orders based on (1) the monthly forecasts; (2) the lead times for assembly, packaging, and sterilization; and (3) current parts, bulk, and finished goods inventory levels. Although the MRP calculation may be run several times each week, the planner is careful not to change weekly production schedules with less than a week's notice. (A schedule change often requires rescheduling workers and procuring more component parts. One week's notice for responding to scheduling changes, therefore, has been deemed adequate by the business unit managers).

In contrast to the forecast-based scheduling of the assembly operation, the packaging and sterilization operations are scheduled based on as-needed replenishment of finished goods inventory. For purposes of scheduling, the packaging and sterilization operations are considered one operation because bulk instruments flow through packaging, into the sterilizer, and into finished goods without being inventoried. (See Figure 1-7 for a diagram of the entire production process.) The entire packaging/sterilization process can be completed for a batch of instruments in about 1 week. The scheduling of packaging/sterilization is done on an order point/order quantity (OP/OQ) basis (i.e., when finished goods inventory drops below the predetermined order point (OP), a replenishment order for more packaged/sterilized product is initiated. The size of the order in terms of the number of instruments is always equal to the predetermined order quantity (OQ)).

Another way to view the scheduling process is to think of material as being "pushed" through assembly into bulk instrument inventory and as being "pulled" through packaging/sterilization into finished goods inventory. The push-through assembly is based on the monthly forecast determined before the month's demand actually arrives. The pull-through packaging/sterilization simply replenishes what was sold from finished goods the day before.

Over the past several years, Meditech has introduced dozens of new products into the market, mostly by updating existing products. Meditech plans to continue this strategy of continuously obsoleting its own products by constantly introducing innovations. While the innovative products have been well accepted by the marketplace, each new product introduction has resulted in a nightmare of supply problems. Dan Franklin felt that customers were beginning to tire of the poor service resulting from each introduction. Through many meetings with hospital material managers, Dan began to realize the full scope of his customers' frustrations.

Franklin could not figure out why Meditech consistently had shortages with each introduction.

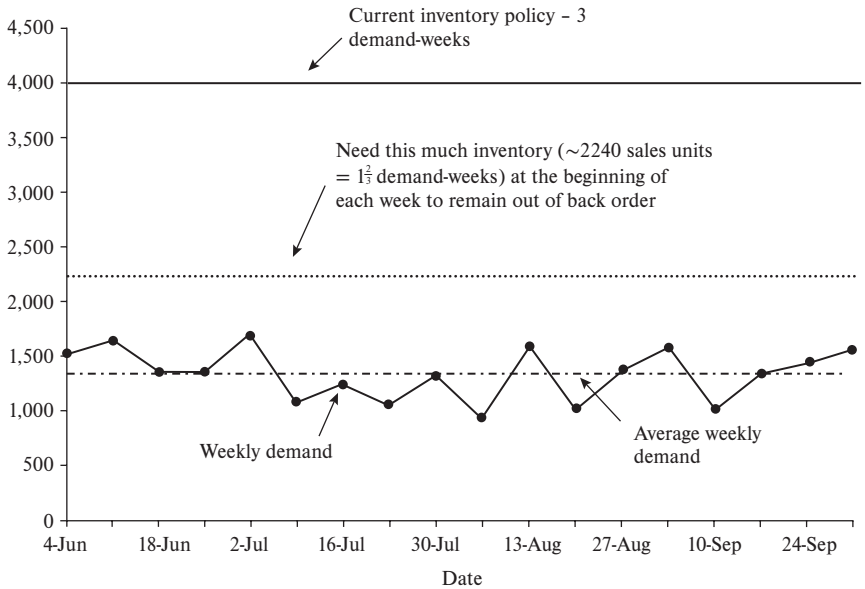
Forecasting had definitely been a problem, but determining its extent was difficult. Data to measure forecast accuracy had not previously been tracked, nor had forecasts and demand information been kept. Data gathering requires a lengthy process of going back through hard copies of prior monthly plans and entering the information by hand into a computer. Even if a better methodology could be determined, forecasts can only be improved by so much.

In addition to new product introduction problems, finished goods inventory levels appeared to be remarkably high. A consultant had recently been hired to study Meditech's inventory. Her findings indicated that overall inventory could be reduced by at least 40 percent without an impact on the delivery service level[2] (see Figure 1-8). Despite the high levels of inventory, the actual service level over the past year was disappointing and below corporate objectives. Management feared that reducing inventory would further damage the already subpar level performance.

Another possible cause of the problem is "panic ordering" from dealers and affiliates. Panic ordering occurs when a dealer or affiliate is unsure of whether or not product will be received in time and therefore increases the size of its orders hoping that Meditech will deliver at least part of the order. The increased orders would cause demand to temporarily rise, helping to explain Meditech's problems with demand consistently exceeding supply. Familiar with past delivery problems, dealers and affiliates had every reason to want to panic order. In one conversation with a representative from Meditech's largest dealer, the representative had indicated that panic ordering was a possibility. Given the decentralized nature of the regional warehouses, the dealer has little control over what an individual warehouse actually orders. Warehouses could, therefore, panic order without the knowledge of the central dealer. On the other hand, the possibility of panic ordering does not mean that it actually occurs. To make matters worse, data proving or disproving its existence had been hard to find.

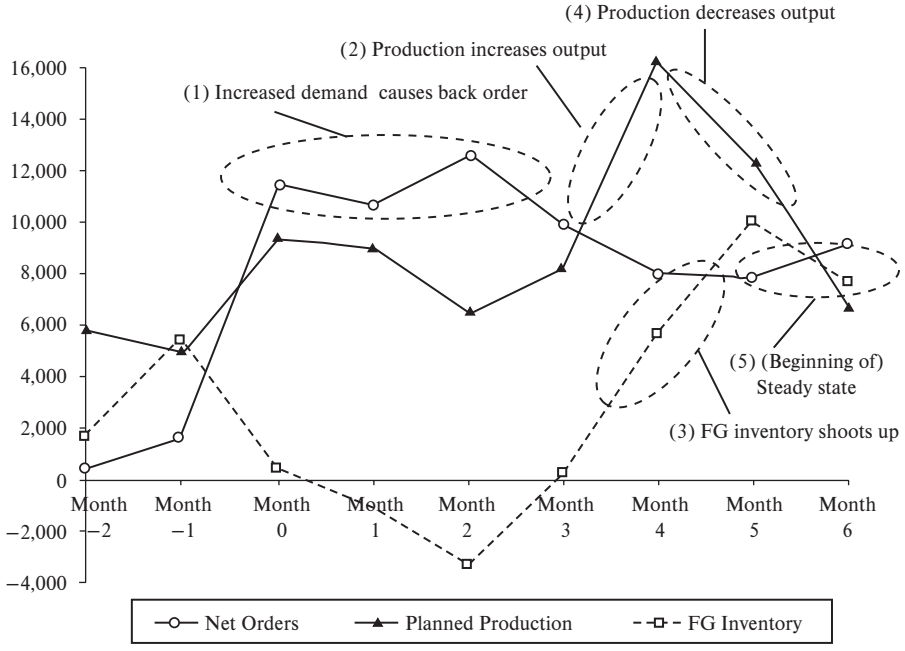
Dan asked one of his staff members to investigate the new product introduction problem and inventory/service level paradox. The staff member spent several months compiling information on demand patterns, production rates, and forecasts. Consistent with Meditech's decentralized nature, the information existed on many different systems in several different areas of the organization. There was no routine way to see incoming demand, inventory, or production rates for a particular instrument. Developing a common format for the data had also been difficult. Some data were expressed in terms of calendar

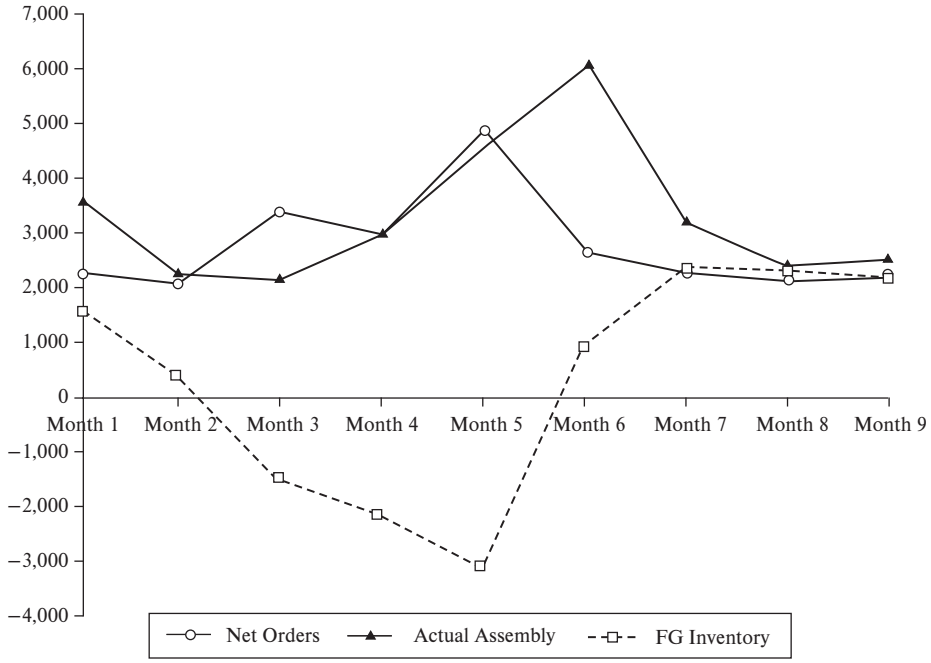
[2]Service level is defined as the percent of orders filled directly with products from finished goods inventory.



months, other data in terms of weeks, and still other data in terms of the corporate financial calendar (alternating 4-week, 4-week, and 5-week months). Once put together, the information conveyed the following:

- New product demand after an introduction followed a consistent pattern of reaching a high peak during the first few weeks but becoming relatively stable immediately afterward (see Figure 1-9).
- Variation in production schedules often exceeded variation in demand (see Figures 1-10 and 1-11).
- Monthly forecasting could be improved substantially using a simple statistical method: generating a linear regression through past data.





With this information in mind, Dan Franklin began thinking about how to fix Meditech's delivery problems.

CASE DISCUSSION QUESTIONS

1. What are Meditech's problems in introducing new products? In manufacturing ALL products?
2. What is driving these problems, both systemically and organizationally?
3. Why is the customer service manager the first person to recognize the major issues?
4. How would you fix these problems?

REFERENCES

1. www3.intel.com/content/dam/www/public/us/en/documents/best-practices/transforming-supply-chain-to-meet-market-challenges.pdf.
2. Raymond, D. "Bull (crap) Market," *Forbes Magazine,* March 2011.
3. www.forbes.com/sites/paularosenblum/2014/05/22/walmart-could-solve-its-inventory-problem-and-improve-earnings/.
4. www.nasdaq.com/article/excess-channel-inventory-derails-littelfuse-cm1188352.
5. Rich, S. "Saturday Interview—with Doug McGraw; A Hurricane and Espresso. What's Next?" *The New York Times*, March 18, 2006.
6. Greenhouse, S. "Labor Lockout as West's Ports Roils Business" *The New York Times*, October 1, 2002.
7. Claudia, F. "Local Reps See Temporary Delays after India Quake," March 9, 2001, www.Aparelnews.net.
8. Simchi-Levi, D.; W. Schmidt; and Y. Wei. "From Superstorms to Factory Fires: Managing Unpredictable Supply Chain Disruptions," *Harvard Business Review* (January–February 2014), pp. 96–101.
9. Anderson, C. *The Long Tail: Why the Future of Business Is Selling Less of More.* New York: Hyperion Books, 2006.
10. Henkoff, R. "Delivering the Goods." *Fortune*, November 28, 1994, pp. 64–78.
11. *Journal of Business Strategy*, October–November 1997.
12. Schoneberger, R.J. "Strategic Collaboration: Breaching the Castle Walls." *Business Horizons* 39 (1996), p. 20.
13. Schrader, C. "Speeding Build and Buy Processes across a Collaborative Manufacturing Network." *ASCET* 3 (2001), pp. 82–88.
14. Accenture, 2018, The Intelligent Supply Chain.
15. The Aberdeen Group. "The Supply Risk Management Benchmark Report: Assuring Supply and Mitigating Risk in an Uncertain Economy." September 2005.
16. Mottley, R. "Dead in Nine Months." *American Shipper* (December 1998), pp. 30–33.

CASE

Steel Works, Inc.

Gary Lemming sat in his new corner office and tapped his pencil on the desk. Lemming had just been named head of Steel Works, Inc.'s new centralized logistics group. After a decade of experience implementing MRP (Materials Requirements Planning) systems throughout the company's manufacturing facilities, Lemming was confident he could handle the job. Until this morning.

"Our inventory levels are ridiculous!" barked Jean Du Blanc, the company's Chief Financial Officer. "Our customer service is the worst in the industry, and getting worse," grumbled Kirk Callow, the CEO. Lemming started to explain, "You see, I've already set up a team to look at all of that. . . ." But before he could finish, Callow stood up. "Sales are down 30 percent and expenses are up 25 percent. Our best customers are calling me and telling me they're going to our competitors, and at the rate we're losing market share, we won't be in business in a year. I don't want to hear about teams; I want you back in here in a week telling me how you're going to fix this thing."

Lemming looked over the list of people he'd asked to meet with him this week. He shook his head—how do I lower expenses and improve performance? How will I ever find the right answer?

Steel Works, Inc. is a manufacturer of custom and specialty use steels with annual sales of $400 million in 1993. Founded in 1980 by three brilliant material scientists from MIT, the company now employs more than 2,500 people at five different locations. With its first product, DuraBend™, the company earned a reputation as a high technology provider and quickly established a niche position in what is typically regarded as a commodity market. Its two divisions, Specialty Products and Custom Products, are very separate and distinct businesses.

Lemming's first interview of the morning was with Stephanie Williams, President of the Custom division. "Our motto is 'The Customer Comes First, Second, and Third, But Never Last,'" explained Ms. Williams. "The Custom division develops most of its products under contract for a single customer, for sale exclusively to that customer, and works very

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Source: This case was prepared by research assistant David Kletter under the direction of Professor Stephen C. Graves as the basis for class discussion rather than to illustrate either effective or ineffective handling of an administrative situation. The company, people, data, and events depicted herein are entirely fictitious. Any resemblance to actual people, businesses, or situations is purely coincidental.

closely with them from before a product is invented until our product is a part of their product. We have the best scientists and engineers in the world, and that is why the biggest companies in the U.S. come to *us*. We've designed the metals that make our customers' products work great. That's why we typically aren't allowed to sell our products to anyone but the original customer—our customers' competitors would love to buy from us."

Williams went on to explain that eventually when a product is no longer a leading-edge, the Custom division will negotiate with the customer to allow Steel Works to sell the product to anyone. "Such discussions are an art form," explains Stephanie, "but it can make a huge difference in sales revenues for us."

"Take DuraFlex™ R23, for example. We developed that under contract for one of the big three auto companies. It took us over a year to develop, and there is still no product like it in the marketplace. Yet we were able to convince our customer to allow us to sell it openly on the market at a 30 percent premium over what we charge them. We still sell in large volumes to our customer, and Specialty Products makes a small fortune manufacturing the exact same steel and selling it at a higher price to four other auto manufacturers and a copier company."

Williams displayed a schematic of Custom Products' manufacturing system. The three manufacturing sites were each located within a few miles of one of Custom Products' three R&D centers, which served the West, Midwest, and Eastern regions of the U.S. Customers, and their products were each assigned to a specific plant and R&D center. Steel Works operated several warehouses located near the plants.

The only question on Lemming's mind was why the inventory levels were so high. The reply was direct and blunt: "We've got to keep our customers happy. Customers aren't satisfied when you tell them that they have to wait three weeks for delivery! We listened to that corporate inventory reduction mandate in 1991 and cut our inventories back 20 percent and we were running out of product every week!"

"Let me tell you something," Barry White said as he stormed into the room, "we are *nothing* like Custom." Mr. White was President of the Specialty division, whose sales have been the hardest hit in recent months.

"That Custom division has nothing to do all day but play in laboratories. We're the ones out in the marketplace selling every day and bringing in 67 percent of this company's revenue. I've got the best sales force around, and they are what makes this business work."

"Custom thinks they're so special because they've got some big customers; well guess what, so do we. Our largest customer in Specialty brings in 10 percent of the revenue for this company, and it is with blood, sweat, and tears that we keep them and everyone else as our customer. You want to solve some problems? Manufacturing is where the problems are; you should talk to them. I've got my plant managers screaming at me every day that the CSRs [customer service representatives] are screaming at them because the customers are screaming at the CSRs for not having any steel in the warehouse to ship. And that's not the CSR's fault, it's manufacturing's fault."

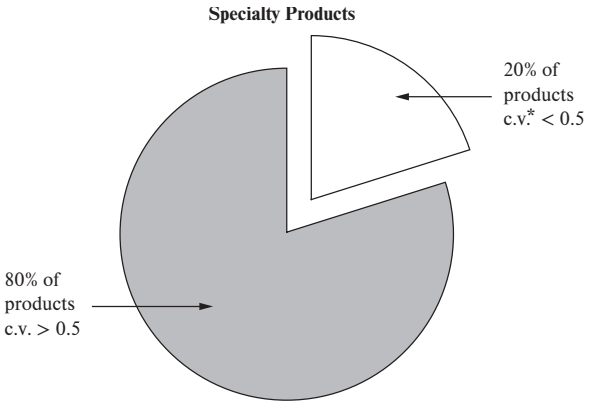
"Last week the IS department comes knocking on my door telling me how great it would be if all of Steel Works was on a common computer system and wants me to pay $12mm for my division. They think they understand our business but they don't. We don't need centralized computer systems, we need to fix manufacturing!"

White explained that like the Custom Products division, Specialty attempted to manufacture its products in a single plant. The division operated three plants that manufactured six different product lines. The division's general strategy was to exploit economies of scale in production and to rely on the logistics network to distribute the product nationwide. To achieve further efficiency, product families were almost always manufactured in the same plant to save manufacturing costs: The change-over costs between products in the same family were often considerably lower than across different families. Products were produced in a rotating sequence. For example, DuraFlex™ R23 is always produced during the first week of the month.

And before Lemming knew it, White had stormed out of the room.

It was now Tuesday and 20 percent of the week was gone. Debby Klein, a senior logistics analyst, sat across from Lemming.

Big customers (> $25mm)	5
Small customers (< $1mm)	107
All others	18
Total	130



"Well it's just like you said it would be. Custom has a lot of products, and something like 90 percent of them are sold to only one customer. On the other hand, Specialty has something like 130 customers for some 120 products. They've got so many products I can't even keep track!"

Debby then related the grim news about customer service levels. "Based on data collected by our order entry systems, approximately 70 percent of the orders entered into the system are scheduled to be shipped from stock within 48 hours. The rest of the orders (30 percent) are either canceled by the customer at the time of entry or placed in a backorder file. I couldn't find out how many of the backorders are canceled, and I wasn't sure if we needed to know that."

Lemming then asked about the big customer. "Yep, they're big all right. They're like 15 percent of the Specialty sales for 1993 but they buy a lot of different products. There are other big customers, though. And small ones, and medium-sized ones too" (see Figure 2-1) "Thanks Debby," said Lemming, feeling more confused than ever.

After lunch, Lemming had the production plan for Specialty's Ohio plant faxed to him. The Ohio plant manufactured the DuraBend™ and DuraFlex™ product families. Production at the plant followed a regular rotating schedule, producing each family about once per month. The plan seemed consistent with Barry White's account of the division's manufacturing strategy.

At the end of the day, a young forecasting expert named Maria stopped by, looking quite upset. "I looked at all the products like you asked. It's a mess just like you said, 80 percent of the products fall in this 'highly volatile' category (see Figure 2-2). With standard deviations that large, I don't think a demand forecasting tool is going to help you very much."

Bright and early on Wednesday morning, Fred Chow, a logistics consultant, walks into Lemming's office. "From what you described on the phone, the answers are all very simple. There are three things you need to do:

1. Get rid of all those products. You've probably got products that have annual sales of a few thousand dollars, and probably have products that aren't selling at all. Discontinue them and focus on your high margin, high volume products to maximize your revenue.
2. Use a statistical forecasting package to predict your demand and this will lower the amount of inventory you need. You see, the inventory levels you need to hold will be a function of the least squares regression and the resulting standard deviation of error in demand in the lead time. So, reduce that and you've reduced your inventory. Voilà!
3. You've probably got too many warehouses. Everybody knows that fewer warehouses mean less inventory."

Lemming was now excited. Although he didn't understand about the least squares-thing, and although Maria said yesterday that forecasting wouldn't work, now he was getting somewhere. Accidentally calling the consultant "Jonah" at one point, Lemming was forever grateful.

The businesses completely rejected the idea of discontinuing the slow-moving products. "We can't do that! Our most important customers buy those products!" So much for that idea.

If that weren't bad enough, Debby happens to stop back in. "Reduce our warehouses? What are you talking about? If we have to ship from fewer