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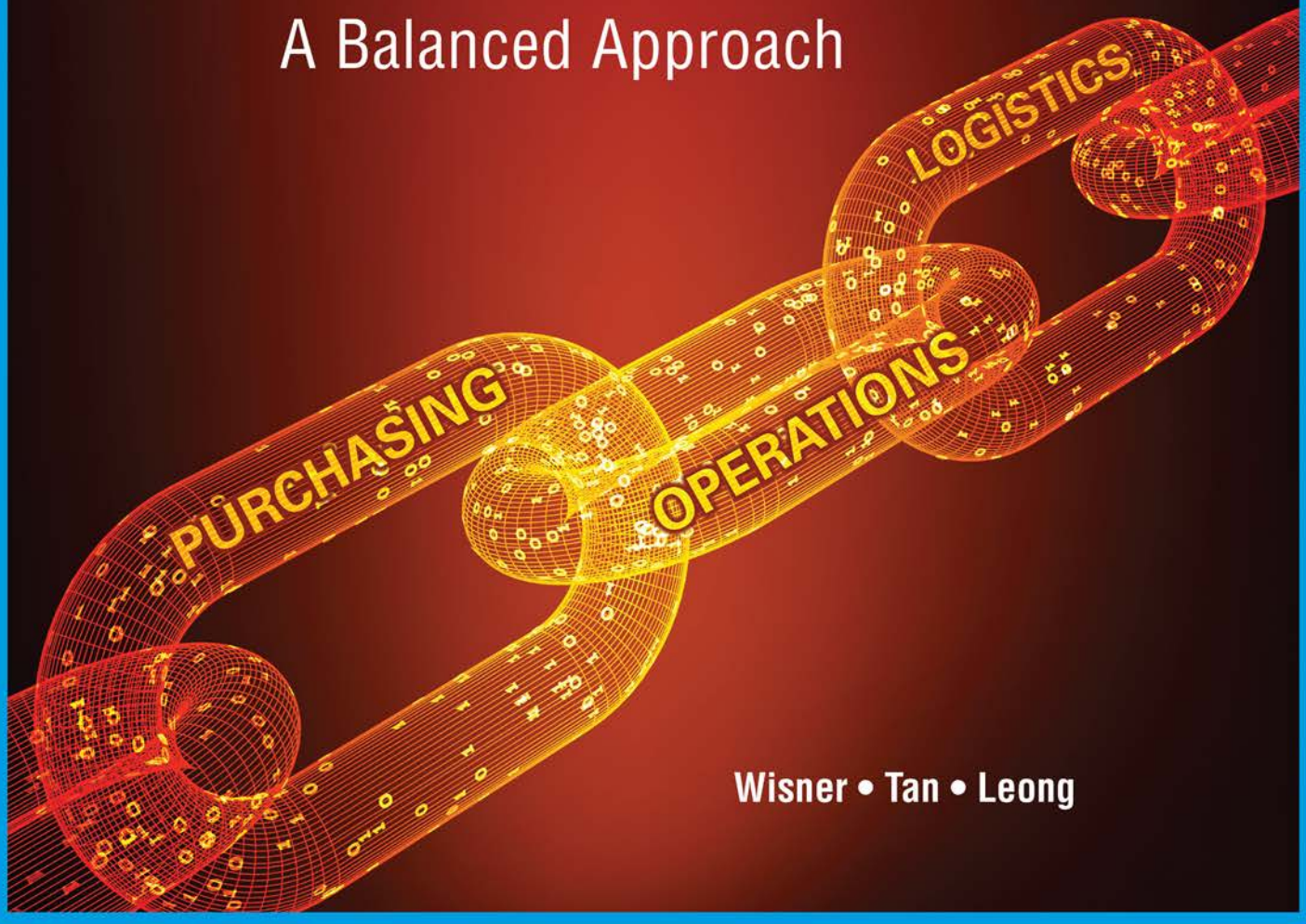
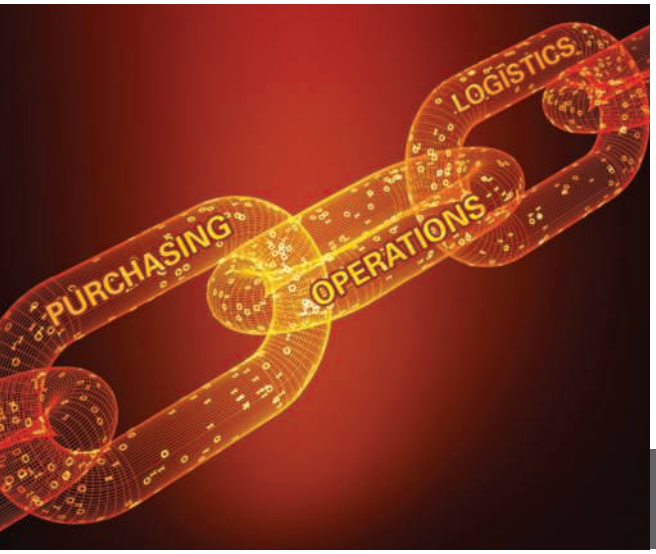
6th Edition

# Principles of Supply Chain Management

## A Balanced Approach




Wisner • Tan • Leong




# Principles of Supply Chain Management

## A Balanced Approach | 6e

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*To CJ, Hayley, Blake, Mary Jane, Phyllis, Bob, and Sally.*

*—Joel Wisner*

*To Shaw Yun, Wen Hui, Wen Jay, and Kevin.*

*—Keah-Choon Tan*

*To Lin and Michelle.*

*—G. Keong Leong*

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# On the Companion Website

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# Preface

## INTRODUCTION

Welcome to the sixth edition of *Principles of Supply Chain Management: A Balanced Approach*. The practice of supply chain management has become widespread in all industries around the globe today, and the benefits to firms of all sizes are being realized. We think this text is unique in that it uses a novel and logical approach to present discussions of this topic from four foundation perspectives: purchasing, operations, logistics, and process integration. We think this book is also somewhat different than the other supply chain management texts available, since we present a more balanced view of the topic—many of the texts available today concentrate primarily on just one of the three areas of purchasing, operations, or logistics.

The objective of the book is to make readers think about how supply chain management impacts all of the various areas and processes of the firm and its supply chain trading partners, and to show managers how to improve their firm's competitive position by employing the practices we describe throughout the text. Junior- or senior-level business students, beginning MBA students, as well as practicing managers can benefit from reading and using this text.

As with the fifth edition, the sixth edition has a tie-in to a wonderfully engaging global supply chain simulation game called SCM Globe. A separate page dedicated to SCM Globe follows this preface. We are very excited about the simulation and hope instructors will take it for a test drive and then use it in their classes.

The sixth edition continues to offer MindTap, the leading digital platform from Cengage. MindTap includes an interactive eBook, quizzes, chapter homework assignments, Excel online activities, and more. New to this edition, the continuing cases from the book are also available in MindTap as Excel-based assignments for students to apply what they have learned in computational, decision-making scenarios. For more information about MindTap and how students can access it with the text, please contact your Cengage representative.

In the Chapter 1 Appendix, there is a discussion of the Beer Game, with inventory tracking sheets to allow instructors to actually play the game with their students. There are also quantitative as well as qualitative problems and questions, essay/project exercises, and Excel problems spread throughout most of the chapters.

## NEW TO THIS EDITION

There are several changes to this sixth edition that we hope you will find interesting and useful. Perhaps the biggest change are the three continuing cases in Parts 2, 3, and 4. (The continuing case for Part 4 is online only.) The teaching notes for all cases can be found in the Instructor's Manual. There is also an emphasis on the pandemic's impacts on the supply chain and a greater emphasis on technological advances and quantitative examples and problems throughout the text. Additionally, each chapter contains a number

of new SCM Profiles, beginning with a chapter-opening profile, and then other smaller company profiles throughout the chapters. The chapter references throughout the text have been updated, with new and interesting storylines, to keep readers engaged and informed. Additionally, new end-of-chapter discussions, essay and project questions, and exercises have been added. There are also cases at the end of each chapter and several extended cases encompassing the chapters in Parts 2, 3, and 4. Other ancillary materials are described below.

## ORGANIZATION OF THE TEXT

Part 1 is the overview and introduction to the topic of supply chain management. This chapter introduces the basic understanding and concepts of supply chain management, and should help students realize the importance of this topic. Core concepts such as the bullwhip effect, supplier relationship management, forecasting and demand management, enterprise resource planning, transportation management, and customer relationship management are briefly discussed. There is also a closing section on current trends in supply chain management.

Part 2 presents supply issues in supply chain management. This very important topic is covered in three chapters, building from an introduction to purchasing management, to managing supplier relationships, and then finally to ethical and sustainable sourcing. Within these chapters can be found sections on government purchasing, global sourcing, e-procurement, software applications, supplier development, ethical purchasing, and green purchasing.

Part 3 includes four chapters regarding operations issues in supply chain management. This section progresses from forecasting, resource planning, and inventory management to lean production and Six Sigma in a supply chain setting. Topics in this section include the basics of forecasting; collaborative planning, forecasting, and replenishment; material requirements planning; enterprise resource planning; inventory models; lean thinking; Six Sigma concepts and tools; and statistical process control techniques.

Part 4 presents distribution issues in supply chain management and consists of four chapters. This section begins with a review of domestic U.S. and international logistics with sections on green transportation, international logistics security, and reverse logistics. This is followed by chapters on customer relationship management, global location decisions, and service response logistics. Content in these chapters includes new software application discussions, social media and cloud computing in customer relationship management, sustainability in logistics, new location trends in the global economy, and cloud computing in services.

The final section is Part 5, which presents discussions of the integration issues in supply chain management and performance measurements along the supply chain. While cooperation and integration are frequently referred to in the text, this section brings the entire text into focus, tying all of the parts together, first by discussing internal and external process integration in detail, followed by a discussion of traditional and world-class performance measurement systems. The topics of supply chain risk management and expanded coverage of performance measurement models are also included.

## SCM Profile

## SCM Globe–Accurate and Easy Supply Chain Simulations

SCM Globe is a serious supply chain game. Students can design supply chains from scratch or use the supply chains provided by the case studies to understand how different designs produce different operating results. And students learn how to manage those results. As they work with the simulations, students get an intuitive and analytical understanding for how supply chains work.

SCM Globe is not just a toy or a game about a make-believe company. It enables a wide range of people to accurately model and simulate real supply chains or design new ones. Users can model and simulate any supply chain with just four types of entities: Products; Facilities; Vehicles; and Routes. Users can define supply chain facilities and see their icons pop up on the screen, then drag-and-drop their icons to place them on a smart map such as Google Maps; put them where they really are in existing supply chains, or where they could be in new supply chains; define products used at the facilities, and define vehicles to move the products between facilities; and finally, specify the routes (road, rail, air, water) to connect the facilities.

This creates a mathematically rigorous model of the supply chain, but students do not have to deal with the math, the software does it for them. Then SCM Globe simulates the operation of the supply chain. As the simulation runs it shows vehicles moving on their routes and displays daily operating and financial data. Simulations identify problem areas—facilities where too many units of products accumulate or where products run out. Students use what the simulations show them, to change their supply chain designs to fix problems and improve their operating results. Students do not need advanced math skills, nor do they need to deal with abstract network diagrams and flow charts.

SCM Globe is designed to be user friendly and works equally well online or in the classroom. Students work individually at first to learn the simulations, then they can work in teams or continue working individually. The simulations produce performance reports that show progress and provide an objective basis to compare different student supply chain designs. The simulations combined with the performance reports become a real-time strategy game where the goal is to create supply chains that meet customer demand for products, while also attaining the lowest operating costs and inventory levels.

A concise online user's guide and video tutorials are available to walk people through the basics of designing a supply chain and simulating its performance. The FAQ section and other in-depth information in the online guide provide additional help for students and instructors. There is also a library of case studies. There is a beginning case and progressively more challenging cases that illustrate different supply chain operating principles. Each case study has an introduction in the online guide to get students started, and there are step by step instructor study guides for some of the more popular cases.

SCM Globe is engaging for students and teaches real-world supply chain skills. What students learn in the simulations is directly applicable for use in real supply chains. SCM Globe costs $64.95 per student per semester and is provided at no charge to instructors, with classes of five or more students. To learn more about SCM Globe, go to www.scmglobe.com. Click on the blue "Get Started Now!" button in the middle of the screen to see more about what SCM Globe can do.

For instructors using the new sixth edition of ***Principles of Supply Chain Management***, a one-time 15 percent discount is available for schools purchasing semester-length student subscriptions. Instructors can request this discount by sending an email to Michael Hugos

at: mhugos@scmglobe.com. Tell us your school name. We will schedule a call at your convenience to set up your instructor account, and show you how to get started with the simulations. We'll also provide you with the number of student subscriptions you need at a 15 percent discount.

If you are an instructor and would like to do a short 2–4 week pilot project, we can train you and provide free demo accounts for you and your students. At the end of the pilot project, you will know if you and your students like using the simulations, and if they enhance your supply chain or logistics class. To inquire about a pilot project, please contact Michael Hugos at: mhugos@scmglobe.com.

## ANCILLARY PACKAGE

Additional instructor resources for this product are available online. Instructor assets include Instructor's Manual, PowerPoint lecture slides, case teaching notes, answers to all of the end-of-chapter questions and problems, and a test bank powered by Cognero. Sign up or sign in at www.cengage.com to search for and access this product and its online resources.

## ACKNOWLEDGMENTS

We greatly appreciate the efforts of a number of fine and hard-working people at Cengage Without their feedback and guidance, this text would not have been completed. The team members are: Aaron Arnsparger, Senior Product Manager; Justin Traister, Content Manager; and Brandon Foltz, Senior Learning Designer. A number of other people at Cengage also need to be thanked including Chris Doughman, Conor Allen, and Steven McMillian. We also would like to thank Sangeetha Vijay and the people at Lumina who put the manuscript into final copy form.

Additionally, we would like to thank all of the case writers who contributed their cases to this textbook, particularly Rick Bonsall and Brian Hoyt, who wrote most of the cases. The other case writers' names, along with their contact information, are printed following their cases in the textbook. Finally, we thank CJ Wisner for all her help in preparing the MindTap quizzes, PowerPoints, and test bank. As with any project of this size and time span, there are certain to be a number of people who gave their time and effort to this textbook, and yet their names remain unknown and so were inadvertently left out of these acknowledgments. We apologize for this and wish to thank you here.

# About the Authors

**Joel D. Wisner** is Professor of Supply Chain Management in the Lee Business School at the University of Nevada, Las Vegas. He earned his BS in Mechanical Engineering from New Mexico State University in 1976 and his MBA from West Texas State University in 1986. During that time, Dr. Wisner worked as an engineer for Union Carbide at its Oak Ridge, Tennessee facility and then worked in the oil industry in the Louisiana Gulf Coast and West Texas areas. In 1991, he earned his PhD in Supply Chain Management from Arizona State University.

He is currently keeping busy teaching courses and writing textbooks in supply chain management and operations management at UNLV. His research and case writing interests are in process assessment and improvement strategies along the supply chain. His articles have appeared in numerous journals including *Journal of Business Logistics, Journal of Operations Management, Journal of Supply Chain Management, Journal of Transportation, Production and Operations Management Journal,* and *Business Case Journal.*

**Keah-Choon Tan** is Professor of Operations Management in the Lee Business School at the University of Nevada, Las Vegas. He received a BSc degree and an MBA from the University of South Alabama, and a PhD in Operations Management from Michigan State University. Prior to academia, Dr. Tan was a hospital administrator and an account comptroller of a manufacturing firm. Dr. Tan has served as the Department Chair of the Marketing Department and Associate Dean for Academic Affairs at the Lee Business School at UNLV.

Dr. Tan has published articles in the areas of supply chain management, quality, and operations scheduling, in academic journals and magazines including *Decision Sciences*, *Decision Support Systems*, *International Journal of Production Research*, *International Journal of Operations & Production Management*, *International Journal of Logistics Management*, *Journal of Supply Chain Management*, and *Omega*, among others. He has served as editor, co-guest editor, and on the editorial boards of several academic journals. Dr. Tan has received numerous research grants and teaching awards, including the UNLV Foundation Distinguished Teaching Award.

**G. Keong Leong** is an instructional faculty and professor emeritus in the Information Systems and Operations Management Department, in the College of Business Administration and Public Policy (CBAPP) at California State University, Dominguez Hills. He served as Associate Dean previously at CBAPP. He received an undergraduate degree in Mechanical Engineering from the University of Malaya and an MBA and PhD from the University of South Carolina. He is professor emeritus at the University of Nevada, Las Vegas and faculty at the Ohio State University, and a clinical faculty member at the Thunderbird School of Global Management.

His publications appear in academic journals such as *Journal of Operations Management, Decision Sciences, Interfaces, Journal of Management, European Journal of Operational Research, and International Journal of Production Research*, among others. He has coauthored three books including *Operations Strategy: Focusing Competitive Excellence,* and *Cases in International Management: A Focus on Emerging Markets* and received research, teaching, and service awards including an Educator of the Year award from the

Asian Chamber of Commerce in Las Vegas, Dennis E. Grawoig Distinguished Service award from Decision Sciences Institute, and OM Distinguished Scholar award from the Operations Management Division, Academy of Management. He has been active in the Decision Sciences Institute, serving as President, Editor of *Decision Line*, At-Large Vice-President, Associate Program Chair, Chair of the Innovative Education Committee, Chair of the Doctoral Student Affairs Committee, and Manufacturing Management Track Chair. In addition, he served as President of the Western Decision Sciences Institute and Chair of the Operations Management Division, Academy of Management.

We think we have compiled a very interesting set of supply chain management topics that will keep readers engaged and we hope you enjoy it. We welcome your comments and suggestions for improvement. Please direct all comments and questions to:

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Keah-Choon Tan: kctan@unlv.edu, or

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# PART 1

# Supply Chain Management: An Overview

## Chapter 1 Introduction to Supply Chain Management

# Chapter 1

# Introduction to Supply Chain Management


*Giant Eagle is really committed to increasing the diversity amongst our supply chain. There's several reasons for that. The first one, if COVID taught us nothing, it taught us that we collectively need to build a more resilient supply chain. We need to have access to more and different kinds of suppliers who are more agile, more nimble.*

**—Laura Shapira Karet, CEO, Giant Eagle[1]**

*Our proprietary logistics network, strong supplier partnerships, and nimble and dedicated team of more than 16,000 employees enabled Wayfair to consistently serve our customers at a time they needed us most, both in North America and Europe. The plans that we put in place in late 2019, combined with these factors, translated to a powerful profitability inflection, and we generated over $1 billion in free cash flow in the quarter.*

**—Niraj Shah, CEO, Wayfair[2]**

## Learning Objectives

**After completing this chapter, you should be able to**

**LO 1** Describe a supply chain and define supply chain management.

**LO 2** Describe the objectives and elements of supply chain management.

**LO 3** Describe local, regional, and global supply chain management activities.

**LO 4** Describe a brief history and current trends in supply chain management.

**LO 5** Understand the bullwhip effect and how it impacts the supply chain.

## Chapter Outline



### SCM Profile — The Top Five Supply Chains of 2020

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Connecticut-based research company Gartner published its 16th annual ranking of the world's leading supply chains in 2020. During an ongoing global pandemic and economic uncertainty in 2020, some countries around the world were attempting to reopen their economies, while tremendous uncertainty remained about the safety involved in such endeavors. Companies were trying to predict how markets would recover in 2021 and beyond, while designing risk-mitigation strategies for future waves of the coronavirus and its variants. The top five companies and their supply chains are described below:

1. High-tech leader Cisco Systems exhibited strengths in revenue growth, and in environmental and social aspects. They were also recognized as a leader in the communities where they operate. Cisco's digital supply chain uses security as a foundation, and its improvements include monitoring and assessing partner IT security capabilities. Cisco has achieved significant performance in the areas of order lead-time, cost savings and inventory reduction, while launching many new products.
2. Colgate-Palmolive and its supply chains showed a commitment to reduce its environmental impact with its certification as a "TRUE Zero Waste" company by the U.S. Green

Building Council (USGBC). Since 2017, 15 Colgate-Palmolive manufacturing sites had achieved TRUE Zero Waste certification, with 10 of the sites achieving the highest level of recognition. The company also received the 2019 Leadership Award from the USGBC "as an organization at the forefront of the green building movement."

3. Johnson & Johnson's commitment to supply chain innovation is evidenced by its Supply Chain Innovation Engine, located in New Brunswick, NJ. It creates collaborations among supply chain team members, key partners and external experts. People who work at Johnson & Johnson develop and prioritize ideas that improve healthcare. To support the early coronavirus control efforts, Johnson & Johnson used its 3D printing expertise to make manifolds for ventilators which allowed two patients to share the same ventilator.
4. Schneider Electric, the French energy management and automation specialist, created EcoStruxure, a suite of tools and services to help further develop the Internet of Things. EcoStruxure provides connectivity across a business, providing support for faster decision making in operations. Schneider Electric also willingly shares what it is doing with its peers, to promote improvements among all supply chains.
5. Nestlé has a strong focus on customers, emphasizing product availability both on the shelf and online. To improve its product availability, Nestlé created additional capacity in several manufacturing facilities. To increase agility, Nestlé is using demand-sensing technologies and integrating processes with key customers.[3]

## Introduction

Successful organizations today must be heavily involved with their suppliers and customers. Creating goods and services that customers want, at a price they are willing to pay, requires firms to be good at a number of things. Managers must pay closer attention to where parts and materials come from; how suppliers' goods are designed, produced, stored, and transported; how their own products are produced and then distributed to customers; and finally, what their direct customers and the end-product consumers really think of the firm's goods and services. (Note that this textbook uses the term *products* to refer to both *goods* and *services*).

Thirty years ago, many large firms were vertically integrated, meaning they owned some of their suppliers and/or customers. Today, this practice is much less common due to the high cost and difficulty in managing such diverse business units. Instead, firms are focusing more of their resources on core capabilities, while trying to create alliances with suppliers, transportation and warehousing companies, and manufacturers. Thus, a collaborative approach to buying, making, and distributing goods and services has become the best way for firms to stay successful—and these are central to the practice of supply chain management (SCM).

Several factors enable firms to work together more effectively than ever before. Communication and information exchange using enterprise resource planning (ERP) system applications (discussed further in Chapter 6) has made global collaboration not only possible but necessary for firms to compete. Communication technologies continue to change rapidly, making partnerships and teamwork much easier than ever before. Competition is also expanding rapidly in all industries and in all markets around the world, bringing new materials, products, people, and resources together, making it more difficult for many of the local, individually owned shops to keep customers satisfied. Additionally, the 2020 global recession made customers more cost-conscious while seeking

higher levels of quality and service, which forces organizations to find even better ways to compete. Customers are also demanding more socially responsible and environmentally friendly goods from organizations. Considering all of these changes to the environment, it is indeed a challenging time for companies to develop new products, find new suppliers and customers, and compete more successfully. Consequently, many job opportunities are opening up in the areas of purchasing, operations, logistics, and supply chain management.

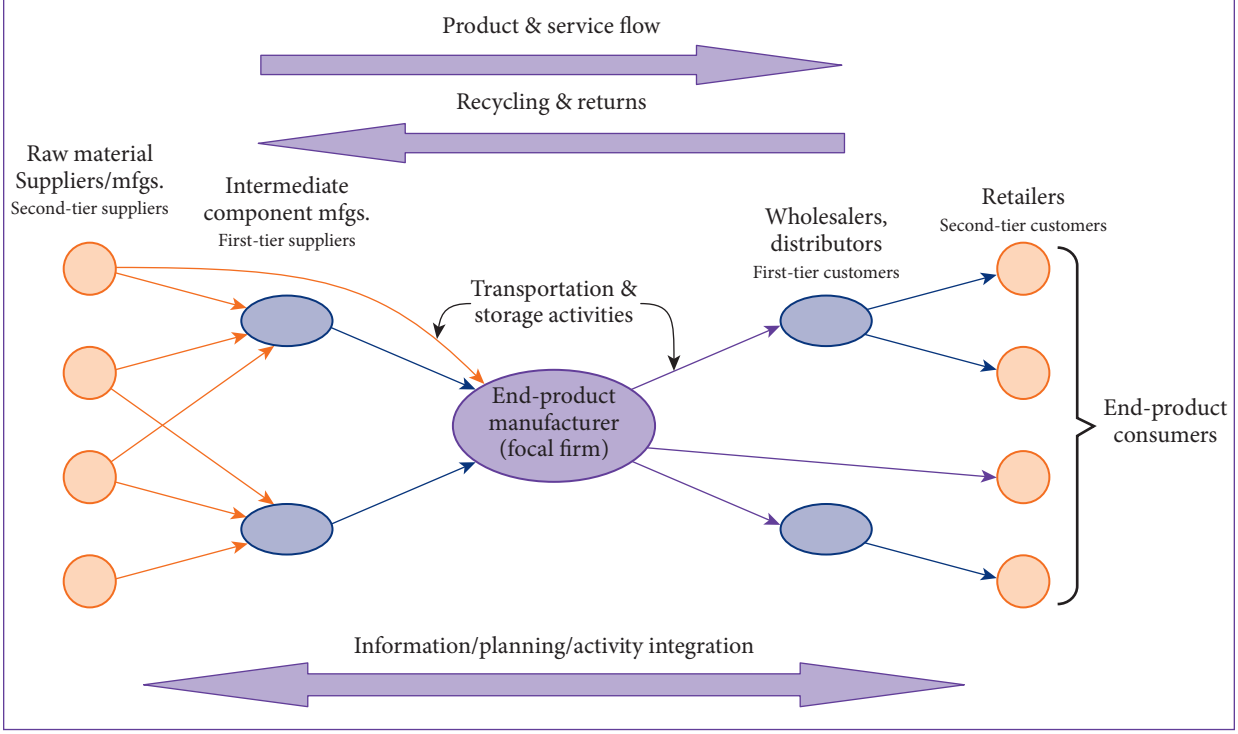
As you read this textbook, you will be introduced to the many concepts of supply chain management and how to use these concepts to become better managers in today's global economy. Examples are used throughout the text to illustrate the topics discussed, and cases at the end of each chapter are provided to enable you to test your problem-solving and decision-making skills in supply chain management. It is hoped that by the end of the text you will have gained an appreciation of the value of supply chain management and will be able to apply what you have learned, both in your profession and in future courses in supply chain management.

In this chapter, the term *supply chain management* is defined, including a discussion of its importance, history, and developments to date. The chapter ends with a look at a few of the current trends in supply chain management.

## Supply Chain Management Defined

To understand supply chain management, one must first begin with a discussion of a supply chain**;** a generic one is shown in Figure 1.1. The **supply chain** shown in the figure starts with firms extracting raw materials from the earth—such as iron ore, oil, wood, and food

**Figure 1.1** A Generic Supply Chain



items—and then selling these to raw material suppliers such as lumber companies, steel mills, and raw food distributors. These firms, acting on purchase orders and specifications they have received from component manufacturers, turn the raw materials into materials that are usable by their customers (materials such as sheet steel, aluminum, copper, lumber, and inspected foodstuffs). The component manufacturers, responding to orders and specifications from their customers (the final product manufacturers), make and sell intermediate components (electrical wire, fabrics, plumbing items, nuts and bolts, molded plastic components, component parts and assemblies, and processed foods). The final product manufacturers (companies such as Boeing, General Motors, and Kraft) assemble the finished products and sell them to wholesalers or distributors, who then resell these products to retailers as their product orders are received. Retailers in turn, sell these products to us, the end-product consumers.

Consumers purchase products based on a combination of cost, quality, customer service, availability, maintainability, and reputation factors, and then hope the purchased items satisfy their requirements and expectations. Companies, along with their supply chains, that can provide all of these desired things will ultimately be successful. Along the supply chain, intermediate and end customers may need to return products or obtain warranty repairs, or they may just throw products away or recycle them. These reverse logistics activities are also included in the supply chain and are discussed further in Chapter 9.

Referring again to Figure 1.1, the firm in the middle of the figure is referred to as the *focal firm* simply because it is the central firm being discussed; the direct suppliers and customers of the focal firm are **first-tier suppliers** and **first-tier customers**. The first-tier suppliers' suppliers are thus the focal firm's **second-tier suppliers**, and the first-tier customers' customers are the focal firm's **second-tier customers**. Not all supply chains look exactly like the one shown in Figure 1.1. Some raw material and end-product manufacturers, for example, may sell directly to end consumers. Some supply chains, such as an automobile supply chain, might have many tiers, while others such as a law office's supply chain might have only one tier of suppliers and customers.

Thus, the series of companies eventually making goods and services available to consumers, including all of the functions enabling the purchase, production, delivery, and recycling of materials, components, end products, and services, is called a supply chain. Companies with multiple products likely have multiple supply chains. All goods reach their customers via some type of supply chain—some much larger, longer, and more complex than others. Some may also involve foreign suppliers or markets.

With this idea of a supply chain in mind, there really is only one true source of income for all supply chain organizations—a supply chain's end customers. According to Manu Vora, the founder and president of Business Excellence Inc., a global management consulting services firm, high performing supply chains are not only essential to delivering goods on time, but global companies also depend on their supply chain processes to manage the divergent expectations of customers, to stay one step ahead of the competition.[4] A **process** by the way, can be defined as a set of activities designed to produce a good or service for an internal or external customer. When companies make business decisions while ignoring the interests of the end customer and other chain members, these decisions create additional risks, costs, and waiting time along the supply chain, ultimately leading to higher end-product prices, lower supply chain service levels, and eventually lower end-customer demand.

A number of other companies are also indirectly involved in most supply chains, and they play a very important role in the delivery of goods to customers. These are the many service providers, such as trucking and airfreight shipping companies, information system providers, public warehousing firms, freight forwarders, agents, and supply chain

consultants. These service providers are extremely useful to the firms in most supply chains because: they can help to get goods where they need to be in a timely fashion, they allow buyers and sellers to communicate effectively, they allow firms to serve outlying markets, they enable firms to save money on domestic and global shipments, and in general they allow firms to adequately serve their customers at the lowest possible cost.

One form of supply chain that has been featured numerous times during the 2020 pandemic on TV and in newsprint is the cold chain. The **cold chain** refers to an alliance of companies that can monitor and protect the temperature of perishable products in order to maintain quality and safety from the point of origin through distribution to the final consumer. While cold chains have been around for many years to protect the temperatures of produce, fresh fish, and other foodstuffs as they travel from farm to retailer, cold chains became a popular news item in 2020 as COVID vaccines began to be distributed globally by Pfizer and Moderna. The two vaccines must be stored and transported at sub-zero temperatures. Satellite Internet of Things company Orbcomm, for example, offers transportation companies a cold chain telematics solution, which is used while transporting the vaccines. Orbcomm supplies hardware that connects to a refrigerated device, which passes information by satellite to Orbcomm's application. The application is integrated into customers' systems, and so managers, dispatchers, and drivers can monitor temperatures in real time and adjust the temperatures if needed.[5]

Now that a general description of a supply chain has been provided, what is **supply chain management** (SCM)? A number of definitions are available in the literature and among various professional associations. A few of these are provided here from various organizations connected to the practice of supply chain management:

- The Council of Supply Chain Management Professionals (CSCMP) defines supply chain management as:

  *The planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers.*[6]

- The Institute for Supply Management (ISM) describes supply chain management as:

  *The design and management of seamless, value-added processes across organizational boundaries to meet the real needs of the end customer.*[7]

- The Business Dictionary defines supply chain management as:

  *Management of material and information flow in a supply chain to provide the highest degree of customer satisfaction at the lowest possible cost. Supply chain management requires the commitment of supply chain partners to work closely to coordinate order generation, order taking, and order fulfillment.*[8]

Consistent across these definitions is the idea of coordinating or integrating a number of goods-related activities among supply chain participants to improve operating efficiencies, quality, and customer service. Thus, for supply chain management to be successful, firms must work together by sharing information on things like demand forecasts, production plans, capacity changes, new marketing strategies, new product and service developments, new technologies employed, purchasing plans, delivery dates, and anything else impacting

the other supply chain members' purchasing, production, and distribution plans. In a supply chain innovation survey conducted by MHI, a material handling association, and Deloitte, the top two strategic priorities for supply chain executives are **supply chain analytics** (tools that harness data from internal and external sources to produce breakthrough insights that can help supply chains reduce costs and risk) and **multi-channel fulfillment** (allowing consumers to shop for what they want, where they want, and when they want, and then have their purchases delivered quickly and consistently).[9]

In theory, companies in a supply chain work as a cohesive, singularly competitive unit, accomplishing what many large, vertically integrated firms tried and failed to accomplish in years past. The difference is that independent firms in a supply chain are relatively free to enter and leave supply chain relationships if these relationships are no longer proving to be beneficial; it is this free market alliance-building that allows supply chains to operate more effectively than vertically integrated conglomerates.

For example, when a particular item is in short supply accompanied by rising prices, a firm might find it beneficial to align itself with one of these suppliers to ensure a continued supply of the scarce item. This alignment may become beneficial to both parties—new markets for the supplier leading to new, future product opportunities, and long-term continuity of supply and stable prices for the buyer. Later, when new competitors start producing the scarce product or when demand declines, the supplier may no longer be valued by the buying firm; instead, the firm may see more value in negotiating with other potential suppliers for its purchase requirements and may then decide to dissolve the original buyer–supplier alignment. Unforeseen weather events and accidents can also create supply chain management problems.

For example, Indiana-based Zimmer Biomet, which makes artificial joints and dental devices, blamed its 2016 declining stock price on supply chain disruption problems. "Our current supply chain, not being fully integrated, did hamper our ability to respond effectively to this shifting product mix," said Daniel Florin, Zimmer Biomet's chief financial officer.[10] In China, in 2015, two blasts tore through a chemical warehouse containing 3,000 tons of hazardous chemicals, including sodium cyanide and explosive ammonium nitrate. Along with destroying buildings and infrastructure within a 1.2-mile radius, the blasts incinerated more than 10,000 new cars. Jaguar Land Rover, Volkswagen, Fiat Chrysler, Hyundai, and Renault all reported significant vehicle losses, which hampered their supply chain effectiveness.[11] As can be seen from these examples, supply chains are often very dynamic, which can create problems in effectively managing them.

While supply chain management may allow organizations to realize the advantages of vertical integration, certain conditions must be present for successful supply chain management to occur. One important prerequisite is a melding of the corporate cultures of the supply chain participants so all parties are receptive to the requirements of successful supply chain management, such as sharing process information. More traditional organizational cultures that emphasize short-term, company-focused performance can conflict with the objectives of supply chain management. Supply chain management focuses on positioning organizations in such a way that all participants benefit. Successful supply chain management requires high levels of trust, cooperation, collaboration, and honest, accurate communications.

The boundaries of supply chains are also dynamic. It has often been said that supply chain boundaries for the focal firm extend from "the suppliers' suppliers to the customers' customers." Today, most supply chain collaboration efforts do not extend beyond these boundaries. In fact, in many cases, firms find it very difficult to extend coordination efforts

beyond a few of their most important first-tier suppliers and customers. However, with time and successful initial results, many firms are extending the boundaries of their managed supply chains to include their second-tier suppliers, second-tier customers, as well as their logistics service (transportation and warehousing) providers. Some of the firms considered to be the best at managing their supply chains have very recognizable names. Each year, for example, the business advisory company Gartner, Inc., announces the twenty-five companies that exhibit the best supply chain management business performance and leadership. The chapter-opening SCM Profile summarizes the five best from this list.

## The Importance of Supply Chain Management

While all firms are part of a chain of organizations bringing goods and services to customers (and most firms operate within a number of supply chains), certainly not all supply chains are managed in a coordinated fashion. Firms continue to operate independently in many industries (particularly small firms). It is often easy for managers to be focused solely on their immediate customers, their daily internal operations, their sales, and their costs. After all, with customers complaining, employees to train, late supplier deliveries, creditors to pay, and equipment to repair, who has time for relationship building and other supply chain coordination efforts? Particularly during times like the economic downturn of 2009 and the global pandemic starting in 2020, firms were struggling to just keep their doors open, and many supply chain management efforts stalled.

In 2020 and 2021, as companies coped with tremendous changes brought about by COVID-19, they all faced the need to adapt to remote work, reconfigured physical workspaces, and revised supply chain networks. Arvind Krishna, CEO of IBM, says that "resiliency is about adaptability in this environment, as well as having a sustainable business for ourselves and for our clients. That's why, within 48 hours, we were able to move more than 95 percent of our employees to work from home. When you're critically dependent upon the cyber technologies, you need to up the level of resilience, and design your applications and your infrastructure in a way that never goes down." At Walmart, Kathleen McLaughlin, chief sustainability officer, said the company redoubled its resolve during the pandemic to bolster the sustainability of its supply chains. Walmart's Project Gigaton initiative, launched in 2017, for example, aims to reduce 1 billion metric tons of greenhouse gas emissions from the company's supply chains by 2030.[12]

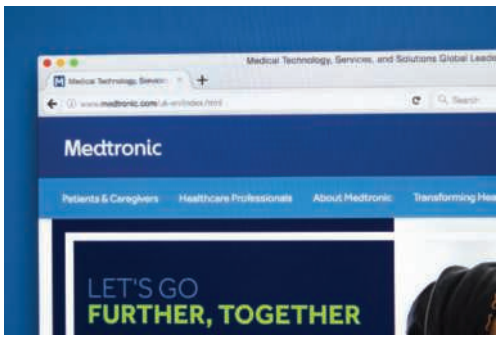
Aside from the recent trends in supply chain resiliency and sustainability, firms with large system inventories, many suppliers, complex product assemblies, and highly valued customers with large purchasing budgets have much to gain from the practice of supply chain management. For these firms, even moderate supply chain management success can mean lower purchasing and inventory carrying costs, better product quality, and higher levels of customer service—all leading to more sales and better profits. According to the U.S. Census Bureau's Annual Survey of Manufactures, the total cost of all materials purchased in 2018 exceeded $3.3 trillion among U.S. manufacturers, up $500 billion from 2017. The total 2018 end-of-year inventory value for all U.S. manufacturers was almost $680 billion, up from $643 billion in 2017.[13] Thus, it can be seen that purchasing and inventory costs can be quite sizable for firms and represent areas where significant cost savings can be realized when using effective supply chain management strategies.

Most recently, enVista, a global software and consulting services provider, conducted a 2020 Supply Chain Survey of retailers, and found that 34 percent said that handling the growth of online business was the top challenge they faced, while demand

planning and forecasting (33 percent), improving efficiencies (30 percent) and reducing supply chain costs (26 percent), were the next most important supply chain issues.[14] Seven years earlier, a similar survey found that over 70 percent of the respondents said that controlling costs was the number one focus area for supply chains. Obviously, the recent pandemic events have changed supply chain planning. The nearby SCM Profile describes Medtronic's use of a digital supply chain model to respond to supply disruptions caused by the pandemic.

Supply chain management efforts can start small—for instance, integrating processes with just one key supplier—and gather momentum over time to include more supply chain participants such as other important suppliers, key customers, and logistics or third-party services. Obviously, other behind-the-scenes activities must also be included such as getting stakeholder buy-in and use of an in-house or cloud IT solution. Finally, supply chain management efforts can include second-tier suppliers and customers. So why are these integration activities so important? As alluded to earlier, when a firm, its customers, and its

## SCM Profile: Medtronic's Digital Supply Chain Model




christsdorney/Shutterstock.com

Medtronic, a large U.S. medical device manufacturer, created a digital model of its supply chain to assist in faster and better decision-making. Medtronic's supply chain includes hundreds of manufacturing and contract manufacturing sites, dozens of sterilization sites, over a thousand suppliers, and over 250,000 products. These products are distributed to hospitals, other distributors, and government health care programs. Over 60,000 daily shipments flow through a network of distribution centers, using various modes of transportation, to over 150 countries.

Medtronic's focus has been on analyzing how its products flow through its distribution network to customers. For example, using a slower mode of transportation means holding more inventory to attain desired service levels. Faster transportation means higher costs but requires less inventory. The company can also see the cost and service impacts of adding or subtracting a warehouse.

In a global pandemic environment, the supply chain impacts have been tremendous. Medtronic's supply chain has been heavily impacted by unexpected demand surges and crashes and countries shutting down their ports. As airlines stopped flying, air capacity vanished. When COVID-19 truly became a global problem, Medtronic was able to respond by placing inventories in countries before inbound shipments became impossible.

While demand has dropped off for many of its products, at some point demand will return. The company can place inventory in warehouses, it can slow down manufacturing, it can change where some products are manufactured, or it can slow down shipments by using ocean carriers. The total costs of all these options can be analyzed. Medtronic's digital model will always be on and constantly updated, improving the company's daily operations and business continuity capabilities.[15]

suppliers all know each other's future plans, and are willing to work together, the planning process is easier and much more productive in terms of decision-making, cost savings, quality improvements, and service enhancements.

On the other hand, lack of effective supply chain management can cause problems for organizations. Using a fictitious setting, Example 1.1 illustrates some of the costs associated with independent planning and lack of supply chain information sharing and coordination.

**Example 1.1 Grebson Manufacturing's Supply Chain**

The Pearson Bearings Co. makes roller bearings for Grebson Manufacturing on an as-needed basis. For the upcoming quarter, Pearson has forecasted Grebson's roller bearing demand to be 25,000 units. Since Grebson's demand for bearings from Pearson has been somewhat erratic in the past due to the number of bearing companies competing with Pearson and also the fluctuation of demand from Grebson's customers, Pearson's roller bearing forecast Includes 5,000 units of safety stock. The steel used in Pearson Bearings' manufacturing process is usually purchased from CJ Steels, Inc. CJ Steels has, in turn, forecasted Pearson's quarterly demand for the high-carbon steel it typically purchases for roller bearings. Their forecast also includes safety stock of about 20 percent over what CJ Steels actually expects Pearson to buy over the next three months.

Since Pearson Bearings does not know with full confidence what Grebson's roller bearing demand will be for the upcoming quarter (it could be zero or it could exceed 25,000 units), Pearson will incur the extra costs of producing and holding 5,000 units of safety stock. Additionally, Pearson Bearings risks having to either scrap, sell, or hold onto any units not sold to Grebson, as well as losing current and future sales to Grebson if their demand exceeds 30,000 units over the next quarter. CJ Steels faces the same dilemma—extra materials, labor costs, and warehouse space for safety stock along with the potential stockout costs of lost present and future sales. Additionally, Grebson's historic demand pattern for roller bearings from its suppliers already includes some safety stock, since it uses roller bearings in other products it makes for a primary customer.

Grebson's safety stock, which they have built into their roller bearing purchase orders, has resulted in still additional safety stock production levels at the Pearson plant. In fact, some of the erratic purchasing patterns of Grebson are probably due to their leftover safety stocks causing lower purchase quantities during subsequent production cycles. This, in turn, creates greater demand variability, leading to a decision at Pearson to produce even higher levels of safety stock. This same scenario plays out between Pearson and CJ Steels, with erratic buying patterns by Pearson and further safety stock production by CJ. This magnification of safety stock, based on erratic demand patterns and forecasts derived from demand already containing safety stock, and from a lack of sharing information, continues to grow as orders pass to more distant suppliers up the supply chain.

The continuing cycle of erratic demand, causing forecasts to include safety stock which in turn magnify supplier forecasts and cause production planning problems is known as the **bullwhip effect**. If Grebson Manufacturing *knew* its customers' purchase plans for the coming quarter along with how their purchase plans were derived, it would be much more confident about what the upcoming demand was going to be, resulting in little, if any, safety stock requirement, and consequently it would be able to communicate its own purchase plans for roller bearings to Pearson. If Grebson purchased its roller bearings from only Pearson and, further, told Pearson what its quarterly purchase plans were, and if Pearson did likewise with CJ Steels, safety stocks throughout the supply chain would be reduced considerably, driving down the costs of purchasing, producing, and carrying roller bearings at each stage. Trade estimates suggest that the bullwhip effect results in excess costs on the order of 12 to 25 percent for each firm in a supply chain, which can be a tremendous competitive disadvantage. This discussion also sets the stage for a supply chain management concept called collaborative planning, forecasting, and replenishment, discussed further in Chapter 5.

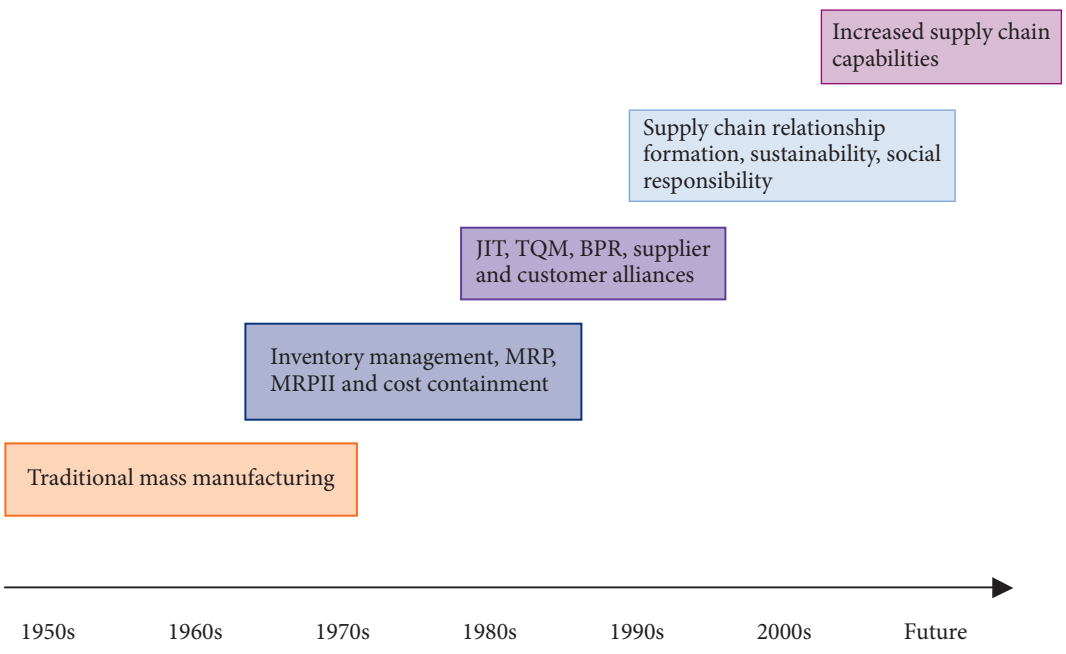
As working relationships throughout the supply chain mature, key trading partners will feel more comfortable investing capital in better facilities, better products, and better services for their customers. With time, customers will share more information with suppliers, and suppliers will be more likely to participate in their key customers' new product design efforts, for instance. These, then, become some of the more important benefits of a well-integrated supply chain. In the following chapters of the text, other associated benefits will also become apparent.

## The Origins of Supply Chain Management in the United States

During the 1950s and 1960s, U.S. manufacturers were employing mass production techniques to reduce costs and improve productivity, while little attention was typically paid to creating supplier partnerships, improving process design and flexibility, or improving product quality (see Figure 1.2). New product design and development was slow and relied exclusively on in-house resources, technologies, and capacity. Sharing technology and expertise through strategic buyer–supplier partnerships was essentially unheard of back then. Processes on the factory floor were cushioned with work-in-process inventories to keep machines running and maintain balanced material flows, products moving through the facility even when equipment broke down, resulting in large inventory carrying cost investments.

In the 1960s and 70s, computer technologies began to flourish and material requirements planning (MRP) and manufacturing resource planning (MRPII) software

**Figure 1.2** Historic Supply Chain Management Events in the United States




*Note:* MRP = material requirements planning, MRPII = manufacturing resource planning, JIT = just-in-time, TQM = total quality management, BPR = business process reengineering.

applications were developed. These systems allowed companies to see the importance of effective materials management—they could now recognize and quantify the impact of high levels of inventories on manufacturing, storage, and transportation costs. As computer capabilities grew, the sophistication of inventory tracking software also grew, making it possible to further reduce inventory costs while improving internal communication of the need for purchased parts and supplies.

The 1980s were the breakout years for supply chain management. One of the first widely recorded uses of the term *supply chain management* came about in a paper published in 1982.[17] Intense global competition beginning in the 1980s (and continuing today) provided an incentive for U.S. manufacturers to make low-cost, high-quality products while offering high levels of customer service. Manufacturers utilized just-in-time (JIT) and total quality management (TQM) strategies to improve quality, manufacturing efficiencies, and delivery times. In a JIT manufacturing environment with little inventory to cushion scheduling and/or production problems, firms began to realize the potential benefits and importance of strategic and cooperative supplier–buyer–customer relationships, which are the foundations of SCM. The concept of these partnerships or alliances emerged as manufacturers experimented with JIT and TQM.

As competition in the United States intensified further in the 1990s accompanied by increasing logistics costs and the trend toward market globalization, the challenges associated with improving quality, cost, customer service, and product design also increased. To deal with these challenges, manufacturers began purchasing from a select number of certified, high-quality suppliers with excellent service reputations and involved these suppliers in their new product design activities as well as in cost, quality, and service improvement initiatives. In other words, companies realized that if they started giving only their best suppliers most of their business, then they, in return, could expect these suppliers to provide continued benefits in the form of on-time deliveries; high-quality, low-cost products; and help with new product design efforts.

Interestingly, the general idea of supply chain management had been discussed for many years prior to the chain of events shown in Figure 1.2. In 1915, Arch W. Shaw of the Harvard Business School wrote the textbook *Some Problems in Market Distribution,* considered by many to be the first on the topic of what we now refer to as supply chain management (Shaw never used this term). The text included discussions of how best to purchase raw materials, transport products, locate facilities, and analyze productivity and waste. He recommended a "laboratory point of view" or what could now be termed a systematic study of supply chain issues.[18]

**Business process reengineering** (BPR), or just **reengineering**, described as the radical rethinking and redesigning of business processes to reduce waste and increase performance, was introduced in the early 1990s and was the result of a growing interest during this time in the need for cost reductions and a return to an emphasis on the key competencies of the firm to enhance long-term competitive advantage. Michael Hammer and James Champy's very popular book, *Reengineering the Corporation: A Manifesto for Business Revolution* combined with the many statements from notable business experts like Peter Drucker along the lines of "Reengineering is vital to success and it has to be done," created a fervor at the time among managers seeking some sort of magic pill or easy method for making their businesses successful.[19] As this fad died down in the late 1990s (reengineering became synonymous with downsizing and thus fell out of favor), the practice of supply chain management rapidly increased in popularity as a source of competitive advantage.

Also during this time, managers, consultants, and academics began developing an understanding of the differences between logistics and supply chain management. Up until then, supply chain management was simply viewed as logistics outside the firm. As companies began implementing supply chain management initiatives, they began to understand the need to integrate key business processes among the supply chain participants, enabling the supply chain to act and react as one entity. Today, logistics is viewed as one important element of the much broader supply chain management concept.

At the same time, companies also saw benefits in the creation of alliances or partnerships with their customers. Developing these long-term, close relationships with customers (referred to as **customer relationship management** or CRM) meant the need for less finished product safety stock (as discussed earlier in the bullwhip effect example) and allowed firms to focus their resources on providing better goods and services to their best customers. In time, when market share improved for its customers' products, the result was more business for the firm.

Thus, supply chain management has evolved along two parallel paths: (1) the inbound purchasing and supply management emphasis from industrial buyers at the focal firm, and (2) the outbound logistics and customer service emphasis from logistics personnel at the focal firm. The increasing popularity of alliances with suppliers and customers (and eventually suppliers' suppliers and customers' customers) has also meant a greater reliance on the inbound and outbound shipping, warehousing, and logistics services that provide transportation, storage, documentation, and customs clearing services to trading partners within a typical supply chain. Relationship building has also occurred increasingly with many of these **third-party logistics providers** (3PLs) to ensure a continuous, uninterrupted supply of goods. The need to periodically assess the performance of these relationships has also accompanied the growth of supply chain management. One of the challenges faced today by many firms involved in supply chain management is how to adequately assess overall end-to-end performance in often extremely complex, global supply chains. This idea of evaluating supply chain performance from numerous perspectives including financial, sustainability, speed, and risk is explored in Chapter 14.

For the wholesaling and retailing industries, the supply chain management focus is on location, logistics, and customer service issues more often compared to manufacturing. Supply chain management in these industries has often been referred to as quick response, service response logistics, or integrated logistics. The advancement of electronic data interchange (EDI) systems, bar coding, Internet systems, logistics software applications, and radio frequency identification (RFID) technologies over the past two decades has greatly aided the evolution of the integrated supply chain concept. Retailers utilize supply chain management to help quickly meet changing demands in the marketplace and to reduce inventories throughout their supply chains.

Most recently, the rapid development of client/server supply chain management software that typically includes integrated supply chain management and e-commerce components has aided in the evolution and adoption of supply chain management. These software applications are commonly referred to as **enterprise resource planning** (ERP) systems, and for years, the top two ERP providers worldwide have been SAP and Oracle. Total worldwide ERP product sales in 2019 were over $38 billion, and sales growth was expected to average about 8.2 percent per year for the following five years.[20] Sharing information with supply chain partners through the Internet using compatible ERP systems has enabled firms to integrate stocking, logistics, materials acquisition, shipping, and other functions to create a more proactive and effective style of business management and customer responsiveness.

Today, an emphasis is being placed on the resilience and the environmental and social impacts of supply chains. Customers are demanding that companies and their supply chains make buying easy in a pandemic environment, and also act in an ethically and socially responsible manner. This includes an attention on how suppliers utilize the Internet, hire and train employees, how they grow and harvest plants, how they manufacture parts, how their activities impact the environment, and what sorts of sustainability policies are being utilized. The term **sustainability** as applied to supply chains is a broad term that includes protecting the environment, some aspects of social responsibility, as well as financial performance (hence the linking of sustainability to what is termed the **triple bottom line**, or people, planet, and profits). Sustainability can be defined as the ability to meet the needs of current supply chain members without hindering the ability to meet the needs of future generations in terms of economic, environmental, and social challenges. Simply put, sustainability is doing the right things in ways that make economic sense. These topics are discussed further in Chapter 4. With these practices in mind, supply chain managers today must also cope with maintaining the most flexible supply chain possible to serve customers in chaotic marketplaces, and to take advantage of new markets, new sources of supply, and new customer demands.

## The Foundations of Supply Chain Management

The foundation elements of supply chain management are introduced in this section. These elements essentially make up the table of contents for this textbook and are shown in Table 1.1 along with the chapters where they are discussed.

### Supply Elements

Traditional purchasing strategies typically emphasized the use of many suppliers, hard bargaining, competitive bidding, and short-term contracts. This typically created adversarial buyer–supplier relationships with a focus primarily on the product's purchase price instead of the capabilities of the suppliers and how they could contribute to the long-term competitiveness of the buying organization. In many cases, purchasing was performed by a clerk, with little training. Over the past thirty years, there has been a shift toward a more strategic approach to purchasing, and this broader approach is more commonly referred to as **supply management**. Supply management professionals holding business degrees now most often perform the purchasing function. Effective supply management has resulted

**Table 1.1** The Foundations of Supply Chain Management

| FOUNDATION ELEMENTS | IMPORTANT ISSUES | CHAPTERS |
|---|---|---|
| Supply | Supplier base reduction, supplier alliances, SRM, global sourcing, ethical and sustainable sourcing | 2, 3, 4 |
| Operations | Demand management, CPFR, inventory management, MRP, ERP, lean systems, Six Sigma quality | 5, 6, 7, 8 |
| Logistics | Logistics management, CRM, network design, RFID, global supply chains, sustainability, service response logistics | 9, 10, 11, 12 |
| Integration | Barriers to integration, risk and security management, performance measurement, green supply chains | 13, 14 |

generally in smaller supplier bases and the development of more long-term, trusting, mutually beneficial supplier relationships (termed **supplier relationship management** or SRM) to achieve the competitive benefits described earlier.

Purchasing and the strategic concepts of supply management are one of the foundations of supply chain management, since incoming material quality, delivery timing, purchase price, product safety, and the impact of purchasing on the environment are all affected by the buyer–supplier relationship and the capabilities of suppliers. A recent survey conducted by the American Productivity and Quality Center (APQC) and Supply Chain Management Review revealed that most organizations are familiar with the principles of SRM, and that nearly 40% of organizations are using SRM with their suppliers to some degree. Many organizations that do not use SRM intend to implement it in the near future. Clearly organizations consider this way of managing suppliers worth adopting. For suppliers that are more integral to an organization's success, or have potential to develop innovations that can benefit both parties, APQC recommends the development of a more strategic and collaborative relationship business model.[21] Chapters 2 through 4 cover the topics associated with supply management.

The global pandemic beginning in 2020 added another problem to the supply side of businesses, namely how the focal firm can continue producing successfully, when several key suppliers go out of business or are unable to export product when ports close down. Supply chain managers today must build better visibility and security into their supply chains using software applications and frequent communications to spot these problems before they become unmanageable.

One of the more crucial issues within the topic of supply management is **supplier management**. Simply put, this means encouraging or helping the firm's suppliers to perform in some desired fashion, and there are a number of ways this is done. It involves assessing the suppliers' current capabilities and then deciding if and how they need to improve. Thus, one of the key activities in supplier management is **supplier evaluation**, or determining the current capabilities of suppliers. This occurs both when potential suppliers are being evaluated for a future purchase and when existing suppliers are periodically evaluated for ongoing performance purposes. A closely related activity is **supplier certification**. Supplier certification allows buyers to assume the supplier will meet certain product quality and service requirements covered by the certification, thus reducing duplicate testing and inspections and the need for extensive supplier evaluations. Farm implement manufacturer Deere & Company, for example, has its Achieving Excellence Program wherein suppliers are evaluated annually across several performance categories. The idea is to reward high performers and provide feedback to promote continuous improvement. EgeTrans Internationale earned recognition as a Partner-level supplier for fiscal year 2019 in the John Deere Achieving Excellence Program. The Partner-level status is Deere & Company's highest supplier rating. Due to the dedication in providing logistics services of outstanding quality as well as the commitment to continuous improvement, EgeTrans was selected for this recognition. EgeTrans holds the record for receiving thirteen consecutive Partner-level awards.[22]

Over time, supplier management efforts allow firms to selectively screen out poor-performing suppliers and build successful, long-term, trusting relationships with top-performing suppliers. These suppliers can provide tremendous benefits to the buying firm and the entire supply chain. As discussed in greater detail in Chapter 2, greater purchase volumes, using fewer suppliers, typically means lower per-unit purchase costs (causing a much greater impact on profits than a corresponding increase in sales) and in many cases higher quality and better delivery service. These characteristics are viewed as strategically

important to the firm because of their impact on the firm's competitiveness. "Our suppliers play a key role in delivering the products, services and experiences our customers deserve, and these award-winning suppliers went above and beyond our expectations," said Shilpan Amin, GM's vice president, Global Purchasing and Supply Chain, when speaking of their top-performing suppliers. "We also believe it's important at this point in time to thank our entire supply base for their efforts the last few months to mitigate the impacts of COVID-19."[23]

Suppliers also see significant benefits from the creation of closer working relationships with customers in terms of long-term, higher-volume sales. These trading partner relationships have come to be termed **strategic partnerships** and are emphasized throughout this text as one of the more important aspects of supply chain management. Diageo, a U.K.-based beverage leader with one of the world's best supply chains, has made a considerable investment in transforming its procurement organization with a focus on supplier partnerships. A robust supplier relationship management framework is enabling end-to-end supply chain engagement on sustainability and collaboration across the business for long-term, strategic-value creation.[24] Chapter 3 explores strategic partnerships and other topics associated with supplier relationship management.

Recently, the supply management discipline has come to include a closer emphasis on **ethical and sustainable sourcing**, or purchasing from suppliers that are governed by environmental sustainability and social and ethical practices. Companies are realizing that suppliers can have a significant impact on a firm's reputation and carbon footprint, as well as their costs and profits. Supply chain managers must therefore learn how to develop socially responsible and environmentally friendly sourcing strategies that also create a competitive advantage for the company. Delaware-based Ashland Global Holdings for example, has required all suppliers to sign a Supplier Code of Conduct since 2014. The code holds suppliers to the same high standards as Ashland with respect to labor and employment rights, environmental health and safety, business ethics and social responsibility, and global trade practices. Additionally, Ashland partners with farmers in Mexico to ensure Ashland's aloe is harvested in an ecologically sustainable way and to maintain the Fair for Life certification. Funds are used as directed by the local farmers to also improve conditions within the communities where Ashland's aloe is grown.[25] These topics along with other supply management topics are discussed in detail in Chapter 4.

## Operations Elements

Once materials, components, and other purchased items are delivered to the buying organization, a number of internal operations elements become important in assembling or processing the items into finished products, ensuring that the right amount of product is produced and that finished goods and services meet specific quality, cost, and customer service requirements. Along with supply management, **operations management** is also considered a foundation of supply chain management and is covered in Chapters 5 through 8.

During a calendar year, seasonal demand variations commonly occur. Firms can predict when these variations will occur based on historic demand patterns, through use of forecasting techniques that guide weekly or monthly production plans. If demand does not occur as forecasted, then the focal firm is left with either too much or too little inventory (or service capacity). Both situations are cost burdens to the firm (inventory carrying costs and stockout costs). As a matter of fact, in one survey, 63 percent of Americans admitted they would be somewhat to highly likely to look for an alternative brand if a product shortage affected their favorite electronics brand. Only 14 percent said they would stay loyal to their favorite brand in the event of a shortage.[26] To minimize lost sales and other

costs, firms often rely on **demand management** strategies and systems, with the objective of matching available capacity to demand, either by improving production scheduling, curtailing demand, using a back-order system, or increasing capacity.

Managing inventories is one of the most important aspects of operations and is certainly value enhancing for the firm. Firms typically have some sort of **material requirements planning** (MRP) software system for managing their inventories, purchases, and production schedules. These systems can be linked throughout the organization and its supply chain partners using **enterprise resource planning** (ERP) systems, providing real-time purchase and sales data, inventory, and production information to all business units and to key supply chain participants. These system configurations vary considerably, based on the number and complexity of products, size of the firm, and design of the supply chain. Retailers like Walmart, for example, scan the bar codes of items when consumers make purchases, causing the local store's MRP system to deduct units from inventory until a preset reorder point is reached. When this occurs, the local computer system automatically contacts Walmart's regional distribution center's MRP system and generates an order. At the distribution center, the order is filled and sent along with other orders to that particular Walmart. Eventually, the inventory at the distribution center needs replenishing, and at that time, the distribution center's MRP system automatically generates an order to the manufacturer which sells and then delivers the product to the Walmart distribution center. This type of order communication creates **inventory visibility** to the supply chain members and may also extend farther up the supply chain, reducing the likelihood of stockouts, excess inventories, and long lead times. Third-party logistics providers (3PLs) play a critical role in helping shippers with inventory visibility and real-time order monitoring. For example, a 3PL can help identify ports that are congested or even closed due to the pandemic or other natural disaster and quickly help shippers divert trade to different ports. Additionally, U.S. retailers can have in-store inventory visibility through the use of MRP and **radio frequency identification** (RFID) systems, which can scan incoming cartons and pallets for RFID tags, which describe the contents of the packages to the MRP.

Another common form of inventory management is through use of a **lean production system** (lean production may also be referred to as just-in-time or the Toyota production system). Lean within a production system refers to operating with low inventory levels. Implementing a lean system takes time but usually results in faster delivery times, lower system inventory levels, fewer stockouts, and better quality. An important aspect of a lean production system is the quality of the incoming purchased items and the quality of the assemblies as they move through the various production processes. Higher quality means less need for safety stock.

Firms employing lean production concepts usually have a **Six Sigma quality management** strategy in place to ensure continued quality compliance among suppliers and with internal production facilities. Six Sigma was originally created at Motorola in the 1980s, and Motorola proved the program's value when it won the Baldrige Quality Award in 1988. Many organizations have reported large savings with use of Six Sigma including $1.7 billion at Ford, $17 billion at Motorola, $1.2 billion at 3M, and $8 billion at General Electric.[27] Lean and Six Sigma are discussed in detail in Chapter 8.

## Logistics Elements

When goods are produced, they can be delivered to customers through a number of different modes of transportation. Delivering products to customers at the right time, right quality, and right volume requires a high level of planning and cooperation between

the firm, its customers, and the various logistics elements or services employed (such as transportation, warehousing, and break-bulk or repackaging services). In contrast, services are produced and delivered to the customer simultaneously in most cases, so services are extremely dependent upon server capacity and successful service delivery to meet customer requirements. **Logistics** is the third foundation of supply chain management, and these topics are presented in Chapters 9 through 12.

Logistics decisions typically involve trade-offs between cost and delivery timing or customer service. Considering the five modes of transportation, motor carriers (trucks) are more expensive to use than rail carriers but offer more flexibility and speed, particularly for short routes. Air carriers are even more expensive but much faster than any other transportation mode. Water carriers are the slowest but are also the least expensive. Finally, pipelines are used to transport oil, water, natural gas, and coal slurry. Many transportation services offer various modal combinations, as well as warehousing and customs-clearing services.

In a typical integrated supply chain environment where JIT deliveries are the norm, **third-party logistics services** or 3PLs are critical to the overall success of supply chains. In many cases, these services are considered supply chain partners and are viewed as key value enhancers for supply chains. From pandemics to earthquakes, to tornadoes, floods, and other risk-prone environments, companies are teaming up with 3PLs to improve visibility, flexibility, and delivery performance while reducing risk in their supply chains. "Globally, manufacturers and retailers are taking a renewed interest in redesigning and reengineering their supply chains in the wake of these events," says Jim McAdam, president of 3PL provider APL Logistics.[28]

The desired goal of logistics is an appropriate level of customer service at a reasonable price. In order to provide the desired level of customer service, firms must identify customer requirements and then provide the right combination of transportation, warehousing, packaging, and information services to successfully satisfy those requirements. Through frequent contact with customers, firms develop customer relationship management strategies for meeting delivery due dates, resolving customer complaints, communicating with customers, and determining other logistics services required. From a supply chain management perspective, these customer activities take on added importance because second-tier, third-tier, and end-product customers are ultimately dependent on the logistics performance at each stage within a supply chain.

Today, supply chains are facing continuing disruption on a global scale. The pandemic shifted consumer demand to e-commerce and faster delivery options, adding to the pressure on shippers and logistics providers. A recent survey by Accenture and GEODIS of 200 large retailers found that companies expect the shift to online sales to continue. However, 52 percent thought their logistics capabilities were not scaled to absorb the quickly growing e-commerce volumes. Shippers need to build greater levels of agility, resiliency and sustainability, while managing costs. New innovative capabilities for delivery, product returns, and warehousing will be increasingly important. Thus, investing in new capabilities and finding the right 3PL providers is more essential than ever.[29] The nearby SCM Profile describes the impact the pandemic had on Whirlpool's global supply chain.

Designing and building an effective **distribution network** is one method of ensuring successful product delivery. Again, there is typically a trade-off between the cost of the distribution network and the level of customer service provided. For example, a firm may utilize a large number of regional or local warehouses in order to deliver products quickly to customers. In this case, the transportation cost from factory to warehouse, the inventory holding cost, and the cost to build and operate multiple warehouses would be quite

## SCM Profile: Whirlpool's Global Supply Chain Produces PPE and Ventilators


Andy Dean Photography/Shutterstock.com

Whirlpool Corp., the world's largest home appliance company, has $20 billion in annual sales and 59 manufacturing centers around the world. Its brands are sold in nearly every country on earth. When the COVID pandemic hit their Benton Harbor, MI headquarters hard in March, 2020, Whirlpool quickly focused on meeting the demand for supplies at Spectrum Health Lakeland, a health system in St. Joseph that serves the greater southwest Michigan and northern Indiana region. Over the following month, using its global supply chain and its China manufacturing unit, the company delivered at no cost many thousands of masks, gloves, thermometers and hospital gowns.

By May, as it became clear there would be a shortage of ventilators, Whirlpool partnered with Dow and Reynolds Consumer Products to make and distribute ventilators. Whirlpool built and distributed them through WIN Health Labs LLC, a subsidiary Whirlpool formed to make supplies needed to fight the pandemic. Dow provided the clear plastic face shields for the ventilators and Reynolds Consumer Products designed and made the units' disposable hoods. Over 4,000 ventilators were distributed free of charge to hospitals across Michigan, Texas, and Louisiana.

Whirlpool also experienced disruptions as their global supply chains experienced parts shortages, and social distancing slowed down manufacturing lines worldwide. Consumers trying to replace their overworked dishwashers and washing machines sometimes faced weeks of shipping delays. According to a Whirlpool statement: "Our 15,000 plant employees in our nine plants across the UNITED STATES have been working tirelessly as we have managed through COVID-19 and our factories are doing everything they can to meet consumer needs. Our plants have experienced a few brief interruptions in production related to the pandemic, including component shortages, but as a whole have remained up and running throughout this challenging time."[30]

high, but the payoff would be excellent customer service. On the other hand, a firm may choose to operate only a few large centralized warehouses, saving money on the inbound transportation costs from factories (since they would be delivering larger quantities to fewer locations) and the warehouse construction and operating costs, but then have to be content with limited customer service capabilities since the warehouses would be located farther from most customers. Today, the use of massive, efficient warehouses to serve large market areas is growing. For example, the Browning Investments/Duke Realty partnership constructed a 900,000-square-foot warehouse at All Points Midwest industrial park in Plainfield, Indiana, and Missouri-based North Point Development built a 741,000-square-foot warehouse near Lebanon Business Park in Indiana. Much of this building surge is driven by retailers opening e-commerce facilities at a dizzying pace as online shopping becomes more prevalent.[31]

When firms operate globally, their supply chains are more complex, making global location decisions (the topic of Chapter 11) a necessary aspect of supply chain

management. The increasing demand for products in emerging global markets like Russia, the Philippines, Thailand, and China combined with growing foreign competition in domestic markets, along with comparatively low labor costs in many Asian countries, have made international business commonplace for many companies. Firms must understand both the risks and advantages of operating in foreign locations and the impact this may have on their **global supply chains**. Some of the advantages include a larger market for products, economies of scale in purchasing and production, lower labor costs, a supplier base of potentially cheaper, higher-quality suppliers, and the generation of new product ideas from foreign suppliers and employees. Some of the risks include fluctuating exchange rates affecting production, warehousing, and purchasing and selling prices; government intervention or political instabilities causing supply disruptions; security concerns; and potential changes in subsidies, tariffs, and taxes.

Companies react to these problems by building flexibility into their global supply chains. This is accomplished by using a number of secondary suppliers as well as manufacturing and storage facilities in various foreign locations. As product demand and economic conditions change, the supply chain can react to take advantage of opportunities or cost changes to maximize profits. "Obviously, those with production capability in multiple regions and/or countries present a lower risk than a single location or a cluster of facilities in a single region or country," says Mark Taylor, vice president at North Carolina-based Risk International Services. "Even if you source 90 percent from the primary, by maintaining a second or third qualified (supplier), you've substantially shortened your lead time in making a change."[32]

For service products, the physical distribution issue is typically much less complex. Making sure services are delivered in a timely fashion is a primary topic of Chapter 12. Services are, for the most part, delivered by a server when customers request service. For instance, consider an example in which a customer walks into an auto repair facility in search of service for their automobile. They may talk to two or three facility employees during this service but eventually will complete a repair form, wait for the service to be completed, and then receive the repaired automobile. They will leave, satisfied with the service they received, as long as a number of things occurred: they got what they came for (the repair job), got the type of service they expected (a reasonable waiting period, knowledgeable servers, and a properly repaired auto), and got the service at a reasonable price. Otherwise, the customer will most likely be dissatisfied.

Successful service delivery depends on service location (service providers must be close to the customers they are trying to serve), service capacity (customers will leave if the wait is too long), and service capability (customers must be able to trust what servers are saying or doing for them). The final requirement of successful service is knowing what customers want. "I think we are very quickly moving toward that world of instant commerce where you'll be able to buy anything you like at any time anywhere, particularly in the United States, and be able to get it in a matter of hours," says AI-based logistics network company Ohi's CEO Ben Jones. "That's the kind of vision fulfillment companies are working toward and I think the COVID situation has accelerated that move, not necessarily by the end of 2020, but definitely by the end of 2021, that will be the new normal."[33]

## Integration Elements

Thus far, three of the four foundations of supply chain management have been discussed: supply, operations, and logistics activities occurring among the firm and its tiers

of customers and suppliers. The final foundation topic—and certainly the most difficult one—is to integrate these processes among the focal firm and its key supply chain trading partners. **Supply chain process integration** is discussed in detail in the final two chapters of the text.

Processes in a supply chain are said to be integrated when trading partners in the supply chain work together to make purchasing, inventory, production, quality, and logistics decisions that impact the overall costs and profits of the supply chain. If one key process activity fails or is performed poorly, then the flow of goods moving along the supply chain is disrupted, jeopardizing the effectiveness of the entire supply chain. Successful supply chain process integration occurs when the participants realize that effective supply chain management must become part of each member's strategic planning process, where objectives and policies are jointly determined based on the end consumers' needs and what the supply chain as a whole can do for them.

Ultimately, trading partners act together to maximize total supply chain profits by determining optimal purchase quantities, product availabilities, service levels, lead times, production quantities, use of technology, and product support at each tier within the supply chain. These integration activities also require high levels of *internal* functional integration of activities within each of the participating firms, such that the supply chain acts as one entity. This idea of supply chain integration can run contrary to some potential supply chain participants' independent profit-maximizing objectives, making supply chain process integration a tough sell in many supplier–buyer–customer situations. Thus, continued efforts are required to break down obstacles, change cultural norms and adversarial relationships, knock down corporate silos, reduce conflicts, and bridge functional barriers within and between companies if supply chain integration is to become a reality.

The need for and value of process integration has impacted the auto industry in particular. Michigan governor Rick Snyder and Ontario, Canada premier Kathleen Wynne went on the offensive in August 2016, by signing a memorandum of understanding to increase the region's competitiveness in the automotive industry. The agreement covers best practices, improved supply chain integration, and technology transfer agreements. Ontario and Michigan account for more than 26 percent of vehicle production in the Great Lakes region. "Collaborating to improve the auto sector is a great use of resources that will lead to continued growth and job creation in both economies. Sharing best practices and integrating our supply chains will advance Michigan's and Ontario's positions as leaders in the auto industry," said Snyder.[34]

One additional integration topic is the use of a **supply chain performance measurement** system. Performance measurements must be utilized along supply chains to help firms keep track of their process integration and supply chain management efforts. It is crucial for firms to know whether certain strategies are working as expected—or not—before they become financial and customer drains on the organizations. Firms work together to develop long-term supply chain management strategies and then devise tactics to implement these strategies. Performance measurements help firms decide the value of these tactics and should be developed to highlight performances within the areas of purchasing, operations, logistics, and integration.

Performance measures should be designed around each important supply chain activity and should be detailed performance descriptors instead of merely sales or cost figures. High levels of supply chain performance occur when the strategies at each of

the firms fit well with overall supply chain strategies. Thus, each firm must understand its role in the supply chain, the needs of the supply chain's end customers, the needs of each firm's immediate customers, and how these needs translate into internal operations requirements and the requirements being placed on suppliers. Once these needs and the goods and services themselves can be communicated and transported through the supply chain effectively, successful supply chain management and its associated benefits can be realized.

## Current Trends in Supply Chain Management

The practice of supply chain management is a fairly recent phenomenon, and many organizations are beginning to realize both the benefits and problems accompanying integrated supply chains. Supply chain management is a complex and time-consuming undertaking, involving cultural change among most or all of the participants, investment and training in new software and communication systems, the building of trust between supply chain members, and a change or realignment of the competitive strategies employed among at least some of the participating firms. Further, as competitors, products, technologies, economic conditions, and customers change, the priorities for supply chain trading partners also change. A look at industry surveys of executives reveals a number of supply chain issues that companies are addressing today, including the use of supply chain analytics, improving supply chain sustainability, and increasing supply chain visibility.[35] While these and other supply chain management issues are discussed in numerous places in this text, these newest trends are discussed below to give the reader a better sense of some of the issues facing executives and their companies' supply chains today.

### Use of Supply Chain Analytics

**Supply chain analytics** refers to examining raw supply chain data and then reaching conclusions or making predictions with the information. It is used in many industries to allow supply chain managers to make better business decisions. The market for supply chain analytics solutions is growing at about 15 percent per year, with the 2018 global revenues exceeding $4.8 billion. The solutions include supply chain planning and procurement, sales and operations planning, forecasting, manufacturing analytics, transportation and logistics analytics, and visualization and reporting tools. The growth is being pushed by the enormous rise in computing capabilities and the huge volumes of data generated (hence the term **big data**) in business organizations including retail, healthcare, manufacturing, and electronics, and the rising awareness levels among executives regarding the benefits of these analytics solutions.[36]

Analytics can be used along the supply chain, for example, to schedule production according to expected supplier deliveries, to route delivery trucks through a distribution network, or to determine when and how much PPE to order at a hospital. At Vanderbilt University Medical Center in Nashville, TN, for example, Teresa Dail, chief supply chain officer, and her team developed a customized PPE model. Clinical feedback helped with time studies and mappings of PPE utilization for COVID-19 patients in the ICU, the emergency room, the operating room, and at the organization's COVID-19 testing and assessment sites. Those standards are built into the model, along with the number of potential encounters per day for an inpatient stay. The supply chain team

can input patient volumes based on either the current census or a projected number and compute how much PPE will be needed for each product category during thirty-day intervals. "We've based our entire plan on buying PPE over the next six months just around that modeling," Dail says.[37] Analytics solution provider Blue Yonder has developed forecasting methods for retailers, where 130,000 SKUs and 200 influencing variables generate 150,000,000 probability distributions every day to ensure the right products are replenished at each store. Increased forecast accuracy generates savings on inventory and other supply chain costs. In a transportation application, UPS has spent 10 years developing its On-Road Integrated Optimization and Navigation system to optimize routes in real time according to traffic. While cost reduction is often the trigger of analytics initiatives, customers benefit from reduced stock-outs and more accurate delivery slots.[38]

## Improving Supply Chain Sustainability

As mentioned earlier in this chapter, supply chain sustainability refers to meeting the needs of current supply chain members without hindering the ability to meet the needs of future generations in terms of economic, environmental, and social challenges. Even retailer JCPenney is getting into the act. They are partnering with the Apparel Impact Institute (AII) to improve its supply chain sustainability performance.

Working with AII will help improve performance related to energy, water and chemicals. "We are pleased to see JCPenney take this leadership position by recognizing the serious environmental impacts of wet processing activities in Tier 2 production by joining our Clean by Design program," Lewis Perkins, AII's president, said. "As the world seeks to build back with better solutions, JCPenney is 'leaning in' to this opportunity to improve existing facilities in the ways that will have the most positive impact for both sustainability and production cost."[39]

According to a Gartner survey of 528 supply chain professionals across the high-tech, industrial and food and beverage industries conducted in 2020, 51 percent of respondents expected their focus on "circular economy strategies" to increase. Additionally, accessing and reprocessing end-of-life products are the biggest challenges organizations face when transitioning from a linear to circular supply model, according to Gartner. (**Circular economy** refers to an economic system aimed at eliminating waste and the continual use of resources). Finally, based on the survey, companies are committed to integrating sustainability practices into their supply chain strategies, as consumer, shareholder, and governmental pressures to reduce the environmental impacts of industrial operations continue. Chief supply chain officers believe that a circular economy remains the road forward.[40]

In 2016, Ford Motor Co. announced an effort to expand its environmental and resource conservation goals along its supply chains, unveiling what it calls its Partnership for a Cleaner Environment. Working with 25 suppliers representing 800 manufacturing plants in 40 countries, Ford's Partnership shared with these suppliers what it considers best practices around reducing water, energy, and carbon dioxide as well as materials reuse. Ms. Mary Wroten, Ford's senior manager of supply chain sustainability, said that by sharing what works in-house with its suppliers, Ford is able to multiply the reductions in water, energy use, and GHG emissions. "Climate is not a competitive space, and more that we can talk about this and share what we are doing, a stronger planet we can create," said Wroten.[41]

## Increasing Supply Chain Visibility

**Supply chain visibility** is defined as the ability of suppliers, manufacturers, business partners, and customers to know exactly where products are, at any point in the supply chain. This inventory visibility is obviously made easier by technology and can prove very advantageous when dealing with disruptive events such as pandemics, floods, hurricanes, and political upheavals. UPS and Fedex tracking methods are good examples of visibility—shipments are tracked and monitored using technology, and alerts are sent to shippers as the item is in transit and then delivered. Today, more sophisticated software applications are being developed and offered to organizations for tracking orders, inventories, deliveries, returned goods, and even employee attendance.[42]

Centauro, Brazil's largest sporting goods retailer with 211 stores, has adopted the RFID-based Mojix Ytem solution to enable, real-time, item-level visibility across all of their supply chains. Mojix claims Centauro can achieve 99.9 percent inventory accuracy, improve supply chain efficiency, reduce safety stock, and improve the customer experience. On average, Centauro manages more than 40 million items per year across all aspects of operations. Using the Mojix solution, Centauro aims to streamline the logistics process, consistently reach its operational goals, and strengthen its customer-focused strategy. "Knowing what I have in stock and what I receive in the store, I control practically my entire supply chain," says Sérgio Silva Jardim Filho, executive manager at Grupo SBF, the operator of Centauro. "We no longer see ourselves as two channels: physical and digital. Omnichannel is already part of the Centauro culture. We are a single company and we want the customers to see that. The Mojix solution has been a key enabler to our omnichannel execution."[43] In another example, Colorado-based transportation management systems provider 10-4 Systems partnered with Anheuser-Busch to add visibility to all of its brewery shipments. "AB recognized an opportunity to improve their customer's product and shipment visibility experience. Our technology was able to help them achieve this goal through centralizing carrier visibility and modernizing the methods in which those events were communicated to their end-users," says 10-4's CEO, Travis Rhyan. According to James Sembrot, Anheuser-Busch's Sr. Director of Logistics Strategy, "We're committed to using technology to enhance our supply chain processes. Using 10-4's platform, we are now tracking all shipments from our U.S. breweries through customer delivery, enabling our logistics operations team to proactively address any transportation issues."[44]

## Summary

Supply chain management is the integration of key business processes from initial raw material extraction to the final or end customer, including all intermediate processing, transportation, and storage activities, along with the final sale to the end-product customer and eventually product returns. It requires supply chain members to work together to provide benefits to all stakeholders. Today, the practice of supply chain management is becoming extremely important to reduce costs and improve quality and customer service, with the end objective of improving competitiveness. Many firms are today becoming adept at managing at least some part of their supply chains. Supply chain management is an outgrowth and expansion of lean and Six Sigma activities and has grown in popularity since the 1980s. The foundations of supply chain management can be found in the areas of purchasing, production, logistics, and collaboration between trading partners. Finally, as markets, political forces, technology, and economic conditions change around the world, the practice of supply chain management must also change and grow. This chapter serves as an opening discussion of the topic of supply chain management and describes what the remaining chapters will cover.

## Key Terms

**big data,** 24

**bullwhip effect,** 12

**business process reengineering,** 14

**cold chain,** 08

**customer relationship management,** 15

**demand management,** 19

**distribution network,** 20

**enterprise resource planning,** 15

**enterprise resource planning,** 19

**ethical and sustainable sourcing,** 18

**first-tier customers,** 07

**first-tier suppliers,** 07

**global supply chains,** 22

**inventory visibility,** 19

**lean production system,** 19

**logistics,** 20

**material requirements planning,** 19

**multi-channel fulfillment,** 09

**operations management,** 18

**radio frequency identification,** 19

**reengineering,** 14

**second-tier customers,** 07

**second-tier suppliers,** 07

**Six Sigma quality management,** 19

**starting conditions,** 32

**strategic partnerships,** 18

**supplier certification,** 17

**supplier evaluation,** 17

**supplier management,** 17

**supplier relationship management,** 17

**supply chain,** 06

**supply chain analytics,** 09

**supply chain management,** 08

**supply chain performance measurement,** 23

**supply chain process integration,** 23

**supply chain visibility,** 26

**supply management,** 16

**sustainability,** 16

**third-party logistics providers,** 15

**third-party logistics services,** 20

**triple bottom line,** 16

## Discussion Questions

1. Define the term *supply chain management* in your own words, and list its most important activities.
2. Can a small business like a local sandwich or bicycle shop benefit from practicing supply chain management? What aspects would they most likely concentrate on?
3. Describe and draw a supply chain for a bicycle repair shop, and list the important supply chain members.
4. Can a bicycle repair shop have more than one supply chain? Explain.

5. What is a cold chain? Why did it become so important in 2020?
6. How has the recent global pandemic impacted supply chain management?
7. What roles do collaboration and trust play in the practice of supply chain management?
8. Why don't firms just become more vertically integrated (e.g., buy out suppliers and customers), instead of trying to manage their supply chains?
9. What types of organizations would benefit the most from practicing supply chain management? What sorts of improvements could be expected?
10. What are the benefits of supply chain management?
11. Can nonprofit, educational, or government organizations benefit from supply chain management? How?
12. What does the term, third-tier supplier mean? What about third-tier customer? What about the focal firm? Provide examples.
13. What is the bullwhip effect and what causes it? How would you try to reduce the bullwhip effect?
14. When did the idea and term, supply chain management, first begin to be thought about and discussed? Which two operations management practices became the origin of supply chain management?
15. Do you think supply chain management is simply the latest trend in management thinking and will likely die out in a few years? Why or why not?
16. How has technology impacted supply chain management?
17. What are the four foundation elements of supply chain management? Describe some activities within each element.
18. Is the use of a large number of suppliers a good idea? Why?
19. Do you think the proper way to choose a supplier is to always find the one that will give you the lowest price? When might this not be a good idea?
20. What is supplier management? What are some of the activities of supplier management?
21. What is the difference between supply chain management and logistics?
22. What is demand management, and why is this an important part of supply chain management?
23. What is the difference between and MRP system and an ERP system?
24. What role do information systems play in supply chain management? Give some examples.
25. Briefly describe the terms, lean production, and, Six Sigma systems.
26. What are 3PLs, and what role do they play in SCM?
27. What is logistics? What is the objective of logistics?
28. What is the triple bottom line and how would you describe it for Walmart?
29. What trade-offs must be considered in designing a distribution system?

30. What are the advantages and risks involved with global supply chains?
31. What does process integration mean? Can supply chain management succeed without it? Why, or why not?
32. Should companies require their suppliers to get certified if they are performing well?
33. At what point should a supplier be considered to have a strategic partnership with the buying firm?
34. Why are performance measurement systems important when trying to manage supply chains?
35. Does a global supply chain have more risk than a domestic supply chain? Why?
36. What are big data and data analytics? How might they be used in supply chains?
37. What are some things supply chain members could do to improve sustainability?
38. Describe supply chain visibility, and why supply chain managers like it.

## Essay/Project Questions

1. Visit the websites of companies like Walmart, Target, and Home Depot and see if you can find discussions of their supply chain management activities. List information you can find on purchasing/supplier, logistics, information system, inventory management, quality, and customer service issues.
2. Search on the term *supply chain management.* How many hits did you get? Describe five of the websites found in your search.
3. Search the term *bullwhip effect,* and write a paper on the impacts of the bullwhip effect and the companies profiled in the papers you find.
4. Search on the term *supply chain management software applications*, and write a paper about how companies use these to improve their financial performance.
5. Search on the term *green supply chains*, and write a paper regarding the global regulatory status of environmental legislation and how it is impacting supply chain management.

## Cases

### Supply Chain Management: The Big Picture*

Cyber Logic Systems is a successful regional company in the United States that specializes in cyber security. Because of the dramatic increase in the hacking of business and government databases, Cyber Logic Systems believes this is the moment to expand its operations. Elmer Armstrong, chief executive officer, met with the board of directors and explained his vision for the company. Mr. Armstrong planned to aggressively expand into Europe and South America. The board of directors gave Elmer the go ahead.

Elmer called a meeting of his senior staff and explained his vision to them. He asked what major issues they saw that required immediate resolution before Cyber Logic Systems could

*Written by Rick Bonsall, D. Mgt., McKendree University, Lebanon, IL. The people and institution are fictional and any resemblance to any person or institution is coincidental. This case was prepared solely to provide material for class discussion. The author does not intend to illustrate either effective or ineffective handling of a managerial situation.

proceed with such an aggressive expansion. Rhonda Mendoza, director of operations, said that their current supply chain structure would not be able to support such an expansion. She further stated that the supply chain structure would collapse under the strain, thus endangering their regional business, as well as the expansion. Elmer tasked Rhonda with developing a plan on how to get the supply chain structure robust enough to move forward with the expansion.

Rhonda began analyzing their supply chain management needs by reviewing the four foundation elements—supply, operations, logistics, and integration. As she performed her analysis, Rhonda realized that not all their current suppliers had the capabilities to support Cyber Logic Systems' operations in Europe and South America. Ms. Mendoza decided to perform a detailed supplier evaluation on each supplier. Through this evaluation she determined that some suppliers could easily support European operations, while others were better suited for the South American operations. Furthermore, some suppliers, who were a tremendous asset to Cyber Logic Systems, would only be capable of supporting their current regional business.

Each market area, United States, Europe, and South America, had regulations with differing standards for cyber security. The technical specifications for the systems Cyber Logic Systems would install varied significantly between the three marketplaces. Rhonda decided this could be a considerable problem. Her solution was simple yet elegant, supplier certification. Supplier certification would ensure that the suppliers supporting the specific operational markets would be qualified to meet the particular regulatory requirements.

Although the systems Cyber Logic Systems installed were primarily software, often new hardware was required to support the software. Ms. Mendoza understood that their current distribution network was insufficient. They needed to redesign and build a more self-sustaining distribution network in order to ensure timely product delivery. They truly needed to move from the mindset of a regional distribution system to a global supply chain. This requirement would mean sourcing from suppliers who were close to the customers. When a customer has a cyber security issue, time is the enemy. The new systems must be in place as quickly as possible to avoid further damage to the customer's databases and to enable them to continue operating.

Rhonda believed she had identified the key elements that must be improved before they could move forward with the expansion. The last hurdle was how to guarantee that the three foundation elements, supply, operations, and logistics, worked as one smooth global supply chain and not as disjointed parts. This was the biggest challenge of all. If Cyber Logic Systems didn't solve this issue, the chance of failure was high.

Ms. Mendoza reflected on her studies in operations and supply chain management. The answer to the issue was process integration. She knew that they had a challenge ahead. They must convince each supply chain partner that this supply chain management structure must be part of everyone's strategic planning process. Only then could they ensure that the individual pieces, purchasing, inventory, operations, logistics, quality, etc. would work together as a single well-oiled machine. Ms. Mendoza was ready to outline her plan to Mr. Armstrong and the other members of his senior staff.

## Discussion Questions

1. When analyzing the supply chain management foundation element "supply," what are some of the specific issues Cyber Logic Systems must address?
2. When analyzing the supply chain management foundation element "operations," what are some of the specific issues Cyber Logic Systems must address?
3. When analyzing the supply chain management foundation element "logistics," what are some of the specific issues Cyber Logic Systems must address?
4. When working on process integration, what type of issues must a company overcome for true integration to be achieved?

# APPENDIX 1.1

# The Beer Game

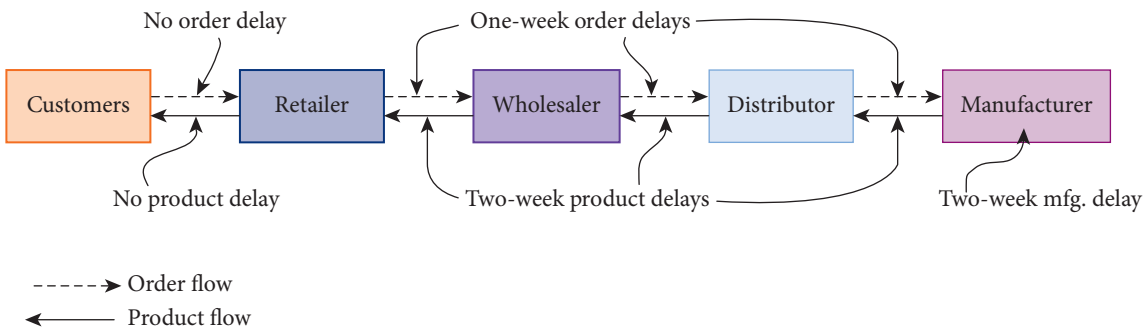
The Beer Game is a popular game played in operations management and supply chain management courses and was developed by MIT in the 1960s.[45] The game simulates the flow of product and information in a simple supply chain consisting of a retailer, a wholesaler, a distributor, and a manufacturer. One person takes the role of each organization in a typical game. The objective is to minimize total supply chain inventory and back-order costs. In this way, a class can be separated into any number of four-person supply chains—each supply chain competing against the others. The game is used to illustrate the bullwhip effect and the importance of timely and accurate communications and information with respect to purchases along the supply chain (in this game, no one is allowed to share any information other than current order quantities, as might be found in unmanaged or unlinked supply chains).

Each supply chain participant follows the same set of activities:

1. The participant fills customer orders from current inventory and creates back orders if demand cannot be met.
2. The participant forecasts customer demand and then orders beer from the supplier (or schedules beer production if the participant is the manufacturer), which then takes several weeks to be delivered.
3. The participant attempts to manage inventories in order to minimize back-order costs (stockouts) and inventory carrying costs.

Figure A1.1 illustrates the beer supply chain, showing the transportation and information delays. There is no product transportation or order delay between the retailer and the end customers. For the other supply chain members, there is a one-week delay between

**Figure A1.1** The Beer Game Supply Chain



customer order and supplier acceptance, and a two-week transportation delay from the time a customer's order is received until that order reaches the customer. It also takes two weeks to complete a production order at the factory, such that beer will be ready to fill customer orders.

Here is how the game progresses:

**Starting conditions.** At the start of the game (Week 0), each supply chain member (except the manufacturer) has twelve cases of beer in ending inventory (see Table A1.1), four cases in the second week of inbound transportation delay, four cases in the first week (updated) of inbound transportation delay, and four cases in the beginning of the first week of inbound transportation delay. The manufacturer has twelve cases of beer in ending inventory, four cases of beer in the second week of production leadtime, four cases in the first week of production leadtime, and four cases at the beginning of the first week of production leadtime. Each player also has an *outgoing order* of four cases sitting in their outgoing order box (or production order box). The retailer must begin with twenty weeks of customer demand information provided by the game coordinator or instructor, such that the retailer can only view one week's demand at a time (these can be written on the underneath side of 20 sticky notes for each retailer, for example).

**Step 1.** Each member *updates their beer inventories.*

- Move the cases of beer from the second week of inbound delay for the previous period and add to the ending inventory of the previous period, putting the total in the beginning inventory column of the current period (see Week 0/Week 1 of Table A1.1). For the manufacturer, this is a production delay.
- Move inventory from the first week of inbound delay (updated column) to the second week of delay (see Table A1.1).
- Move inventory from the first week of inbound delay (beginning column) to the first week of inbound delay (updated column) (see Table A1.1).

**Step 2.** Each member *fills their customer orders.*

- The retailer uncovers and reads the current week's customer demand slip, and then places the slip face down in the discard area, *such that it cannot be seen by the wholesaler.*
- The retailer then fills this order (after first satisfying any back orders) and subtracts demand from beginning inventory. This amount then becomes the ending inventory amount. If ending inventory is negative, then a back order of this amount is created, and ending inventory becomes zero.
- Next, the retailer places last week's outgoing order on the wholesaler's incoming demand order box.
- Finally, the retailer forecasts future demand and orders beer from the wholesaler by writing an order on the slip provided and places it face down in the retailer's outgoing order box, *such that it cannot be seen by the wholesaler.* (This order will go to the wholesaler next week—remember the one-week delay).

The wholesaler follows the same steps as above: it reads the incoming demand order slip, discards it, satisfies any back orders, and fills as much of the incoming order as possible from beginning inventory. At this point, the wholesaler must tell the retailer

how much of the order it can satisfy, and the retailer records this amount in the first week beginning delay for the current period. The wholesaler then updates its ending inventory and back-order quantities, it sends last week's outgoing order to the distributor's incoming demand, and then it decides how much to order and places the order sheet face down in the wholesaler's outgoing order box, *such that it cannot be seen by the distributor.*

The distributor goes through the same steps as the wholesaler when it gets an incoming order from the wholesaler.

The manufacturer follows the same steps also, except instead of sending last week's outgoing order somewhere, it reads the outgoing order and fills the production request by transferring that number of cases from its raw materials storage area to the first week's beginning production delay (it simply creates the cases needed for the order).

**Step 3.** Repeat Steps 1 and 2 until the game limit is reached. Calculate total costs at game's end.

A typical game progresses in this fashion for twenty weeks (this is usually sufficient to introduce the bullwhip effect into the game). The game is played with sticky notepads for beer orders, using Table A1.1 to keep track of inventories, orders, and back orders. Players must take care *not to talk* to the other players during the game *or to show what orders they are receiving or planning* for the next week. The retailer must *not look at future customer demand data,* provided by the instructor. Remember, this game is meant to illustrate what happens when *no communication* about future orders or order strategies occurs between supply chain members.

At the end of twenty weeks (or shorter if time does not permit), players determine the total cost of their inventories and back orders on the inventory record sheet (back-orders cost $2 per unit per week, and inventories cost $1 per unit per week). Given these costs, the basic strategy should be to attempt to avoid stockouts or back orders, while to a lesser degree, trying to minimize total inventory carrying costs. This requires attempting to forecast future demand accurately (as time progresses, firms should use their inventory record sheet demand information for forecasting purposes). The winning team is the team with the lowest total supply chain costs.

## Beer Game Questions and Exercises

1. All players but the retailer should answer this question—what do you think the retailer's customer demand pattern looked like? How did your customer orders vary throughout the game?
2. What happened to the current inventory levels, looking back up the supply chain from retailer to manufacturer? Why?
3. How could the supply chain members reduce total inventory and back-order costs in the future?
4. Go to https://beergame.masystem.se, and try playing this Internet version of the game. Report on your experiences playing the game.

## Table A1.1 Inventory Record Sheet

Your supply chain role:

Your name: Team name:

| Incoming demand from supply chain customer | Discard area | Outgoing orders to supply chain supplier, OR production orders for manufacturer |
|---|---|---|

| Week | Ending Inventory | Beginning Inventory | Back Orders | Second Week Inbound Delay | First Week Inbound Delay | |
|---|---|---|---|---|---|---|
| | | | | | Updated | Beginning |
| 0 | 12 | | 0 | 4 | 4 | 4 |
| 1 | | 16 | | 4 | 4 | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 7 | | | | | | |
| 8 | | | | | | |
| 9 | | | | | | |
| 10 | | | | | | |
| 11 | | | | | | |
| 12 | | | | | | |
| 13 | | | | | | |
| 14 | | | | | | |
| 15 | | | | | | |
| 16 | | | | | | |
| 17 | | | | | | |
| 18 | | | | | | |
| 19 | | | | | | |
| 20 | | | | | | |
| Totals | | | | | | |

Amount of outgoing order received

*Note:* Ending inventories must be zero when you have a back order. If the ending inventory is greater than zero, back orders must be equal to zero. Back orders equal previous period back orders plus the incoming order, minus current inventory. At the end of the game: Sum *ending inventory* column and *back-orders* column and determine total cost as—[Total ending inventories × $1] + [Total back orders × $2] = $_____. Then sum total costs for all supply chain members. Total supply chain costs = $_____.

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# PART 2

## Supply Issues in Supply Chain Management

Chapter **2**

# Purchasing Management


*Almost all companies are involved in buying and selling. Buying raw materials for manufacturing or finished products for distribution, companies seem to be more focused on the selling process than on the buying process. But consider this basic math: A company that spends one million dollars a year on purchasing can add $100,000 to its bottom line by saving 10% on how it makes its purchases.*

**—David Millington, Director of Education, Next Level Purchasing Association**[1]

*Developing a procurement strategy can be a complex undertaking. There has been a profound transformation within public procurement over the last 10 years. Procurement's traditional cost-only control function is a far cry from what it is today. These days, procurement is a pillar of management, innovation, and sustainability within an organization.*

**—Jason Axelrod, The American City & County, Pittsfield**[2]

## Learning Objectives

**After completing this chapter, you will be able to**

**LO 1** Describe the role of purchasing and its strategic impact on an organization's competitive advantage.

**LO 2** Describe the traditional purchasing process, e-procurement, public procurement, and green purchasing.

**LO 3** Recognize and know how to handle small-value purchase orders.

**LO 4** Analyze the sourcing decisions and the factors impacting supplier selection and diversity.

**LO 5** Analyze the total cost of ownership.

**LO 6** Analyze the pros and cons of single sourcing versus multiple sourcing.

**LO 7** Describe the key characteristics of centralized, decentralized, and hybrid purchasing organizations.

**LO 8** Describe the opportunities and challenges of global sourcing.

**LO 9** Describe the basic international trade law and commercial terms.

## Chapter Outline



## SCM Profile — Triple Bottom Line Performance and Green Purchasing

Profit has been the sole objective and performance measure for many manufacturing firms and service organizations, but there are other crucial measures that contribute to a firm's long-term overall health and sustainability. Sustainability is the ability of a firm to address current business needs and successfully develop a long-term strategy to preserve resources for future

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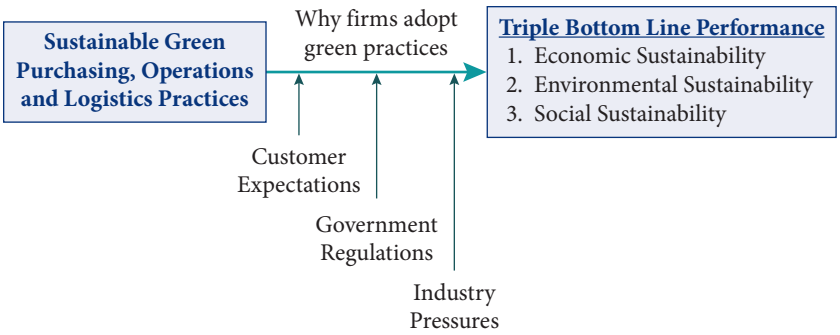
generations. In response to customer expectations, government regulations and industry pressures, businesses have begun to focus on triple bottom line performance which advocates that besides economic sustainability, organizations must also focus on social and environmental sustainability (see figure below). Social sustainability measures the firm's policies that support social issues such as healthcare, education, safety, housing, working conditions and employment terms that impact the wellbeing of its employees and the society. Environmental sustainability measures the firm's precautionary environmental initiatives and adaptations such as green spaces, recycling, displacement and involuntary resettlement, biodiversity conservation, water treatment plants, air pollution management and renewal energy.




For government agencies, economic sustainability is not as important compared to social and environmental sustainability. Since they are nonprofit establishments, public procurement is one of their most important activities. Many government agencies are placing an increasing emphasis on green public procurement to reduce the adverse impact of their programs and services on the environment and human health. By adopting green procurement to choose socially and environmentally friendly goods and services, government agencies can make an important contribution to sustainable production and consumption. Green public procurement ensures that public goods and services purchased are sustainable and sets a good example for the private sector. The challenge to maintain green public procurement goals has escalated in the middle of a COVID-19 pandemic and amidst budget cuts. However, that doesn't mean government agencies can't maintain or expand their sustainable procurement practices.

The National Association of State Procurement Officials, an American nonprofit association for public procurement officials in the United States, published green purchasing guidelines and resources for state and local governments to leverage their procurement power to improve social and environmental sustainability. The city of Seattle, Washington is one of many local governments that has established green procurement policies to promote environmental and social sustainability. The city's procurement officials developed green specifications and selection criteria for purchases and contracts, and its public utilities waste reduction program provides environmental technical assistance. The city of Seattle is also committed to socially responsible procurement and promotes social equality by providing equal access and utilizing women- and minority-owned businesses, when applicable.[3]

Besides economic sustainability, many large multinational corporations in the private sector are deeply engaged in social and environmental sustainability. For example, the Intel

Corporation has committed over $60 million to accelerate technology access to combat the COVID-19 pandemic and to support frontline healthcare workers. Some of the most ambitious environmental objectives of Intel are absolute carbon emissions reductions, 100 percent renewable energy use, net positive water use, and zero total waste to landfills. Some notable achievements of the company in 2020 include 39 percent reduction in greenhouse gas emissions, increased energy efficiency of notebook computers by 14 times, zero hazardous waste to landfills, 93 percent recycling of non-hazardous waste globally, one billion gallons of water restored, installed ninety-eight on-site alternate energy sources, and increased annual spending with diverse-owned suppliers to $1 billion.[4]

## Introduction

In the context of supply chain management (SCM), purchasing can be defined as the act of obtaining merchandise; capital equipment; raw materials; services; or maintenance, repair, and operating (MRO) supplies in exchange for money or its equivalent. Purchasing can be broadly classified into two categories: **merchant buyers** and **industrial buyers**. The first category, merchant buyers, includes the wholesalers and retailers who primarily purchase for resale purposes. Generally, merchants purchase their merchandise in volume to take advantage of quantity discounts and other incentives such as transportation economy and storage efficiency. They create value by consolidating merchandise, breaking down bulk deliveries, and providing the essential logistical services. The second category is the industrial buyers, whose primary task is to purchase raw materials for conversion purposes. Industrial buyers also purchase services, capital equipment, and MRO supplies. The typical industrial buyers are the manufacturers, although some service firms such as restaurants, landscape gardeners, and florists also purchase raw materials for conversion purposes.

An effective and efficient purchasing system is crucial to the success of a business. Indeed, the *Annual Survey of Manufactures*[5] consistently shows that the total cost of materials exceeds value added through manufacturing in the United States. Thus, it is not surprising that purchasing concepts and theories that evolved over the last four decades focused on industrial buyers' purchases of raw materials and how purchasing can be exploited to improve competitive success.

The primary focus of this chapter is the industrial buyer. The chapter describes the role of purchasing in an organization, the processes of a traditional purchasing system and the common documents used, how an electronic purchasing system works, various strategies for handling small order problems, the advantages and disadvantages of centralized versus decentralized purchasing systems, purchasing for nonprofits and government agencies, sourcing issues including supplier selection, and other important topics affecting the role of purchasing and supply management in supply chain management.

## A Brief History of Purchasing Terms

*Purchasing* is a key business function that is responsible for acquisition of required materials, services, and equipment. However, acquisition of services is widely called *contracting*. The increased strategic role of purchasing in today's business setting has brought

a need for higher levels of skill and responsibility on the part of purchasing professionals. Consequently, the term **supply management** is increasingly being used in place of purchasing to describe the expanded set of responsibilities of purchasing professionals. The traditional purchasing function of receiving requisitions and issuing purchase orders is no longer adequate; instead, a holistic and comprehensive acquisition strategy is required to meet the organization's strategic objectives.

Supply management is the act of identifying, acquiring, and managing resources and suppliers to meet the organization's needs in the attainment of its strategic objectives. Key activities of supply management have expanded beyond the basic purchasing function to include negotiations, logistics, contract development and administration, inventory control and management, supplier management, and other activities. However, purchasing remains the core activity of supply management. Although the term *procurement* is frequently used in place of *purchasing*, procurement typically includes the added activities of specifications development, value analysis, negotiation, expediting, contract administration, supplier quality control, and some logistics activities; hence, it is widely used by government agencies due to the type of purchases and frequent service contracting they made with government suppliers. However, it is difficult to clearly distinguish where purchasing activities end and the supply management function begins. Moreover, many organizations use these terms interchangeably. In many parts of this book, we have retained the traditional term purchasing in place of supply management to emphasize the term's original meaning.

## The Role of Supply Management in an Organization

Traditionally, purchasing was regarded as being a service to production, and corporate executives paid limited attention to issues concerned with purchasing. However, as global competition intensified in the 1980s, executives realized the impact of large quantities of purchased materials and work-in-process inventories on manufacturing cost, quality, new product development, and delivery lead time. Savvy managers adopted new supply chain management concepts that emphasized purchasing as a key strategic business process rather than a narrow specialized supporting function to overall business strategy.

The *Annual Survey of Manufactures* (as shown in Table 2.1), conducted by the U.S. Census Bureau, shows that manufacturers spend more than 50 percent of each sales dollar (shown as "value of shipments") on raw materials (shown as "cost of materials"). Purchases of raw materials exceeded value added through manufacturing (shown as "manufacture"), which accounted for less than 50 percent of sales. Purchases as a percent of sales dollars for merchants are expected to be much higher since merchandise is primarily bought for resale purposes. Unfortunately, aggregate statistics for merchants are not readily available.

However, individual information can easily be obtained from the annual report, Form 10K, of publicly traded companies, either directly or from the U.S. Securities and Exchange Commission (SEC). For example, Walmart Inc. reported that its cost of revenue ranged from 74.4 to 75.7 percent of its total revenue for the ten most recent fiscal years ending January 31, 2011 to 2020 (as shown in Table 2.2). This ratio shows the potential impact of purchasing on a company's profits. Therefore, it is obvious that many successful businesses are treating purchasing as a key strategic process.

**Table 2.1** Cost of Materials as a Percentage of the Value of Shipments

| | VALUE OF SHIPMENTS | COST OF MATERIALS | | MANUFACTURE | | EXPENDITURES | |
|---|---|---|---|---|---|---|---|
| YEAR | $ MILLIONS | $ MILLIONS | % | $ MILLIONS | % | $ MILLIONS | % |
| 2019 | 5,731,187 | 3,180,441 | 55.5 | 2,579,382 | 45.0 | 177,616 | 3.1 |
| 2018 | 5,890,663 | 3,301 ,381 | 56.0 | 2,606,338 | 44.2 | 179,142 | 3.0 |
| 2017 | 5,548,797 | 2,831,502 | 51.0 | 2,463,183 | 44.4 | 168,438 | 3.0 |
| 2016 | 5,354,694 | 2,942 ,556 | 55.0 | 2,408,996 | 45.0 | 168,318 | 3.1 |
| 2015 | 5,546,998 | 3,117,562 | 56.2 | 2,430,098 | 43.8 | 175,388 | 3.2 |
| 2014 | 5,880,890 | 3,486 ,762 | 59.3 | 2,400,063 | 40.8 | 173,310 | 2.9 |
| 2013 | 5,846,768 | 3,456,983 | 59.1 | 2,398,392 | 41.0 | 172,992 | 3.0 |
| 2012 | 5,704, 167 | 3,384 ,339 | 59.3 | 2,348,112 | 41.2 | 166,458 | 2.9 |
| 2011 | 5,498,599 | 3,240,477 | 58.9 | 2,295,220 | 41.7 | 146,652 | 2.7 |
| 2010 | 4,916,647 | 2,763 ,128 | 56.2 | 2, 185,326 | 44.4 | 127,952 | 2.6 |
| 2009 | 4,436, 196 | 2,438,427 | 55.0 | 1,978,017 | 44.6 | 130,081 | 2.9 |
| 2008 | 5,486,266 | 3,213,708 | 58.6 | 2,274,367 | 41.5 | 168,505 | 3.1 |
| 2007 | 5,338,307 | 2,975,906 | 55.7 | 2,390,643 | 44.8 | 159,422 | 3.0 |
| 2006 | 5,015,553 | 2,752 ,904 | 54.9 | 2,285,929 | 45.6 | 135,801 | 2.7 |
| 2005 | 4,742,077 | 2,557,601 | 53.9 | 2,210,349 | 46.6 | 128,292 | 2.7 |
| 2004 | 4,308,971 | 2,283 ,144 | 53.0 | 2,041,434 | 47.4 | 113,793 | 2.6 |
| 2003 | 4,015,387 | 2,095,279 | 52.2 | 1,923,415 | 47.9 | 112,176 | 2.8 |
| 2002 | 3,914,719 | 2,022 ,158 | 51.7 | 1,889,291 | 48.3 | 123,067 | 3.1 |
| 2001 | 3,967,698 | 2,105,338 | 53.1 | 1,850,709 | 46.6 | 142,985 | 3.6 |
| 2000 | 4,208,582 | 2,245 ,839 | 53.4 | 1,973,622 | 46.9 | 154,479 | 3.7 |
| 1999 | 4,031,885 | 2,084,316 | 51.7 | 1,954,498 | 48.5 | 150,325 | 3.7 |
| 1998 | 3,899,810 | 2,018,055 | 51.7 | 1,891,266 | 48.5 | 152,708 | 3.9 |
| 1997 | 3,834,701 | 2,015,425 | 52.6 | 1,825,688 | 47.6 | 151,510 | 4.0 |
| 1996 | 3,715,428 | 1,975 ,362 | 53.2 | 1,749,662 | 47. 1 | 146,468 | 3.9 |
| 1995 | 3,594,360 | 1,897,571 | 52.8 | 1,711,442 | 47.6 | 134,318 | 3.7 |

*Source: Annual Survey of Manufactures,* 1995–2019 U.S. Census Bureau.

The primary goals of purchasing are to ensure uninterrupted flows of raw materials at the lowest total cost, to improve quality of the finished goods produced, and to maximize customer satisfaction. Purchasing can contribute to these objectives by actively seeking better materials and reliable suppliers, working closely with, and exploiting the expertise of strategic suppliers to improve the quality of raw materials, and involving suppliers and purchasing personnel in product design and development efforts. Purchasing is the crucial link between the sources of supply and the organization itself, with support coming from overlapping activities to enhance manufacturability for both the customer and the supplier. The involvement

**Table 2.2** Walmart's Cost of Revenue as a Percentage of Total Revenue

| FISCAL YEAR END | TOTAL REVENUE | COST OF REVENUE | | OPERATING EXPENSE | |
|---|---|---|---|---|---|
| | $ MILLIONS | $ MILLIONS | % | $ MILLIONS | % |
| 1/31/2020 | 523,964 | 394,605 | 75.3 | 108,791 | 20.8 |
| 1/31/2019 | 514,405 | 385,301 | 74.9 | 107,147 | 20.8 |
| 1/31/2018 | 500,343 | 373,396 | 74.6 | 106,510 | 21.3 |
| 1/31/2017 | 485,873 | 361 ,256 | 74.4 | 101,853 | 21.0 |
| 1/31/2016 | 482,130 | 360,984 | 74.9 | 97,041 | 20.1 |
| 1/31/2015 | 485,651 | 365,086 | 75.2 | 93,418 | 19.2 |
| 1/31/2014 | 473,076 | 358,069 | 75.7 | 91,353 | 19.3 |
| 1/31/2013 | 466,114 | 352,488 | 75.6 | 88,873 | 19.1 |
| 1/31/2012 | 443,854 | 335,127 | 75.5 | 85,265 | 19.2 |
| 1/31/2011 | 418,952 | 314,946 | 75.2 | 81,361 | 19.4 |

*Source:* Annual Reports (Form 10-K), United States Security and Exchange Commission.

of purchasing and strategic suppliers is essential for selecting components and raw materials to ensure that requisite quality is designed into the product and to aid in collapsing the design-to-production cycle time.

## The Financial Significance of Supply Management

Undoubtedly, purchasing has become more global and gained more strategic corporate focus over the last three decades. The increasing use of outsourcing of noncore activities has further elevated the role of purchasing in a firm. In addition to affecting the competitiveness of a firm, purchasing also directly affects profitability. Next, we discuss the financial significance of purchasing on a firm.

### Profit-Leverage Effect

**Purchase spend** is the money a firm spends on goods and services. The **profit-leverage effect** of purchasing measures the impact of a change in purchase spend on a firm's profit before taxes, assuming gross sales and other expenses remain unchanged. The measure is commonly used to demonstrate that a decrease in purchase spend directly increases profits before taxes by the same amount. However, it is important to remember that a decrease in purchase spend must be achieved through better purchasing strategy, thus enabling the firm to acquire materials of similar or better quality and yield at a lower total acquisition cost. The profit-leverage effect example in Table 2.3 shows that if a firm manages to lower its purchase spend on materials by $20,000, profits before taxes increase by $20,000 because purchase spend on materials is a part of the cost of goods sold. Indeed, the reduction in purchase spend has an identical impact on gross profits. Table 2.3 shows that gross profits also increased by $20,000 from $500,000 to $520,000. This direct effect of purchasing on a firm's profitability is a key reason that drives business executives to continually refine and elevate the sourcing function. Thus, boosting sales and cutting costs are not the only ways to increase profits. An often overlooked but very efficient means of improving profits is through smarter purchasing.

**Table 2.3 Profit-Leverage Effect**

| | SIMPLIFIED PROFIT & LOSS STATEMENT | REDUCE MATERIAL COSTS BY $20,000 |
|---|---|---|
| **Gross Sales/Net Revenue** | $1,000,000 | $1,000,000 |
| – Cost of Goods Sold (Materials + Manufacturing Cost) | $500,000 | $480,000 |
| **Gross Profits** | $500,000 | $520,000 |
| – General & Administrative Expenses (45% of Gross Sales) | $450,000 | $450,000 |
| **Profits Before Taxes** | $50,000 | $70,000 |

## Return on Assets Effect

**Return on assets** (ROA) is a financial ratio of a firm's net income in relation to its total assets. The ratio is also referred to as **return on investment** (ROI). In the context of accounting, total assets consist of current and fixed assets. Current assets include cash, accounts receivable, and inventory, whereas fixed assets include equipment, buildings, and real estate. ROA indicates how efficiently management is using its total assets to generate profits. A high ROA suggests that management can generate large profits with relatively small investments. The formula for ROA is:

$$\text{Return on assets (ROA)} = \frac{\text{net income}}{\text{total assets}}$$

Assuming the firm in Table 2.3 has total assets of $500,000, its ROA is then 10 percent ($50,000 ÷ $500,000). If the firm reduces its purchase spend on materials by $20,000 through a more effective purchasing strategy, its ROA then increases to 14 percent ($70,000 ÷ $500,000). The $20,000 reduction in purchase spend on materials is also likely to result in a lower raw material inventory (and thus lower total assets). However, the effect on ROA from this potential change in inventory is difficult to quantify because the ratio of a firm's raw material inventory to its total assets, and the ratio of raw materials cost to its total cost of goods sold, vary widely depending on the firm and industry.

## Inventory Turnover Effect

**Inventory turnover** shows how many times a firm's inventory is utilized and replaced over an accounting period, such as a year. There are numerous ways to compute the inventory turnover ratio, but a widely used formula is the ratio of the cost of goods sold to average inventory at cost. To compute a monthly ratio, it is a common practice to use the mean of beginning and ending monthly inventory as the average monthly inventory. The mean of the twelve monthly inventory averages is a good measure to compute the annual inventory turnover ratio, especially if the monthly inventory levels fluctuate widely. In the absence of monthly inventory data, it is common for firms to use the mean of the beginning and ending annual inventory to compute annual inventory turnover ratio.

In general, low inventory turnover indicates poor sales, overstocking, and/or obsolete inventories. A firm must compare its inventory turnover ratio against the industry standard to judge how fast the company turns over its inventory compared to competitors. We will discuss some company-specific examples of inventory turnover ratios in Chapter 7.

Through a more effective sourcing strategy, purchasing can help to reduce inventory investment, and thus improve the firm's inventory turnover. Several inventory turnover formulas are shown here:

$$\text{Inventory turnover ratio} = \frac{\text{Cost of goods sold}}{\text{Average inventory}}$$

$$\text{Monthly inventor turnover ratio} = \frac{\text{Cost of goods sold for the month}}{(\text{Beginning inventory} + \text{Ending inventory})/2}$$

$$\text{Annual inventory turnover ratio} = \frac{\text{Cost of goods sold for the year}}{\text{Mean of the 12 monthly inventory averages}}$$

Consider a hypothetical example in which a firm has an ending inventory of $50,000 as of its fiscal year-end December 31, 2020 and the following accounting information. The monthly and annual inventory turnover ratios can be computed as follows:

| MONTH (2021) | ENDING INVENTORY | COST OF GOODS SOLD | MONTHLY INVENTORY TURNOVER RATIO |
|---|---|---|---|
| January | $52,000 | $85,000 | $\frac{\$85,000}{(\$50,000 + \$52,000)/2} = 1.67$ |
| February | $88,000 | $1,250,000 | $\frac{\$1,250,000}{(\$52,000 + \$88,000)/2} = 17.86$ |
| March | $85,000 | $950,000 | $\frac{\$950,000}{(\$88,000 + \$85,000)/2} = 10.98$ |
| April | $55,000 | $750,000 | $\frac{\$750,000}{(\$85,000 + \$55,000)/2} = 10.71$ |
| May | $75,000 | $950,000 | $\frac{\$950,000}{(\$55,000 + \$75,000/2} = 14.62$ |
| June | $85,000 | $850,000 | $\frac{\$850,000}{(\$75,000 + \$85,000)/2} = 10.63$ |
| July | $156,000 | $555,000 | $\frac{\$555,000}{(\$85,000 + \$156,000)/2} = 4.61$ |
| August | $215,000 | $1,325,000 | $\frac{\$1,325,000}{(\$156,000 + \$215,000)/2} = 7.14$ |
| September | $65,000 | $985,000 | $\frac{\$985,000}{(\$215,000 + \$65,000)/2} = 7.04$ |
| October | $100,000 | $850,000 | $\frac{\$850,000}{(\$65,000 + \$100,000)/2} = 10.30$ |
| November | $165,000 | $1,250,000 | $\frac{\$1,250,000}{(\$100,000 + \$165,000)/2} = 9.43$ |

| MONTH (2017) | ENDING INVENTORY | COST OF GOODS SOLD | MONTHLY INVENTORY TURNOVER RATIO |
|---|---|---|---|
| December | $45,000 | $1,050,000 | $\frac{\$1,050,000}{(\$165,000 + \$45,000)/2} = 10.00$ |

Total cost of goods sold for the year = $85,000 + $1,250,000 + $950,000 + $750,000 + $950,000 + $850,000 + $555,000 + $1,325,000 + $985,000 + $850,000 + $1,250,000 + $1,050,000 = $10,850,000

Mean of the 12 monthly inventory averages = [($50,000 + $52,000)/2 + ($52,000 + $88,000)/2 + ($88,000 + $85,000)/2 + ($85,000 + $55,000)/2 + ($55,000 + $75,000)/2 + ($75,000 + $85,000)/2 + ($85,000 + $156,000)/2 + ($156,000 + $215,000)/2 + ($215,000 + $65,000)/2 + ($65,000 + $100,000)/2 + ($100,000 + $165,000)/2 + ($165,000 + $45,000)/2]/12 = $99,042

Thus, the annual inventory turnover ratio is: $\frac{\$10,850,000}{\$99,042} = 109.55$ times.

However, if the monthly ending inventory data are unavailable, the annual inventory turnover ratio can be computed using the beginning and ending annual inventory values. A criticism of this approach is that firms can artificially inflate annual inventory turnover ratios by liquidating their fiscal year-end inventory.

$$\text{Annual inventory turnover ratio} = \frac{\text{Cost of goods sold}}{\text{Average inventory}} = \frac{\$10,850,000}{(\$50,000 + \$45,000)/2} = 228.42 \text{ times.}$$

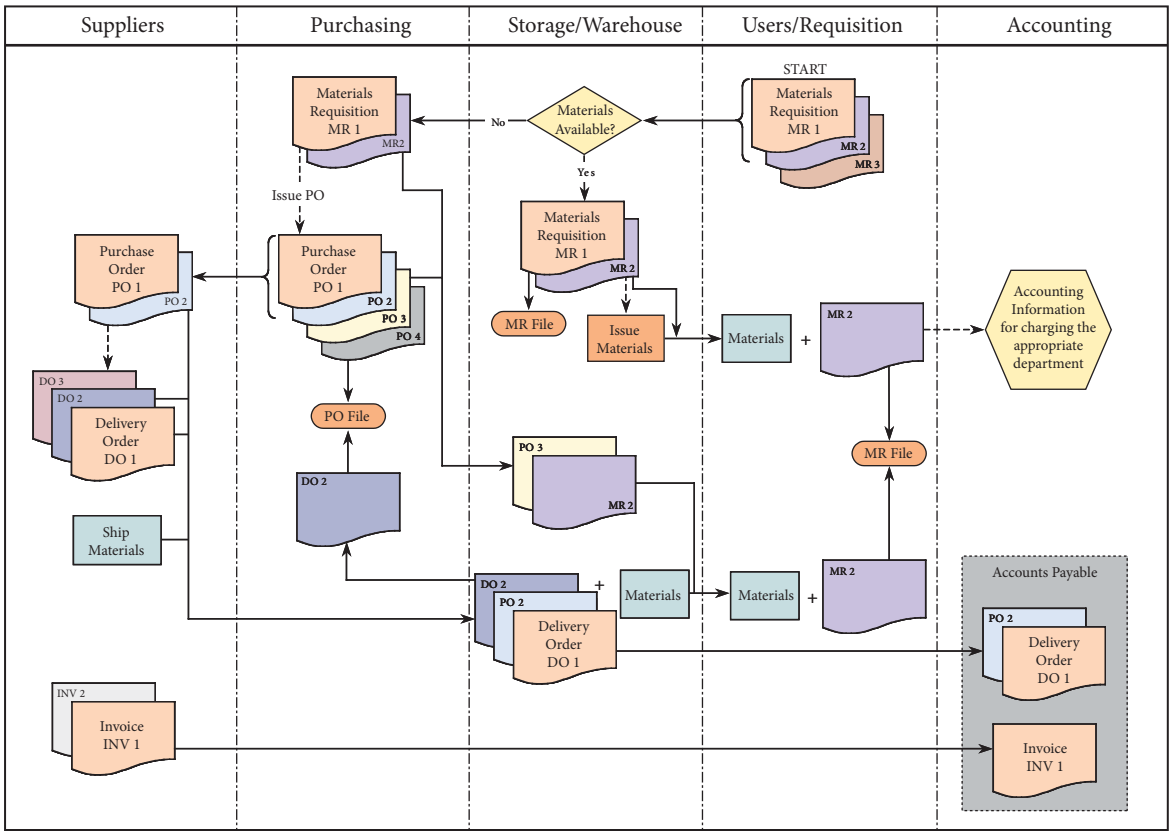
## The Purchasing Process

The traditional purchasing process is a manual, paper-based system. However, with the advent of information technology and the Internet, many companies are moving toward a more automated, electronic-based system. The goal of a proper purchasing system is to ensure the efficient transmission of information from the users to the purchasing personnel and, ultimately, to the suppliers. Once the information is transmitted to the appropriate suppliers, the system must also ensure the efficient flows of the purchased materials from the suppliers to the users and the flow of invoices from the suppliers to the accounting department. Finally, the system must have adequate operational or internal control to prevent abuse of purchasing funds. For example, purchase orders (POs) should be prenumbered and issued in duplicate, and buyers should not be authorized to pay invoices. Prenumbered purchase orders make it easier to trace any missing or unaccounted-for purchase orders. A duplicate purchase order should be issued to the accounting department for internal control purposes and to inform the department of a future payment or commitment of resources. The authority to approve payments should be different from the authority to approve purchase orders.

### The Manual Purchasing System

Figure 2.1 shows a simplified traditional manual purchasing system. While some manual systems may look slightly different than what is shown in Figure 2.1, it captures the essential elements of a good purchasing system that is easy to use and yet exerts adequate internal control of the process. The manual purchasing system is slow and prone to errors due to duplication of data entries during various stages of the purchasing process. For example, similar information on the material requisition, such as the product description, is reproduced on the purchase order.

**Figure 2.1** Traditional Manual Purchasing System




## The Material Requisition

The purchasing process starts when the material user initiates a request for material by issuing a **material requisition** (MR) in duplicate. A **purchase requisition**, instead of a material requisition, is used in some firms. The product, quantity, and delivery due date are clearly described on the material requisition. The number of duplicates issued depends on the internal control system of the organization. Generally, the issuer retains a copy and the warehouse receives the original plus a duplicate. The duplicate accompanies the material as it moves from the warehouse to the user. This copy also provides the essential information for the accounting department to charge the appropriate user or department for the material.

While most requisitions are transmitted through the generic material requisition, a **traveling requisition** is used for materials and standard parts that are requested on a recurring basis. Instead of describing the product on the generic material requisition, the product description and other pertinent information, such as delivery lead time and lot size, are preprinted on the traveling requisition. When a resupply is needed, the user simply enters the quantity and date needed and submits it to the warehouse. Once the resupply information is recorded, the traveling requisition is returned to the user for future requests.

**Planned order releases** from the material requirements planning (MRP) system or a bill of materials (BOM) can also be used to release requisitions or to place orders directly with the suppliers. This approach is suitable for firms that use the same components to make standard goods over a relatively long period of time.

If the requested material is available in the warehouse, the material is issued to the user without going through the purchasing department. Otherwise, the requisition is assigned to a buyer who is responsible for the material. If there is a better substitute for the material, purchasing recommends and works with the user to explore whether it is a viable substitute. However, purchasing personnel should not change the specifications of the materials or parts without the user's knowledge and agreement. While it is the right and responsibility of purchasing personnel to select the appropriate supplier, the user in many cases may suggest a list of potential suppliers when requesting new material. A sample purchase requisition is shown in Figure 2.2.

**Figure 2.2** Sample Purchase Requisition

BabiHutan Inc.
523 Las Vegas Blvd
Las Vegas, NV 89154
Tel: 702-123-4567

**Purchase Requisition**

RX #: 6334554

Requestor: _____ Department: _____

Phone #: _____ Account #: _____ Date: _____

Suggested Vendor: _____

Address: _____ Phone: _____

| No. | Description | Price | Quantity |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

Special instructions: _____

_____

_____

Approval Authority: _____ Date: _____

Distribution: White-Purchasing/Yellow-Purchasing (return to requestor)/Pink-Department

### The Request for Quotation and the Request for Proposal

If the material is not available in the warehouse, the material requisition is routed to the purchasing department. If there is no current supplier for the item, the buyer must identify a pool of qualified suppliers and issue a **request for quotation** (RFQ). A **request for proposal** (RFP) may be issued instead for a complicated and highly technical component part, especially if the complete specification of the part is unknown. An RFP allows suppliers to propose new material and technology, thus enabling the firm to exploit the technology and expertise of suppliers.

A growing trend among firms that practice supply chain management is **supplier development**. When there is a lack of suitable suppliers, firms may assist existing or new suppliers to improve their processing capabilities, quality, delivery, and cost performance by providing the needed technical and financial assistance. Developing suppliers in this manner allows firms to focus more on core competencies, while outsourcing noncore activities to suppliers.

### The Purchase Order

When a suitable supplier is identified, or a qualified supplier is on file, the buyer issues a purchase order (PO) in duplicate to the selected supplier. Generally, the original purchase order and a duplicate are sent to the supplier. An important feature of the purchase order is the terms and conditions of the purchase, which is typically preprinted on the back. The purchase order is the buyer's offer and becomes a legally binding contract when accepted by the supplier. Therefore, firms should require the supplier to acknowledge and return a copy of the purchase order to indicate acceptance of the order. A sample purchase order is shown in Figure 2.3.

The supplier may offer the goods at its own terms and conditions, especially if it is the sole producer or holds the patent to the product. Then a supplier's **sales order** will be used. The sales order is the supplier's offer and becomes a legally binding contract when accepted by the buyer.

Once an order is accepted, purchasing personnel need to ensure on-time delivery of the purchased material by using a **follow-up** or by **expediting** the order. A follow-up is considered a proactive approach to prevent late delivery, whereas expediting is considered a reactive approach that is used to speed up an overdue shipment.

The **Uniform Commercial Code** (UCC) governs the purchase and sale of goods in the United States, except in the state of Louisiana. Louisiana has a legal system that is based on the Napoleonic Code.

## Electronic Procurement Systems (e-Procurement)

Electronic data interchange (EDI) was developed in the 1970s to improve the purchasing process. However, its proprietary nature required significant up-front investments. The rapid advent of information technology in the 1990s spurred the growth of more flexible Internet-based e-procurement systems. Many e-commerce service providers surfaced in the late 1990s, but many are no longer in business after the dot-com bubble burst in 2000. Today, many well-managed e-commerce firms are thriving as users realize the benefits of their services.

Figure 2.4 describes the Internet-based electronic purchasing system used by the University of Nevada, Las Vegas. The database that drives the e-procurement system resides on a server, but the software is installed on workstations. The e-procurement system is also accessible via the Internet. The e-procurement system allows users to submit

**Figure 2.3** Sample Purchase Order

BabiHutan Inc.
523 Las Vegas Blvd
Las Vegas, NV 89154
Tel: 702-123-4567

**Purchase Order**

PO#: 885729
Date: _____

Vendor:

Required Delivery Date: _____
Payment Terms: _____
FOB Terms: _____
Price Agreement No.: _____

Ship To:

Include PO # in all packages, invoice, shipping papers & correspondence. Mail original and one copy of invoice attached to second copy of Purchase Order for payment.

| No. | Description | Unit Price | Quantity | Total Price |
|---|---|---|---|---|
| | | | | |
| | | | **Total $ of Order** | |

Buyer: _____ Phone: _____ Fax: _____

Buyer Signature: _____ Requisition No.: _____

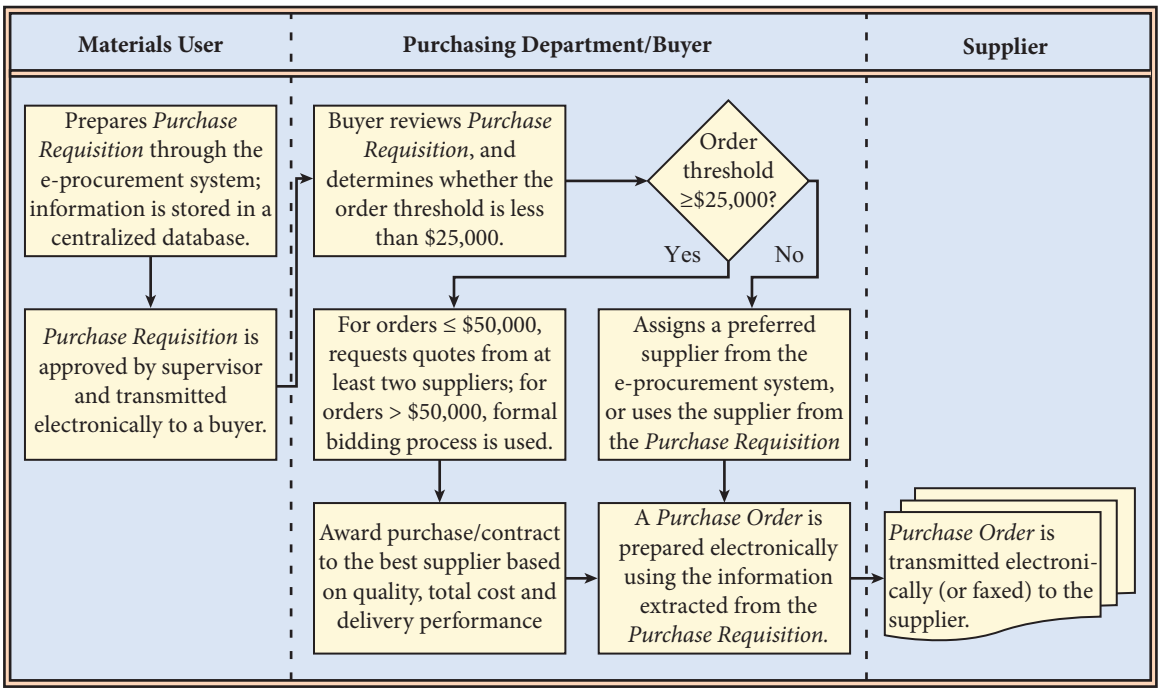
**SEE REVERSE FOR TERMS & CONDITIONS**

Distribution: White-Vendor/Yellow-Vendor(return with invoice)/Pink & Blue-Purchasing/Green-Fixed Assets

their purchase requisitions to the purchasing department electronically and enables buyers to transmit purchase orders to suppliers over the Internet, fax, e-mail, or snail mail.

The material user initiates the e-procurement process by entering a purchase request and other pertinent information, such as quantity and date needed, into the purchase requisition module. The material user may recommend suppliers or potential sources for the requisition. Next, the purchase requisition is approved and transmitted electronically to a buyer at the purchasing department. The buyer reviews the purchase requisition for accuracy and appropriate approval level and determines the value of the requisition. If the amount is below $25,000, the buyer extracts details of the purchase requisition stored in the database to prepare an electronic purchase order. Next, the buyer assigns a preferred supplier from the e-procurement database or uses a supplier from the purchase requisition. If the amount of the purchase requisition is between $25,000 and $50,000, two formal

**Figure 2.4** Internet-Based Electronic Purchasing System




requests for quotation are needed before a purchase order can be released. However, if the amount exceeds $50,000, a supplier must be chosen by means of a formal bidding process. At the specified time and place, bids are opened publicly. The purchase is awarded to the lowest responsible bidder whose bid conforms to all requirements of the solicitation. Then an electronic purchase order (or formal contract for purchase of services) is prepared and transmitted (or mailed) to the selected supplier.

## Advantages of the e-Procurement System

The traditional manual purchasing system is a tedious and labor-intensive task of issuing material requisitions and purchase orders. Although EDI solved some of these problems, its proprietary nature requires a high start-up cost, making it inaccessible to small firms with limited budgets. E-procurement systems have changed the infrastructure requirement, making it readily affordable to most firms. Benefits derived from implementing an e-procurement system include:

1. *Time savings*: E-procurement is more efficient when (a) selecting and maintaining a list of potential suppliers, (b) processing requests for quotation and purchase orders, and (c) making repeat purchases. Individual buyers can create preferred supplier lists for each category of products and services. For example, a small tools supplier group may consist of fifteen suppliers. The buyer uses this group to purchase small tools. The list can be edited and shared with all buyers in the firm. Supplier performance data can be updated quickly and made available online in real time. Collecting, sorting, reviewing, and comparing RFQs are labor-intensive and time-consuming processes. Using the manual purchasing system, a typical firm may have to sort and match hundreds of bids

daily. E-procurement eliminates these non-value-adding activities. Duplicate data entry on the purchase order is eliminated since the information can be extracted from the RFQ, originally entered by the user. Also, an e-procurement system minimizes the need for interdepartmental routing of paper purchase requisitions, streamlines the approval process, and automates purchase order issuance.

E-procurement systems can be programmed to handle automatic bidding of frequently ordered items on a fixed interval, such as daily or weekly—a commonly used practice. The ability to submit automatic bidding is invaluable for handling perishable goods, which must be ordered in small lot sizes, and other frequently purchased items where the specifications are known.

2. *Cost savings*: Buyers can handle more purchases, and the manual task of matching bids to purchase requisitions is reduced. Other cost savings include lower prices of goods and services (since more suppliers can be contacted), reduced inventory costs (due to the ability to purchase on a more frequent basis), use of fewer buyers, lower administrative costs, elimination of the need for preprinted purchase requisition forms, and faster order fulfillment.
3. *Accuracy*: The system eliminates double-key inputs—once by the material users and then once again by the buyers. The system also enhances the accuracy of communications between buyers and suppliers. More up-to-date information on suppliers, with goods and services readily available online, allows users to assess their options before preparing a purchase requisition.
4. *Real-time use*: Buyers have real-time access to the purchase requisition once it is prepared. Once the purchase requisition is processed, the buyer can post the bid instantly, instead of waiting to contact all the suppliers individually to alert them of the bids. The system enables buyers to initiate bids and suppliers to respond in real time on a 24/7 basis.
5. *Mobility*: The buyer can submit, process, and check the status of bids, as well as communicate with suppliers regardless of the buyer's geographical location and time of day. Thus, the e-procurement system is highly flexible.
6. *Trackability*: The e-procurement system allows submitters and buyers to track each purchase requisition electronically through the process—from submission, to approval, and finally conversion to a purchase order. Moreover, audit trails can be maintained for all transactions in electronic form. Tracing an electronic bid and transaction is much easier and faster than tracking paper trails. Buyers and suppliers can ask for additional information online, leave comments, or indicate whether they are interested in bidding.
7. *Management benefits*: The system can be designed to store important supplier information, including whether suppliers are minority or locally owned, thus allowing the buyers to support such businesses. Summary statistics and supplier performance reports can be generated for management to review and utilize for future planning.
8. *Supplier benefits*: Benefits include lower barriers to entry and transaction costs, access to more buyers, and the ability to instantly adjust to market conditions, thus making e-procurement attractive to most suppliers.

## Small-Value Purchase Orders

The administrative costs to process an order can be quite substantial. It has been estimated that the cost of placing an order using the manual purchasing system can be as high as $175.[6] The figure could be higher when we consider the salary of senior purchasing

personnel and other indirect costs incurred by purchasing personnel. It is not uncommon to find that the cost to process a purchase order exceeds the total dollar value of the order itself. While *small dollar value* is a relative term depending on the size of the firm, $500 to $1000 can be considered a reasonable threshold.

Small-value purchases, particularly in a manual purchasing system, should be minimized to ensure that buyers are not overburdened with trivial purchases that may prevent them from focusing on more crucial purchases. Due to the efficiency of the e-procurement system, buyers are less likely to be overburdened by small-value purchases. Nevertheless, all firms should have a system in place to handle small-value purchases. To control unnecessary administrative costs and reduce order cycle time, purchasing managers have various alternatives to deal with small-value purchases. Generally, the alternatives are used for purchases of office supplies and other indirect materials. Let's review the alternatives.

## Procurement Card or Purchasing Card

**Procurement cards** or **purchasing cards** (P-cards) are credit cards with a predetermined credit limit, usually not more than $5000 depending on the organization, issued to authorized personnel of the buying organization to make low-dollar purchases. It is not uncommon that in many companies, more than half of their purchases are less than $500. American Express, MasterCard, Visa, and Diners Club are commonly used for this purpose. The P-card allows the material user to purchase the material directly from the supplier without going through purchasing. Usually, the user must purchase the needed materials from a list of authorized suppliers. Procurement cards were initially developed in the late 1980s for the U.S. Federal Government's General Services Administration and rapidly gained wide market acceptance in both the private and public sectors since the 1990s because of their ease of use and flexibility.

In a 2012 P-card study, it was reported that P-card transactions for small-value purchases under $2500 have exceeded paper checks since 2009.[7] P-card spending in North America has continued to grow from $196 billion in 2011 to more than $350 billion in 2018.[8] A P-card survey reports that the growth in the private sector (31%) has slightly outpaced the public sector (29%). The average transaction size is about $454, and the average monthly spend and number of monthly transactions per card is about $2767 and 6.1 respectively.[9] In the government sector, a study estimated that the transactional cost savings of a P-card compared to traditional purchase order is about $50 to $90.[10]

Many large firms and government agencies have expanded the usage of P-cards to allow authorized employees to charge travel expenses such as lodging and meals directly to their procurement cards, thus eliminating the need to process travel expenses in advance for the users. At the end of the month, an itemized statement is sent to the purchasing department, the cardholder's department, or directly to the accounting department. Generally, the purchasing department is responsible for managing the overall program, but the individual unit is responsible for managing its cardholder accounts. To ensure appropriate internal control of the procurement credit card system, a supervisor should be assigned to review the monthly statement of each cardholder to prevent fraud. Cardholders should maintain proper supporting documents and records for each purchase. The U.S. Department of Defense's **Government Travel Charge Card** (GTCC) is a travel P-card that provides government employees with a safe, effective, and convenient method to pay for expenses related to official travel.

Despite the success of the P-card program, there are unique challenges in expanding the program globally. P-card programs are more common in English-speaking regions, such as the United Kingdom, the United States, and Australia, and less common in

France, Germany, and Italy, where automatic transfers are more common. In some Asian markets where employee turnover is high, employers are concerned about card fraud. Card-issuing banks may not have coverage in all countries to enable a corporation to expand its P-card program globally. There are also country-specific challenges. Germany, for instance, has complicated data protection laws, and new programs must be reviewed by each company's Workers Council. The same issues with data protection laws are also found in France, where direct debit is preferred. In Eastern Europe, the commercial card market is still in its infancy.[11]

## Blanket or Open-End Purchase Orders

A **blanket purchase order** covers a variety of items and is negotiated for repeated supply over a fixed period, such as quarterly or yearly. The subtle difference of an **open-end purchase order** is that additional items and expiration dates can be renegotiated. Price and estimated quantity for each item, as well as delivery terms and conditions, are usually negotiated and incorporated in the order. A variety of mechanisms, such as a **blanket order release** or production schedule, may be used to release a specific quantity against the order. Blanket or open-end purchase orders are suitable for buying MRO supplies and office supplies. At a fixed interval, usually monthly, the supplier sends a detailed statement of all releases against the order to the buying firm for payment.

While blanket purchase orders are frequently used to handle small-value purchases, when used in conjunction with blanket order releases, cooperative supplier relationships, and single sourcing, blanket purchase orders are a formidable tool for handling the complex purchasing needs of a large, multidivisional corporation.

## Blank Check Purchase Orders

A **blank check purchase order** is a special purchase order with a signed blank check attached, usually at the bottom of the purchase order. Due to the potential for misuse, it is usually printed on the check that it is not valid for over a certain amount (usually $500 or $1000). If the exact amount of the purchase is known, the buyer enters the amount on the check before passing it to the supplier. Otherwise, the supplier enters the amount due on the check and cashes it after the material is shipped. Nevertheless, purchasing managers are embracing the use of P-cards and phasing out blank check purchase orders.

## Stockless Buying or System Contracting

**Stockless buying** or **system contracting** is an extension of the blanket purchase order. It requires the supplier to maintain a minimum inventory level to ensure that the required items are readily available for the buyer. It is stockless buying on the buyer's perspective because the burden of keeping the inventory is on the supplier. Some firms require suppliers to keep inventory at the buyer's facilities to minimize order cycle time.

## Petty Cash

**Petty cash** is a small cash reserve maintained by a midlevel manager or clerk. Material users buy the needed materials and then claim the purchase against the petty cash by submitting the receipt to the petty cashier. A benefit of this system is that the exact reimbursement is supported by receipts. Nonetheless, petty cash is also being phased out in favor of P-cards.

### Standardization and Simplification of Materials and Components

Where appropriate, purchasing should work with design, engineering, and operations to seek opportunities to standardize materials, components, and supplies to increase the usage of standardized items. For example, a car manufacturer could design different models of automobiles to use the same starter mechanism, thus increasing its usage and reducing storage space requirements while allowing for large quantity price discounts. This will also reduce the number of small-value purchases for less frequently used items.

**Simplification** refers to a reduction of the number of components, supplies, or standard materials used in a product or process. For example, a computer manufacturer could integrate the video card directly onto the motherboard instead of using different video card modules for different models. Thus, simplification can further reduce the number of small-value purchases while reducing storage space requirements, as well as allowing for quantity purchase discounts.

### Accumulating Small Orders to Create a Large Order

Numerous small orders can be accumulated and mixed into a large order, especially if the material request is not urgent. Otherwise, purchasing can simply increase the order quantity if the ordering cost exceeds the inventory holding cost. Larger orders also reduce the purchase price and unit transportation cost.

### Using a Fixed Order Interval for a Specific Category of Materials or Supplies

Another effective way to control small orders is to group materials and supplies into categories and then set fixed order intervals for each category. Order intervals can be set to biweekly or monthly depending on usage. Instead of requesting individual materials or supplies, users request the appropriate quantity of each item in the category on a single requisition to be purchased from a supplier. This raises the dollar value but reduces the number of small orders.

## Sourcing Decisions: The Make-or-Buy Decision

The term **outsourcing** is commonly used to refer to buying materials or components from suppliers instead of making them in-house. In recent years, the trend has been moving toward outsourcing combined with the creation of supply chain relationships to replace the practice of backward or forward vertical integration. **Backward vertical integration** refers to acquiring upstream suppliers, whereas **forward vertical integration** refers to acquiring downstream customers. For example, an end-product manufacturer acquiring a supplier's operations that supplied component parts is an example of backward vertical integration. Acquiring a distributor or other outbound logistics providers would be an example of forward vertical integration. The nearby SCM Profile discusses several myths and motivations regarding outsourcing.

The **make-or-buy decision** is a strategic one that can impact an organization's competitive position. It is obvious that most organizations buy their MRO and office supplies rather than make the items themselves. Similarly, seafood restaurants usually buy their fresh seafood from fish markets. However, the decision on whether to make or buy technically advanced engineering parts that impact the firm's competitive position is a complex one. For example, do you think the Honda Motor Company would rather make or buy the engines used in its automobiles? Why?

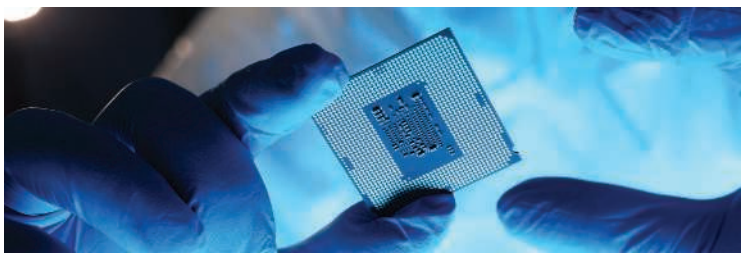
## SCM Profile

## Outsourcing Myths and Motivations

Outsourcing is a common method for organizations, especially manufacturing firms to exploit suppliers' technologies and capabilities, to enhance their core competencies. However, the term outsourcing is usually associated with many negative social and economic perceptions such as employee layoffs, questionable customer service, and poor quality. Contrary to popular beliefs, outsourcing can make a firm more agile and competitive. Outsourcing can liberate a firm's top management from noncore operations.

Misconceptions of outsourcing are generally due to a lack of understanding about how outsourcing works. Some of the myths of outsourcing are that it is expensive, leads to layoffs, compromises control of business, and the business is too complicated or too small to outsource.[12] However, the reality is that outsourcing can be a very cost-effective means to secure high quality materials and services from the best suppliers. For example, Bridgestone Corp can invest more money in tire R&D and achieve economies of scale because it produces tires for multiple automobile manufacturers such as Ford, General Motors, and Toyota. Moreover, a good outsourcing partner can fully understand the intricate challenge and complexity of its client's needs, regardless of the company size or business complexity. Clear communication, expectation and transparency are key to positive outsourcing partnership with strategic suppliers. Finally, outsourcing does not compromise control of the business; it simply replaces in-house manufacturing with vendor management. Outsourcing makes it easier for the buying firm to secure the best quality components or services.

Outsourcing has matured over the years that businesses are using the strengths and capabilities of strategic suppliers to save costs, accelerate growth and strengthen competitive advantage. Outsourcing is no longer about saving money, it is about being more efficient, getting products into the market faster than competitors and gaining access to high quality employees and materials that the firms otherwise could not afford. Knowing what to outsource is the driving force of a successful outsourcing strategy. The basic philosophy is to outsource noncore activities to focus on core competencies. Core competencies are the strategic capabilities that lead to a firm's inimitable competitive advantage and improve customer value, whereas noncore activities are the tasks that add little value to customer satisfaction and can be easily duplicated by competitors. Outsourcing provides a firm the flexibility and opportunity to use the best suppliers to obtain the highest quality materials, components, and services.[13]



H_Ko/Shutterstock.com

While it is easy to understand the outsourcing concept, the distinction between core competencies and noncore activities is not easily defined. For example, Intel Corporation and Advanced Micro Devices (AMD) designed and produced microprocessors for desktops,

servers, and mobile devices in-house. The primary competitive priority of both companies was technological innovation. In 2003, AMD, a smaller rival of Intel, with less financial resources, decided to focus on designing microprocessors while outsourcing its manufacturing to outside foundries, such as the Taiwan Semiconductor Manufacturing Company.[14] The move is in stark contrast to the long-held position that producing microprocessors in-house is a core competency that should not be outsourced. However, the huge capital costs of operating a leading-edge microprocessor plant and keeping it up to date with the latest manufacturing technologies, led AMD to outsource its manufacturing. AMD's unconventional decision to outsource its manufacturing helped to capture microprocessor market share from Intel. In 2020, Intel signaled that it might give up manufacturing its own components after falling far behind its schedule to develop its manufacturing technologies.[15]

Traditionally, cost has been the major driver when making sourcing decisions. However, organizations today focus more on the strategic impact of the sourcing decision on the firm's competitive advantage. For example, the Honda Motor Company would not outsource the making of its engines because it considers engines to be a vital part of its automobiles' performance and reputation. However, Honda may outsource the production of brake rotors to a high-quality, low-cost supplier that specializes in brake rotors. Generally, firms outsource noncore activities while focusing on core competencies. Finally, the make-or-buy decision is not an exclusive either-or option. Firms can always choose to make some components or services in-house while buying the rest from suppliers.

## Reasons for Buying or Outsourcing

Organizations buy or outsource materials, components, and/or services from suppliers for many reasons. Let us review these now:

1. *Cost advantage*: For many firms, cost is an important reason for outsourcing, especially for supplies and components that are nonvital to the organization's operations and competitive advantage. This is usually true for standardized or generic supplies and materials for which suppliers may have the advantage of **economies of scale** because they supply large quantities of the same item to multiple users. In most outsourcing cases, the quantity needed is so small that it does not justify the investment in capital equipment to make the item. Some foreign suppliers may also offer a cost advantage because of lower labor and/or materials costs.
2. *Insufficient capacity*: A firm may be running at or near capacity, making it unable to produce the components in-house. This can happen when demand grows faster than anticipated or when expansion strategies fail to meet demand. The firm buys parts or components to free up capacity in the short term to focus on vital operations. Firms may even subcontract vital components and/or operations under very strict terms and conditions to meet demand. When managed properly, **subcontracting** instead of buying is a more effective means to expand short-term capacity because the buying firm can exert better control over the manufacturing process and other requirements of the components or end products.
3. *Lack of expertise*: The firm may not have the necessary technology and expertise to manufacture the item, or financial resources to keep up with leading-edge manufacturing technology. Maintaining long-term technological and economic viability

for noncore activities may be affecting the firm's ability to focus on core competencies. Moreover, suppliers may hold the patent to the process or product in question, thus precluding the make option, or the firm may not be able to meet environmental and safety standards to manufacture the item.

4. *Quality*: Purchased components may be superior in quality because suppliers have better technologies, processes, skilled labor, and the advantage of economies of scale. Suppliers' superior quality may help firms stay on top of product and process technologies, especially in high-technology industries with rapid innovation and short product life cycles.

## Reasons for Making

An organization also makes its own materials, components, services, and/or equipment in-house for many reasons. Let us briefly review them:

1. *Protect proprietary technology*: A major reason for the make option is to protect proprietary technology. A firm may have developed an equipment, product, or process that needs to be protected for the sake of competitive advantage. Firms may choose not to reveal the technology by asking suppliers to make it, even if it is patented. An advantage of not revealing the technology is to be able to surprise competitors and bring new products to market ahead of competition, allowing the firm to charge a price premium.
2. *No competent supplier*: If existing suppliers do not have the technology or capability to produce a component, the firm may be forced to make an item in-house, at least for the short term. The firm may use supplier development strategies to work with a new or existing supplier to produce the component in the future as a long-term strategy.
3. *Better quality control*: If the firm is capable, the make option allows for the most direct control over the design, manufacturing process, labor, and other inputs to ensure that high-quality components are built. The firm may be so experienced and efficient in manufacturing the component that suppliers are unable to meet its exact specifications and requirements. On the other hand, suppliers may have better technologies and processes to produce better-quality components. Thus, the sourcing option ensuring a higher quality level is a debatable question and must be investigated thoroughly.
4. *Use existing idle capacity*: A short-term solution for a firm with excess idle capacity is to use the excess capacity to make some of its components. This strategy is valuable for firms that produce seasonal products. It avoids layoff of skilled workers and, when business picks up, the capacity is readily available to meet demand.
5. *Control of lead time, transportation, and warehousing costs*: The make option provides better control of lead time and logistical costs since management controls all phases of the design, manufacturing, and delivery processes. Although raw materials may have to be transported, finished goods can be produced near the point of use, for instance, to minimize holding cost.
6. *Lower cost*: If technology, capacity, and managerial and labor skills are available, the make option may be more economical if large quantities of the component are needed on a continuing basis. Although the make option has a higher fixed cost due to initial capital investment, it has a lower variable cost per unit due to the lack of supplier profits.

## Make-or-Buy Break-Even Analysis

The current sourcing trend is to buy equipment, materials, and services unless manufacturing in-house provides a major benefit such as protecting proprietary technologies, achieving superior characteristics, or ensuring adequate supplies. However, buying or outsourcing has its own shortcomings, such as loss of some control and exposure to supplier risks. While cost is rarely the sole criterion in strategic sourcing decisions, **break-even analysis** is a handy tool for computing the cost-effectiveness of sourcing decisions when cost is the most important criterion. Several assumptions underlie the analysis: (1) all costs involved can be classified as either fixed or variable cost, (2) fixed cost remains the same within the range of analysis, (3) a linear variable cost relationship exists, (4) fixed cost of the make option is higher because of initial capital investment in equipment, and (5) variable cost of the buy option is higher due to supplier profit margins.

Consider a hypothetical situation (shown below) in which a firm has the option to make or buy a part. Its annual requirement is 15,000 units. A supplier can supply the part at $7 per unit. The firm estimates that it costs $500 to prepare the purchase contract. To make the part, the firm must invest $25,000 in equipment, and the firm estimates that it would cost $5 per unit to make the part.

| COSTS | MAKE OPTION | BUY OPTION |
|---|---|---|
| Fixed Cost | $25,000 | $500 |
| Variable Cost | $5 | $7 |
| Annual Requirement = 15,000 units | | |

### Break-even Point

The break-even point, Q, is found by setting the total cost of the two options equal to each other and solving for Q (also see Figure 2.5):

| | |
|---|---|
| Total Cost to Make | = Total Cost to Buy |
| $\Rightarrow$ $25,000 + $5Q | = $500 + $7Q |
| $\Rightarrow$ 7Q – 5Q | = 25,000 − 500 |
| $\Rightarrow$ 2Q | = 24,500 units |
| $\Rightarrow$ Break-even point, Q | = 12,250 units |

The Total Cost for both options at the Break-even Point is:

$$TC_{BE} = \$25{,}000 + (\$5 \times 12{,}250) = \$86{,}250$$

For the annual requirement of 15,000 units:

The Total Cost for the Make Option is:

$$TC_{Make} = \$25{,}000 + (\$5 \times 15{,}000) = \$100{,}000$$

The Total Cost for the Buy Option is:

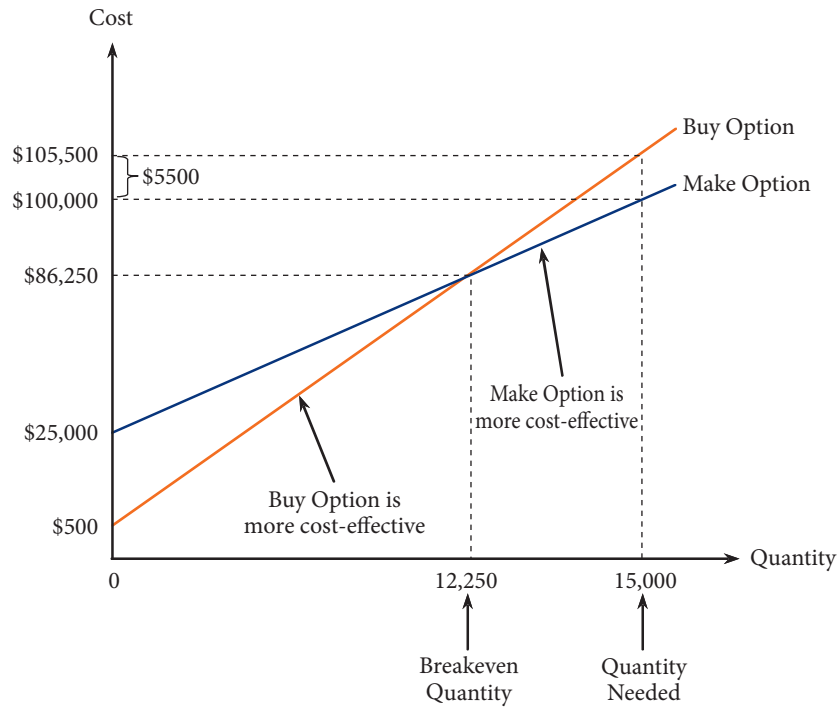
$$TC_{Buy} = \$500 + (\$7 \times 15{,}000) = \$105{,}500$$

The Cost Difference is:

$$TC_{Buy} - TC_{Make} = \$105{,}500 - \$100{,}000 = \$5{,}500$$

The analysis shows that the break-even point is 12,250 units. The total cost at the break-even point is $86,250. If the requirement is less than 12,250 units, it is cheaper to buy. It is cheaper to make the part if the firm needs more than 12,250 units. With small purchase requirements (less than 12,250 units), the low fixed cost of the buy option is cheaper. With higher purchase requirements (greater than 12,250 units), the low variable cost of the make option is cheaper. The analysis shows that the firm should make the item since the quantity is large enough to warrant the capital investment.

**Figure 2.5** Break-even Analysis




## Roles of the Supply Base

The **supply base** or **supplier base** refers to the list of suppliers that a firm uses to acquire its materials, services, supplies, and equipment. Firms engaging in supply chain management emphasize long-term strategic supplier alliances by reducing the variety of purchased items and consolidating volume into one or a few suppliers, resulting in a smaller supply base. For example, both Xerox and Chrysler reduced their supply bases by about 90 percent in the 1980s. Similarly, Delphi Automotive, the world's largest auto parts supplier, cut its global supply base by about 75 percent in the 2000s.[16] An effective supply base that enhances a firm's competitive advantage is critical to its success. Savvy purchasing managers develop a sound supply base to support the firm's overall business and supply chain strategies, based on an expanded role for suppliers. It is thus vital to understand the strategic role of suppliers.

Besides supplying the obvious purchased items, key or preferred suppliers also supply:

1. Product and process technology and expertise to support the buyer's operations, particularly in new product design and value analysis;
2. Information on the latest trends in materials, processes, or designs;
3. Information on the supply market, such as shortages, price increases, or political situations that may threaten supplies of vital materials;
4. Capacity for meeting unexpected demand; and

5. Cost efficiency due to economies of scale since the supplier is likely to produce the same item for multiple buyers.

When developing the supply chain, preferred suppliers are developed to provide services to the firm. Supply base plays an important role in the success of the supply chain.

## Supplier Selection

The decision to select a supplier for office supplies or other noncritical materials is likely to be an easy one. However, the process of selecting a group of competent suppliers for important materials, which can potentially impact the firm's competitive advantage, is a complex one and should be based on multiple criteria. In addition to cost and delivery performance, firms should also consider how suppliers can contribute to product and process technology. Factors that firms should consider while selecting suppliers include:

1. *Process and product technologies*: Suppliers should have competent process technologies to produce superior products at a reasonable cost to enhance the buyer's competitive edge.
2. *Willingness to share technologies and information*: With the current trend that favors outsourcing to exploit suppliers' capabilities and to focus on core competencies, it is vital that firms seek suppliers that are willing to share their technologies and information. Suppliers can assist in new product design and development through **early supplier involvement** (ESI) to ensure cost-effective design choices, develop alternative conceptual solutions, select the best components and technologies, and help in design assessment. By increasing the involvement of the supplier in the design process, the buyer is free to focus more attention on core competencies.
3. *Quality*: Quality levels of the purchased item should be a very important factor in supplier selection. Product quality should be high and consistent since it can directly affect the quality of the finished goods.
4. *Cost*: While the unit cost of an item is not typically the sole criterion in supplier selection, total cost of ownership is an important factor. **Total cost of ownership** or **total cost of acquisition** includes the unit cost of the item, payment terms, cash discount, ordering cost, carrying cost, logistical costs, maintenance costs, and other more qualitative costs that may not be easy to assess. An example of a total cost of ownership analysis is provided in the following section. The total cost analysis demonstrates how other costs besides the unit cost can affect purchase decisions.
5. *Reliability*: Aside from a reliable product quality level, reliability can refer to other supplier characteristics. For example, is the supplier financially stable? Otherwise, it may not be able to invest in research and development or stay in business. Is the supplier's delivery lead time reliable? Otherwise, production may have to be interrupted due to a shortage of material.
6. *Order system and cycle time*: How easy to use is a supplier's ordering system, and what is the normal order cycle time? Placing orders with a supplier should be easy, quick, and effective. Delivery lead time should be short, so that small lot sizes can be ordered on a frequent basis to reduce inventory holding costs.
7. *Capacity*: The firm should also consider whether the supplier has the capacity to fill orders to meet requirements and the ability to fill large orders if needed.

8. *Communication capability*: Suppliers should possess a communication capability that facilitates communication between the parties.
9. *Location*: Geographical location is another important factor in supplier selection, as it impacts delivery lead-time, transportation, and logistical costs. Some firms require their suppliers to be located within a certain distance from their facilities.
10. *Service*: Suppliers must be able to back up their products by providing good services when needed. For example, when product information or warranty service is needed, suppliers must respond on a timely basis.

There are numerous other factors—some strategic, others tactical—that a firm must consider when choosing suppliers. The days of using competitive bidding to identify the cheapest supplier for strategic items are long gone. The ability to select competent strategic suppliers directly affects a firm's competitive success. Strategic suppliers are trusted partners and become an integral part of the firm's design and production efforts.

A tiered supply chain model is widely used in the aerospace, automotive, and computer industries where the finished goods consists of many complex sub-assemblies that must comply with stringent quality standard and complex manufacturing process. **Original equipment manufacturers** (OEM) are the companies that make the final products. **Tier-1** suppliers provide parts or services directly to the OEM; **Tier-2** suppliers provide their outputs to Tier-1 suppliers, but not directly to the OEM; and **Tier-3 suppliers** sell their outputs to Tier-2 suppliers.

## Supplier Diversity

The origins of many supplier diversity programs in the United States can be attributed to U.S. public procurement legislation. The passage of Public Law 95-507 in 1978 made it mandatory that public contracts over $10,000 include a clause that small business concerns owned and controlled by socially and economically disadvantaged individuals be given the maximum practicable opportunity to participate in such contracts. Supplier diversity programs in the private sector in the United States began in order to comply with the public procurement legislation. However, the growth of minority and other disadvantaged populations and their purchasing power in the United States over the last few decades has given rise to a market-driven case for supplier diversity.[17]

Supplier diversity is a strategic sourcing initiative to ensure a diverse supplier base that includes businesses owned by diverse individuals or groups, including minority-owned, women-owned, veteran-owned, disability-owned, and small-business enterprises. A diverse supplier is a business that is at least 51 percent owned and operated by an underrepresented individual or group. In the United States, diverse suppliers can verify their diversity status by seeking a third-party certification from one of the relevant certification organizations, such as the National Minority Supplier Development Council, Women's Business Enterprise National Council, National Veterans Business Development Council, National Veteran Owned Business Association, Department of veterans Affairs' Office of Small & Disadvantaged Business Utilization, and Disability:IN.

Supplier diversity has gained traction in the United States and Canada, especially among large corporations and the public sector. A report published in 2019 estimated that 97 percent of the Fortune 500 companies in the United States engaged in supplier diversity.[18] Sourcing from well-developed diverse suppliers can create a win-win opportunity to reduce costs, enhance innovation and quality, and reach new markets for both parties. Besides fulfilling corporate social responsibility requirements, supplier diversity can help corporations improve customer satisfaction and revenues by using a supply base that is representative of their customer base. Also, a supplier base

that reflects the diverse backgrounds of employees can improve job satisfaction and retention. Besides helping under-represented businesses, supplier diversity uplifts the communities where they are located through job creation, tax revenue, increased wages, and standard of living. Since diverse suppliers tend to be small businesses, they have lower overhead costs and are more agile.

With the current focus on corporate social responsibility and consumers' awareness, the risk of not including diverse suppliers could be a loss in market share. Before embracing any supplier diversity program, organizations must ensure that their goals are achievable and that proper policies and measurement plans are in place. Supplier diversity is not limited to the purchase spend of the buying firms alone. For example, an OEM can engage its Tier-1 suppliers to stipulate diversity benchmarks in their contracts with Tier-2 and Tier-3 suppliers.[19]

## The Total Cost of Ownership Concept

The total cost of ownership concept extends the traditional break-even analysis beyond considering only the original purchase cost and capital equipment cost; other qualitative and quantitative factors, including freight and inventory costs, tooling, tariffs and duties, currency exchange fees, payment terms, maintenance, and nonperformance costs should be considered. Firms can use a total cost analysis to select the most cost-effective supplier or as a negotiation tool to inform suppliers regarding areas where they need to improve. Example 2.1 and Figure 2.6 demonstrate a total cost of ownership analysis.

### Example 2.1 Kuantan ATV Inc.: A Total Cost of Ownership Analysis

Kuantan ATV, Inc. assembles five different models of all-terrain vehicles (ATVs) from various ready-made components to serve the Las Vegas, Nevada, market. The company uses the same engine for all its ATVs. The purchasing manager, Ms. Jane Kim, needs to choose a supplier for engines for the coming year. Due to the size of the warehouse and other administrative restrictions, she must order the engines in lot sizes of 1,000 each. The unique characteristics of the standardized engine require special tooling to be used during the manufacturing process. Kuantan ATV agrees to reimburse the supplier for the tooling. This is a critical purchase since late delivery of engines would disrupt production and cause 50 percent lost sales and 50 percent back orders of the ATVs. Jane has obtained quotes from two reliable suppliers but needs to know which supplier is more cost-effective. She has the following information:

| | |
|---|---|
| Requirements (annual forecast) | 12,000 units |
| Weight per engine | 22 pounds |
| Order processing cost | $125 per order |
| Inventory carrying rate | 20% per year |
| Cost of working capital | 10% per year |
| Profit margin | 18% |
| Price of finished ATV | $4500 |
| Back-order cost | $15 per unit backordered |

Two qualified suppliers have submitted the following quotations:

| ITEMS | SUPPLIER 1 | SUPPLIER 2 |
|---|---|---|
| 1 to 999 units/order | $510/unit | $505/unit |
| 1,000 to 2,999 units/order | $500/unit | $498/unit |
| 3,000+ units/order | $490/unit | $488/unit |
| Tooling Cost | $22,000 | $20,000 |
| Terms | 2/10 net 30 | 1/10 net 30 |
| Distance | 125 miles | 100 miles |
| Supplier Quality Rating (defects) | 2% | 3% |
| Supplier Delivery Rating (late delivery) | 1% | 2% |

Jane also obtained the following freight rates from her carrier:

| | |
|---|---|
| Truckload (TL ≥ 40,000 lbs): | $0.80 per ton-mile |
| Less-than-truckload (LTL): | $1.20 per ton-mile |

**Note:** per ton-mile = 2000 lbs per mile; number of days per year = 365

### *Total Cost of Ownership Computation–Supplier 1*

Note that due to the size of the warehouse, order lot size, Q, is limited to 1000 units. The total cost of ownership for supplier 1 can be computed as follows (see Figure 2.6):

(1) Total Engine Cost = Annual requirement × Unit cost
= 12,000 units × $500/unit = $6,000,000.00

(2) Cash Discount (based on 365 days per year)
A cash discount of *2/10 net 30* means the invoice must be paid within 30 days, but a 2% discount is given if the invoice is paid within 10 days of the invoice date. The calculation of the cash discount is done in two parts—whether the buyer pays the invoice on the 10th day (receives a 2% discount) or 30th day (pays the full amount). It is assumed that the buyer will take advantage of the largest discount.
(A) Net 30 = Saving on the cost of capital by paying invoices on the 30th day
= Total engine cost × cost of capital × 30/365
= $6,000,000.00 × 10% × 30/365 = $49,315.07
(B) 2/10 cash discount = Saving on the cost of capital and 2% discount by paying invoices on the 10th day
= Total engine cost × (cost of capital × 10/365 + 2% discount)
= $6,000,000.00 × (10% × 10/365 + 2%)
= $136,438.36
Hence, the buyer should pay invoices on the 10th day to take advantage of the $136,438.36 cash discount provided by the 2/10 term.

(3) Tooling Cost = $22,000.00

(4) Transportation Cost
Since the order size is 1,000 units, the total weight of each shipment is 22,000 pounds (1,000 units × 22 lbs/unit). Since it is less than 40,000 pounds, the buyer must use less-than-truckload shipment at $1.20 per ton-mile.
Total Transportation Cost = distance × quantity × weight/unit × rate/ton-mile
= 125 miles × 12,000 units × 22 lbs/unit × $1.20/2000 lbs-mile
= $19,800.00

(5) Since the number of orders = annual requirement ÷ order size,
Ordering Cost = number of orders × order processing cost
= (12,000 units ÷ 1000 units) × $125 = $1500.00

(6) Since average inventory = order size ÷ 2,
Carrying Cost = Average inventory × price per unit × inventory carrying rate
= (order size ÷ 2) × price per unit × inventory carrying rate
= (1,000 units ÷ 2) × $500/unit × 20% = $50,000.00

(7) Quality Cost = Total engine cost × defect rate
= $6,000,000.00 × 2% = $120,000.00

(8) Delivery Rating
(A) Backorder Cost (50%) = Total quantity × late delivery rate × Back-order percentage × unit Back-order cost
= 12,000 units × 1% × 50% × $15/unit = $900.00
(B) Lost Sales (50%) = Total quantity × late delivery rate × lost sales percentage × price of ATV × profit margin
= 12,000 units × 1% × 50% × $4500/unit × 18%
= $48,600.00

(9) Total Cost of Supplier 1 = $6,000,000.00 − $136,438.36 + $22,000.00 + $19,800.00 + $1500.00 + $50,000.00 + $120,000.00 + $900.00 + $48,600.00 = $6,126,361.64

The total cost of ownership for supplier 2 can be computed using the same logic. The total cost analysis (see Figure 2.6) shows that Supplier 1 is more cost-effective, although its unit price and tooling costs are slightly higher than those of Supplier 2. The cash discount, quality cost, and delivery performance set Supplier 1 apart from Supplier 2. Using unit cost as the sole criterion to select a supplier would have ultimately cost the company $138,925.75 ($6,265,287.40 − $6,126,361.64) more in total purchase cost.

**Figure 2.6** Total Cost of Ownership Analysis

| Description | Supplier 1 | | | Supplier 2 | | |
|---|---|---|---|---|---|---|
| 1. Total Engine Cost | 12,000 units × $500 | | $6,000,000.00 | 12,000 units × $498 | | $5,976,000.00 |
| 2. Cash Discount | | | | | | |
| n/30 | $6,000,000 × 10% × 30/365 | $49,315.07 | | $5,976,000 × 10% × 30/365 | $49,117.81 | |
| 1/10 | N/A | | | $5,976,000 (10% × 10/365 + 1%) | $76,132.60 | |
| 2/10 | $6,000,000 (10% × 10/365 + 2%) | $136,438.36 | | N/A | | |
| Largest discount | | | $(136,438.36) | | | $(76,132.60) |
| 3. Tooling Cost | | | $22,000.00 | | | $20,000.00 |
| 4. Transportation Cost (22,000 lb LTL) | 125 miles × 12,000 units × 22 lb × $1.20/2000 | | $19,800.00 | 100 miles × 12,000 units × 22 lb × $1.20/2000 | | $15,840.00 |
| 5. Ordering Cost | (12,000/1000) × $125 | | $1500.00 | (12,000/1000) × $125 | | $1500.00 |
| 6. Carrying Cost | (1000/2) × $500 × 20% | | $50,000.00 | (1000/2) × $498 × 20% | | $49,800.00 |
| 7. Quality Cost | $6,000,000 × 2% | | $120,000.00 | $5,976,000 × 3% | | $179,280.00 |
| 8. Delivery Rating | | | | | | |
| Backorder (50%) | 12,000 × 1% × 50% × $15 | | $900.00 | 12,000 × 2% × 50% × $15 | | $1800.00 |
| Lost Sales (50%) | 12,000 × 1% × 50% × $4500 × 18% | | $48,600.00 | 12,000 × 2% × 50% × $4500 × 18% | | $97,200.00 |
| TOTAL COST | | | $6,126,361.64 | | | $6,265,287.40 |

## How Many Suppliers to Use

The issue of how many suppliers to use for each purchased item is a complex one. While numerous references propose the use of a single source for core materials and supplies to facilitate cooperative buyer–supplier partnerships, single sourcing can be a very risky proposition. Although Xerox and Chrysler had substantially reduced their supply bases in the 1980s, it was not documented that they resorted to single sourcing for their vital materials and components. The current trends in sourcing favor using fewer sources, although not necessarily a single source. Theoretically, firms should use single or a few sources, whenever possible, to enable the development of close relationships with the best suppliers. However, by increasing reliance on one supplier, the firm increases its risk that poor supplier performance, tsunamis, or some other natural disaster will result in plant shutdowns or poor-quality finished products. Although **sole sourcing** and **single sourcing** are sometimes used interchangeably, sole sourcing typically refers to the situation when the supplier is the only available source, whereas single sourcing refers to the deliberate practice of concentrating purchases of an item with one source from a pool of viable suppliers. A comparison follows, of some of the reasons favoring the use of a single supplier versus using two or more suppliers for a purchased item.

### Reasons Favoring a Single Supplier

1. *To establish a good relationship*: Using a single supplier makes it easier for the firm to establish a mutually beneficial strategic alliance relationship with the supplier, as with well-managed supply chains, especially when the firm can benefit from the supplier's technologies and capabilities.

2. *Less quality variability*: Since the same technologies and processes are used to produce the parts when using a single source, variability in the quality levels is less than if the parts are purchased from multiple suppliers.
3. *Lower cost*: Buying from a single source concentrates purchase volume with the supplier, typically lowering the purchase cost per unit. Due to the large purchase volume, the supplier is more likely to ensure that it meets all of its performance goals to keep the business. Single sourcing also avoids duplicate fixed costs, especially if the part requires special tooling or expensive setups.
4. *Transportation economies*: Because single sourcing concentrates volume, the firm can take advantage of truckload (TL) shipments, which are cheaper per unit than the less-than-truckload (LTL) rate. By moving up to full truckloads, the firm has the option of using both rail and motor carriers. Rail carriers are more efficient for hauling heavy loads over long distances.
5. *Proprietary product or process purchases*: If it is a proprietary product or process, or if the supplier holds the patents to the product or process, the firm has no choice but to buy from the sole source.
6. *Volume too small to split*: If the requirement is too small, it is not worthwhile to split the order among many suppliers. Single sourcing is a good approach for acquiring supplies and services that do not contribute to the firm's core competencies.

## Reasons Favoring Multiple Suppliers

1. *Need capacity*: When demand exceeds the capacity of a single supplier, the firm has no choice but to use multiple sources.
2. *Spread the risk of supply interruption*: Multiple sources allow the firm to spread the risk of supply interruptions due to a strike, quality problem, political instability, tariffs, pandemics, and other supplier problems.
3. *Create competition*: Using multiple sources encourages competition among suppliers in terms of price and quality. While modern supplier management philosophy opposes the use of multiple sources simply to create competition, this may still be the preferred approach for sourcing nonvital items that do not affect the firm's competitive advantage. Using a single source to develop alliances for these types of purchases may not be cost-effective.
4. *Information*: Multiple suppliers usually have more information about market conditions, new product developments, and new process technologies. This is particularly important if the product has a short product life cycle.
5. *Supplier diversity*: The firms, particularly government contractors, may need to give portions of their purchases to small, local, or women- or minority-owned businesses, either voluntarily or as required by law such as the Public Law 95-507 in the United States.

The number of suppliers to use for one type of purchase has changed from the traditional multiple suppliers to the use of fewer, more reliable suppliers and even to the extent of using a single, highly rated, and trusted supplier. Relationships between buyers and suppliers traditionally were short-term, adversarial, and based primarily on cost, resulting in a mutual lack of trust. Buyer–supplier relationships, particularly in integrated supply chain settings, have evolved today into trusting, cooperative, and mutually beneficial long-term relationships. Firms today reduce their supply base to only the best suppliers.

## Purchasing Organization

Purchasing's organization within the firm has evolved over the years as the responsibilities of the purchasing function of firms changed from a clerical, supporting role to an integral part of corporate strategy that directly affects the competitiveness of the firms. In addition to the actual buying process, purchasing personnel are now involved in product design, production decisions, supplier relationship management, and other aspects of a firm's operations. The decision of how to organize purchasing to best serve its purpose is firm and industry-specific and dependent on many factors, such as market conditions and the types of parts and materials required. Purchasing structure can be viewed as a continuum, with centralization at one extreme and decentralization at the other. While there are few firms that adopt a pure centralized or decentralized structure, the benefits of each are worth a closer examination. The current trend is toward purchasing centralization for the vital materials where firms can take advantage of economies of scale and other benefits.

**Centralized purchasing** is where a single purchasing department, usually located at the firm's corporate office, makes all the purchasing decisions, including order quantity, pricing policy, contracting, negotiations, and supplier selection and evaluation. **Decentralized purchasing** is where individual, local purchasing departments, such as at the plant level, make their own purchasing decisions. A discussion of advantages and disadvantages to each of these purchasing structures follows.

### Advantages of Centralization

1. *Concentrated volume*: An obvious benefit is the concentration of purchase volume to create quantity discounts, less-costly volume shipments, and other more favorable purchase terms. This is often referred to as **leveraging purchase volume**. A centralized system also provides the buying firm more clout and bargaining power. Suppliers generally are more willing to negotiate, give better terms, and share technology due to the higher volume.
2. *Avoid duplication*: Centralized purchasing eliminates the duplication of job functions. A corporate buyer can research and issue a large purchase order to cover the same material requested by all units, thus eliminating duplication of activities. This also results in fewer buyers, reducing labor costs.
3. *Specialization*: Centralization allows buyers to specialize in a particular product or group of items instead of being responsible for all purchased materials and services. It allows buyers to spend more time and resources to research items for which they are responsible, thus becoming specialized buyers.
4. *Lower transportation costs*: Centralization allows larger shipments to be made to take advantage of truckload or railcar shipments, and yet smaller shipments still can be arranged for delivery directly from suppliers to the points of use.
5. *No competition between units*: Under the decentralized system, when different units purchase the same material, a situation may be created in which units are competing among themselves, especially when scarce materials are purchased from the same supplier. Centralization minimizes this problem. This is a major reason that COVID-19 vaccines are procured by the U.S. federal government and then allocated to the 50 states and territories, instead of allowing each state to procure its own vaccines directly from the manufacturers.[20]
6. *Common supply base*: A common supply base is used, thus making it easier to manage and negotiate contracts.

## Advantages of Decentralization

1. *Better knowledge of unit requirements*: A buyer at the individual unit is more likely to know its exact needs better than a central buyer at the home office.
2. *Local sourcing*: If the firm desires to support local businesses, it is more likely that a local buyer will know more about local suppliers. The proximity of local suppliers allows materials to be shipped more frequently in small lot sizes and is conducive to the creation of closer supplier relationships.
3. *Less bureaucracy*: Decentralization allows quicker response due to less bureaucracy and closer contact between the user and the buyer. Coordination and communication with operations and other divisions are more efficient.

Thus, while centralized purchasing may result in lower costs and better negotiating power, the centralized system may also be too rigid and even infeasible for large, multi-unit organizations consisting of several unrelated business operations. For these reasons, a **hybrid purchasing organization** may be warranted. Large multi-unit organizations may use a **decentralized/centralized purchasing structure** to decentralize purchasing at the corporate level, while centralizing the procurement function at the business unit level. Conversely, a firm may utilize a **centralized/decentralized purchasing structure** to negotiate national contracts at the corporate level, while decentralizing buying at the business unit level. These hybrid purchasing organizations allow firms to exploit the advantages of both the centralized and decentralized systems.

## Global Sourcing

International agreements aimed at relaxing trade barriers and promoting free trade have provided opportunities for firms to expand their supply bases to participate in **global sourcing** (also occasionally referred to as international purchasing). Indeed, world merchandise exports and commercial services trade were $19.051 trillion and $5.898 trillion, respectively in 2019.[21] In 2019, the world's largest merchandise exporters were the European Union (exports were $5.815 trillion, imports were $5.532 trillion), followed by China (exports were $2.499 trillion, imports were $2.078 trillion), the United States (exports were $1.643 trillion, imports were $2.567 trillion), and Germany (exports were $1.489 trillion, imports were $1.234).[22] In the same year, the United States was the world's largest exporter of commercial services (exports were $853 billion, imports were $564 billion), followed by the United Kingdom (exports were $412 billion, imports were $279 billion), Germany (exports were $335 billion, imports were $363 billion), France (exports were $287 billion, imports were $263 billion), and China (exports were $282 billion, imports were 564 billion).[23] For 2020, world merchandise trade was predicted to decline by 9.2 percent due to the COVID-19 induced slump, but was forecasted to rise by 7.2 percent in 2021.[24]

While global sourcing provides opportunities to improve quality, cost, and delivery performance, it also poses unique challenges for purchasing personnel. Engaging in global sourcing requires additional skills and knowledge to deal with international suppliers, logistics, communication, political, cultural, and other issues not usually encountered in domestic sourcing. The total cost of ownership illustration in Example 2.1 can also be used to compare the cost-effectiveness of domestic versus global sourcing. Various methods are employed for global sourcing. It is not merely limited to setting up an international purchasing office or using existing purchasing personnel to handle the transactions

in-house. An **import broker** or **sales agent**, who performs transactions for a fee, can be used. Import brokers and sales agents do not take title to the goods. Instead, title passes directly from the seller to the buyer. International purchasers can also buy foreign goods from an **import merchant**, who buys and takes title to the goods and then resells them to the buyer. Purchasing from a **trading company**, which carries a wide variety of goods, is another option.

There are numerous international trade organizations designed to reduce tariff and nontariff barriers among member countries. A **tariff** is an official list or schedule showing the duties, taxes, or customs fees imposed by the host country on imports or exports. **Nontariff barriers** are import quotas, licensing agreements, embargoes, laws, and other regulations imposed on imports and exports. A discussion of major international trade organizations follows.

1. The *World Trade Organization* (WTO) is the largest and most visible international trade organization dealing with the global rules of trade between nations. It replaced the General Agreement on Tariffs and Trade (GATT) on January 1, 1995. Its main goal is to ensure that international trade flows smoothly, predictably, and freely among member countries. The WTO Secretariat is based in Geneva, Switzerland, and is headed by a Director-General. It has had 164 member countries since July 2016.[25]
2. The *United States-Mexico-Canada Agreement* (USMCA) was signed by the named countries and took effect on July 1, 2020. It replaced the *North American Free Trade Agreement* (NAFTA) which was enacted in 1994 to remove trade and investment barriers for the United States, Canada, and Mexico. Under NAFTA, all nontariff agricultural trade barriers between the U.S and Mexico were removed, and most agricultural trade tariffs between the United States and Canada were removed by 1998. NAFTA was fully implemented as of January 1, 2008.[26] The new USMCA modernizes and addresses some deficiencies in the 25-year-old NAFTA, including intellectual property protection and enforcement, digital trade (such as e-books, videos, music, software, and games), financial services, currency, labor, and the environment.[27]
3. The *European Union* (EU) was set up on May 9, 1950, and was comprised of Belgium, France, Luxembourg, Italy, the Netherlands, and Germany. The United Kingdom, Denmark, and Ireland joined the EU in 1973. As of March 2021, the EU has twenty-seven member countries. The United Kingdom withdrew from the EU on 31 January 2020.[28] One of the primary goals of the EU is to create a single market without internal borders for goods and services, allowing member countries to better compete with markets like the United States and China. The EU also allows its citizens to study, live, work, and retire in any EU country.

## Reasons for Global Sourcing

Firms expand their supply bases to include foreign suppliers for many reasons. These can include lower price, better quality, an overseas supplier holding the patent to the product, faster delivery to overseas facilities, better services, and better process or product technologies.

A primary reason that many firms purchase from foreign suppliers is to lower the price of materials. As stated earlier, price generally is an important factor when purchasing standard materials and supplies that do not impact the competitive position of the firm.

Many factors can contribute to cheaper materials from overseas suppliers—for example, cheaper labor costs and raw materials, favorable exchange rates, more efficient processes, or intentional dumping of products by foreign suppliers in overseas markets.

Additionally, the quality of overseas products may be better due to newer and better product and process technologies. Further, while foreign suppliers may be located farther away, they may be able to deliver goods faster than domestic suppliers due to better transportation and logistical systems. Foreign suppliers may even maintain inventory and set up support offices in the host country to compete with domestic sources and to provide better services.

Firms may buy from foreign suppliers to support the local economy where they have subsidiaries, or they may be involved in **countertrade**, in which the contract calls for the exchange of goods or services for raw materials from local suppliers. While foreign purchasing may provide several benefits to the buyer, some problems may also be encountered.

## Potential Challenges for Global Sourcing

Despite the recent trade tensions between the world's two largest economies, the United States and China, global sourcing has surged over the last several decades due to many factors, such as the improvement of communication and transportation technologies, the reduction of international trade barriers, and deregulation of the transportation industry. However, global sourcing poses additional challenges that purchasing personnel must know how to handle effectively. For example, the complexity and costs involved in selecting foreign suppliers and dealing with duties; tariffs; customs clearance; currency exchange; the global pandemic; and political, cultural, labor, and legal problems, present sizable challenges for the international buyer.

Unlike dealing with domestic suppliers, the costs involved in identifying, selecting, and evaluating foreign suppliers can be prohibitive. A foreign supplier in a distant location, with customs clearance, transportation, and other logistical issues may render delivery lead time unacceptable, especially for perishable goods. The recent COVID-19 pandemic underscored an acute challenge of global sourcing that has not been seen before. The global crisis forced many manufacturers to reassess their sourcing strategies that might have overly relied on overseas suppliers. While many multinational corporations source globally for better quality materials and component parts, the opposite can also be true. It is not uncommon for multinational corporations to suffer irreparable damage to their reputations and incur expensive legal liabilities for unknowingly purchasing tainted raw materials or faulty component parts from overseas suppliers.

### Countertrade

Global sourcing may involve countertrade, in which goods and/or services of domestic firms are exchanged for goods and/or services of equal value or in combination with currency from foreign firms. This type of arrangement is sometimes used by countries where there is a shortage of hard currency or as a means to acquire technologies. Countertrade transactions are more complicated than currency transactions because goods are exchanged for goods.

The various forms of countertrade include barter, offset, and counterpurchase. **Barter** is the complete exchange of goods or services of equal value without the exchange of currency. The seller can either consume the goods or services or resell the items. **Offset** is an exchange agreement for industrial goods or services as a condition of military-related

export. It is also commonly used in the aerospace and defense sectors. Most of the offset packages are divided into direct and indirect offsets. **Direct offset** usually involves coproduction, or a joint venture and exchange of related goods or services; whereas **indirect offset** involves exchange of goods or services unrelated to the initial purchase. **Counterpurchase** is an arrangement whereby the original exporter agrees to sell goods or services to a foreign importer and simultaneously agrees to buy specific goods or services from the foreign importer. Many developing countries mandate the transfer of technology as part of a countertrade or offset arrangement.

## International Trade Law and Commercial Terms

In addition to the Uniform Commercial Code (UCC), which governs the purchase and sale of goods in the United States (except the state of Louisiana), global purchasers must also know the United Nations' **Contracts for the International Sale of Goods** (CISG). The CISG applies to international sales of goods between private businesses, unless both parties elect to opt out. The CISG is the backbone for international sales contracts but it is irrelevant to the sales of services or sales of goods to consumers.[29] The UCC allows either party to modify the terms of acceptance for the purchase contract; however, the terms of acceptance cannot be modified under the CISG.

Global purchasers must also deal with more complex shipping terms than domestic buyers. The International Chamber of Commerce created a uniform set of three-letter trade terms or rules, called **incoterms** (which is the acronym for **International Commercial Terms**), to simplify international transactions of goods with respect to transport obligations, costs, and risks of buyer and seller. However, incoterms do not deal with transfer of title and contractual payment terms of the goods, dispute resolutions, effect of sanctions, tariffs, or consequences for breach of performance; hence incoterms are not a substitute for a sales contract, but are an important part of the contract. Incoterms are often used in conjunction with a geographical location and its version; for example, FOB Port of Los Angeles Incoterms 2020 or CPT Customer warehouse Las Vegas, U.S. Incoterms 2020. The two terms, FOB and CPT are defined below. *Incoterms 2010* revised the thirteen incoterms adopted in 2000 from four categories to eleven rules in two categories. Subsequently, on January 1, 2020, *Incoterms 2010* was revised to become *Incoterms 2020,* which replaced the term DAT (Delivered at Terminal) with DPU (Delivered at Place Unloaded) and refined the term CIP (Carriage and Insurance Paid To). However, parties to a domestic or international sales transaction can agree to use any version of incoterms. Incoterms 2020 also consists of eleven rules that are divided into two categories based on method of delivery. Seven of the eleven rules are applicable to sales that involve any mode or modes of delivery, whereas the remaining four rules are applicable to sales that involve transportation over water.[30] The two categories and eleven incoterms are:

(I) Rules for Any Mode or Modes of Transport

1. EXW (Ex Works)

   The seller delivers the goods at the buyer's disposal at the seller's premises or a named place such as factory or warehouse. The seller is not responsible for contract of carriage, insurance, export clearance formalities or loading the goods into collecting vehicle. Delivery occurs and the risk of loss or damage transfers from the buyer to seller when goods are placed at the agreed place for buyer's disposal.

2. FCA (Free Carrier)

   The seller delivers the goods to the carrier or a person nominated by the buyer at the seller's premises or a named place. If the seller's premises is the place of delivery, the seller must load the goods. Otherwise, the seller is not responsible for unloading. The risk of loss or damage passes to the buyer when goods are delivered at the named place, hence the precise point of delivery must be explicitly stated. The seller is responsible for export clearance formalities, but not contract of carriage or insurance.

3. CPT (Carriage Paid To)

   The seller delivers the goods to the carrier or a person nominated by the seller at an agreed place. The seller is not responsible for insurance but must contract and pay for carriage to the named place. Also, the seller is responsible for export clearance formalities, whereas the buyer is responsible for import clearance formalities.

4. CIP (Carriage and Insurance Paid To)

   The seller has the same responsibilities as CPT, but they also contract and pay for insurance coverage against the risk of loss or damage to the goods during the carriage until the named place of destination. In the case of loss or damage, the buyer can claim directly with the insurance company.

5. DAP (Delivered at Place)

   The seller delivers the goods to a mutually agreed destination that is usually further than the arriving terminal. This rule is normally used when more than one transport mode is used. The seller delivers when the goods are placed at the buyer's disposal on the arriving transport vehicle ready for unloading at the named place of destination. The seller is not required to unload the goods from the transport vehicle or provide insurance against the risk of loss or damage but is responsible for contract of carriage to the agreed delivery point and export clearance formalities. The seller bears the risk of loss or damage until the goods are delivered at the named place.

6. DPU (Delivered at Place Unloaded)

   The DPU rule replaced the former DAT rule by requiring the seller to unload the goods from the arriving transport vehicle. The seller delivers and unloads the goods from arriving transport vehicle at the buyer's disposal at a named place of destination. The seller is responsible for contract of carriage to the agreed delivery point and export clearance formalities but not require insuring the goods although they bear the risk of loss or damage until the goods are delivered at the named place.

7. DDP (Delivered Duty Paid)

   This rule put the maximum obligation and risk on the seller. The seller delivers the goods at the buyer's disposal on the arriving vehicle, cleared for import formalities, paid all duties, taxes and other destination charges, and ready for unloading at the named place of destination. This rule is usually used when more than one transport mode is used. The seller is responsible for all transport costs and contract of carriage until the goods are delivered to the buyer at the named place. However, the seller does not pay for unloading the goods from the arriving vehicle or require insuring the goods against risk of loss or damage.

(II) Rules for Sea and Inland Waterway Transport

8. FAS (Free Alongside Ship)

   The seller clears the goods for export and delivers them alongside the vessel nominated by the buyer. Delivery occurs when the goods are placed alongside the vessel. The seller is responsible for paying export clearance expenses, but not obligated to contract for carriage or insure the goods. This rule is used for sea or inland waterway transport, whereas FCA is more appropriate for goods handed to a carrier in a container terminal. The FAS rule is widely used for sales of bulk commodities like grains and oil.

9. FOB (Free on Board)

   The seller clears the goods for export and delivers them on board the vessel nominated by the buyer at the named port of shipment. The risk of loss or damage to the goods passes to the buyer when the goods pass the ship's rail at the agreed port. The seller is responsible for export customs clearance, origin terminal handling charge, and other costs associated with moving the goods on board the vessel at the origin port. However, the seller is not obligated to contract for carriage or insuring the goods. The FOB rule is also widely used for sales of bulk commodities like grains and oil. If goods are packed in containerized cargo and handled at a container terminal, then the FCA rule is more appropriate.

10. CFR (Cost and Freight)

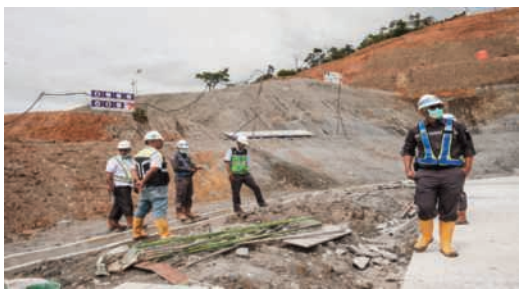
    The seller clears the goods for export and delivers them on board the vessel at the port of loading. The seller contracts for carriage and pays for freight to transport the goods to the named port of destination, but delivery occurs and the risk of loss or damage transfers to buyer once the goods are on board the vessel at port of loading. The seller is not obligated to insure the goods. This rule is normally used for bulk chemical or agricultural products where the seller has the buying power and logistics expertise. For containerized goods, the CPT rule is more appropriate.

11. CIF (Cost Insurance and Freight)

    This rule is like the CFR term, except that the seller is also obligated to insure the goods against risk of loss or damage until the named port of destination. Similar to the CFR rule, delivery occurs and the risk of loss or damage transfers to buyer once the goods are on board the vessel at port of loading.

## SCM Profile — Public Procurement and Market Instability

Carillion was a British multinational construction and facilities management services public limited company listed on the London Stock Exchange. It was founded in July 1999, headquartered in Wolverhampton in the United Kingdom, and expanded to become the second largest construction company in the United Kingdom. Unfortunately, it collapsed



Kingfajr/Shutterstock.com

in January 2018 to become one of the largest ever trading liquidations in the United Kingdom. After its government refused to bail it out, Carillion folded under the weight of a whopping £1.5 billion debt. Prior to its liquidation, Carillion held 450 government contracts, maintained 50 prisons and 50,000 homes for U.K. military personnel, provided 11,500 in-patient hospital beds, with 43,000 global employees.[31]

Carillion's insiders cited Brexit uncertainty, an unpaid bill owed by Qatar, and problems building the Royal Liverpool Hospital, for the company's liquidation. As the company underperformed on its contracts and debts soared, it needed a cash injection, but banks refused to infuse new cash and the U.K. government refused to bail it out, despite it being one of the largest government outsourcing suppliers. Carillion's external auditor, KPMG, was under investigation by the United Kingdom's Financial Conduct Authority and faced a £250 million negligence lawsuit. Carillion's collapse compromised 30,000 pensions and 20,000 jobs were lost.

Globally, governments have increasingly outsourced functions and services that were traditionally performed in-house like prison management and facilities maintenance, thus creating an intricate relationship between the government and its contractors. This also exposed the government to higher levels of risk with underperforming contractors such as Carillion. In many instances, government contractors need the government to sustain their businesses, and conversely, the government needs its contractors to deliver services and build projects at lower costs.

The colossal failure of Carillion in the United Kingdom leads to the question of whether the U.S. government is vulnerable to a similar disaster? Some government procurement experts argue that the U.S. government is unlikely to encounter a crisis like Carillion's collapse in the United Kingdom because of supplier diversity requirements in the United States. The passage of Public Law 95-507 in 1978 made it mandatory that small businesses owned and controlled by socially and economically disadvantaged individuals be given maximum practical opportunity to participate in public contracts over $10,000. Also, the U.S. Congress has mandated that small businesses must be awarded at least 23 percent of all federal government contracting dollars. Government purchases greater than the micro-purchase threshold of $10,000 but less than the simplified acquisition threshold of $250,000 are automatically reserved for small businesses. These requirements make it implausible for a single large company to secure large segments of government contracts. Instead, a significant portion of the U.S. federal government contracts are spread out among multiple contractors.

There is a major difference in the public procurement market in the Europe Union. The Treaty for the Functioning of the European Union forbids setting aside government contracts to favor small and med-size enterprises. The major goal of the European Union is to promote competition in an open market among sovereign states. Preferential policies for specific sectors of the economies are forbidden. The treaty suggests that procuring government contracts in the open market could lower costs because of cheaper foreign sources in the European Union and domestic firms are forced to lower prices to compete against foreign firms. However, when cost becomes the primary factor for winning government contracts, a single large company might secure most of the contracts, even if they are attained at below market prices.

While U.S. government contracts are protected by supplier diversity requirements, the risk to individual small and mid-size businesses is greater because these businesses must limit their awarded contracts to remain small or mid-size. Therefore, the potential impacts from the failure of a contract can have substantial consequence on these businesses. While critics argue that small and mid-size businesses are less efficient and more expensive, they insulate the U.S. government from the impacts of a Carillion-like crisis. The bottom line is that, regardless of the market structure, government contracting officers must pay close attention to their contractors' financial positions and going concerns to minimize performance risk.[32]

## Procurement in Government and Nonprofit Agencies

**Public procurement** or **public purchasing** refers to the management of the purchasing and supply management function in the government and nonprofit sectors, such as educational institutions; hospitals; and federal, state, and local governments. Although public procurement is subjected to political pressure and public scrutiny, its goals are similar to the private sector. However, public procurement is subjected to special rules and regulations that are established by the federal, state, and local governments. For example, all U.S. federal government purchases must comply with the **Federal Acquisition Regulation** (FAR).[33] Consequently, the procedures for public procurement differ from the private sector—in addition to ensuring that purchases for goods and services are in strict compliance with statutes and policies, public procurement procedures are generally designed to **maximize competition**. The e-procurement system described in Figure 2.4 is an example of a public procurement system. In addition to the typical operations control, the e-procurement system in Figure 2.4 requires additional treatments of purchases exceeding $25,000.

In the United States, the **General Services Administration** (GSA), passed by the 81st Congress and signed into law by President Harry Truman in 1949, is responsible for most federal purchases. The GSA, based in Washington, D.C., has eleven regional offices in Boston, New York, Philadelphia, Atlanta, Chicago, Kansas City, Fort Worth, Denver, San Francisco, Auburn (Washington), and Washington, D.C. It is one of the world's largest purchasing entities. The **Department of Defense** (DOD) and the **National Aeronautics and Space Administration** are the other two major public procurement entities in the United States.

### Characteristics of Public Procurement

A unique characteristic of public procurement is the preference to use competitive bidding to encourage competition among suppliers. For example, a local government agency may implement procurement procedures that require a written quote for purchases that are more than $3000 but less than $10,000, two written quotes for purchases that are less than $25,000, three written quotes for purchases less than $100,000, and competitive bids for purchases over $100,000.

In competitive bidding, the contract is usually awarded to the *lowest-priced bidder* determined to be *responsive* and *responsible* by the buyer. A responsive bid is one that conforms to the invitation to bid, and a responsible bid is one that is capable and willing to perform the work as specified.

The bidding process is usually very time-consuming and not cost-efficient for small purchases. On October 13, 1994, U.S. President Bill Clinton signed the **Federal Acquisition Streamlining Act** (FASA) to remove many restrictions on government purchases below the **simplified acquisition threshold** of $100,000. The threshold was raised to $250,000 in 2018. Instead of using full and open competitive bidding, government agencies can now use simplified procedures that require fewer administrative details, lower approval levels, and less documentation for soliciting and evaluating bids up to $250,000. **Micro-purchases**, government purchases of $10,000 and below, can now be made without obtaining competitive quotes. Additionally, all federal purchases above the micro-purchase threshold of $10,000 but below

the simplified acquisition threshold of $250,000 are reserved for small businesses, unless the buyer cannot obtain offers from two or more small businesses that are competitive on price, quality, and delivery. A small business is a privately owned corporation, partnership or sole proprietorship that has fewer employees and less annual revenue than a regular-sized business in the same industry. The U.S. Small Business Administration published guidelines and size standards based on the number of employees or annual revenues to determine whether a business can compete for contracts reserved for small businesses.

When the requirements are clear, accurate, and complete, the government agency usually uses an **invitation for bid** (IFB) to solicit **sealed bids**. The specifications for the proposed purchase; instructions for preparation of bids; and the conditions of purchase, delivery, and payment schedule are usually included with the IFB. The IFB also designates the date and time of bid opening. Sealed bids are opened in public at the purchasing office at the time designated in the invitation, and facts about each bid are read aloud and recorded. A contract is then awarded to the lowest responsible and responsive bidder.

Generally, bidders are also required to furnish bid bonds to ensure that the successful bidder will fulfill the contract as stated. There are three basic types of bid bond: **bid** or **surety bonds** guarantee the successful bidder will accept the contract; **performance bonds** guarantee the work of the successful bidder meets specifications and in the time stated; and **payment bonds** protect the buyer against any third-party liens not fulfilled by the bidder.

Another characteristic of public procurement is the **Buy American** Act that mandates U.S. government purchases and third-party purchases that utilize federal funds to buy domestically produced goods, if the price differential between the domestic product and an identical foreign-sourced product does not exceed a certain percentage amount. The two necessary conditions for the act to be applied are that the procurement is intended for public use within the United States, and the materials to manufacture the goods are available in the United States in satisfactory quality and sufficient quantity. However, the provisions of the act may be waived if the head of the procuring agency determines that it is inconsistent with public interest or the cost of the domestic product is unreasonable.

While **green purchasing** is not a new sourcing concept, there is a push to expand green purchasing requirements in the public sector. There are many federal statutes and presidential executive orders requiring federal purchasing officials to include environmental considerations and human health when making purchasing decisions. Public procurement advocates the purchase of more energy-efficient products, bio-based products, recycled content products, non-ozone-depleting substances, green power, and other environmentally friendly products. The GSA consolidates and publishes a comprehensive green purchasing resource for federal contracting personnel and program managers.[34]

## Summary

Over the last two decades, the purchasing function has evolved into an integral part of supply chain management. Purchasing is an important strategic contributor to overall business competitiveness. It is the largest single function in most organizations, controlling activities and transactions valued at more than 50 percent of sales. Every dollar saved due to better purchasing impacts business operations and profits directly. Purchasing personnel talk to customers; users; suppliers; and internal design, finance, marketing, and operations personnel, in addition to top management. The information they gain from all this exposure can be used to help the firm to provide better, cheaper, and more timely products and services to both internal and external customers. Savvy executives are thus turning to purchasing to improve business and supply chain performance.

## Key Terms

**backward vertical integration,** 59
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**total cost of ownership,** 65
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**traveling requisition,** 51
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## Discussion Questions

1. Describe the steps in a traditional manual purchasing system.
2. Describe the e-procurement system and its advantages over the manual system. Are there any disadvantages to the electronic system? Do you think the e-procurement system will ultimately replace the manual system? Why or why not?
3. How can purchasing help to improve the competitive edge of an organization?
4. What is the profit-leverage effect of purchasing? What is the return-on-assets effect of purchasing?
5. What does inventory turnover measure? Is a higher or lower turnover preferred in general?
6. How does a merchant differ from an industrial buyer?
7. Describe the purpose of a material requisition, a purchase order, a request for quotation, and a request for proposal. Does the material requisition serve the same purpose as the purchase order?
8. Why are small-value purchase orders problematic? How can purchasing more effectively deal with this problem?
9. Should unit price be used as the sole criterion for selecting suppliers? Why?
10. Explain backward vertical integration. What are the advantages of outsourcing compared to backward vertical integration?
11. When should a firm outsource instead of making the items in-house?
12. What factors should be considered while choosing suppliers?
13. What is supplier diversity, and how does a supplier prove their diversity status?
14. Describe the difference between sole source and single source.
15. What are the reasons to use a single supplier? Is this the most efficient way to purchase materials in general?
16. Describe centralized and decentralized purchasing and their advantages.
17. Describe how the hybrid purchasing organization works.
18. Describe how blanket orders and blanket order releases can be used to manage the procurement system of a business that owns a dozen large restaurants in a city.
19. What are the two categories of Incoterms 2020? How many rules are in each category?
20. How does public procurement differ from corporate purchasing?
21. Describe the different types of bid bonds.
22. What are micro-purchases? How can they be used to improve public procurement?
23. What is the current simplified acquisition threshold? How does simplified acquisition help to improve public procurement?
24. Why do firms purchase from foreign suppliers? What are the risks involved in global sourcing?
25. What is countertrade? Describe the various types of countertrade.

26. Describe how a typical government bidding process is conducted.
27. How can global sourcing enhance a firm's competitiveness?
28. Describe the disadvantages of global sourcing and how it can adversely affect a firm's competitiveness.
29. Describe Tier-1, Tier-2, and Tier-3 suppliers.

## Essay/Project Questions

1. Go to the World Trade Organization's website and use the information to write a report that includes (a) the functions of the WTO, (b) the latest number of membership countries, (c) its relationship with GATT, (d) the number of countries that had originally signed the GATT in 1994, and (e) the last five countries that became members of the WTO.
2. Go to the European Union's website and use the information to write a report that includes its purpose and membership countries. Is the United Kingdom a member of the European Union?
3. Utilize the Internet to search for "incoterms 2020." Write a report to (a) summarize the incoterms into two groups and (b) describe each of the eleven terms.
4. Go to the General Services Administration's website and use the information to write a brief report to summarize the roles of GSA. Additionally, discuss the roles of the Federal Acquisition Regulation (FAR), Federal Management Regulation (FMR), and the Federal Travel Regulation (FTR).

## Spreadsheet Problems

1. If a firm's net income (profits before taxes) is $120,000 and it has total assets of $1.5 million, what is its return on assets?
2. If a firm's total assets is $1.2 million and its net income is $100,000, what is its return on assets?
3. If a firm's total assets is $2.5 million and its return on assets is 12 percent, what is its net income?
4. If a firm's net income is $100,000 and its return on assets is 10 percent, what is its total assets?
5. If a firm can sustain the same level of operations in terms of sales and administrative expenses but reduces its materials cost by $50,000 through smarter purchases, what is the profit-leverage effect on gross profits? What is the profit-leverage effect on profits before taxes?
6. If a firm's cost of goods sold is $2.5 million and its average inventory is $500,000, what is the inventory turnover?
7. If a firm's cost of goods sold for the year is $2 million, and beginning and ending inventories for the year are $280,000 and $120,000 respectively, what is the annual inventory turnover?
8. If a firm's cost of goods sold is $5 million and its inventory turnover is ten times, what is the average inventory?

**9.** If a firm's inventory turnover is eight times and its average inventory is $160,000, what is the cost of goods sold?

**10.** A retailer in Las Vegas has an ending inventory of $250,000 as of December 31, 2019, and the following accounting information.

| MONTH | ENDING INVENTORY | COST OF GOODS SOLD |
|---|---|---|
| January 2020 | $225,000 | $1,200,000 |
| February 2020 | $325,000 | $1,250,000 |
| March 2020 | $240,000 | $1,350,000 |
| April 2020 | $325,000 | $1,500,000 |
| May 2020 | $460,000 | $950,000 |
| June 2020 | $220,000 | $850,000 |
| July 2020 | $85,000 | $1,650,000 |
| August 2020 | $156,000 | $1,325,000 |
| September 2020 | $220,000 | $1,750,000 |
| October 2020 | $265,000 | $850,000 |
| November 2020 | $100,000 | $2,200,000 |
| December 2020 | $350,000 | $3,500,000 |

**a.** Compute the monthly inventory turnover ratio for each of the twelve months.
**b.** What are the annual cost of goods sold and the average inventory for the year?
**c.** Compute the annual inventory turnover ratio. How is the retailer's performance compared to the industry standard, assuming its business is similar to Walmart's?

**11.** A small firm has a beginning inventory of $52,000 as of January 1, 2020, and the following accounting information.

| MONTH | ENDING INVENTORY | COST OF GOODS SOLD |
|---|---|---|
| January 2020 | $75,000 | $225,000 |
| February 2020 | $56,000 | $325,000 |
| March 2020 | $25,000 | $240,000 |
| April 2020 | $85,000 | $325,000 |
| May 2020 | $125,000 | $460,000 |
| June 2020 | $95,000 | $220,000 |
| July 2020 | $72,000 | $85,000 |
| August 2020 | $45,000 | $156,000 |
| September 2020 | $52,500 | $220,000 |
| October 2020 | $120,000 | $265,000 |
| November 2020 | $162,500 | $100,000 |
| December 2020 | $255,000 | $350,000 |

**a.** Compute the monthly inventory turnover ratio for each of the twelve months.
**b.** What are the annual cost of goods sold and the average inventory for the year?
**c.** Compute the annual inventory turnover ratio. What can the purchasing department do to improve the firm's performance?

**12.** You are given the following information:

| COSTS | MAKE OPTION | BUY OPTION |
|---|---|---|
| Fixed Cost | $125,000 | $5000 |
| Variable Cost | $15 | $17 |

**a.** Find the break-even quantity and the total cost at the break-even point.
**b.** If the requirement is 150,000 units, is it more cost-effective for the firm to buy or make the components? What is the cost savings for choosing the cheaper option?

**13.** You are given the following information:

| COSTS | MAKE OPTION | BUY OPTION |
|---|---|---|
| Fixed Cost | $25,000 | $3000 |
| Variable Cost | $8 | $12 |

**a.** Find the break-even quantity and the total cost at the break-even point.
**b.** If the requirement is 4500 units, is it more cost-effective for the firm to buy or make the components? What is the cost savings for choosing the cheaper option?
**c.** If the requirement is 6000 units, is it more cost-effective for the firm to buy or make the components? What is the cost savings for choosing the cheaper option?

**14.** Ms. Jane Kim, Purchasing Manager of Kuantan ATV, Inc., is negotiating a contract to buy 20,000 units of a common component part from a supplier. Ms. Kim has done a preliminary cost analysis on manufacturing the part in-house and concluded that she would need to invest $50,000 in capital equipment and incur a variable cost of $25 per unit to manufacture the part in-house. Assuming the total fixed cost to draft a contract with her supplier is $1000, what is the maximum purchase price that she should negotiate with her supplier? What other factors should she negotiate with the suppliers?

**15.** A Las Vegas, Nevada, manufacturer has the option to make or buy one of its component parts. The annual requirement is 20,000 units. A supplier can supply the parts for $10 each. The firm estimates that it costs $600 to prepare the contract with the supplier. To make the parts in-house, the firm must invest $50,000 in capital equipment and estimates that the parts cost $8 each.
**a.** Assuming that cost is the only criterion, use break-even analysis to determine whether the firm should make or buy the item. What is the break-even quantity, and what is the total cost at the break-even point?
**b.** Calculate the total costs for both options at 20,000 units. What is the cost savings for choosing the cheaper option?

**16.** Given the following information, use total cost analysis to determine which supplier is more cost-effective. Late delivery of raw material results in 60 percent lost sales and 40 percent back orders of finished goods.

| | |
|---|---|
| Order lot size | 1000 |
| Requirements (annual forecast) | 120,000 units |
| Weight per engine | 22 pounds |
| Order processing cost | $125/order |
| Inventory carrying rate | 20% per year |
| Cost of working capital | 10% per year |
| Profit margin | 15% |
| Price of finished goods | $4500 |
| Back-order cost | $15 per unit |

| ITEMS | SUPPLIER 1 | SUPPLIER 2 |
|---|---|---|
| 1 to 999 units/order | $50.00/unit | $49.50/unit |
| 1000 to 2999 units/order | $49.00/unit | $48.50/unit |
| 3000+ units/order | $48.00/unit | $48.00/unit |
| Tooling cost | $12,000 | $10,000 |
| Terms | 2/10, net 30 | 1/10, net 30 |
| Distance | 125 miles | 100 miles |
| Supplier quality rating | 2% | 2% |
| Supplier delivery rating | 1% | 2% |

Truckload (TL ≥ 40,000 lbs): $0.85 per ton-mile

Less-than-truckload (LTL): $1.10 per ton-mile

Note: per ton-mile = 2000 lbs per mile; number of days per year = 365

**17.** A buyer received bids from three suppliers for a vital component part for its latest product. Given the following information, use total cost analysis to determine which supplier should be chosen. Late delivery of the component results in 70 percent lost sales and 30 percent back orders of finished goods.

| | |
|---|---|
| Order lot size | 2000 |
| Requirements (annual forecast) | 240,000 units |
| Weight per engine | 40 pounds |
| Order processing cost | $200/order |
| Inventory carrying rate | 20% per year |
| Cost of working capital | 10% per year |
| Profit margin | 15% |
| Price of finished goods | $10,500 |
| Back-order cost | $120 per unit |

| ITEMS | SUPPLIER 1 | SUPPLIER 2 | SUPPLIER 3 |
|---|---|---|---|
| 1 to 999 units/order | $200.00/unit | $205.00/unit | $198.00/unit |
| 1000 to 2999 units/order | $195.00/unit | $190.00/unit | $192.00/unit |
| 3000+ units/order | $190.00/unit | $185.00/unit | $190.00/unit |
| Tooling Cost | $12,000 | $10,000 | $15,000 |
| Terms | 2/10, net 30 | 1/15, net 30 | 1/10, net 20 |
| Distance | 120 miles | 100 miles | 150 miles |
| Supplier quality rating | 2% | 1% | 2% |
| Supplier delivery rating | 1% | 1% | 2% |

Truckload (TL ≥ 40,000 lbs): $0.95 per ton-mile

Less-than-truckload (LTL): $1.20 per ton-mile

Note: per ton-mile = 2000 lbs per mile; number of days per year = 365

# Cases

## 1.3 Bees Buttermilk Corporation—Supplier Selection*

Basil Brandenburg, Bernie Boatwright, and Buford Baumgartner own the 3 Bees Buttermilk Corporation. The 3 Bees Buttermilk Corporation is an international corporation that sources its supplies from around the globe. The company had expanded from its original business of selling buttermilk to selling a multitude of food products. The food industry is very competitive. Basil's, Bernie's, and Buford's principal business strategy is low-cost leadership. They are intent on keeping expenses as low as possible. They believe this is their chief sustainable competitive edge.

Because of the large number of items, they source worldwide, and supplier selection is a major activity for the 3 Bees. It is essential to cost management. Buck Baumgartner, Buford's son, is studying supply chain management and is doing an internship with the 3 Bees Buttermilk Corporation. This year Buford decided they would teach Buck what was involved in the supplier selection process.

Basil, chief executive officer, took the first turn. He explained to Buck that for him communication capability was the most critical factor when selecting suppliers. In the food industry, products have an expiration date. Getting the correct item to the correct locations in time was essential. Consequently, communication of schedules, deliveries, and any issues is a must in their business. Basil felt that reliability was another important factor to consider and that it complemented communication capability.

Bernie, chief financial officer, is big on the cost factor. He explained to Buck that they had to determine the total cost of ownership. This went beyond the price. Total cost of ownership also included payment terms, cash discount, ordering cost, carrying cost, and much more.

Buford, chief technology officer, emphasized the importance of supplier process and product technology. In addition, he focused on the supplier's willingness to share technologies. Because of Buford's stance on these factors, he ensured the 3 Bees Buttermilk Corporation engaged in early supplier involvement when deciding to procure a new product.

As Buck listened to them, he knew that these weren't the only factors to consider. He planned to discover what other factors were necessary to consider and ask 3 Bees about them.

### Discussion Questions

1. Name and explain two factors of the supplier selection process that were not mentioned in the case.
2. What are the advantages of ESI, early supplier involvement?
3. Identify qualitative and quantitative factors that are taken into consideration when looking at the total cost of ownership.

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## 2. Frank's Driving Appurtenances—A Make-or-Buy Decision*

Frank Ziegler is a car buff. From his early childhood days Frank loved to tinker with cars. As he grew older, Frank's interest in cars evolved into how to enhance the comfort, convenience, and enjoyment of driving. Frank always had an entrepreneurial spirit, so he decided to open his own business, Frank's Driving Appurtenances.

Frank investigated the industry of car accouterments. He discovered that, like himself, many people enjoyed adding accessories to their car that expressed their unique personalities. He had designed many unique items for himself and his friends such as cup holders, objects to hang from the mirror, as well as things to adorn the outside of the vehicle. Frank believes that there is an enormous market for these items.

Mr. Ziegler was confident in his skill to design, manufacture, and sell unique accessories. His research showed that there were many suppliers for the type of items Frank made for himself and his friends. Consequently, he didn't have to make things himself; he could purchase and then resell them. Therefore, Frank believed his first step in creating Frank's Driving Appurtenances was to complete a make-or-buy breakeven analysis. Although his primary motivation was to share his own creations, Frank was a realist. He knew that initially the best approach was to ascertain which method, make or buy, was the best financial decision. If buying and reselling was more financially sound, he could later move to making the items himself once his reputation for quality and individuality was established.

Mr. Ziegler had to calculate the costs for both options. Frank had to determine what his fixed cost would be if he made the items. He would need additional tools and machinery and a place to work. His garage would not be sufficient space to make the volume of items he thought he needed.

As Frank evaluated the buy option, he discovered that one element of the variable cost was shipping. Most of the suppliers who sold the types of items Frank wanted were in foreign markets. Although their base price for the items varied slightly, the shipping cost added to the base cost was somewhat volatile.

As Frank prepared to calculate the make-or-buy break-even point, he understood that the one critical piece of data was the volume of sales. How much did Frank think he could sell? An inaccurate estimate of sales could result in the wrong break-even point and potential failure.

### Discussion Questions

1. What is the purpose for using the break-even analysis?
2. What are the two types of cost Frank must consider when doing the break-even analysis?
3. Generally speaking, which type of cost is higher for the make option and which type of cost is higher for the buy option? Why?

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## 3. Middleton Fine Furniture—Supply Chain Savings Opportunities*

The furniture industry is a tough industry to complete in. It is a very price-driven business and every expense must be constantly reviewed and reduced as much as possible. Middleton Fine Furniture was feeling the pressure of the economic downturn and needed to cut expenses. If they could not accomplish this, the only alternative was to lay off employees.

Sally Sherman was the chief executive officer of Middleton Fine Furniture. In its 100 years of operations, Middleton Fine Furniture was extremely proud of the fact that its employees were like family and Sally didn't feel layoffs were an option. Sally knew that until the economy turned around her company would need to tighten its belt. However, Sally wanted more than immediate financial relief, she wanted sustainable cost reductions.

Ms. Sherman met with Kenisha Yost, chief financial officer, and Ellie Gomez, vice president of supply chain management to discuss Middleton's financial predicament. Sally emphasized that she wanted a solution that enabled Middleton Fine Furniture to manage expenses in a manner that potentially could result in recurring savings. She didn't just want to survive this current financial crisis, she wanted to avoid it happening again.

Kenisha and Ellie began brainstorming on what they could do to provide a long term solution. Kenisha mentioned that inventory, while essential to their business, was money on the shelf. It did no good sitting there. How could they reduce inventory without endangering the business?

Ellie pointed out that the initial step to reducing inventory was to calculate their current inventory turnover ratio. Once they had that as a baseline, they could work on specific actions to reduce inventory. Furthermore, by analyzing their current inventory turnover ratio they could identify actions in other departments, other than just the supply department, that may be contributing to having too much money sitting on the shelf. Ellie explained that low inventory turnover can also be an indicator of poor sales, overstocking, and obsolete inventory. Issues that would need marketing's support to correct.

Ellie looked deeper into Middleton Fine Furniture's supply chain management processes. She discovered that Middleton had preferred to use multiple sourcing as its procurement method. Although multiple sourcing has many advantages, single sourcing can be advantageous as well. Although not all the parts they procured for the furniture could be single sourced, there were several that could. These were large-volume parts where quality was critical. Consequently, switching to single sourcing for these particular parts would ensure less quality variability and potentially less waste, a true cost reduction. Another advantage would be the opportunity to lower the cost of the parts because of the volume they would purchase from a single vendor. The increased volume for a single vendor would result in a lower purchase cost per unit for Middleton Fine Furniture.

As Ellie continued to ponder the problem, she reflected on the changes in Middleton's processes over the years. In its early years Middleton made all the parts for its furniture. As it grew it sourced more and more pieces from suppliers. Ellie decided the time was right for a make-or-buy break-even analysis on the parts they still made in-house and the parts they bought. This would be a challenging task and it would take time; however, the potential benefit of reducing costs outweighed the effort required.

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Kenisha and Ellie met with Sally. They outlined the three major initiatives they were pursuing, inventory turnover analysis, single versus multiple sourcing for specific parts, and an evaluation of whether to change from make or buy where applicable. Sally believed their solutions would generate the savings they needed and the processes put in place as a result would facilitate sustainable cost reductions.

### Discussion Questions

1. Explain the reasoning of determining the inventory turnover ratio. What value does this action have for Middleton?
2. What are the two main ways single sourcing can help reduce expenses? What is the risk?
3. What are the two types of cost that Kenisha and Ellie must consider when reevaluating the company's make-or-buy decisions?

## Part 2 Continuing Case

### Vanlandingham Robotics – Purchasing Management*

Emogene Edgerton is Chief Executive Officer of Vanlandingham Robotics. The robotics industry is a rapidly growing market with estimates of it moving from $26 billion in 2020 to $74 billion by 2026. However, the competition is fierce. In the healthcare sector alone, there are over 200 companies involved in robotics manufacturing.

Vanlandingham Robotics is a relatively new and small company. Despite that fact, Vanlandingham Robotics has a lot going for it. Jodie Johansson is the Chief Engineer. Jodie is considered the best in the industry. Another valuable employee is Alfonso Abdalla, Chief Financial Officer. Alfonso is data driven and an expense management savant. He understands that with such high-quality competition, in order to make the profit margins Emogene desires then, revenue isn't enough. Low expenses are a must!

The key to success in managing expenses is to focus on Supply Chain Management; specifically, the area of purchasing management. The formula is simple, reduce purchase spend and profits will increase (assuming all else remains constant). How can Vanlandingham Robotics do this? They must increase their profits through smarter purchasing.

Alfonso decides he must talk with Aaron Lykes, Director of Supply Chain Management, about the actions required to ensure low expenses. As they discussed the matter Aaron said he would design a scorecard with the critical metrics so they can track the results. They agreed on the following metrics: Return on Assets (ROA), Monthly Inventory Turnover Ratio, and Annual Inventory Turnover Ratio. In addition, Aaron was going to assign Dori Lenser, Purchasing Manager, to complete a make-or-buy break-even analysis on some of their expensive supply items. Possibly, they will discover additional opportunities to reduce their purchase spend.

Accounting Information for Ending Inventory and Cost of Goods Sold

Vanlandingham Robotics has an ending inventory of $275,000 as of December 31, 2019 and the following accounting information:

| MONTH | ENDING INVENTORY | COST OF GOODS SOLD |
|---|---|---|
| January 2020 | $230,000 | $1,200,000 |
| February | $300,000 | $1,250,000 |
| March | $240,000 | $1,350,000 |

| | | |
|---|---|---|
| April | $330,000 | $1,500,000 |
| May | $450,000 | $950,000 |
| June | $250,000 | $850,000 |
| July | $95,000 | $1,650,000 |
| August | $136,000 | $1,325,000 |
| September | $220,000 | $1,750,000 |
| October | $255,000 | $850,000 |
| November | $100,000 | $2,200,000 |
| December | **$360,000** | $3,500,000 |

The last action in their cost reducing initiative was for Dori to complete a make-or-by break-even analysis. Dori obtained the following costs for making and buying of a key component for their robots.

| COSTS | MAKE | BUY |
|---|---|---|
| Fixed Costs | $10,000 | $7500 |
| Variable Costs | $500 | $850 |
| Annual Requirement = 60,000 units | | |

## Discussion Questions

**1.** Compute the monthly inventory turnover ratio for each of the twelve months.

**2.** What is the annual cost of goods sold?

**3.** What is the average inventory for the year?

**4.** Compute the annual inventory turnover ratio.

**5.** What is the breakeven point?

**a.** Which option is less expensive, making or buying?

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Chapter 3

# Creating and Managing Supplier Relationships


*During times like this [COVID-19 pandemic], supply chain delays are inevitable and often out of our control. Our biggest piece of advice would be to make sure you're developing a strong relationship, both personally and professionally, with your suppliers.*

**Patrick Rynne, founder of Waterlust**[1]

*Ensuring the best prices through strategic sourcing is no longer perceived as a strategic capability of the procurement function. As a result of further outsourcing of non-core competencies, organizations are starting to realize that they have become more reliant on suppliers in terms of innovative power, security of supply, corporate social responsibility, and on-going cost savings. Strategic partnerships are at the top of the corporate agenda of many global organizations and Supplier Relationship Management (SRM) is seen as one of the few remaining procurement topics that can still make a significant difference.*

**PricewaterhouseCoopers website**[2]

*The greatest change in corporate culture—and the way business is being conducted—may be the accelerated growth of relationships based... on partnership.*

**Peter F. Drucker, business author and thinker**[3]

## Learning Objectives

**After completing this chapter, you should be able to**

**LO 1** Explain the importance of supplier partnerships.

**LO 2** Understand the key factors for developing successful partnerships.

**LO 3** Understand the impact of the COVID-19 pandemic on supplier relations.

**LO 4** Develop a supplier evaluation and certification program.

**LO 5** Explain the importance of a supplier recognition program.

**LO 6** Understand how to manage supplier relationships during a pandemic.

**LO 7** Understand the capabilities of supplier relationship management.

**LO 8** Explain the benefits of using SRM software to manage suppliers.

## Chapter Outline



## SCM Profile: The Evolving Ford One Program and Aligned Business Framework


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In 2005 Ford suffered a $1.1 billion operating loss in one quarter. Ford then initiated the Aligned Business Framework (ABF) program to consolidate the supplier base from 2,700 to 1,100.[4] Basically these preferred suppliers would receive long-term contracts, and access to Ford's demand forecast and product plans, with additional involvement in new product development. In return, these suppliers would be asked to commit to financial data sharing, technological innovations, and using women-owned and minority suppliers.

Next, Ford implemented its One Ford program in early 2007, which reduced the number of global automobile platforms from 30 to 9. Alan Mulally who was the President and CEO at that time, was credited with initiating the One Ford program. The significant reduction in platforms resulted in economies of scale and reduced costs. It involved developing a collaborative working relationship with its suppliers. This collaborative working model entailed long-term development and purchasing agreements with select suppliers. According to Thai-Tang, vice president of global purchasing at Ford, "It was modeled after some of the best practices in the industry. It's not about sourcing to the lowest-cost bidder on something that's very much a true commodity … It's more, 'Who are our long-term strategic partners that we want to align ourselves with, that we want to count on to help us innovate?'"

Ford is actively pursuing supplier development when Ford starts manufacturing in new global markets. For example, in India, Ford found a supplier who was not already in the automotive industry and worked with the supplier to transfer their experience doing harness work for the appliance industry to producing parts for Ford. According to Ford it takes three or more years to develop a supplier. Engaging suppliers early in the design process is key. Thai-Tang said, "Talk with them about what is the customer problem that we're trying to solve, and how do we collaborate to get to the best design cost and ensure that they make a fair margin. Then we're actually leveraging their knowledge, their expertise, and learning from their best practices based on all the customers they serve."[5]

Each year Ford has increased its list of Aligned Business Framework (ABF) suppliers. ABF companies enter into long-term relationships with Ford to improve collaboration and mutual profitability and development of innovative technology. Ford is committed to long-term sourcing, financial transparency, and information sharing of product and manufacturing plans with ABF suppliers. In the 2020 listing of ABF suppliers, Ford has 79 production suppliers and 29 indirect suppliers. The implementation of the ABF has resulted in Ford becoming the preferred domestic automaker among its suppliers. According to Birgit Behrendt, Ford vice president of global programs and purchasing operations, "The evolution of the Aligned Business Framework helps us to further integrate with our product development team, and encourages our suppliers to bring their best and most innovative technologies to Ford."[6]

## Introduction

In general, companies that have focused on short-term cost reduction strategies will likely not be able to take advantage of supplier capabilities. Supply chain sourcing and procurement professionals should move from a strict fixation on cost management to creating value using strategic suppliers. As companies place more emphasis on their core competencies, the level of outsourcing will continue to rise. Increasingly, companies are requiring their suppliers to deliver innovative and quality products not only in just-in-time (JIT) fashion but also at a competitive price. In the last few decades, we have learned that good supplier relations can provide many benefits such as delivery flexibility, better quality, better information, and faster material flows between buyers and suppliers. Many companies believe strongly that better supplier partnerships are important to achieving competitive corporate performance. As such, companies are realizing the importance of developing win–win, long-term relationships with suppliers. It is critical that customers and suppliers develop stronger relationships and partnerships based on a strategic rather than a tactical perspective and then manage these relationships to create value for all participants. Successful partnerships with key suppliers can contribute to innovations and have the potential to create a competitive advantage for the firm. Selecting the right supply partners and successfully managing these relationships over time is thus strategically important; it is often stated that "a firm is only as good as its weakest suppliers."

According to the Institute for Supply Management's glossary of terms, a supplier partnership is defined as:

> *A commitment over an extended time to work together to the mutual benefit of both parties, sharing relevant information and the risks and rewards of the relationship. These relationships require a clear understanding of expectations, open communication and information exchange, mutual trust and a common direction for the future. Such arrangements are a collaborative business activity that does not involve the formation of a legal partnership. The term strategic alliance is used in many organizations to mean the same thing as a supplier partnership. In some organizations, however, the term strategic alliance is used to describe a more inclusive relationship involving the planned and mutually advantageous joint utilization of additional operating resources of both organizations.*[7]

As described in the chapter-opening SCM Profile, Ford Motor Company's Aligned Business Framework (ABF) focuses on "collaborative and transparent work in areas such as ethical business practices, working conditions, global manufacturing and development footprints, and sourcing from minority-, veteran- and women-owned businesses."[8] This rigorous framework is beneficial to Ford since it enables the company to reduce costs and obtain suppliers' innovative technologies. To achieve Ford's goals in managing its supply chains, Ford fosters long-term relationships with its suppliers through active engagement and communication of its expectations on critical issues such as human rights, working conditions, and environmental sustainability, and ensuring that their suppliers have management systems in place to mitigate potential risks, while safeguarding continuity of supply.[9] Ford publishes a current list of their ABF suppliers on their website.[10]

The chapter-opening SCM Profile also shows the improvement of supplier relationships at Ford. Ford started the Partnership for a Cleaner Environment (PACE) program at the G7 Alliance Forum on Resource Efficiency workshop in Washington, DC in 2016. Ford uses the PACE program to educate its suppliers about the energy, water, and carbon dioxide emissions savings initiatives that Ford has implemented in its manufacturing and office operations. The objective is to motivate Ford suppliers to execute several of the initiatives in their own facilities. "We are committed to expanding our stewardship with our global suppliers to help minimize our environmental impact more broadly," said Hau Thai-Tang, Ford group vice president, global purchasing.[11] Good supplier relationships and collaborations are necessary for developing end-to-end, integrated, and sustainable supply chains. Ford plans to be carbon neutral by 2050.[12]

The Supplier Working Relations Index (WRI®) is an annual survey of the working relationships between North America-based OEM customers and their Tier 1 suppliers (see the next SCM Profile on WRI). The study by Plante Moran shows "an increasing gap between the best and the worst working relations among FCA, Ford, FGM, Honda, Nissan and Toyota and their suppliers."[13] The same study also shows that "suppliers provide greater support above and beyond contract requirements with OEMs that earn higher WRI scores." In addition, the survey result also finds that "suppliers are more willing to invest in new technologies, share ideas for development, and provide other nonprice benefits to OEMs with which they have deeper, better working relationships." Auto manufacturers with the highest WRI scores are more likely to have a larger group of suppliers committed to invest in innovations and new technology. The survey provides clear evidence of the importance of supplier relationships. It is also encouraging that we now have a common working relationship index that companies can use to compare its supplier relationship performance with their competitors. The Plante Moran WRI study indicates that commercializing new innovative technology requires high trust in supplier relationships. Companies can now use the WRI survey findings to improve trust and profitability. Hopefully, the index can be expanded to other industries.

The COVID-19 pandemic has wreaked major havoc on global supply chains. Some products are out of stock while many other products have had hardly any demand. Surprisingly, toilet paper was in short supply as were eggs, milk, hand sanitizer, face masks, cleaning wipes and spray, paper towels, hand soap, diapers, thermometers, and tissue paper. The service industry took a big hit. Hotels, restaurants, cruises, and airlines were badly affected. Businesses that were able to navigate the pandemic with help from their suppliers were more likely to survive. Buyers and suppliers must manage their relationships in the face of these disruptions. Another issue is what impact will the reduced cash flow problem have on the relationship between vendor and supplier. These issues and others will be discussed later in the chapter.

## SCM Profile: Plante Moran's North American Automotive-Suppliers Working Relations Index (WRI®)[14]


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The North American Automotive OEM-Supplier Working Relations Index (WRI) Study is "a comprehensive annual survey that examines the working relations between Tier 1 suppliers and their North American-based OEM customers from the suppliers' perspective."[15] Professor John Henke started the study in the early 2000s. His motivation was "to independently survey suppliers and discover their perceptions of working with their North American OEM customers and what was driving these perceptions."[16] The Henke survey continued on with Planning Perspectives, Inc. (PPI), and eventually joined Plante Moran in January 2019. Using the company's proprietary WRI methodology, "the qualitative working relations of each OEM are quantitatively determined and ranked on a 500-point scale." The 2019 study included over 600 suppliers. Six key areas covered in the survey are as follows:

1. Supplier trust of the OEM.
2. The OEM exaggerates needs to get what it desires.
3. The OEM promises to do things, even if they apparently have no intention of following through.
4. You believe the OEM obstructs important information from your firm.
5. You believe the OEM is concerned that your business succeeds.
6. The OEM lives up to the spirit of its commitments.

Several key findings from the 2019 WRI survey were[17]:

1. Suppliers need to respond to diverse situations among their customer base, since each vehicle manufacturer is facing unique circumstances, challenges, and opportunities.
2. Improvement in alignment between engineering and purchasing.
3. Hard to earn B2B trust and requires inputs from promises made, realistic asks, and open information sharing.
4. Suppliers are more likely to invest in new technologies if they have better working relationships.
5. High-performing suppliers are not rewarded as consistently as in previous years. This trend is disturbing because it is one of the pillars of strong supplier relationships.
6. Margin is not the key driver. Suppliers seek a reasonable return on their investments, and are more than willing to support OEMs that support them.

The survey found the following actions are needed to build trust: improving communications, reducing barriers, aligning business functions, offering assistance programs, and providing mutual profit opportunities.

## Developing Supplier Relationships

According to Kenichi Ohmae, global management consultant, and known as "Mr. Strategy" worldwide, "Companies are just beginning to learn what nations have always known: in a complex, uncertain world filled with dangerous opponents, it is best not to go it alone."[18] Building strong supplier partnerships requires a lot of hard work and commitment by both buyers and sellers. Developing true partnerships is not easily achieved, and much has to be done to get the partnership to work. An example is Raytheon, which has developed close supplier relationships with its suppliers (see the nearby SCM Profile). Several key ingredients for developing successful partnerships are discussed below.

### SCM Profile: Supplier Relationship Management and COVID-19 at Raytheon[19]

metamorworks/Shutterstock.com

Raytheon's journey to be the "Customer of Choice" started in 2015. The objective was to earn preferential treatment from its suppliers. As a first step, the defense contractor decided to develop a Supplier Advisory Council for advice, ideas, and innovation. Raytheon realized that in the highly competitive U.S. defense industry, great technology alone is not sufficient to win orders. Factors such as purchase price and lifetime maintenance costs were becoming more critical. Consequently, Raytheon had to revamp how it collaborated with its suppliers. The thinking was that Raytheon had to move from a tactical relationship based on negotiated price to a more strategic one where suppliers participate early in the design of new products, where real cost reductions can be made. Raytheon lists the following key ingredients needed to be a customer of choice[20]:

- Open communication—We believe an open, honest and forthright exchange of ideas and opportunities is the foundation for collaboration.
- Early engagement—We recognize our suppliers are our best partners for understanding the cost and manufacturability of our products. We want to bring suppliers in during the earliest stages of our customer programs because problem solving skills are improved from a variety of perspectives.
- Forward looking technology development—We're looking to solve the hardest, most unimaginable technological challenges. That requires vision and investment. And sharing that long-term vision with our suppliers is what fuels future success.
- Rewarding Excellence—Across our supply base, there are countless men and women who take affordability, quality, performance and partnership as seriously as we do. We want to seek out and reward those suppliers.

The following is posted at Raytheon's website on suppliers[21]:

> *Our suppliers are an integral part of the global Raytheon Technologies team. They deliver innovative, cost-effective solutions that meet our high standards of quality and performance and enable us to solve our customers' most pressing challenges.*

*Raytheon Technologies seeks to develop strategic relationships with suppliers who hold the same values and who share the same commitment to delivering solutions that define the future of aerospace and defense.*

During the COVID-19 pandemic Raytheon continued to maintain its relationships with key suppliers. Raytheon is part of The Defense Industrial Base (DIB), which is identified as a Critical Infrastructure Sector by the Department of Homeland Security. As such Raytheon is expected to maintain their normal work schedules. For this to happen, Raytheon needs the support and dedication of its suppliers during these trying times to ensure the continuity of work.

Raytheon realized that communications is key to maintaining supplier relations during this disruptive environment. Shown below is the letter that Raytheon sent to their suppliers:[22]

Dear Valued Supplier of Raytheon Technologies, We appreciate your partnership as we deal with the impact of the COVID-19 Coronavirus. Our top priority is the safety of all employees at Raytheon Technologies and its valued suppliers. We hope you and your employees' families are safe and taking every necessary precaution.

This site is available to all Raytheon Technologies suppliers and will be your resource for Coronavirus-related supplier communications and other resources. In the resources below, you will find communications from our government customers and details concerning a visitor process for all company locations and other precautionary measures we have taken.

Your continued support is critical to our national security.

Thank you again for your continued partnership in this challenging time.

## Building Trust

Trust is critical for any partnership or alliance to work. It must be built not just at the senior management level but at all levels of the organization. Trust enables organizations to share valuable information, devote time and resources to understand each other's business, and achieve results beyond what could have been done individually. Jordan Lewis, in his book *Trusted Partners*, points out that "Trust does not imply easy harmony. Obviously, business is too complex to expect ready agreement on all issues. However, in a trusting relationship conflicts motivate you to probe for deeper understandings and search for constructive solutions. Trust creates goodwill, which sustains the relationship when one firm does something the other dislikes."[23] With trust, partners are more willing to work together; find compromise solutions to problems; work toward achieving long-term benefits for both parties; and in short, go the extra mile. In addition, there is goodwill developed over time between the partners. This can be beneficial when one partner gets into a difficult situation and the other partner is willing to help out.

## Shared Vision and Objectives

All partnerships should state the expectations of the buyer and supplier, reasons and objectives of the partnership, and plans for the dissolution of the relationship. According to Lenwood Grant, sourcing expert with Bristol-Myers-Squibb, "You don't want a partnership that is based on necessity. If you don't think that the partnership is a good mix, but you do it because you have to—possibly because that supplier is the only provider of that material in the market, because you've signed an exclusive contract in the past, or for some other reason—it's not a true partnership and is likely to fail."[24] Both partners must share the same vision and have objectives that are not only clear but mutually agreeable. Many

alliances and partnerships have failed because objectives are not well aligned or are overly optimistic. The focus must move beyond tactical issues and toward a more strategic path to corporate success. When partners have equal decision-making control, the partnership has a higher chance of success.

## Personal Relationships

Interpersonal relationships in buyer–supplier partnerships are important since it is people who communicate and make things happen. According to Leonard Greenhalgh, author of Managing Strategic Relationships, "An alliance or partnership isn't really a relationship between companies, it's a relationship between specific individuals. When you are considering strategic alliances of any kind, the only time the company matters is in the status associated with it [strategic alliance]. Whoever is interfacing with the other company, they are the company."[25]

## Mutual Benefits and Needs

Partnering should result in a win–win situation, which can only be achieved if both companies have compatible needs. Mutual needs not only create an environment conducive for collaboration but opportunities for increased innovation. When both parties share in the benefits of the partnership, the relationship will be productive and long lasting. An alliance is much like a marriage: if only one party is happy, the marriage is not likely to last. For example, highly qualified Toyota engineers who work as consultants on projects support Toyota's performance improvement programs with suppliers. Any cost savings arising from this program are shared with the suppliers. Toyota also ensures that their suppliers earn a reasonable return. An important recipe for success is when the buyer is respectful, fair, and trustworthy in its dealings with suppliers.

## Commitment and Top Management Support

First, it takes a lot of time and hard work to find the right partner. Having done so, both parties must dedicate their time, best people, and resources to make the partnership succeed. According to author Stephen R. Covey, "Without involvement, there is no commitment. Mark it down, asterisk it, circle it, underline it. No involvement, no commitment."[26] Commitment must start at the highest management level. Partnerships tend to be successful when top executives are actively supporting them. The level of cooperation and involvement shown by the organization's top leaders is likely to set the tone for joint problem solving further down the line.

Successful partners are committed to continuously looking for opportunities to grow their businesses together. Management must create the right kind of internal attitude needed for alliances to flourish. Since partnerships are likely to encounter bumps along the way, it is critical that management adopt a collaborative approach to conflict resolution instead of assigning blame.

## Change Management

With change comes stress, which can lead to a loss of focus. Companies must avoid distractions from their core businesses as a result of the changes brought about by the partnership. Companies must be prepared to manage change that comes with the formation of new partnerships. According to author Stephen Covey, "The key to successful change

management is remaining focused on a set of core principles that do not change, regardless of the circumstances."[27] In a case study on delivering value through strategic supplier relationships, Hewlett Packard identified several key steps to ensure better change management:[28]

- Identify internal champions
- Secure executive buy-in
- Coordinate internal communication and support teams
- Train and survey impacted managers
- Conduct business reviews with key client groups

HP realized that having internal champions and coordination enabled better change management.

## Information Sharing and Transparent Communications

Both formal and informal lines of communication should be set up to facilitate free flows of information. When there is high degree of trust, information systems can be customized to serve each other more effectively. Confidentiality of sensitive financial, product, and process information must be maintained. Any conflict that occurs can be resolved if the channels of communication are open. For instance, early communication to suppliers of specification changes and new product introductions are contributing factors to the success of purchasing partnerships. Buyers and sellers should meet regularly to discuss any change of plans, evaluate results, and address issues critical to the success of the partnerships. Since there is free exchange of information, nondisclosure agreements are often used to protect proprietary information and other sensitive data from leaking out. It is not the quantity but rather the quality and accuracy of the information exchanged that indicates the success of information sharing. **Communication transparency** means full disclosure of any obstacles, intentions, limitations, and issues you've discovered—in-house or anywhere in the supply chain—as soon as possible. It's also productive to offer, in good faith, to work together to fix them.[29]

While collaboration has many positives, there is also the fear of the loss of trade secrets when sensitive information is shared between partners. According to the U.S. Economic Espionage Act of 1996, the definition of trade secrets is: "All forms and types of financial, business, scientific, technical, economic, or engineering information, including patterns, plans, compilations, programmed devices, formulas, designs, prototypes, methods, techniques, processes, procedures, programs, or codes, whether tangible or intangible, and whether or how stored, compiled, or memorialized physically, electronically, graphically, photographically, or in writing."[30] Trade secrets tend to be more critical in the high-technology sector where the unique technique or process used in the company's business can provide it with tremendous competitive advantage. Vendors have been known to steal or misappropriate trade secrets, terminate the partnership, and become competitors. One of the most basic and successful approaches for protecting trade secrets is to require employees and vendors to sign a nondisclosure agreement.

## Relationship Capabilities

Organizations must develop the right capabilities for creating long-term relationships with their suppliers. In a study on world-class procurement organizations, the Hackett Group found that one of the two best practices for top-performing companies is using

cross-functional teams to achieve common objectives.[31] Thus, companies aspiring to be world class must develop cross-functional team capabilities. In addition, the employees must not only be able to collaborate successfully within the company in a cross-functional team setting but also have the skills to do so externally. Key suppliers must have the right technology and capabilities to meet cost, quality, and delivery requirements. In addition, suppliers must be sufficiently flexible to respond quickly to changing customer requirements. Before entering into any partnership, it is imperative for an organization to conduct a thorough investigation of its suppliers' capabilities and core competencies. Organizations prefer working with suppliers who have the technology and technical expertise to assist in the development of new products or services that would lead to a competitive advantage in the marketplace.

## Performance Metrics

The old adage "You can't improve what you don't measure" is particularly true for buyer–supplier alliances. Measures related to quality, cost, delivery, and flexibility have traditionally been used to evaluate how well suppliers are doing. Information provided by supplier performance will be used to improve the entire supply chain. Thus, the goal of any good performance evaluation system is to provide metrics that are understandable, easy to measure, and focused on real value-added results for both the buyer and supplier.

By evaluating supplier performance, organizations hope to identify suppliers with exceptional performance or developmental needs, improve supplier communication, reduce risk, and manage the partnership based on an analysis of reported data. Northrup Grumman rates their supplier performance using a scorecard format based on four categories: quality profile rating, late delivery, customer satisfaction, and process health/lean Six Sigma.[32] After all, it is not unusual that the best customers want to work with the best suppliers. Additionally, the best suppliers are commonly rewarded and recognized for their achievements. Supplier awards will be discussed later in this chapter.

Although price or cost is an important factor when selecting suppliers, other criteria such as technical expertise, lead times, environmental awareness, and market knowledge must also be considered. In the electronics industry, which pioneered the Six Sigma revolution, quality is the prime supplier selection criteria due to its strategic importance. Thus quality and the ability of suppliers to bring new technologies and innovations to the table, rather than cost, are often the key selection drivers. A multicriteria approach is therefore needed to measure supplier performance. Examples of broad performance metrics are shown in Table 3.1.

The **total cost of ownership** (TCO), a broad-based performance metric, has been widely discussed in the supply chain literature. As mentioned in Chapter 2, TCO is defined as "the combination of the purchase or acquisition price of a good or service and additional costs incurred before or after product or service delivery." Costs are often grouped into **pretransaction costs**, **transaction costs,** and **posttransaction costs**.[33] These three major cost categories are described as follows:

- *Pretransaction costs*: These costs are incurred prior to order and receipt of the purchased goods. Examples are the cost of certifying and training suppliers, investigating alternative sources of supply, and delivery options for new suppliers.
- *Transaction costs*: These costs include the cost of the goods/services and cost associated with placing and receiving the order. Examples are purchase price, preparation of orders, and delivery costs.
- *Posttransaction costs*: These costs are incurred after the goods are in the possession of the company, agents, or customers. Examples are field failures, company's goodwill/reputation, maintenance costs, and warranty costs.

**Table 3.1 Examples of Supplier Performance Metrics**

1. **Cost/Price**
   - Competitive price
   - Availability of cost breakdowns
   - Productivity improvement/cost reduction programs
   - Willingness to negotiate price
   - Inventory cost
   - Information cost
   - Transportation cost
   - Actual cost compared to: historical (standard) cost, target cost, cost-reduction goal, benchmark cost
   - Extent of cooperation leading to improved cost
2. **Quality**
   - Percent defect free
   - Use of statistical process control
   - Use of continuous process improvement
   - Fitness for use
   - Use of corrective action program
   - Use of documented quality program such as ISO 9000
   - Warranty characteristics
   - Actual quality compared to: historical quality, specification quality, target quality
   - Quality improvement compared to: historical quality, quality-improvement goal
   - Extent of cooperation leading to improved quality
3. **Delivery**
   - Delivery time
   - Delivery reliability
   - Percentage of defect-free deliveries
   - Actual delivery compared to promised delivery window (i.e., two days early to zero days late)
   - Extent of cooperation leading to improved delivery
4. **Responsiveness and Flexibility**
   - Responsiveness to customers
   - Accuracy of record keeping
   - Ability to work effectively with teams
   - Responsiveness to changing situations
   - Participation/success of supplier certification program
   - Short-cycle changes in demand/flexible capacity
   - Changes in delivery schedules
   - Participation in new product development
   - Solving problems
   - Willingness of supplier to seek inputs regarding product/service changes
   - Advance notification given by supplier as a result of product/service changes
   - Receptiveness to partnering or teaming
5. **Environment**
   - Environmentally responsible
   - Use of environmental management system such as ISO 14000
   - Extent of cooperation leading to improved environmental issues
6. **Technology**
   - Proactive improvement using proven manufacturing/service technology
   - Superior product/service design
   - Extent of cooperation leading to improved technology

**7. Business Metrics**

- Reputation of supplier/leadership in the field
- Long-term relationship
- Quality of information sharing
- Financial strength such as Dun & Bradstreet's credit rating
- Strong customer support group
- Total cash flow
- Rate of return on investment
- Extent of cooperation leading to improved business processes and performance

**8. Total Cost of Ownership**

- Purchased products shipped cost-effectively
- Cost of special handling
- Additional supplier costs as the result of the buyer's scheduling and shipment needs
- Cost of defects, rework, and problem solving associated with purchases

TCO provides a proactive approach for understanding costs and supplier performance leading to reduced costs. However, the challenge is to effectively identify the key cost drivers needed to determine the total cost of ownership.

Ernst & Young (EY) presents three sourcing business models: Transaction-based, performance-based and outcome-based.[34] New business conditions require new ways of thinking. The transaction-based model is focused on cost savings and traditional contracts. The performance-based model is focused on tactical value, output-based, and relational contract (trust-based). Finally, the outcome-based model is focused on strategic value, outcome, and relational contract (trust-based). According to Professor Kate Vitasek, University of Tennessee, "Conventional transaction-based approaches have inherent flaws because the economics of the deal structure keeps buyers and suppliers at arm's length. This approach is not conducive to collaboration, innovation or value sharing, especially for complex, multidimensional business relationships."[35] EY's vested partnership, which is derived from the outcome-based model, has been implemented at several companies. Some of the words used by respondents from companies that have implemented the Vested partnerships are "increased efficiency," "improved collaboration," "improved satisfaction," and "total cost of ownership reduction." EY's argument is that new market conditions require agile business models. The objective is to "structure partnerships that achieve greater flexibility, innovation, and improve bottom-line results."[36] EY's Vested partnerships are different from performance-based models by including gain-sharing concepts with buyers and sellers structuring contracts that create value above savings and a collaborative relationship with shared risk and reward.

## Continuous Improvement

The process of evaluating suppliers based on a set of mutually agreed performance measures provides opportunities for continuous improvement. As discussed further in Chapter 8, **continuous improvement** involves continuously making a series of small improvements over time, resulting in the elimination of waste in a system. Both buyers and suppliers must be w*illing to continuously improve their capabilities in meeting customer requirements pertaining to things like cost, quality, delivery, sustainability, and technology*. Partners should not focus on merely correcting mistakes, but work proactively toward eliminating them completely. For continuous improvement to succeed, employees must first identify areas

that are working to understand the improvements made. These improvements provide the basis for implementing improvements in other processes, which in turn will lead to even more success. In today's dynamic environment, staying ahead of change means that you have to practice continuous improvement. Companies must work with suppliers on continuous improvement programs to ensure that products and services are meeting customer requirements.

## Monitoring Supplier Relationships

Unless an organization has a firm grasp of the key issues surrounding supplier relationships, it cannot reap the benefits of such relationships. An assessment of how the relationships with an organization's suppliers are doing will enable these relationships to be managed better. In a study of the food industry, five key performance indicators were identified to objectively measure supply chain relationship performance:[37]

- Creativity—promoting quality, innovation, and a long-term approach by encouraging high performance.
- Stability—investment, synchronization of objectives, and confidence building.
- Communication—frequent, open dialogue and information sharing.
- Reliability—concentrating on service and product delivery, lowering joint costs.
- Value—creating a win–win relationship in which each side is delighted to be a part.

In the same study, several intrinsic characteristics of relationship performance were also identified as follows:[38]

- Long-term Orientation—encouraging stability, continuity, predictability, and long-term, joint gains.
- Interdependence—loss in autonomy is compensated through the expected gains.
- $C^3$ Behavior—Collaboration, Cooperation, Coordination, jointly resourcing to achieve effective operations.
- Trust—richer interaction between parties to create goodwill and the incentive to go the extra mile.
- Commitment—the relationship is so important that it warrants maximum effort to maintain it.
- Adaptation—willingness to adapt products, procedures, inventory, management, attitudes, values, and goals to the needs of the relationship.
- Personal Relationships—generating trust and openness through personal interaction.

The assessment of key performance indicators should create a clear understanding of what the issues are, so that the problems can be resolved to further improve the relationship.

Plante Moran has now developed a North American Automotive OEM-Supplier Working Relations Index (WRI©). Please refer to the earlier SCM Profile on Plante Moran for more details of WRI©. This index allows companies in the North American automotive industry to compare how they are performing in supplier relationships with other OEMs.

## Key Takeaways

It must be noted that developing supplier partnerships is not easy. All the factors mentioned above have to be in place for the supplier relationship to be successful. While there are numerous instances where supplier partnerships work well, there are also examples where the relationship did not turn out as expected. An example is the horsemeat scandal in the United Kingdom several years ago. Hamburgers containing horsemeat DNA were made by the Silvercrest factory of the ABP Group in Ireland. According to Ryan Finstad, director of operations at California-based supply chain solutions provider Cathay Solutions, "Companies that have long-standing relationships with their manufacturers have naturally become more lax over time. As these firms searched for ways to cut costs, they may have reduced or eliminated monitoring of manufacturers that had historically performed well."[39] As a result, without a good quality verification program, it is easy for suppliers to compromise on quality and to deliver substandard products. The importance of supplier relationships cannot be overstated, and cultivating these relationships is an essential part of doing business globally.

In another example, the Volkswagen emission scandal is one of the most expensive in automotive history and caused the company to pay $14.7 billion to settle with three federal agencies. Bosch, one of VW's major suppliers was also investigated. Transparency and communication are necessary to avoid problems like these in supply chains.

## Managing Supplier Relationships During the Covid-19 Pandemic

No industry was more severely affected by the pandemic than healthcare supply chains. We have seen major disruptions of critical supplies such as PPE, ventilators, and masks. Additional costs were incurred due to the increased demand for critical supplies in attempting to meet patients and staff needs. The existing hospital–supplier dynamic has been altered causing changes to the vendor marketplace and raising concerns about how emergency stocks are managed. As a result of global shortages and market dynamics, healthcare providers had to develop relationships with new vendors in the short term. Changing patient volumes and system consolidation will mean that providers will be looking for more support and assistance from their vendors in the long run.

Organizations are now finding out that supplier relationships are more important than ever to mitigate the risk of supply chain disruptions. Experts agree that the stronger the existing supplier relations are, the more likely that the company will have the capability to navigate through the crisis. The crisis also provides an opportunity to develop even stronger relationships with current and future suppliers.

There is no better time to discuss supplier relationships than during the COVID-19 pandemic, one of the biggest disruptions in global supply chain history. We can be assured that with a strong pre-existing relationship, companies were better able to persevere through this predicament. During the COVID-19 pandemic companies were likely to experience cash flow problems. How would this affect relationships and collaboration? The advice here is to keep channels of communication open and to ensure there is open and transparent information sharing. Keep your suppliers in the loop regarding changes in operations and customer orders that might affect your suppliers. There might be situations where your suppliers might be able to help with your firm's dilemma. Likewise keep in touch with suppliers to see how they are doing and to offer any assistance if needed. While it may not seem obvious, cybersecurity is of utmost importance since hackers are out to exploit any weaknesses when your guard is down.[40]

A likely battle brewing in procurement is the clash between contract language and supplier relationships. The pandemic caused havoc in the workplace. Disruptions in supply chains caused cancelations and invalidated or ignored contracts. "At the end of the day, contracts are just pieces of paper and hard to enforce and we must rely on the depth of our strategic relationships with suppliers and customers to get through this crisis," said Erin McFarlane, head of strategy and execution for Fairmarkit.[41] However, McFarlane recommends that buyers look at their key supplier contracts closely especially the force majeure clauses so they are not caught by surprise. Rich Weissman notes that "The foundations built in the past work to support ongoing operations now. In this emergency, it's too late to make friends."[42] In a survey of 100 chief procurement officers in Europe, carried out in 2020 by WBR Insights, "64% of the respondents will be rewriting supplier terms and conditions as a consequence of the pandemic.[43] The same survey found that "while 94% felt they had good or excellent visibility into their supply chain before the virus, that number has now dropped to just 44%; 36% say they have more contact with their suppliers during the crisis than they did before, while 37% say they have less contact."

While the pandemic presented problems, it is also a good time to work on strengthening relationships with new and existing suppliers. The objective is to build a more resilient supply chain to soften the disruptions in the event of another global crisis. With the pandemic, the supply chain environment has changed. Given this new landscape, the following are several essential elements for establishing strong supplier relationships:[44,45]

1. **Mutual Respect.** Very few relationships can have long lasting success without a feeling of respect going both ways. In addition, without integrity it would difficult to keep the respect from diminishing in the relationship.
2. **Shared vision.** Companies and their suppliers must have a shared vision for collaboration to work. Only if there is collective vision would each party derive the most out of their relationship. As such it is important to have shared goals, ideas, and costs and benefits.
3. **Communication.** Open and consistent communication is central to any healthy relationship. Be proactive as frequent contacts mean fewer miscommunications, better expectations and, in the end, there will be less back-pedaling and damage control. Transparency means that any problems, changes, and issues that were discovered whether in-house or elsewhere in the supply chain must be fully disclosed as quickly as possible. Transparency is important because it shows respect, trust, and good faith.
4. **Positive conduct.** To promote strong and effective relationships, employees must exhibit a good balance of empathy, patience, and urgency especially during a trying pandemic. Always keep bridges open and unburned even when relationships come to an end.
5. **Supporting suppliers.** Many suppliers faced cash flow problems during the pandemic which potentially affected staffing and long-term viability. Supply chain finance became popular following the 2008 financial crisis, with companies providing support for their suppliers, and as a result avoided disruption to their own business. Supply chain finance (or SCF) is "a form of supplier finance in which suppliers can receive early payment on their invoices. Supply chain finance reduces the risk of supply chain disruption and enables both buyers and suppliers to optimize their working capital. It's also known as reverse factoring."[46] In a competitive industry, exceptional service is the major differentiator. Suppliers are more willing to work with companies that go above and beyond the norm with respect to communications, support, and attention to details.

## Supplier Evaluation and Certification

Only the best suppliers are targeted as partners. Companies want to develop partnerships with the best suppliers to leverage their expertise and technologies to create a competitive advantage. Learning more about how an organization's key suppliers are performing can lead to greater visibility, which can provide opportunities for further collaborative involvement in value-added activities. Many organizations are tracking product and service quality, on-time deliveries, customer service efforts, and cost-control programs as part of the supplier rating system. This information can be used to develop supplier programs that will help eliminate problems or improve supply chain performance.

A supplier evaluation and certification process must be in place so that organizations can identify their best and most reliable suppliers. In addition, sourcing decisions are made based on facts and not perception of a supplier's capabilities. Providing frequent feedback on supplier performance can help organizations avoid major surprises and maintain good relationships.

One of the goals of evaluating suppliers is to determine if the supplier is performing according to the buyer's requirements. An extension of supplier evaluation is supplier certification, defined by the Institute of Supply Management as "an organization's process for evaluating the quality systems of key suppliers in an effort to eliminate incoming inspections."[47] The certification process implies a willingness on the part of customers and suppliers to share goals, commitments, and risks to improve their relationships. This would involve making visits to observe the operations at the supplier organizations. For example, dirty bathrooms and messy shop floors could indicate that an emphasis on quality is lacking in the production facility. A supplier certification program also indicates long-term mutual commitment. For example, a certification program might provide incentives for suppliers to deliver parts directly to the point of use in the buyer firm, thus reducing costs associated with incoming inspection and storage of inventory.

Implementing an effective supplier certification program is critical to reducing the supplier base, building long-term relationships, reducing time spent on incoming inspections, improving delivery time and responsiveness, recognizing excellence, developing a commitment to continuous improvement, and improving overall performance. Supplier certification allows organizations to identify the suppliers who are most committed to creating and maintaining a partnership and who have the best capabilities. Listed below are several criteria generally found in certification programs:

- No incoming product lot rejections (e.g., less than 0.5 percent defective) for a specified time period
- No incoming nonproduct rejections (e.g., late delivery) for a specified time period
- No significant supplier production-related negative incidents for a specified time period
- ISO 9001/Q9000 certified or successfully passing a recent, on-site quality system evaluation
- ISO 14001 certified
- Mutually agreed upon set of clearly specified quality performance measures
- Fully documented process and quality system with cost controls and continuous improvement capabilities, and
- Supplier's processes are stable and in control.

## The Weighted Criteria Evaluation System

One approach toward evaluating and certifying suppliers is to use the weighted criteria evaluation system described in the steps below:

1. Select the key dimensions of performance mutually acceptable to both customer and supplier.
2. Monitor and collect performance data.
3. Assign weights to each of the dimensions of performance based on their relative importance to the company's objectives. The weights for all dimensions must sum to one.
4. Evaluate each of the performance measures on a rating between 0 (fails to meet any intended purpose or performance) and 100 (exceptional in meeting intended purpose or performance).
5. Multiply the dimension ratings by their respective importance weights and then sum to get an overall weighted score.
6. Classify vendors based on their overall scores, for example:
   - Unacceptable (less than 50)—supplier dropped from further business
   - Conditional (between 50 and 70)—supplier needs development work to improve performance but may be dropped if performance continues to lag
   - Certified (between 70 and 90)—supplier meets intended purpose or performance
   - Preferred (greater than 90)—supplier will be considered for involvement in new product development and opportunities for more business
7. Audit and ongoing certification review.

The above evaluation and certification process technique is shown in Example 3.1.

Tenneco acquired Federal-Mogul in 2018 and eventually spun it off as DRiV Corporation. DRiV uses a weighted scorecard to evaluate its suppliers. The company has a SupplyNet Scorecard website[48] that provides its Supplier Rating Qualifications and rates suppliers on three main categories, with the weights shown in parentheses: delivery (40 percent), quality (40 percent), and supplier cost-saving suggestions (20 percent). The quality score is based on two equally weighted components: parts

**Example 3.1 Supplier Scorecard Used for the KLM Company**

| PERFORMANCE MEASURE | RATING | WEIGHT | FINAL VALUE |
|---|---|---|---|
| Technology | 80 | 0.10 | 8.00 |
| Quality | 90 | 0.25 | 22.50 |
| Responsiveness | 95 | 0.15 | 14.25 |
| Delivery | 90 | 0.15 | 13.50 |
| Cost | 80 | 0.15 | 12.00 |
| Environmental | 90 | 0.05 | 4.50 |
| Business | 90 | 0.15 | 13.50 |
| | Total score | 1.00 | 88.25 |

Note: Based on the total score of 88.25, the KLM Company is considered a certified supplier.

per million defective and the quantity of supplier corrective action requests issued. The on-time delivery score is computed as "the average percentage across using plants for the current month. On-time delivery percentage has a window of one day early and zero days late to the due date and ± 5 percent of order quantity. The on-time delivery percentage is determined by line items received on time divided by the number of line items due by the supplier for the month." The *Overall Rating Weighted Point Score* ranges from 0 to 100. Suppliers are considered "preferred" if they score between 90 and 100. Preferred suppliers are those that Federal-Mogul will work with on new product development, approve for new business, and assist in maintaining a competitive position. An "acceptable" supplier rating is between 70 and 89. In this category, the supplier is required to provide a plan to DRiV on how to achieve preferred status. A score of 0 to 69 means that the supplier has a "developmental" supplier rating. Here, DRiV requires the vendor to take corrective action if the supplier is rated at this level for three consecutive months during the calendar year.

## External Certifications

Today, external certifications such as ISO 9000 and ISO 14000 have gained popularity globally as natural extensions of an organization's internal supplier evaluation and certification program. These evaluation criteria are frequently used to evaluate suppliers and are briefly discussed next.

### ISO 9000

In 1987, the global network of national standards institutes, called the International Organization for Standardization (ISO), developed ISO 9000, a series of management and quality assurance standards in design, development, production, installation, and service. There are many standards in the ISO 9000 family, including:[49]

- ISO 9000:2015—covers the basic concepts and language
- ISO 9001:2015—sets out the requirements of a quality management system
- ISO 9001:2015 for Small Enterprises—What to Do?—a handbook for SMEs wishing to implement a quality management system based on ISO 9001:2015
- ISO 9004:2009—focuses on how to make a quality management system more efficient and effective
- ISO 19011:2011—sets out guidance on internal and external audits of quality management systems
- ISO 9004: 2018—Quality of an organization—guidance to achieve sustained success
- Sector-specific applications of ISO 9001
- ISO 13485:2016—Medical devices—quality management systems—Requirements for regulatory purposes
- ISO/TS 54001:2019—Quality management systems—particular requirements for the application of ISO 9001:2015 for electoral organizations at all levels of government
- ISO 18091:2019—Quality management systems—guidelines for the application of ISO 9001 in local government

- ISO/TS 22163:2017—Railway applications—Quality management system—business management system requirements for rail organizations: ISO 9001:2015 and particular requirements for application in the rail sector
- ISO 29001:2020—Petroleum, petrochemical and natural gas industries—Sector-specific quality management systems—requirements for product and service supply organizations
- ISO/IEC/IEEE 90003:2018—Software engineering—guidelines for the application of ISO 9001:2015 to computer software

The European Union in 1992 adopted a plan that recognized ISO 9001 as a third-party certification; the result is that many European companies (as well as companies outside Europe) prefer suppliers with ISO 9001 certifications. Thus, companies wanting to sell in the global marketplace are compelled to seek ISO 9001 certifications.

Based on an ISO survey in 2019, more than 883,521 ISO 9001 certificates have been awarded globally.[50] In the United States, 20,956 certificates have been issued. China, which has the largest number of ISO 9001 certificates, has issued over 280,386, representing 31.7 percent of the total certificates issued worldwide.[51] Obtaining the ISO 9001 certification provides further verification that the supplier has an established quality management system in place. ISO certification will lead organizations to consistently deliver products that meet customer and applicable statutory and regulatory requirements. In addition, organizations seek to enhance customer satisfaction by continual improvement of their quality management systems. A recent survey clearly showed that the primary reason for seeking ISO 9001 certification is improved customer satisfaction. The basic ISO 9000/9001 standards are discussed further in Chapter 8.

## ISO 14000

In 1996, **ISO 14000**, a family of international standards for environmental management, was first introduced. In 2004, it was revised to make the standards easier to understand and emphasized compliance and compatibility with ISO 9000 for businesses that wanted to combine their environmental and quality management systems. There are many standards in the ISO 14000 family and these are covered in ISO's publication, "Environmental Management—The ISO 14000 Family of International Standards."[52] Organizations can only be certified to ISO 14001:2004, which sets the criteria and framework for an organization to develop an effective environmental management system but does not state requirements for environmental performance. The 14004:2016 Environmental Management System presents general guidelines on implementation. The latest addition to the family is the ISO 14005:2019 Environmental Management System, which provides guidelines for a flexible approach to phased implementation.

The benefits of investing in an **Environmental Management System (EMS)** based on ISO 14000 standards include the following:[53]

- Demonstrate compliance with current and future statutory and regulatory requirements
- Increase leadership involvement and engagement of employees
- Improve company reputation and the confidence of stakeholders through strategic communication
- Achieve strategic business aims by incorporating environmental issues into business management

- Provide a competitive and financial advantage through improved efficiencies and reduced costs
- Encourage better environmental performance of suppliers by integrating them into the organization's business systems

As of 2019, there were 312,580 ISO 14001 certificates issued globally in 197 countries.[54] China and Japan are the top two countries with ISO 14001 certificates. Given the interest in sustainability, investments in environmental management systems and ISO 14001 are likely to increase in the future. Additionally, as more organizations are certified in ISO 14001, they are likely to pass this requirement on to their suppliers. ISO 14001 enables an organization's management, employees, and external stakeholders to measure and improve environmental impacts.

## Supplier Development

Supplier development is defined as "any activity that a buyer undertakes to improve a supplier's performance and/or capabilities to meet the buyer's short- and/or long-term supply needs."[55] Supplier development requires financial and human resource investments by both partners and includes a wide range of activities such as training of the supplier's personnel, investing in the supplier's operations, and ongoing performance assessment. As companies outsource more and more parts, a larger portion of costs lies outside the company in a supply chain, and it becomes increasingly difficult to achieve further cost savings internally. One way out of this dilemma is for companies to work with their suppliers to lower the total cost of materials purchased. Companies that are able to leverage their supply base to impact their total cost structure will have a competitive advantage in their markets.

A seven-step approach to supplier development is outlined below:[56]

1. *Identify critical goods and services.* Assess the relative importance of the goods and services from a strategic perspective. Goods and services that are purchased in high volume, do not have good substitutes, or have limited sources of supply are considered strategic supplies.
2. *Identify critical suppliers not meeting performance requirements*. Suppliers of strategic supplies not currently meeting minimum performance in quality, on-time delivery, cost, technology, or cycle time are targets for supplier development initiatives.
3. *Form a cross-functional supplier development team*. Next, the buyer must develop an internal cross-functional team and arrive at a clear agreement for the supplier development initiatives.
4. *Meet with the top management of suppliers.* The buyer's cross-functional team meets with the suppliers' top management to discuss details of strategic alignment, supplier performance expectations and measurement, a time frame for improvement, and ongoing professionalism.
5. *Rank supplier development projects*. After the supplier development opportunities have been identified, they are evaluated in terms of feasibility, resource and time requirements, supply base alternatives, and expected return on investment. The most promising development projects are selected.

6. *Define the details of the buyer–supplier agreement*. After consensus has been reached on the development project rankings, the buyer and supplier representatives jointly decide on the performance metrics to be monitored such as percent improvement in quality, delivery, and cycle time.
7. *Monitor project status and modify strategies*. To ensure continued success, management must actively monitor progress, promote exchange of information, and revise the development strategies as conditions warrant.

Intel's Supplier Continuous Quality Improvement (SCQI) program is a "corporate-wide program that utilizes critical Intel supplier management tools and processes to drive continuous improvements in a supplier's overall performance and business."[57] The SCQI program was started in 1987 with the objective of improving supplier quality and minimizing the time needed to inspect incoming products. Intel suppliers are rewarded with the company's prestigious SCQI Award if they demonstrate "an elite performance in all critical management systems supporting quality, cost, availability, technology, customer service, and sustainability."[58]

According to Intel, the SCQI program accomplishes the following:

- Establishes aligned goals, indicators, and metrics
- Enables benchmarking of supplier performance
- Identifies potential quality issues before they impact Intel
- Drives supplier agility and ability to provide leading-edge products and services
- Matures critical Intel–supplier relationships
- Encourages collaborative agreements, team problem resolution, and two-way continuous learning
- Encourages continuous improvement throughout the year
- Provides data to support supplier recognition

With the SCQI program, Intel was able to reap valuable benefits from their suppliers. Additionally, as the quality of the suppliers' products improves, greater opportunities exist for making further improvements.

In summary, it is critical that an organization has an active supplier development program. The program should be managed such that it can meet both current and future needs. With a proactive supplier development program, suppliers are forced to stay on top of today's dynamic environment so that customers are not stuck with products or services that are not leading edge.

## Supplier Recognition Programs

While a large percentage of companies track supplier performance, only about half recognize excellent performance with supplier awards and appreciation banquets. Today, it is not sufficient just to reward your best suppliers with more business; companies need to recognize and celebrate the achievements of their best suppliers. As award-winning suppliers, they serve as role models for a firm's other suppliers. Intel understands that supplier performance excellence is critical to its success and

has three recognition awards under its SCQI Program: Certified Supplier Award (CSA), Preferred Quality Supplier (PQS) Award, and Supplier Continuous Quality Improvement (SCQI) Award. The CSA is given to suppliers who consistently meet Intel's expectations and have a proven commitment to continuous improvement. Intel's PQS award is for outstanding commitment to quality, excellent performance, and excellence at meeting and exceeding high expectations and tough performance goals. The SCQI Award, which is the most prestigious of Intel's three recognition awards, is given to suppliers who have a score of at least 95 percent on performance and the capability to meet cost, quality, availability, delivery, technology and environmental, social, and governance goals. In addition, suppliers must score 90 percent or greater on a challenging improvement plan and show outstanding quality and business systems. According to Bob Swan, Intel's chief executive officer, "At Intel, listening to our customers, suppliers and stakeholders is an integral part of our culture. Intel values the ecosystem partners who embrace a deep commitment to quality, role model affordability and drive innovation."[59]

Hormel Food Corporation's No. 1 Award program differs from other programs because they only give this award once every five years. Hormel gave out its first award in 1996, with the last award presented in 2016. To qualify for the No. 1 Award, a supplier must have met the following criteria:[60]

- Have a supplier rating index of 96 percent or better in the fourth calendar quarter of the reporting year. The average of the five-year supplier rating index must be equal to or greater than 96 percent.
- Must be a recipient of the Spirit of Excellence Award—an annual award given by Hormel Foods—for a minimum of four times over the last five consecutive years.
- Meet additional requirements in the areas of number of products sold by the supplier to Hormel Foods, dollars of exposure and deliveries to Hormel Foods, number of Hormel Foods locations serviced, and participation in continuous improvement processes.

Hormel also has a yearly Spirit of Excellence Award given to suppliers achieving a minimum Supplier Rating Index score of 92 over a twelve-month period. The criteria for the Supplier Rating Index include an ability to meet requirements, make timely deliveries, provide accurate administrative support, and maintain inventories. Additional criteria such as customer support, awareness of environmental concerns, and sales representative performance are considered but are not a requirement for the award. "I would like to congratulate these suppliers on this special recognition," said Bryan D. Farnsworth, senior vice president of supply chain at Hormel Foods. "Thank you all for the outstanding contributions you make to our company in respect to the goods and services you provide us."[61] The Spirit of Excellence Award also recognizes the role these suppliers play in Hormel's continuous improvement process throughout the year.

## Supplier Relationship Management

**Supplier relationship management (SRM)** has garnered increasing attention among firms actively practicing supply chain management. According to global consultant Accenture, SRM "…encompasses a broad suite of capabilities that facilitate collaboration, sourcing, transaction execution, and performance monitoring between an organization and its trading partners.

SRM leverages the latest technology capabilities to integrate and enhance supplier-oriented processes along supply chains such as design-to-source, source-to-contract, and procure-to-pay."[62] In a nutshell, SRM involves streamlining the processes and communication between the buyer and supplier and using software applications that enable these processes to be managed more efficiently and effectively.

The success of e-procurement, which has a predominantly internal focus, created the need for SRM solutions for managing the supply side of an organization's supply chain. SRM software automates the exchange of information among several layers of relationships that are complex and too time-consuming to manage manually and results in improved procurement efficiency, lower business costs, real-time visibility, faster communication between buyer and seller, and enhanced supply chain collaboration.

Many organizations are investing in SRM software modules due to the wealth of information that can be derived from these systems. SRM software can organize supplier information and provide answers to questions such as:

- Who are our current suppliers? Are they the right set of suppliers?
- Who are our best suppliers, and what are their competitive rankings?
- What are our suppliers' performances with respect to on-time delivery, quality, and costs?
- Can we consolidate our buying to achieve greater scale economies?
- Do we have consistency in suppliers and performance across different locations and facilities?
- What goods/services do we purchase?
- What purchased parts can be reused in new designs?

SAP's Supplier Relationship Management application (SAP SRM) provides companies with innovative approaches to effectively coordinate business processes with key suppliers. SAP SRM enables companies to optimize their procurement strategy, to work more efficiently with their suppliers, and therefore gain long-term benefits from their supplier relationships. SAP SRM enables companies to examine and forecast purchasing behavior, shorten procurement cycles, and work with their partners in real time. As a result, companies are able to develop long-term relationships with all those suppliers that have proven to be reliable partners. [63]

In general, SRM software varies by vendors in terms of capabilities offered. AMR Research has identified five key tenets of an SRM system:[64]

- Automation of transactional processes between an organization and its suppliers.
- Integration that provides a view of the supply chain that spans multiple departments, processes, and software applications for internal users and external partners.
- Visibility of information and process flows in and between organizations. Views are customized by role and aggregated via a single portal.
- Collaboration through information sharing and suppliers' ability to input information directly into an organization's supply chain information system.
- Optimization of processes and decision-making through enhanced analytical tools such as data warehousing and online analytical processing (OLAP) tools with the migration toward more dynamic optimization tools in the future.

There are two types of SRM: transactional and analytic. Transactional SRM enables an organization to track supplier interactions such as order planning, order payment, and returns. The volume of transactions involved may result in independent systems maintained by geographic region or business lines. **Transactional SRM** tends to focus on short-term reporting and is event driven, focusing on such questions as: What did we buy yesterday? What supplier did we use? What was the cost of the purchase? On the other hand, **analytic SRM** allows the company to analyze the complete supplier base. The analysis provides answers to questions such as: Which suppliers should the company develop long-term relationships with? Which suppliers would make the company more profitable? Analytic SRM enables more difficult and important questions about supplier relationships. Thus, we can see that transactional SRM addresses tactical issues such as order size, whereas analytic SRM focuses on long-term procurement strategies. With analytic SRM, an organization can assess where it was yesterday, where it stands today, and where it wants to go in the future to meet its strategic purchasing goals.

The challenges in any SRM software implementation are assembling all the data needed for an SRM application to work and employee training. For example, analysis of supplier information requires access to applications containing data about suppliers, as well as enterprise resource planning (ERP) and accounting and existing supplier information databases. Before SRM implementation, buyers typically spend 10 percent of their time on supplier relationship development, 40 percent on expediting, and 50 percent on order processing/tracking. After SRM implementation, the buyer's time allocation is estimated to be 50 percent on collaborative planning, 30 percent on supplier relationship development, 10 percent on expediting, and 10 percent on exception management.

Today, purchasing professionals have access to the latest technologies to help them perform their jobs effectively. Automating procurement activities can lead to significant cost savings as buyers move toward managing processes by exception. This effectively frees buyers to focus on more strategic and value-added activities such as collaborative planning. In addition, purchasing professionals can work effectively on maximizing the return on their relationships with suppliers. Greater procurement visibility from using SRM software also translates into smoother processes, faster cycle times, reduced new product development, improved time to market, streamlined purchasing, and reduced inventory costs. Examples of companies using SAP SRM for Supplier Relationship Management include: BP, a U.K.-based oil, gas, and chemicals organization with 67,600 employees and revenues of $278.40 billion; Samsung Electronics, a U.S.-based manufacturing organization with 287,439 employees and revenues of $206.19 billion; Allianz, a Germany-based insurance organization with 147,425 employees and revenues of $135.73 billion; Gazprom, a Russia-based oil, gas, and chemicals organization with 466,100 employees and revenues of $110.96 billion; Valero Energy Corporation, a U.S.-based oil, gas, and chemicals organization with 10,222 employees and revenues of $108.32 billion and many others.[65]

Currently, the SRM software market is booming globally based on a survey by HTF Market Intelligence Consulting Private Limited. Major players covered in this study include Zycus Inc., Intelex Technologies Inc., Epicor Software Corporation, DXC Technology Company, Determine, Inc., JDA Software Group, Inc., Ariba, Inc., Oracle, NEOCASE SOFTWARE, and Biznet Solutions.[66]

## Summary

Over the past few decades, we have seen the buyer–supplier relationship evolve from an arms-length/adversarial approach to one favoring the development of long-term partnerships. Significant competitive advantage can be achieved by organizations working closely with their suppliers. Without a shared vision, mutual benefits, and top management commitment, partnerships are likely to be short-lived. Other ingredients necessary for developing and managing lasting supplier relationships are trust, creating personal relationships, effective change management, sharing of information, and using performance metrics to create superior capabilities. We have also seen how companies manage their supplier relationships during the COVID-19 pandemic and present the essentials for establishing strong supplier working relationships. Mutually agreeable measures to monitor supplier performance provide the basis for continuous improvement to enhance supplier quality, cost, and delivery. Supplier certification ensures that buyers continue to work with their best suppliers to improve cost, quality, delivery, and new product development to gain a competitive advantage. Finally, supplier relationship management software automates the exchange of information and allows for improved efficiency and effectiveness in managing supplier relationships and improving performance. Organizations that successfully implement supplier relationship management can improve quality, reduce cost, access new technologies from their suppliers, increase speed to market, reduce risk, and achieve high performance.

## Key Terms

**analytic SRM** 118

**communication transparency** 103

**continuous improvement** 106

**environmental management system (EMS)** 113

**ISO 14000** 113

**posttransaction costs.** 104

**pretransaction costs,** 104

**total cost of ownership (TCO)** 104

**supplier relationship management (SRM)** 116

**transactional SRM** 118

**transaction costs** 104

## Discussion Questions

1. Explain the importance of supplier relationships to the performance of an organization.
2. Compare and contrast the arm's-length or adversarial approach to the partnership approach to building customer–supplier relationships.
3. Explain how an organization can manage its suppliers more effectively.
4. The COVID-19 pandemic has wreaked havoc on supply chains in general. How was procurement affected by the pandemic?
5. The healthcare industry appears to be severely affected by the COVID-19 pandemic. Go online and investigate how hospitals managed the high demand for healthcare services due to the pandemic.
6. What were the essentials for having strong supplier relationships during the COVID-19 pandemic?
7. What are the key factors that contribute to a lasting buyer–supplier partnership?

8. Explain how manufacturers can leverage their suppliers to gain a competitive advantage.
9. Describe the key performance indicators used to objectively measure the performance of supplier relationships.
10. Explain why the majority of strategic alliances fail.
11. What are the criteria used in evaluating a supplier?
12. Discuss how an organization develops a supplier evaluation and certification program.
13. What are the benefits and challenges of investing in supplier development programs?
14. Describe the steps needed to develop a successful supplier development program.
15. What are the benefits of ISO 9000 certification?
16. Do sustainability issues influence purchasing decisions? What are the benefits of ISO 14000 certification?
17. Research ISO's website (www.iso.ch), and discuss the growth of ISO 9000 and 14000 certifications by regions of the world such as Africa/West Asia, Central and South America, North America, Europe, Far East, and Australia/New Zealand.
18. Explain the key capabilities of supplier relationship management software.
19. Why do organizations have supplier awards programs?
20. What is supplier certification? Why do companies want to have a supplier certification program?
21. How can supplier development and relationships help in avoiding scandals such as product fraud and recalls, which are damaging to an organization's reputation and profitability?
22. List the similarities and differences in the capabilities of SRM software offered by JDA, Oracle, and SAP.
23. What are the advantages of using SRM solutions to manage suppliers?
24. What are the differences between transactional and analytic SRM?

## Problems

1. The Sun Devils Manufacturing Company is performing an annual evaluation of one of its suppliers, the Carson Company. Sony, who is the purchasing manager of the Sun Devils Manufacturing Company, has collected the following information on the company.

| PERFORMANCE CRITERIA | SCORE | WEIGHT |
|---|---|---|
| Continuous improvement | 90 | 0.10 |
| Cost | 85 | 0.20 |
| Delivery | 80 | 0.15 |
| Quality | 95 | 0.25 |
| Responsiveness | 90 | 0.15 |
| Sustainability | 80 | 0.05 |
| Technology | 90 | 0.10 |
| | Total score | 1.00 |

A score based on a scale of 0 (unsatisfactory) to 100 (excellent) has been assigned for each performance category considered critical in assessing the supplier. A weight is assigned to each of the performance criteria based on its relative importance. Vendors are classified based on their overall scores as follows:

- Unacceptable (less than 50)—supplier dropped from further business
- Conditional (between 50 and 70)—supplier needs development work to improve performance but may be dropped if performance continues to lag
- Certified (between 70 and 90)—supplier meets intended purpose or performance
- Preferred (greater than 90) )—supplier will be considered for involvement in new product development and opportunities for more business

What is the Sun Devils Manufacturing Company's score and how would you evaluate their performance as a supplier?

2. The Kentucky Equipment Company is in the process of ranking its suppliers for one of its key components. To assist in the evaluation process, the information on their four suppliers is shown in the table below.

| | | SCORES | | | |
|---|---|---|---|---|---|
| PERFORMANCE CRITERIA | WEIGHT | TOROS | SUN DEVILS | GAMECOCKS | BUCKEYES |
| Price | 0.10 | 85 | 95 | 90 | 90 |
| Payment terms | 0.20 | 90 | 80 | 95 | 85 |
| Quality | 0.10 | 95 | 80 | 85 | 90 |
| Delivery | 0.10 | 95 | 90 | 90 | 85 |
| Suggestions for quality improvement | 0.20 | 85 | 90 | 90 | 95 |
| Reputation | 0.10 | 85 | 90 | 90 | 85 |
| Responsiveness | 0.10 | 80 | 85 | 95 | 80 |
| Sustainability | 0.10 | 90 | 80 | 85 | 90 |
| Total score | 1.00 | | | | |

Each performance category is scored on a scale from 0 (unsatisfactory) to 100 (excellent) and assigned a weight based on its relative importance. Suppliers are considered "preferred" if they score between 90 and 100. Preferred suppliers are those that the Kentucky Equipment Company will work with on new product development, approve for new business, and assist in maintaining a competitive position. An "acceptable" supplier rating is between 70 and 89. In this category, the supplier is required to provide a plan to Michelle Equipment on how to achieve preferred status. A score of 0 to 69 means that the supplier has a "developmental" supplier rating. What are the scores of the four suppliers and how would you evaluate each of them? Which supplier would you pick?

## Essay/Project Questions

1. Go to the Institute for Supply Management website (www.ism.ws), and find the listing for the latest ISM Annual International Supply Management Conference. Then find the conference proceedings, and report on a paper that was presented regarding a topic covered in this chapter.
2. Go online and find an organization that managed its supplier relationships well during the COVID-19 pandemic.

3. Find a company online that is using a development program to improve a supplier's performance and/or capabilities and report on its experiences.
4. Find a company online that has successfully implemented a supplier certification program and write an essay on this company and its experiences.
5. Pick a company online that is using SRM, and report on its success and/or challenges with the software solution.
6. Many organizations find it necessary to recognize and celebrate the achievements of their best suppliers. Go online and identify a company that has used a supplier recognition program and report on its experiences. What are some of the benefits the company derives from its suppliers?
7. Find companies online that are providing SRM software solutions. Provide examples of their success stories.
8. The Planning Perspectives, Inc. regularly surveys auto manufacturers on the level of supplier relations. Please select a major auto manufacturer and trace the progress made in supplier relations over time. What factors contributed to the rise or fall in the rankings?
9. Pick a recent supply chain scandal reported in the popular press or online. Describe what led to the scandal and the contributing factors. How could the company have avoided the pitfall?

## Cases

### 1. Donnell Truong Ventures*

Donnell Truong is the chief operating officer of a vast real estate empire. His major holding is resort hotels. His resort properties are rated five-star hotels and are in over forty countries. The challenge of keeping such a high rating in an extremely competitive industry that relies so heavily on customer perception and expectations is enormous. All Donnell's hotels contain a casino. He expects each of his hotel/casino general managers to ensure the clientele are treated as special. More importantly, Donnell demands that the customer satisfaction ratings are always a 5, a rating of outstanding in the survey his hotels administer.

The hotel industry is an excellent example of an industry that depends extensively on suppliers. In addition to the services it provides within its confines, Mr. Truong's hotels/casinos offer recommendations to five-star dining, connections to cruises, access to golf courses, membership to local spas, and much more. Consequently, although it does have a supplier relationship management program for its direct suppliers such as food suppliers, liquor suppliers, etc., Mr. Truong decided they must go beyond this "routine" approach and develop a supplier certification for the businesses they recommend to their guests. Donnell believes this is necessary because his five-star rating depends on his clientele's total experience, including his resorts' recommendation of a cruise, restaurant, etc., to rich clientele. Therefore, these indirect or complementary suppliers must be certified as well.

Mr. Truong is confident that the business that "supply" the added amenities that influence the total experience for his clientele would be supportive of this initiative. Much of their business is dependent on his resorts' recommendation and goodwill. In theory,

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being part of his complementary supplier certification program is a win–win for everyone. The challenge is that these "complementary suppliers" provide services, not goods. What would be the key metrics?

Donnell and his executive team perused the research on strong supplier relationships. For their situation, they believed four intrinsic characteristics were paramount—trust, commitment, adaptation, and personal relationships. Donnell was big on quantitative performance metrics. The next action was to identify the specific metrics that would demonstrate the "complementary suppliers" adherence to the four intrinsic characteristics.

### Discussion Questions

1. Are the four intrinsic characteristics the best ones to base the relationship performance measures for Donnell Truong Ventures? If not, what characteristics would be more suitable? In either case, justify your answer with specific examples.
2. Since Donnell Truong Ventures is developing a certification for "complementary suppliers", should they use the same metrics they use for direct suppliers? Explain why or why not.
3. List and defend any other metrics you think should be used for this certification.

## 2. Jaeger Industrial Solutions*

Nora Forrester, director, supply chain management for Jaeger Industrial Solutions, is planning her budget requirements for the next fiscal year. Jaeger Industrial Solutions provides custom control panels, specialized wiring harnesses, etc., for chemical processing facilities, water treatment and cooling systems, and electrical power stations. This hardware is crucial to the productivity and safety of these facilities.

Her predecessor, Jerimiah Cosgrove, was a strong advocate for multiple sourcing. He had always believed that having multiple suppliers gave Jaeger a financial edge. Jerimiah's approach was to pit the suppliers against each other. Using this method, he was able to squeeze out every extra cent from their bids. Cost was his primary and, in many cases, his only consideration. This approach led to a glut of suppliers.

Nora's philosophy was different. Although she was cost conscious, Nora believed that quality outweighed penny pinching. Furthermore, Nora believed that in today's competitive environment strong supplier relationships were worth the additional cost. Plus, with so many suppliers, the task of monitoring their performance added a level to her team's workload that didn't seem justifiable based on the benefit it actually provided. Consequently, Nora decided to trim the list of suppliers from 1,000 to 100. Obviously, this would be a challenging task.

Nora had her team analyze all 1,000 suppliers. Under Jerimiah they had basically focused only on cost; however, to some degree they had captured data on eight major performance categories—cost, quality, delivery, responsiveness, environment, technology, business metrics, and total cost of ownership. Since the data were limited, Nora determined that for this task they would initially concentrate on cost, quality, responsiveness, and business metrics. Nora decided to place an emphasis on a fundamental criterion that spanned these four categories. She chose C3 Behavior—collaboration, cooperation, and coordination.

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## Discussion Questions

1. Is Nora's choice of $C^3$ Behavior the best way to measure suppliers moving forward? If so, explain the benefits of using $C^3$ Behavior. If not, then provide another option and justify your choice.
2. Considering the $C^3$ Behavior, identify two of the items listed under business metrics in Table 3.1, Examples of Supplier Performance Metrics, and explain why and how they fit this fundamental criterion.
3. Comment on Nora's strategy of trimming the number of suppliers—what would she hope to accomplish? Do you think it is a smart plan?

## 3. Cyber Logic Systems – Supplier Relationships*

Cyber Logic Systems is a U.S. company that specializes in cyber security. It recently expanded its operations to Europe and South America. During this expansion Rhonda Mendoza was promoted from director of operations to vice president of supply chain management. Although Cyber Logic's primary product is software, often new hardware is required to support the robust software. Because the regulations and specifications for hardware differ in each market area, Rhonda instituted a supplier certification process. She felt this was crucial to ensure supplier compliance with the applicable regulations and specifications.

Because new cyber security systems must be in place as quickly as possible to avoid further damage to customers' databases from hackers, any new hardware must be ready for immediate use. Therefore, to guarantee suppliers can meet this requirement, a weighted criteria evaluation system is utilized as part of the supplier certification process. Rhonda's department collects performance data on all suppliers. A weight is assigned to each element of the performance criteria based on its criticality to the customer's needs (service specifications) and the emphasis placed on it in the applicable regulations. This information is monitored and the suppliers are graded based on their performance. Suppliers who fail to meet the standards set by Cyber Logic Systems are immediately replaced. The following Supplier Scorecard shows how suppliers A, B, C, and D are performing on the specific performance measures.

| | SUPPLIER RATINGS | | | | | SUPPLIER FINAL VALUE | | | |
|---|---|---|---|---|---|---|---|---|---|
| PERFORMANCE MEASURE | SUPPLIER A | SUPPLIER B | SUPPLIER C | SUPPLIER D | WEIGHT | SUPPLIER A | SUPPLIER B | SUPPLIER C | SUPPLIER D |
| Cost | 80 | 85 | 70 | 78 | 0.10 | | | | |
| Delivery | 85 | 80 | 85 | 82 | 0.15 | | | | |
| Environmental | 75 | 85 | 65 | 88 | 0.10 | | | | |
| Quality | 95 | 93 | 90 | 89 | 0.20 | | | | |
| Responsiveness | 80 | 90 | 95 | 84 | 0.25 | | | | |
| Technology | 92 | 90 | 87 | 98 | 0.20 | | | | |
| Total scores | | | | | 1.00 | | | | |

Vendors are classified based on their overall performance.

- Unacceptable—less than 60—the supplier is dropped from further business

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- Conditional—equal to 60 and less than 70—supplier needs development to improved performance and may be dropped if performance continues to lag
- Certified—equal to 70 and less than 90—the supplier meets intended purpose or performance
- Preferred—90 or higher—supplier will be considered for involvement in new product development and opportunities for more business

However, Rhonda realized that although suppliers must meet the standards of her supplier certification process, Cyber Logic Systems has a responsibility as well to the suppliers. To support quality focused suppliers, Rhonda established a supplier development process to complement and enhance the supplier certification process. One very important aspect of the supplier development process was to create a cross-functional supplier development team. This team is composed of Cyber Logic Systems personnel and supplier personnel. The objective is to discuss strategic alignment, performance expectations, and measurement. The communication and relationship functions of the cross-functional team provide a win–win situation that helps improve the supplier's performance.

Rhonda believes in the carrot-and-stick approach to supplier relationships. In addition to the supplier evaluation and certification processes, she has also introduced a supplier recognition program. The suppliers are recognized annually for outstanding performance in several areas such as on-time delivery, quality, responsiveness, cost savings, and much more.

Administering supplier relationships is a huge task for any organization; therefore, to enhance the ability of Cyber Logic Systems to manage supplier relationships effectively and efficiently, Rhonda launched a supplier relationship management (SRM) system. She chose an analytic SRM that allows her to analyze her entire supplier base. Rhonda's focus as vice president of supply chain management is on long-term procurement strategies. Analytic SRM provides her the capability to assess the past state of supplier relations, the current state of supplier relations, and determine the best direction for Cyber Logic Systems to go in the future.

The SRM system provides Cyber Logic Systems the capability to integrate both internal users and external partners into the system; thus, providing everyone a view of the supply chain. Furthermore, it allows increased collaboration through information sharing. Since some information is sensitive and cannot or should not be shared with everyone, SRM systems can be customized by role, for example, suppliers or internal users. Rhonda explained to her team that the obvious benefit is information visibility. Internal users and external partners have access to information pertinent to their roles. Finally, for Rhonda, it allows optimization of decision making.

## Discussion Questions

1. Based on the Supplier Scorecard, what classification does each supplier fit into?
2. Are there any suppliers Rhonda should be concerned about, i.e., replace, give additional business to, or place into her supplier development program? Why or why not?
3. Assuming Cyber Logic Systems recognizes suppliers at the annual awards banquet if they meet the preferred classification standard for any of the specific performance measures, would any of the four suppliers qualify for an award? If so, who and for which performance measures?

# Part 2 Continuing Case

## Vanlandingham Robotics—Supplier Relationship Management Program*

Vanlandingham Robotics is excited about its future. The robotics industry is a rapidly growing market with estimates of it moving from $26 billion in 2020 to $74 billion by 2026. However, the competition is fierce. For example, the global agriculture drones market is predicted to be valued at $6.2 billion by 2024.

Emogene Edgerton is chief executive officer of Vanlandingham Robotics. She has put together a strong team that has kept Vanlandingham Robotics in the top 25 percent of the robotics companies. This has been a tough challenge. The key to their success has been their suppliers. However, because of the intense rivalry between companies, many up-and-coming enterprises are trying to poach Vanlandingham's suppliers. This has Emogene very concerned. Suppliers are essentially the life blood of the corporation. Vanlandingham Robotics has always treated their suppliers well; however, they do not have a formal supplier–relationship program.

Freda Farmer has been promoted to the position of supply quality manager. One of her duties is to provide functional support for implementation of supplier performance management techniques and procedures to drive overall progress in supplier performance with a rigorous emphasis on the highest impact and poorest performing suppliers. She cultivates a strategy to establish and enhance relationships with suppliers that drive comprehensive business metrics.

Freda believes the key to a successful and robust supplier performance management system is for it be objective versus subjective. Therefore, she works with her suppliers to develop a set of mutually acceptable supplier performance metrics. These metrics are price, quality, delivery, responsiveness, technology, and total cost of ownership (TCO).

As part of the process Freda begins collecting data on the metrics. For example, for price she collects data related to unit price and inventory and transportation costs. For some of the other metrics the focus is on percent defect-free deliveries, delivery time, changes in delivery schedule, percent of products shipped cost effectively, etc. The data will be used to score the six metrics.

Candi Cody, vice president of supply chain management, works with Freda to develop a scorecard with four performance categories: unacceptable, conditional, certified, and preferred. The performance categories are based on a range of points from zero to 100. Less than 50 points is unacceptable, 50 to 74 is conditional, 75 to 89 is certified, and greater than 89 is preferred. Candi determines what the weight of each of the metrics will be, with the weights summing to 100 percent. These weights will be reassessed annually and adjusted according to the needs of the business.

Emogene, Candi, and Freda meet to determine how best to begin the process of assessing their vendors. They determine that the most manageable method is to evaluate five vendors at a time. They decide to use the new supplier performance management system

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to objectively rank the suppliers. Once the assessments are complete, they will ascertain which vendors they will consolidate their purchase through; thus, reducing the number of current vendors to the best rated suppliers.

The first five vendors selected for evaluation are Bailey Technologies, Gomez Automation, Khan Software, McKay Mechanization Inc., and Stafford Systems. Their scores for each metrics are as follows:

| METRIC | BAILEY | GOMEZ | KHAN | MCKAY | STAFFORD |
|---|---|---|---|---|---|
| Price | 80 | 72 | 80 | 90 | 78 |
| Quality | 70 | 85 | 65 | 95 | 95 |
| Delivery | 84 | 87 | 82 | 60 | 75 |
| Responsiveness | 85 | 80 | 85 | 65 | 85 |
| Technology | 80 | 92 | 55 | 88 | 90 |
| TCO | 90 | 91 | 80 | 88 | 84 |

**Option 1 Weighting**

| METRIC | WEIGHT |
|---|---|
| Price | 0.10 |
| Quality | 0.25 |
| Delivery | 0.20 |
| Responsiveness | 0.05 |
| Technology | 0.10 |
| TCO | 0.30 |

**Option 2 Weighting**

| METRIC | WEIGHT |
|---|---|
| Price | 0.25 |
| Quality | 0.40 |
| Delivery | 0.20 |
| Responsiveness | 0.05 |
| Technology | 0.10 |

## Discussion Questions

1. Based on the information provided in the case, metrics, weighting (option 1), and scores for each vendor, who are the top two vendors?
2. Based on the information in the case, what performance category does each vendor fall under?
3. If Vanlandingham Robotics decides to use option 2 weighting, do the vendor final values change?
    a. If so, what is the difference?
    b. Does the performance category for any vendor change? If so, how?
4. Which weighting option would you recommend Vanlandingham Robotics use?
    a. Explain why.

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Chapter **4**

# Ethical and Sustainable Sourcing


*Public opinion is such that if a business doesn't carry on ethically or doesn't recruit a diverse staff it will be ostracized. Everyone is under so much scrutiny these days that they will have no choice.*

**—Jenny Herrera, CEO, Good Business Foundation**[1]

*At our heart is safety and sustainability, and responsible sourcing and CO2 footprint are a big part of that. At first it was a bit funny, because everyone was like, 'Oh, you really mean this?' Now our suppliers are well educated and want the same things.*

**—Martina Buchhauser, Director of Procurement, Volvo**[2]

## Learning Objectives

**After completing this chapter, you should be able to**

**LO 1** Understand and appreciate the trends in ethical and sustainable sourcing.

**LO 2** Define and describe the terms used in ethical and sustainable sourcing.

**LO 3** Describe the differences between ethical and sustainable sourcing.

**LO 4** Understand how ethical and sustainable sourcing strategies are developed and implemented.

**LO 5** Understand the use of environmental supplier certifications.

**LO 6** Discuss the benefits of strategic supplier alliances.

**LO 7** Describe how and why sourcing practices are benchmarked.

**LO 8** Discuss why firms would want to assess their sourcing capabilities.

## Chapter Outline



## SCM Profile: Luxury Clothing Partnership Assures Ethical Sourcing

majeczka/Shutterstock.com

In 2018, U.S. nonprofit cotton promoter Supima, Italian shirt fabric manufacturer The Albini Group, and New Zealand-based traceability systems provider Oritain entered into a partnership with French luxury clothing company Kering to provide organic cotton for Kering's brands. The partnership made headlines because the cotton fabrics became 100 percent forensically traceable. While companies have used scientific traceability in the past to ensure sustainably and ethically sourced materials, this unique partnership gave new legs to the idea of traceable apparel sourcing.

According to Marc Lewkowitz, CEO of Supima, integrating traceability into luxury fashion was inevitable. "For brands, the hard work has already been done to build the brand's message and

position," Lewkowitz said. "Now, authentication and verification is a way to reinforce that message." The product's origin, explained Lewkowitz, is the key to its authenticity, and the same goes for luxury fashions. "When a consumer picks a product from a storied brand group like Kering, it means something to them," he said. "Each product showcases the authentic characteristics of the materials used in the garment, and the craftmanship that went into creating it."

Rupert Hodges, executive director at Oritain, explained that now there are scientific methods to verify luxury fabric sourcing, which is meaningful to consumers. "Consumers are suddenly awake to the indirect implications their purchasing decisions can have on people's lives," Hodges said. "Luxury fashion's higher price points and lower volumes lend themselves to more responsible sourcing," he said. Hodges went on to explain that consumers who don't seek out sustainable brands will still react in a positive way to brands' moves toward ethical sourcing.

Traceability efforts also benefit the retailers who partner with luxury brands. "Protecting brand reputation and financial investment from substitution with inferior product provides additional reassurances that can be passed onto both the consumer and brand partners," Hodges said. By reducing fraud and providing knowledge of the supply chain, luxury manufacturers are giving retail partners even more reasons to seek out partnerships.[3]

## Introduction

As discussed in Chapters 2 and 3, purchasing, sourcing, or supply management departments are today seen as highly valued and strategic contributors to their organizations because of their ability to impact product design and quality, cost of goods sold, and manufacturing cycle time, all of which impact the firm's profitability. Several concerns which have emerged for purchasing departments over the past eight to ten years, are the use of ethical and sustainable sourcing practices. Global population growth, the increasing awareness of environmental issues, and consumers' desires for better corporate responsibility have combined to place unprecedented pressures on company personnel to effectively manage the firm and its supply chains. Additionally, as world economies expand and contract, this places pressure on managers to squeeze costs out of operations to survive over the long haul. Corporate concerns regarding cost, environmental, and ethical performances have allowed purchasing personnel to have a tremendous impact on their companies' and their supply chains' successes and reputations. These and other strategic purchasing topics are discussed in this chapter.

The influence of the purchasing department both within the organization and outside its boundaries is quite unique in that it interacts with customers and suppliers; internal design, production, finance, marketing, and accounting personnel; and also the firm's executive managers. As companies take a more proactive role in managing their supply chains, purchasing departments are then seen as one of the primary designers and facilitators of important inward- and outward-facing sourcing policies. These policies might include a number of ethical, sustainable, and cost-oriented practices such as those described in this chapter. Since the launch of her fashion house in 2021, Stella McCartney, for example, has been a pioneer in environmental sensibility of designs, ethical sourcing, and recycling. Her designs include collections with organic cotton, ethical wool, and no leather or fur. Recently, her designer house presented collections based on her initiative titled 'There She Grows', aimed at protecting vulnerable rainforests. Another example is TenTree, which plants 10 trees for every garment produced. "We believe that planting trees is one of the

most important environmental missions today. It provides jobs, protects eco-systems and wildlife, sequesters carbon and more," says Derrick Emsley, CEO of TenTree.[4]

World events that have impacted supply chains such as the pandemic, global recessions, the tsunami in Japan, and the exit of the United Kingdom from the European Union, hastened many organizations' plans to institute better supply chain strategies. The goals of these strategies include reducing dependencies on only a few foreign suppliers, reducing delivery cycle times and carbon footprints, and improving quality, customer service, and ethical reputations. Additionally, the increasing number of global competitors, demands by customers for companies to become more ethically and environmentally focused, and the high costs of fuel and materials place added pressures on firms to improve their supply chain management performance.

Today, these trends have become the drivers of strategic sourcing and supply chain management initiatives. Taking the notion of sourcing one step further, **strategic sourcing** can be thought of as managing the firm's external resources in ways that support the long-term goals of the firm. This includes the development of ethical and sustainable sourcing initiatives, managing and improving supplier relationships and capabilities, identification and selection of environmentally and socially conscious suppliers, and monitoring and rewarding supplier performance. Some of these topics have been introduced in earlier chapters and will only be lightly touched upon here, while others particularly related to ethical and sustainable sourcing will be covered in greater detail in this chapter.

Developing socially responsible and environmentally friendly sourcing strategies that also create a competitive advantage is no easy task. Creating and implementing these strategies might provide some benefits for the firms involved but can ultimately fail, because of misaligned strategies, lack of commitment, unrealized goals, and loss of trust in buyer–supplier relationships. Particularly during the pandemic, trust between trading partners has been difficult to maintain. Kohl's, for example, canceled orders worth $100 million from South Korean factories and $50 million from Bangladeshi factories as the coronavirus outbreak deepened into a pandemic in March 2020. The Korean Federation of Textile Industries urged Kohl's to honor its obligations with suppliers instead of invoking force majeure clauses in its contracts to renege on paying for clothing that had already been made and was ready to ship.[5] Purchasing managers proactively managing their firms' supply chains must also come to understand that some sourcing strategies are better suited to some supply chains than to others. Indeed, firms may have dozens of supply chains associated with their most important inbound purchased items and outbound finished products. Some of these supply chains may be driven by a low-cost overall strategy, while others may have the environment, quality, or customer service as the overriding objective. Even different parts and components used in one product may have diverging supply chain strategies. In the following sections, the development of successful ethical and sustainable sourcing strategies is discussed.

## Ethical and Sustainable Sourcing Defined

### Ethical Sourcing

To establish a common ground for further discussion, it is necessary to first define and describe the origins of the terms *ethical* and *sustainable* sourcing. To begin with, **business ethics** is the application of ethical principles to business situations, and has been very widely studied. A library search, for instance, would reveal over 250 books dedicated solely

to the topic of business ethics. Generally speaking, there are two approaches to deciding whether or not an action is ethical. The first approach is known as **utilitarianism**. This would mean that an ethical act creates the greatest good for the greatest number of people. The second approach is known as **rights and duties**, and states that some actions are right in themselves without regard for the consequences. This approach maintains that ethical actions recognize the rights of others and the duties those rights impose on the ones performing the actions.

The practice of business ethics is also referred to as **corporate social responsibility** (CSR). Much of the discussion to date of corporate social responsibility assumes that a corporation can act ethically just as an individual can. Many companies, for instance, have formal CSR initiatives that include ethical sourcing. According to the Governance and Accountability Institute, about 85 percent of S&P 500 companies are now publishing CSR reports, up from 20 percent in 2011. [6]CSR initiatives and reporting are also growing globally. In 2014, the European Union adopted annual corporate social responsibility reporting requirements. Under this directive, companies exceeding an average of 500 employees on their balance sheet are subject to mandatory reporting. This amounts to about 6,000 companies. [7]In another example, Professional Sports Authenticator (PSA), the largest third-party trading card authentication and grading company in the world, recently launched its corporate social responsibility program. "Our employees have been the driving force in getting PSA involved in supporting our communities," says Bill Bozeman, CEO of PSA. "I'm constantly impressed by their willingness to jump in and help. Just during COVID-19, we have written letters to senior citizens who have been isolated from their families and friends, as well as funded a donation to youth aging out of the foster system. We are proud and honored to have such service-minded employees at PSA." [8]

Extending from business ethics, the term **ethical sourcing** can be defined as:

> *That which takes into account the public consequences of organizational buying, or bringing about positive social change through organizational buying behavior.*[9]

Ethical sourcing practices include promoting diversity by intentionally buying from small firms, ethnic minority businesses, and women-owned enterprises; discontinuing purchases from firms that use child labor or other unacceptable labor practices; or buying from firms in underdeveloped nations.

Purchasing managers and corporate executives play a central role in promoting ethical sourcing by creating a supportive organizational culture, developing policies that outline the firm's desire to practice ethical sourcing, communicating these policies to trading partners, and then developing tactics that specifically describe how ethical sourcing will be implemented. The nearby SCM Profile describes the Starbucks ethical sourcing initiative.

Massachusetts-based athletic footwear retailer Reebok launched its ethical sourcing program in the early 1990s. It emphasizes the roles played by supplier factory managers in maintaining ethical workplace conditions. Reebok also tries to collaborate with its competitors in establishing common human rights guidelines, since they all may be buying merchandise from the same suppliers. In 2002, Reebok unveiled an Internet-based human rights compliance-monitoring software application, generating considerable interest from other firms about buying the application. In response, Reebok established a not-for-profit organization built around the technology and in 2004 launched the Fair Factories Clearinghouse with the backing of the National Retail Federation.[11] U.K.-based Lush Fresh Handmade Cosmetics sources its raw materials globally, and suppliers must sign a pledge confirming no animal testing has been done. The company supports Fair

## SCM Profile: Starbucks' Ethical Sourcing Practices

Odessa25/Shutterstock.com

Since 1971, Starbucks Coffee Company has been committed to ethically sourcing coffee. Starbucks made their first farmer loan investment in 2000 with Root Capital, a nonprofit organization operating in poor rural areas of Africa, Latin America, and Southeast Asia, for a project in Chiapas, Mexico. This fund helped establish a revolving line of credit focused on short-term financing for farmer cooperatives. This work directly impacts coffee quality and sustainability for the specialty coffee industry.

In 2008, Starbucks made another investment of $20 million, distributed through Root Capital and the Fairtrade Access Fund, which is designed to provide rural people with opportunities to increase their market access through financial products and technical assistance. To date, this financing has impacted more than 62 cooperatives in 8 countries benefiting more than 40,000 farmers. In 2015, Starbucks announced an additional investment of $30 million as part of its Global Farmer Fund program, which is one aspect of the company's ethical sourcing initiative, which also supports the sustainability of the specialty coffee industry. "In 2015, we have achieved a number of milestones across our ethical sourcing initiatives but we know that the work isn't done. This new investment demonstrates how we remain steadfast in our support of farmers around the world," said Craig Russell, executive vice president of Global Coffee for Starbucks. "By providing access to capital, farmers have the ability to make strategic investments in their infrastructure, offering the stability they need to manage ongoing complexities so that there is a future for them and the industry.

As of 2015, 99 percent of Starbucks' coffee is verified as ethically sourced. Starbucks' ethical sourcing program includes a network of six farmer support centers around the world (Rwanda, Tanzania, Colombia, China, Costa Rica, and Ethiopia) as well as a farm in Costa Rica acting as a global agronomy center.[10]

Trade and Community Trade initiatives. "At the heart of our brand is a commitment to look after people, animals and the planet," says Mark Wolverton, president and CEO, Lush North America.[12]

Purchasing goods from suppliers in developing countries can be risky in that if human rights, animal rights, safety, or environmental abuses become associated with the firm's suppliers or foreign manufacturing facilities, this could lead to negative publicity for the buyer, along with product boycotts, a tarnished company image, brand degradation, lower employee morale, and ultimately lower sales, profits, and stock prices. This very thing happened to running gear manufacturer Nike in the mid-1990s when it contracted with Pakistani suppliers to make footballs. Unfortunately, the work was subcontracted to local villagers, where children as young as ten were used in the production processes. Similar problems for Nike also cropped up in Cambodia and Malaysia at about the same time. In 1998, CEO Phil Knight acknowledged that, "Nike product has become synonymous with slave wages, forced overtime, and arbitrary abuse." Nike then pledged to reform this

company image. In Malaysia, for example, Nike reimbursed workers, paid to relocate them, and then met with representatives of its 30 contract Malaysian factories about enforcing labor standards.[13]

As described above, companies seeking to reduce production costs through use of foreign facilities, expose themselves to a number of risks. To minimize these risks, ethical sourcing policies should include:

- Determining where all purchased goods come from and how they are made;
- Knowing if suppliers promote basic workplace principles (such as the right to equal opportunity and to earn a decent wage; the prohibition of bonded, prison, or child labor; and the right to join a union);
- Use of ethical ratings for suppliers alongside the other standard performance criteria;
- Use of independent verification of supplier compliance;
- Reporting of supplier compliance performance to shareholders; and
- Providing detailed ethical sourcing expectations to suppliers.[14]

Use of ethical supply chain sourcing practices can be fraught with difficulties. Modern supply chains can encompass many countries, each with its own set of labor issues, wages, and working and living conditions. Many companies may not even be aware of their complete supply chains (beyond their immediate or first-tier suppliers and customers). For example, today in China, Uighur workers from Xinjiang are brought to labor camps under threat of arrest, and the companies operating at these camps are guaranteed a labor force immune to any sort of labor rights. Evidence shows that if any of them protest, they get sent to re-education camps. At least 83 well-known global brands in the clothing, technology, and automotive sectors from 16 different countries were linked to this practice, according to a 2020 Australian Strategic Policy Institute report. These labor camps are the first- and second-tier suppliers, so many global companies don't even realize these camps are part of their supply chains. Adidas is one example—they claim no relationships with any of the factories; however, satellite imagery shows the Adidas logo is on one factory site.[15]

The **Ethical Trading Initiative** (ETI) is an alliance of organizations seeking to take responsibility for improving working conditions and agreeing to implement the ETI Base Code, a standard for ethical practices for the firm and its suppliers. The ETI Base Code is shown in Table 4.1.

The purchase of **fair trade products** is an activity that is becoming increasingly popular as firms seek to demonstrate a more ethical approach to purchasing. A fair trade product refers to one that is manufactured or grown by a disadvantaged producer in a developing country that receives a fair price for its goods. Typically, the term refers to farming products such as coffee, cocoa, bananas, sugar, tea, and cotton which are produced in developing countries and exported to large firms in developed countries. However, the term is increasingly applied to all sorts of products. For instance, J. Crew Group will expand its sustainability efforts by launching its first Fair Trade USA certified collection today for its J. Crew and Madewell brands. The initial product will be an assortment of more than 30 styles of denim jeans for men and women that were made in a newly certified factory in Vietnam. "We have admired Fair Trade and all they do and have been working with them for the past year or so," said Libby Wadle, Madewell brand president. Fair Trade USA is a third-party firm that works with companies and their suppliers to ensure safe working conditions, environmental protection,

**Table 4.1 The Ethical Trading Initiative's Base Code**

| CLAUSES | ABBREVIATED EXPLANATIONS |
|---|---|
| 1. Employment is freely chosen | No forced, bonded, or involuntary prison labor. Workers are not required to pay "deposits" to their employer and are free to leave after reasonable notice. |
| 2. Freedom of association and the right to collective bargaining are respected | Workers have the right to join trade unions and to bargain collectively. Employers adopt an open attitude toward the activities of trade unions. Worker representatives are not discriminated against. Where the right to collective bargaining is restricted under law, employers facilitate the development of parallel means for bargaining. |
| 3. Working conditions are safe and hygienic | A safe and hygienic work environment shall be provided. Adequate steps shall be taken to minimize the causes of hazards in the workplace. Workers shall receive regular health and safety training. Accommodations shall be clean, safe, and meet the basic needs of workers. The company shall assign responsibility for health and safety to a senior management representative. |
| 4. Child labor shall not be used | There shall be no new recruitment of child labor. Persons under 18 shall not be employed at night or in hazardous conditions. Policies and procedures shall conform to the provisions of the relevant International Labor Organization standards. |
| 5. Living wages are paid | Wages and benefits for a standard work week meet national legal or industry standards, whichever is higher. Wages should be enough to meet basic needs. All workers shall be provided with written and understandable information about their employment conditions before they enter employment and about the particulars of their wages each time that they are paid. |
| 6. Working hours are not excessive | Working hours comply with national laws and benchmark industry standards, whichever affords greater protection. Workers shall not on a regular basis be required to work in excess of 48 hours per week and shall be provided with at least one day off for every 7 day period. Overtime shall be voluntary, shall not exceed 12 hours per week, and shall always be compensated at a premium rate. |
| 7. No discrimination is practiced | There is no discrimination in hiring, compensation, access to training, promotion, termination, or retirement based on race, caste, national origin, religion, age, disability, gender, marital status, sexual orientation, union membership, or political affiliation. |
| 8. Regular employment is provided | Work performed must be on the basis of recognized employment relationships established through national law and practice. Obligations to employees under labor or social security laws shall not be avoided through the use of labor-only contracting, subcontracting, or apprenticeship schemes. |
| 9. No harsh or inhumane treatment is allowed | Physical abuse or discipline, the threat of physical abuse, sexual or other harassment, or other forms of intimidation shall be prohibited. |

*Source*: Ethical Trading Initiative website: www.ethicaltrade.org

build sustainable livelihoods for employees, and help them earn additional money to give back to their communities.[16]

Agencies such as the Fairtrade Foundation, Fairtrade International, and the World Fair Trade Organization seek out and certify products as being fair trade products.[17] Leading retailers offer items for sale that are designated as fair trade products. Fair Trade USA reports that consumers are increasing their commitment to fair trade faster than ever before. Today, Fairtrade USA partners with over 800 brands, as well as over 1.3 million farmers in 70 countries.[18] According to Fairtrade International, nearly six out of ten consumers have seen the Fairtrade mark and almost nine in ten of them trust it.[19]

## Sustainable Sourcing

While the concept of **sustainable sourcing** can vary quite substantially from company to company, in 2007, the U.K. Food Industry Sustainability Strategy Champions Group on Ethical Trade identified three key areas to focus on to establish sustainable sourcing:

- Respect human rights and reduce poverty by creating profitable trading;
- Work within the finite limits of the planet's resources; and
- Move towards a low carbon economy.

In other words, purchasing fairly, profitably, and environmentally were the organization's three priorities and these tend to be the common thread in most other sustainable sourcing concepts today. For Unilever, the multinational consumer goods company with over 400 product brands, sustainable agriculture sourcing means growing food in ways which sustain the soil, minimize water and fertilizer use, and protect biodiversity while enhancing farmers' livelihoods. It defines sustainable sourcing using eleven social, economic and environmental indicators including soil health, soil loss, pest management, energy, water, the local economy and animal welfare. Unilever's biggest brand Knorr now sources 92 percent of its top 13 vegetable and herb ingredients from sustainable sources. In line with their original commitment, 62 percent of Unilever's agricultural raw materials were sustainably sourced by the end of 2019.[20]

The notion of protecting the earth's environment has been a topic of concern for many years, and has recently become a popular topic of debate as politicians and voters have made global warming a political issue. Former U.S. Vice President and longtime environmentalist Al Gore, for example, starred in the award-winning 2006 global warming documentary *An Inconvenient Truth* (he won the Nobel Peace Prize in 2007 for his environmental work). Additionally, awards such as the Goldman Environmental Prize have served as a support mechanism for environmental reform, providing global publicity for specific environmental problems.

The Goldman Environmental Prize began in 1989 and awards $200,000 to each prize recipient from six inhabited continental regions. Winners are announced every April to coincide with Earth Day. As of 2020, there have been 199 prize winners, including the 1991 prize winner, Dr. Wangari Maathai from Kenya. In the 1970s, Maathai founded the Green Belt Movement, an environmental organization concentrating on the planting of trees, environmental conservation, and women's rights in Africa. In 2004, she also became the first African woman to receive the Nobel Peace Prize for "her contribution to sustainable development, democracy and peace."[21] Other people such as David Brower, the former executive director of the Sierra Club; Eileen O'Neill, head of Discovery Channel and proponent of their Planet Green multimedia initiative; Patrick Moore, Director and cofounder of Greenpeace International; and many others have played major roles in championing the modern environmental movement.[22]

Growing out of this environmental awareness was the idea of **green purchasing**. Green purchasing is a practice aimed at ensuring that purchased products or materials meet environmental objectives of the organization such as waste reduction, hazardous material elimination, recycling, remanufacturing, and material reuse. According to the globally recognized Institute for Supply Management, green purchasing is defined as *making environmentally conscious decisions throughout the purchasing process, beginning with product and process design, and through product disposal*.[23] Companies such as California-based healthcare provider Kaiser Permanente and beer producer

Anheuser-Busch have been recognized as corporate trailblazers in green purchasing. In 2001, Kaiser Permanente formed an environmental stewardship council focusing on green buildings, green purchasing, and environmentally sustainable operations. Anheuser-Busch, for example, worked with its suppliers to reduce the lid diameter of four types of cans, saving millions of pounds of aluminum each year as well as reducing the energy needed to produce and transport the cans.[24]

The term **sustainability** as applied to supply chains is a broad term that includes green purchasing as well as financial performance and some aspects of social responsibility. It can be defined as *the ability to meet the needs of current supply chain members without hindering the ability to meet the needs of future generations in terms of economic, environmental and social challenges*. The idea of sustainability is certainly not new as evidenced by the way early Native Americans thought and lived and as Gifford Pinchot, the first Chief Forester of the U.S. Forest Service, wrote in an article in 1908:

> *Are we going to protect our springs of prosperity, our raw material of industry and commerce and employer of capital and labor combined; or are we going to dissipate them? According as we accept or ignore our responsibility as trustees of the nation's welfare, our children and our children's children for uncounted generations will call us blessed, or will lay their suffering at our doors.*[25]

For businesses and their trading partners, sustainability is seen today as doing the right things in ways that make economic sense. Some have begun referring to sustainability in terms of supporting the **three Ps**, which refers to *people*, *planet*, and *profit*. The objectives then are not only to sustain the world we live in, but to sustain employees and the firm's balance sheet as well.

**Sustainable sourcing** is one activity within the larger umbrella term of sustainability—it includes green purchasing, some form of financial benefit, as well as aspects of ethical sourcing. Very simply, it has been defined as:

> *A process of purchasing goods and services that takes into account the long-term impact on people, profits, and the planet.*[26]

Leading companies practicing sustainable sourcing seek to:

- *Grow revenues* by introducing new and differentiated sustainable products and services;
- *Reduce costs* by increasing resource efficiencies, avoiding use of noncompliant suppliers, and rethinking transportation and distribution systems;
- *Manage risk* by managing brand and reputation, and developing approaches for meeting regulations and capturing sustainability-conscious customers; and
- *Build intangible assets* by further enhancing brand and reputation through social and environmental responsibility.[27]

To accomplish these goals, companies must develop collaborative relationships with their key suppliers and customers to make sustainable sourcing a beneficial reality.

ASDA, the U.K.-based supermarket chain for example, has launched a new clothing take-back scheme which encourages shoppers to return unwanted items by offering a 10 per cent discount on its George brand of apparel. The initiative will see ASDA join hands with British recycling firm Yellow Octopus. "It's really important for our customers and colleagues that we tackle the issue of not just sourcing our clothes more sustainably, but also encouraging everyone in the UK to think about the issues of waste and how to make

fashion and textiles more circular so that we can really reduce the number of garments that go into landfill," says Mel Wilson, Global Professional Lead for Sustainable Sourcing and Quality at ASDA.[28]

Local and national governments are now getting involved to set some clear targets for organizations to achieve. China's approach to sustainability can be found in its goals for energy use per unit of GDP, water use per unit of value-added industrial output, and sulfur dioxide emissions. When a surge of manufacturing output in 2010 resulted in greenhouse gas emissions in excess of what China's five-year plan called for, the government cut off power to heavy industrial districts, forcing many plants to close temporarily. This dramatic move (unthinkable in most industrialized countries) demonstrated that, in China, sustainability goals are no less important than economic goals.[29]

Today, sustainability is increasingly moving from voluntary to legally mandated initiatives, including sustainability reporting requirements. The KPMG Survey of Sustainability Reporting 2020 included 5,200 companies in 52 countries. Overall, 80 percent of companies as of 2020 report on sustainability, compared with only 12 percent in 1993, and up 5 percent from 2017. Companies in the Americas lead in sustainability reporting, with 90 percent of companies in North America and Latin America reporting on sustainability, up 7 percentage points since 2017. By comparison, 77 percent of European companies, 59 percent of Middle Eastern and African companies, and 84 percent of Asia-Pacific companies currently report on sustainability. Mexico (100 percent), the United States (98 percent) and Canada (92 percent) have among the highest rates of sustainability reporting in the world.[30]

From the supplier's perspective, there are methods used to help determine what buyers want, in terms of environmentally friendly goods. COVID-19 may have devastated the retail landscape, but U.S. consumers' requirements for sustainability has been unchanged, a new survey claims. If anything, sustainability has grown from a "fringe preference" to a "core imperative across American life," according to a Method Research poll of 2,000 adults nationwide. The survey found that 85 percent of respondents said they've been thinking about sustainability the same amount or more during the pandemic. They are advocating for action—more than half (56 percent) of Americans said they want both the government and brands to prioritize the environment.[31]

Companies and government agencies alike are coming to realize that every purchase has a global environmental impact, and with careful sourcing, money can be saved. Collection, transport, manufacturing, and scrapping of raw materials and finished goods require the use of fossil fuels; goods purchased from distant suppliers require greater amounts of fuel for transportation; goods transported via ship or rail use less fuel than trucks or airlines; plant-based goods generally have a smaller environmental impact than petroleum-based goods; factories powered by solar or wind energy have a smaller carbon footprint than factories powered by oil or coal; and energy-efficient goods consume less energy.

## Developing Ethical and Sustainable Sourcing Strategies

To achieve the objectives described thus far in this chapter, a number of sourcing strategies must be considered and implemented. Care must be taken, though, when developing these plans. Failure to align sourcing strategies with overall supply chain objectives, for example, may result in considerable resources being expended to design and manage a set of sourcing activities, only to find that the resulting impact on the firm and its supply chains is something other than what was ultimately desired.

In one of the more important papers written on this topic, Martin Fisher uses two types of supply chains as examples—those for **functional products** and those for **innovative products**.[32] Functional products are maintenance, repair, and operating (MRO) materials and other commonly purchased items and supplies. These items are characterized by low profit margins, relatively stable demands, and high levels of competition. Thus, companies purchasing functional products most likely concentrate on finding a dependable supplier that is selling at a low price. Equipment maintenance and office cleaning products, as well as office supplies, for example, fall into this category.

Examples of some well-known innovative consumer goods are the Amazon Kindle and Tesla's Model S automobile; in factory settings, innovative products might be new types of control mechanisms, new software applications, or new robotics systems. Innovative products are characterized by relatively short product life cycles, volatile demand, high profit margins, and relatively less competition. Consequently, the sourcing criteria for these products may be more closely aligned with a supplier's quality reputation, delivery speed and flexibility, and communication capabilities, rather than simply low price.

The Edison Awards recognize and honor some of the most innovative goods and services each year. Originally established in 1987 by the American Marketing Association and now an independent organization, the Edison Award, named after Thomas Edison, is focused on fostering innovation and takes nominations from around the world for products which are then judged for their excellence in concept, value, delivery and impact.[33] Winners from around the world each year are given the Edison Award winning seal and are allowed to publicize the honor. They can also participate in a customized marketing plan that includes product sampling, social media, product reviews, and national media outreach. Some of the past award winners include GM, Harvard Business School, Tesla, Lenovo, Apple, TED, MIT, and Black and Decker. Table 4.2 describes some of the winners for 2020.

**Table 4.2 Some of the 2020 Edison Award Winners**

| | |
|---|---|
| **Marketing Integrity** | Protects enterprises from sophisticated bots by verifying the humanity of more than one trillion online interactions every week. The most sophisticated bots look and act like humans. Marketing Integrity stops them. |
| **Kupaa** | A payment platform that enables parents and caregivers to pay school fees and other expenses with their mobile devices securely, easily and on time. |
| **NextGenU** | NextGenU.org is offering the world's first free degree, a Master's degree in Public Health. Universities, Health Ministries, and learners have already begun adopting this resource in 191 countries. |
| **4ocean** | 4ocean is founded to help end the ocean plastic crisis by recovering and recycling ocean plastic, advocating for sustainable innovation and inspiring people around the world to reduce their consumption of single-use plastic. |
| **Somewear Global Hotspot** | Whether you're hiking in the wilderness or working in a remote area, the Somewear satellite hotspot provides 100% global connectivity and coverage when you're out of cell phone range. The device uses an app on your smartphone. |
| **Randori Attack Platform** | Helps cybersecurity defenders view their company like an attacker, and trains teams to be resilient against compromise through an authentic and continuous sparring experience. |
| **Narwal T10** | A robot mop and vacuum featuring innovative self-cleaning technology. The robot will wash, rinse and dry the mop automatically in the base station. |

*Source*: Edison Awards, found at www.edisonawards.com

Overlaying both functional and innovative purchases is whether or not to invoke an ethical or sustainable sourcing strategy. This adds yet another layer of complexity to the sourcing decision. Many of the commonly used sourcing strategies of thirty years ago do not work well today. For instance, "squeezing" or hard-bargaining suppliers to generate a lower annual **purchasing spend** (or purchasing expense) may ultimately prove harmful to buyer–supplier relationships, eventually leading to deteriorations in quality, ethical reputation, sustainability performance, and customer service as suppliers seek ways to cut corners in order to keep their profit margins at desired levels. If long-term plans are to be successful, they must support the firm's long-term strategies; and suppliers must also see some benefit from the initiatives implemented. A framework for ethical and sustainable sourcing strategy development is shown in Table 4.3.

In Step 1 in Table 4.3, the firm formalizes its ethical and sustainable sourcing policies. Obviously, these policies will vary based on use of foreign suppliers, types of items purchased, and the firm's experiences with this type of sourcing. Ethical sourcing policies should include the importance placed on fair working conditions; use of minority, women-owned, and small businesses; guidelines on human rights and use of child labor; use of subcontracting; and supplier reporting and verification procedures. Sustainable sourcing policies should include supplier compliance issues in terms of waste reduction, energy conservation, use of renewable energy, hazardous material elimination, recycling, remanufacturing, and material reuse.

In Step 2, training and communication of the policies occurs. It is all well and good to develop ethical and/or sustainable sourcing policies, but the firm must also do an adequate job of implementing these policies. In early 2000, for instance, iconic Canadian retailer

**Table 4.3 Ethical and Sustainable Sourcing Strategy Framework**

| STEPS | DESCRIPTION |
|---|---|
| 1. Establish corporate ethical and sustainable sourcing policies. | Establishes a vision and direction and enforces the importance of ethical and sustainable sourcing. |
| 2. Train purchasing staff; communicate policies to suppliers and customers. | Ensures that buyers are skilled in environmental and social considerations in sourcing and that suppliers and customers understand why and how purchasing decisions are made. |
| 3. Prioritize items based on ethical and sustainability opportunities and ease of implementation. Get started. | Allows buyers to "pick low hanging fruit" to provide evidence for successful strategy implementation. |
| 4. Develop a performance measurement system. | Measurement provides accountability and a way to improve over time. Should be reviewed periodically. |
| 5. Monitor progress, make improvements. Increase use of certified fair trade and green products and services. | Use performance measures to identify weaknesses. Step up efforts to develop better capabilities in the firm and its supply base. |
| 6. Expand focus to include other departments and customers. Increase brand value. | Use the purchasing department's success and influence to grow awareness in the firm and among customers. Communicate successes and programs to stakeholders. |

*Source*: Based in part on Newman, D., "Steps You Can Take to 'Green' Your Procurement," *Summit* 9(4), 2006: 10; and "Buying a Better World," found at www.forumforthefuture.org

Hudson's Bay had begun developing proactive sustainable sourcing plans, but in 2002 they were accused of using sweatshops for their outsourced manufacturing. As it turned out, they had not properly communicated their new vendor codes of conduct to their suppliers. Additionally, the shareholders and general public had no idea of their social compliance programs. This caused a number of actual and perceived problems for Hudson's Bay to overcome. Today, their social compliance programs are formalized and widely communicated, and they audit all supplier facilities for compliance to their codes of conduct.[34]

Step 3 is all about getting started. It is important to keep efforts simple early on, find successes quickly, and then build on these successes. If companies cannot show some financial benefit from ethical and sustainable sourcing policies, then ultimately these efforts will fail. Buyers might consider concentrating on products where the market for fair trade and green products is mature, as with office supplies, cleaning supplies, and some apparel.

Step 4 calls for the design of performance metrics to gauge the success of the firm's efforts. Measures can be qualitative or quantitative and in the general areas of cost, quality, time, flexibility, and innovativeness. In managed supply chains, performance indicators should be standardized across trading partners. Metrics for sustainability can be used in the areas of packaging, energy use, hazardous materials, and recycling. Metrics could include the number of fair trade certified products purchased, the number of ethical standards adopted by suppliers, the number of suppliers adopting the Ethical Trading Initiative's Base Code, and the number of small and minority suppliers used. As products, suppliers, and markets change, these metrics should be revisited and potentially revised. More on performance measurement can be found in Chapters 13 and 14.

Step 5 is to monitor performance and outcomes, while adjusting the work plans, priorities, policies, and use of suppliers to more adequately meet the ethical and sustainability goals of the firm. It may be that certain elements in the various programs or conduct codes need to be revised as the firm and its operating environments change. Over time as the firm and its suppliers adjust to these policies, improvements can be made, more fair trade products and green products will be identified, and further initiatives will be developed.

Finally, Step 6 addresses the impact of ethical and sustainable sourcing on other facets of the organization, its trading partners, and ultimately the firm's brand. As successes are realized, it will become easier for the firm to operate more ethically and sustainably. Eventually, other divisions and trading partners will become interested. Consumers will start expecting it. Increasingly, companies are taking their ethical and sustainable factors and leveraging them for greater brand value. Even during the recent pandemic and global recession, consumers preferred organizations that addressed various ethical and sustainable issues. In fact, a recent survey of nearly 30,000 consumers in 35 countries by consulting giant Accenture, found that more than half of the U.K. respondents wanted companies to take a stand on issues they cared about, and 62 per cent were attracted to brands that were improving the environment.[35]The nearby SCM Profile describes Proctor & Gamble's commitments to a number of ethical and sustainable issues.

As personnel in design, marketing, production, and other departments begin working with purchasing personnel to develop these and other strategies, a number of initiatives, some of which have already been introduced in earlier chapters, may be used separately or in some combination to support the organization's long-term goals. Proactive sourcing initiatives, when combined with internal operations and customer relationship initiatives, form the foundation for successful supply chain management and, ultimately, competitive advantage for the firm. The following section discusses a number of ethical and sustainable sourcing initiatives.

## SCM Profile Proctor and Gamble's Commitments to Ethical and Sustainable Values

Monkey Business Images/Shutterstock.com

Proctor & Gamble (P&G) has been open about its desire to take the lead in issues of gender, equality, stereotypes, and bias in advertising. Ms. Allison Tummon Kamphuis is the company's program leader for gender equality and its Children's Safe Drinking Water Program. "There's a number of our brands that have been playing a role in this way, particularly in equality and inclusion," she explains.

For example, their 'Like a girl' campaign, launched in 2014, was successful because it turned a stereotype in popular culture on its head. The campaign, listed among the ten best PR campaigns of the decade, changed a phrase that had typically been used as an insult into an empowering message. "It was really about tackling gender bias and it had a very clear message on this. It's very easy for stereotypes to become too familiar, so it was also about portraying men and women as equal partners across all our brands," said Tummon Kamphuis.

Instilling purpose across all P&G's brands globally, and keeping ethical and sustainable values in its employees, down through its supply chains is something they try do. In a business operating in 70 countries, ensuring best practices is a tremendous challenge. In 2014, P&G announced a no-deforestation policy in the production of its products, including requiring traceable palm oil from suppliers, after a report by Greenpeace described palm-oil suppliers in Indonesia allegedly engaging in destructive deforestation.

P&G's Ambition 2030 program focuses on community impact, diversity and inclusion, gender equality and environmental sustainability. Its goals include removing barriers to education for girls and economic opportunities for women. The program also seeks to create an inclusive, gender equal environment inside P&G. Finally, the company plans to purchase only renewable electricity globally by 2030.[36]

# Ethical and Sustainable Sourcing Initiatives

## Ethical and Sustainable Supplier Certification Programs

Seeking and then creating **strategic supplier alliances** have become important objectives of firms actively managing their supply chains. Strategic alliances are a more formalized type of collaborative relationship, involving commitments to long-term cooperation and trust, shared benefits and costs, joint problem solving, continuous improvement, and information sharing. Because of these relationships, suppliers invest more of their resources toward becoming specialized in areas required by the buyer, to establish production and/or storage facilities close to the buyer's facilities, to purchase compatible communication and information systems, and to invest in better technologies that will ultimately improve supplier performance.

Ethical and sustainable supplier certifications are one way to identify strategic alliance candidates or to further develop existing alliances. In many cases, certification

programs are simply based on internationally recognized certifications such as the Switzerland-based International Organization for Standardization's ISO 9000 family of quality certifications and the ISO 14000 family of environmental certifications. [37]For some organizations, these types of certification requirements are good, but may not be specific enough in areas of importance to the firm. In these cases, firms develop their own formal certification programs, which may include ISO certification as one element of the certification process. Other certification requirements might include, for example, the Forest Stewardship Council (FSC) certification for recycled paper, Energy Star certification for various environmental standards, or fair trade certifications for social and ethical performance.

The use of **ethical and environmental certifications** for suppliers is increasing. The New York-based nonprofit Rainforest Alliance and California-based nonprofit Fair Trade USA certify billions of dollars' worth of coffee, bananas, and cocoa each year from suppliers in dozens of countries, and in exchange, suppliers work to preserve the environment and improve conditions for farm workers. [38]The pandemic has potentially changed things though—according to Nick Kightley, strategic lead on food, farming, and fisheries at the Ethical Trading Initiative, panic buying in 2020 initially drove higher sales, but he believes it also exposed a worrying consumer mindset. "Nobody was looking at whether pasta was Fair Trade or organic or anything. As soon as consumer confidence is shaken that supply is always there, they stop being picky and selective." [39]

## Supply Base Rationalization Programs

As first mentioned in Chapter 2, firms in many cases seek to reduce purchases from marginal or poor-performing suppliers while increasing and concentrating purchases among their more reliable, top-performing suppliers. Firms doing this are practicing **supply base rationalization**, also referred to as **supply base reduction** or **supply base optimization**; this has been a common occurrence since the late 1980s. Indeed, activities aimed at fostering buyer–supplier partnerships and increasing the performance and value of suppliers are simply easier when fewer suppliers are involved. Thus, supply base rationalization programs have the benefits of reduced purchase prices due to quantity discounts, fewer supplier management problems, closer and more frequent collaborations between buyer and supplier, and greater overall levels of quality and delivery reliability (since only the best suppliers remain in the supply base).

Companies can design supply base rationalization initiatives based in part on ethical and sustainable performance requirements—in this way, firms will interact more frequently and closely with suppliers exhibiting preferred ethical and sustainable habits. Building relationships with suppliers that are leaders in these areas can bring many benefits to the firm, including those mentioned above, along with brand enhancement and better environmental and ethical performance. Two international standards by the World Resources Institute (WRI) and the World Business Council on Sustainable Development (WBCSD), known as the GHG Protocol standards, cover individual product carbon footprints and for the first time allow buyers to measure and question their suppliers' greenhouse gas emissions. Recently, there have been calls for the EPA to adopt zero emissions standards for 100 percent of new truck sales by 2040. The Environmental Defense Fund (EDF) in 2021 released a report that touts the environmental, health and economic benefits of moving quickly to zero emissions vehicles (ZEVs). "Adopting national multi-pollutant standards would save Americans up to $27 billion annually by 2040 in pollution benefits and $485 billion cumulatively by 2050," says the report.

"Getting clean freight trucks on our roads is one of the most important things we can do to protect our health, climate and economy," EDF senior transportation director Peter Zalzal said. [40]

## Outsourcing Products and Services

Purchasing spend as a percentage of sales has been increasing over the years, in part because firms have opted to **outsource** the production of materials, parts, services, and assembled components to concentrate more resources and time on the firm's core business activities. As first described in Chapter 2, many organizations are outsourcing more, while making fewer of the parts that go into their finished goods. In managed supply chains where a higher level of trust permeates buyer–supplier relationships, the use of outsourcing continues to grow. Firms are also outsourcing to suppliers with outstanding ethical and sustainable reputations, due in part to brand enhancement and the lower potential costs of sustainability.

Outsourcing solely based on low cost can be quite dangerous, as witnessed by the devastating loss of 1,100 workers after the collapse of the Rena Plaza in Dhaka, Bangladesh, in April 2013. The facility housed a number of low-cost clothing manufacturers that were being used by several large and well-known clothing companies. The nonprofit Supplier Ethical Data Exchange (Sedex) focuses on responsible and ethical business practices and provides reports to industrial buyers to help avoid these and other outsourcing risks. Over 22 percent of independent audits, for example, revealed fire safety noncompliance in Bangladesh (the leading noncompliance country) followed by 18 percent in China and 17 percent in Pakistan. "Fire safety concerns are at the top of risk issues. If a building is vulnerable in any way, it provides big risks to suppliers, companies, and investors," says Mark Robertson, a spokesperson at Sedex. "Companies and their investors ignore these risks at their peril," he adds. [41]A number of other strategic sourcing initiatives are discussed in the following sections.

## Early Supplier Involvement

As relationships with suppliers become more trusted, reliable, and long-term in nature, key suppliers often become more heavily involved in the internal operations of their industrial customers, including managing inventories of their own products at their customers' points of use and participating in their customers' new product and process design activities. Key supplier representatives might participate in making decisions on product part and assembly designs, new product materials usage, and even the design of the processes to be used in manufacturing new products. Thus, strategic suppliers play a greater role in their customers' decision-making processes as trading relationships mature, which in turn further strengthens the supply chain. According to Deb Schroeder, VP of purchasing for Toyota in North America, early supplier involvement is becoming even more important as Toyota expands in the United States in the coming years. Toyota buys about $25 billion per year from North American suppliers. "We need to ensure that the supplier, our designers and purchasing are all working together much earlier than we've done in the past. We want to be able to innovate before somebody already has an idea of where we should be," she explains.[42]

While serving on a customer's new product development team, a supplier representative's input can help the firm to reduce material cost, improve product quality and innovation, and reduce product development time. Cost reductions occur with use of more standardized parts, fewer parts, and less expensive materials. Cost, quality, innovation,

and delivery timing improvements can all occur when suppliers use the information gained through **early supplier involvement** to design parts at their own facilities to match a buyer's specifications. These parts can be timed to be in place and available when first needed by the buyer. Use of these **value engineering** techniques with help from the supplier allows firms to design better quality and cost savings into the products from the time a product first hits the shelves. Over the product's life, this can generate significant savings and revenues while reducing the need for cost-savings initiatives later on.

Early supplier involvement is perhaps one of the most effective supply chain integration techniques. Buyers and suppliers working together—sharing proprietary design and manufacturing information that competitors would love to see—establishes a level of trust and cooperation that results in many future collaborative and potentially successful projects. Discussions of several other early supplier involvement activities follow.

## Vendor Managed Inventories

**Vendor managed inventory** (VMI) service is perhaps one of the more value-enhancing activities performed by trusted suppliers. When past performance allows companies to develop trust in a supplier's ability to manage its own inventories at the buyer's site, then carrying costs can be reduced and stockouts avoided. From the buyer's perspective, allowing a supplier to track and manage purchased inventories, while determining delivery schedules and order quantities, saves time and money. From the supplier's perspective, it means avoiding ill-advised orders from buyers, deciding how and where inventories are to be placed, as well as when to ship and how to ship. Further, suppliers have the opportunity to educate their customers about other products.

VMI has been particularly helpful during the pandemic. Vendors can help a company respond to demand swings, since they would have the product visibility and real-time data to respond quickly. 2020 was a grim reminder of just how vulnerable companies are to stockouts. VMI lets suppliers manage re-supply by monitoring customer stock levels, thus suppliers can produce, ship, and store more efficiently. As a result, customers have a smoother supply of product delivered at the right time and do not have to worry as much about stockouts.

Ideally, these valued suppliers manage their customers' inventories using real-time visibility of inventory movements in customers' storage areas or at the point of assembly or sale. This can be accomplished with bar code labels and scanners that instantly update computer counts of inventories as the items are used or sold, or through use of radio frequency identification systems (discussed in Chapter 7). These data can then be made available to suppliers using compatible inventory management systems or via a secured website. This allows a supplier to profile demand, determine an accurate forecast, and then ship an order quantity when the inventory levels become low enough.

Walmart is generally given credit for popularizing the use of VMI in the mid-1990s when it initiated an arrangement with Procter & Gamble to manage Walmart's diaper inventories. A similar arrangement with Rubbermaid soon followed. Walmart's Supplier Portal Allowing Retail Coverage (SPARC) provides real-time inventory information to suppliers, allowing them to avoid stockouts while maintaining the lowest total inventory levels. The result has been improved gross margin return on inventory investment. Del Monte Foods decided to see what a similar system could do for them. The results were an eye-opening 27 percent reduction in inventory levels, and a decrease of in-store stockouts to 1percent.[44]

A shared form of VMI is termed **co-managed inventories**. In this case, the buyer and supplier reach an agreement regarding how information is shared, order quantities, when an order is generated, and the delivery timing and location. This type of controlled VMI may be preferable for very high-value, strategic item purchases, where the customer desires more input into the day-to-day supply activities, or perhaps when the customer is still assessing a supplier's ability to take full responsibility for the order fulfillment process.

## Strategic Alliance Development

As the growth of supply chain management continues, firms become more adept at managing their suppliers and more willing to assist them in improving their production and service capabilities. Simply put, **strategic alliance development**, an extension of supplier development (covered in Chapter 3), refers to increasing the firm's key or strategic suppliers' capabilities. As supply bases become smaller, more opportunities for creating collaborative relationships with these suppliers also occur. As a whole then, supply bases become more manageable. The more basic supplier management activities tend to become somewhat less time-consuming as strategic supplier alliances begin to constitute more and more of the supply base. Consequently, strategic alliance development starts to occupy more of the purchasing function's time and resources.

Many business owners and executives realize that strategic supplier alliances, if successful, can result in better market penetration, better service, and access to new technologies and knowledge, compared to companies with no such alliances. Memphis Light, Gas and Water Division for example, has a strategic alliance with SPX for the supply of transformers. Both companies benefit from the alliance, as described in the nearby SCM Profile.

### SCM Profile — MLGW's Strategic Alliance with SPX

Surasak_Photo/Shutterstock.com

Memphis Light, Gas and Water Division (MLGW), located in Memphis, Tennessee, is one of the largest power utilities in the United States. When MLGW needs a power transformer, the selection and approval process can take up to eight months, if the supplier has not already been approved. In times of high demand, a supplier alliance can allow procurement of equipment that might not be quickly available for other customers. During such times, it is essential to have an alliance in place particularly for long lead time parts and equipment. MLGW's power transformer alliance partner is SPX Transformer Solutions.

Nationwide, it is not unusual to find utilities with 40 year old power transformers. A majority of those transformers are coming to the end of their useful life. When demand trends up, lead times for transformers typically begin to rise unless there are existing alliances. Consequently,

MLGW has entered into five-year purchasing alliances for power transformers, high-voltage circuit breakers and substation switchgear. MLGW has seen huge benefits that include better delivery times and excellent equipment pricing. Having a strategic alliance also helps operations and maintenance crews. The crews do not have to learn an entirely new piece of equipment each time a new transformer is ordered. Alliances reduce the inventory of spare parts since the same manufacturer's product is already in the system. Alliances also allow access to the supplier's subject-matter experts in the event technical guidance on an application or piece of equipment is needed.

One of the biggest advantages of an alliance is reserving slots in the supplier's manufacturing schedule. This advantage is huge when unexpected events occur. During one emergency, having an alliance in place allowed MLGW to receive a power transformer in just twelve weeks - from the time the purchase order was placed until the time the transformer was delivered. This was made possible by the cancellation of a production slot by another customer. Because of the alliance, MLGW was able to reap the benefit of last-minute changes in the manufacturing schedule.[45]

Supplier development activities become more vital to companies as they come to depend more and more on a smaller group of high-performance suppliers. Alliance development can even extend to a firm's second-tier suppliers, as the firm's key suppliers begin to form their own supplier alliance development activities. Alliance development among the firm and its key suppliers tends to be much more of a collaborative activity, requiring both sides to commit time, people, communication, and monetary resources to achieving goals that will benefit both parties. The company and its strategic suppliers jointly decide on improvement activities, resources required, and the means to measure progress. As the improvements take place, suppliers eventually become capable of passing these same capabilities on to their key suppliers, thus extending these capabilities up their supply chains.

Strategic alliance development requires companies to improve their relationships, learn from their mistakes and successes, and make investments to enable collaborative problem solving. Many firms are hiring strategic relationship managers, whose job is to build trust, commitment, and mutual value with alliance partners. These relationship managers work on negotiating win–win collaborations resulting in mutual benefits, such that alliances become the norm among the various business units in the organization. Raytheon, a U.S. government defense systems contractor, is going a step further by forming an Enterprise Supplier Advisory Council as a way to communicate and improve relationships with its most strategic suppliers. The group meets quarterly to review key initiatives such as its Exostar portal, its new supplier rating system, and any discrepancies noted by Raytheon's top suppliers. Additionally, trending topics in the defense industry such as cybersecurity are discussed. Raytheon's first Supplier Advisory Council was in 2014, with a goal to earn and provide preferential treatment as the Customer-of-Choice, or the customer who receives the best terms, manufacturing capacity as needed, and supplier innovations that can win in the marketplace.[46] Strategic supplier alliances, like products, have their own life cycles, requiring ongoing management, development, and negotiating activities to monitor success, manage conflict, evaluate the current fit with partners, revisit the ground rules for working together, and make adjustments through mutual problem solving and information sharing. Organizing and managing a successful alliance program is thus very important to a firm's competitiveness. Table 4.4 describes the strategic alliance organization process.

**Table 4.4 Maintaining a Successful Strategic Alliance Program**

| STEPS | DISCUSSION |
|---|---|
| 1. Determine the key strategic parameters to organize around. | Can be based on business units, geographic areas, industries, key alliance partners, or combinations of these. |
| 2. Facilitate the dissemination of information. | Alliance management and development information should be centrally controlled and available through internal websites, pamphlets, and workshops. |
| 3. Elevate the importance of the strategic alliance program. | Assign a director or vice president of alliance programs, reporting to top management. Establish consistent procedures for alliance programs throughout the organization. |
| 4. Provide continuous evaluation of alliance performance, visibility, and support. | Management can increase the value and acceptance of alliance programs when successes are made visible to the firm's lower-level managers and employees. Alliance management requires resources and ongoing reevaluations. |
| 5. Reward suppliers as performance merits. | Rewards typically include increased business and other nonmonetary awards. |

Source: Adapted from Dyer, J., P. Kale, and H. Singh, "How to Make Strategic Alliances Work," *Sloan Management Review* 42(4), 2001: 37–43.

To make strategic alliance programs successful, firms must determine how to organize a program that can cut across functional boundaries; disseminate program information quickly and effectively throughout the organization; acquire the necessary resources; create program acceptance by the line managers and their employees; achieve concrete, measurable success; and reward supplier performance. Some firms have chosen to organize around their key alliance partners by assigning alliance managers to each of these partners. Others have decided to create an alliance board to oversee alliances and coordinate alliance managers in various divisions within the organization or in different geographic regions of the world.

The supplier alliance management function can act as a clearinghouse for information regarding all types of alliance needs, from negotiation strategies to problem-solving assistance to outreach programs and workshops. To give the alliance management function credibility, the program director should report to the organization's top management. This facilitates the use of company resources as well as provides internal visibility to the function. Alliance strategies, goals, policies, and procedures can then be generated and communicated across the entire organization. Finally, since alliance goals change over time, they should be evaluated periodically. Performance evaluation metrics are then established; and, as alliances show signs of success, strategies can be shared across the various alliance boundaries. As briefly mentioned earlier, continued success depends on both the supplier and the buyer receiving value from the alliance. The topic of negotiations with strategic alliance partners follows.

## Negotiating Win–Win Strategic Alliance Agreements

When negotiating with alliance partners, the most advantageous outcome occurs when both parties utilize **collaborative negotiations**. This is sometimes also referred to as **integrative** or **win–win negotiations**. In other words, both sides work together to maximize the joint outcome or to create a joint optimal result. The belief is that there is more to

gain from collaborating rather than trying to seek an outcome that favors primarily one side's interests (referred to as **distributive negotiations**). For collaborative negotiations to succeed, members from both parties must trust each other, believe in the validity of each other's perspective, and be committed to working together. From the perspective of key supply chain trading partners, these requirements should already be present, so collaborative negotiations may be easier to achieve in actively managed supply chains.

Successful collaborative negotiations require open discussions and a free flow of information between parties, preferably in face-to-face meetings. Professor Kate Vitasek, an international authority on collaborative relationships, describes in her book, "Getting to We: Negotiating Agreements for Highly Collaborative Relationships," the process for moving from "what's in it for me" to "what's in it for we". Collaborative partners must abide by a set of principles—reciprocity, autonomy, honesty, equity, loyalty, and integrity, to drive collaborative behaviors and achieve mutually successful outcomes. Jaguar's successful deal with Unipart Logistics for over 25 years illustrates this. Both companies were having problems. Jaguar buyers were waiting too long for replacement parts from Unipart, making both companies look bad. The CEOs of both companies decided to create a partnership with a shared vision and internal and external alignments. Ultimately, the luxury car manufacturer went from ninth to first in JD Power and Associates' survey of customer satisfaction. The result was that Jaguar sold more cars because of the increased service and Unipart Logistics earned more money. This was collaborative negotiating at its best.[47]

In contrast, distributive negotiations are adversarial (I win, you lose) and usually mean that some information will be withheld, distorted, delayed, or completely misrepresented. The likelihood that one or the other or some combination of these two negotiation methods occurs depends on the nature of the trading relationship, the strategic nature of the item(s) being negotiated, and potentially the balance of power in the relationship. In the automotive sector, particularly at Toyota, collaborative negotiations are described to be part of a *lean thinking* approach to supplier relationships, although automobile manufacturers typically enjoy high levels of buyer dominance that may tilt the negotiating scales somewhat in the buyer's favor.

To maximize the likelihood of achieving equitable collaborative negotiations, supply chain partners should first develop a collaborative negotiation infrastructure and then facilitate a negotiating approach that supports win–win outcomes. Table 4.5 describes the steps in developing a collaboration infrastructure. Over time, purchasing representatives will get better at collaborative negotiations as they become more familiar with their trading partners' interests, learn from previous negotiations, and determine how best to work with each trading partner. Managers or negotiating team leaders can also aid in this process by encouraging exchanges of information, dealing fairly with negotiating problems, and brainstorming options for achieving mutual gains.

## Rewarding Supplier Performance

**Rewarding suppliers** for improving or maintaining high levels of performance accomplishes several objectives. For one thing, it provides an incentive to all suppliers to meet and surpass specific performance goals. It also can provide an incentive to marginal suppliers to achieve a level of performance that will allow their status to be upgraded, potentially resulting in continued business. Finally, it can give suppliers an incentive to create and share rewards, in turn, with *their* suppliers.

**Table 4.5 Developing a Collaborative Negotiation Infrastructure**

| STEPS | DESCRIPTION |
|---|---|
| 1. Build a preparation process | Gain an understanding of both parties' interests; brainstorm value-maximizing solutions and terms; identify objective criteria wherein both sides evaluate fairness of an agreement. |
| 2. Develop a negotiation database | Review previous negotiations to catalogue standards, practices, precedents, metrics, creative solutions used, and lessons learned. |
| 3. Design a negotiation launch process | Create an environment allowing parties to first focus on how they will work together to create a shared vocabulary, build working relationships, and map out a shared decision-making process. |
| 4. Institute a feedback mechanism | Create a debriefing process to provide feedback to negotiating teams and capture lessons learned. |

Source: Adapted from Kliman, S., "Enabling Win-Win," *Executive Excellence* 17(4), 2000: 9–11.

Rewards can either be monetary or non-monetary. Sharing the benefits of good performance is one of the central foundations of building effective supply chains. As mentioned at the start of the chapter, both suppliers and buyers must be able to realize benefits from supply chain relationships. Without this incentive, suppliers may keep any improvements within their operations quiet, while also keeping the benefits. With time, this lack of information and benefit sharing stunts the growth of relationships within the supply chain and results in lower overall supply chain trust and performance. According to Ellen Malfliet, marketing and communications manager at PearlChain, a supply chain software provider in Belgium, "Everyone within the value chain is focused on the customer right now. Take automobile manufacturing, for example, where raw materials suppliers, manufacturers, distributors, and dealers must all work together in a collaborative environment in order to turn out a viable end product. In the end, the successful customer experience translates into success for all parties across the supply chain, not just those that are actually facing the customer. Everyone wins."[48]

More and more, companies are rewarding their suppliers for ethical and environmental performance. Walmart and Target hold their suppliers to task regarding their products and their own company sustainability initiatives. Supplier performance is measured or scored, and the scoring system determines which suppliers will get repeat business from Walmart and Target (the reward). For instance, one of the items a supplier must address for Target is its packaging policy: "A product's packaging should be made with recycled or sustainable content, and itself be fully recyclable. A product's labeling should inform guests about how to recycle the packaging." Target has incorporated its sustainability initiatives, and wants its vendors on the same page.

Additionally, firms are finding they save money when they adopt sustainability initiatives. About twelve years ago, Walmart began packaging 300 products using sustainable packaging materials. The company later determined in one year it saved 3,425 tons of corrugated materials, 1,358 barrels of oil, 5,190 trees, and $3.5 million in transportation costs.[49]

Performance motivation can come in several forms, including punishment and various reward mechanisms. Motivational tools can be used as an integral part of supplier management and supplier development programs. Punishment may take the form of a reduction or elimination of future business, a downgrade of the supplier's status from key to marginal, or a **billback penalty** equal to the costs resulting from a late delivery or poor material

quality, for example. On the other hand, when performance meets or exceeds expectations, suppliers can be rewarded in some way.

Many formal strategic supplier agreements allow suppliers to benefit in the following ways:

- a share of the cost reductions resulting from supplier improvements;
- a share of the cost savings resulting from a supplier's suggestions made to the focal firm;
- more business and/or longer contracts for higher performance;
- access to in-house training seminars and other resources; and
- company and public recognition in the form of awards.

These benefits tend to stimulate further capital investment among suppliers to improve their operating capabilities, leading to even greater levels of quality, service, and environmental, ethical, or cost performance. The U.S. healthcare industry is a good case in point. Hospital costs in the United States continue to escalate rapidly, so hospitals commonly offer incentives to suppliers to keep costs down. Ed Hardin, the system vice president of supply chain management at Texas-based CHRISTUS Health, says "Frankly, it's an honorable and profitable thing to do business with CHRISTUS Health. Today, third-parties seek the privilege to work with an organization that is highly collaborative, keeps their word, and rewards high-performing suppliers with more business. Not only is it a privilege, but we also find a willingness from these third-parties to provide value-adds beyond our agreements. Violating our trust, doing the end-run around supply chain has consequences."[50]

## Benchmarking Successful Sourcing Practices

**Benchmarking**, the practice of copying what other businesses do best, is a very effective way to quickly improve sourcing practices and supply chain performance. Without benchmarking, firms must learn through their own experiences the methods and tools that work the best. Benchmarking allows firms to potentially leapfrog the experience-gaining stage by trying things that have worked well for other companies. Meaningful benchmarking data regarding sourcing practices can be obtained in any number of ways, both formal and informal—from using evaluation surveys distributed to a firm's customers and suppliers regarding *their* sourcing and supplier management practices, to discussing sourcing strategies with colleagues at business association meetings or conferences, to collecting published trade information on benchmarking studies.

A large number of resources are available for firms seeking to learn about and implement successful sourcing practices. The Center for Advanced Purchasing Studies (CAPS), a nonprofit, independent research center at Arizona State University, helps firms achieve competitive advantage by providing leading-edge research information regarding strategic purchasing. For instance, CAPS provides research studies, benchmarking reports, and best practices case studies, along with organizing purchasing symposiums and roundtable discussions for purchasing professionals and academics.[51]

Another organization, the Supply Chain Council, a subsidiary of ASCM, the Association for Supply Chain Management, (formerly APICS), helps practitioners reduce their supply chain costs and improve customer service by providing their Supply Chain Operations Reference (SCOR-E) model as a framework for supply chain improvement. They also provide case studies and bring together practitioners to discuss best practices in periodic business conferences around the world.[52]

The Arizona-based Institute for Supply Management (ISM), established in 1915, provides a wide variety of resources to supply management professionals worldwide, including a monthly publication featuring the latest supply management trends and information and the globally recognized Certified Professional in Supply Management (CPSM) and Certified Professional in Supplier Diversity (CPSD). programs. They also publish the globally recognized *Inside Supply Management Magazine*, organize several annual global supply management conferences, and support many seminars and Web conferences for supply management professionals.[53]

The topic of best purchasing practices has been the subject of a number of research studies over the years, and these findings have proven very beneficial for firms seeking to benchmark best sourcing practices.[54] Some of the research has found a positive relationship between purchasing benchmarking and firm performance. A number of the successful purchasing practices found to be common among the companies studied were:

- use of a central database to access information on parts, suppliers, lead times, and other purchasing information;
- software applications for sharing information with suppliers;
- use of the Internet for supplier searches;
- alliances with key suppliers for specific components;
- supplier certification and the elimination of the need for incoming quality checks for key supplier deliveries;
- involving suppliers in the research and development processes of new products;
- reducing the firm's supply base;
- continuous measurement of supplier performance, and establishing supplier improvement targets; and most recently,
- creating an ethical and sustainable supply chain.

With specific regards to the best ethical purchasing practices, the U.K.-based Chartered Institute of Procurement & Supply (CIPS) has developed a code of ethics for procurement, which is summarized below.

- Commit to eradicating unethical business practices including bribery, fraud, corruption and human rights abuses, such as modern slavery and child labor.
- Conduct all business relationships with respect, honesty and integrity, and avoid causing harm to others as a result of business decisions.
- Actively support and promote corporate social responsibility (CSR).
- Avoid any business practices which might bring the procurement profession into disrepute.
- Use procurement strategies to drive unethical practices from the supply chain.
- Ensure procurement decisions minimize any negative impact on human rights and the environment whilst endeavoring to maximize value and service levels.
- Put ethical policies and procedures in place, regularly monitored and updated, and ensure compliance.
- Take steps to prevent, report and remedy unethical practices.
- Provide a safe environment for the reporting of unethical practices.[55]

## Assessing and Improving the Firm's Sourcing Function

As stated throughout this textbook so far, the sourcing function is one of the most value-enhancing functions in an organization. Today, purchasing staff members are viewed as strategic members of the organization, and are expected to generate cost savings and quality enhancements of goods and services. Consequently, it is preferable to periodically monitor the purchasing function's performance against set standards, goals, and/or industry benchmarks. Thus, as the firm strives to continuously improve its products and processes, purchasing can also gauge its success in improving its own value-enhancing contributions to the firm and its supply chains.

As stated earlier, criteria can be utilized to provide feedback to the purchasing department staff regarding their contributions to the strategic goals of the firm. Surveys or audits can be administered among purchasing personnel as part of the annual evaluation process; assessments can include feedback from internal customers of the sourcing function, such as engineering, sales, marketing, and finance personnel. Feedback may even be included from supplier representatives. Assessment criteria to evaluate the purchasing department's performance should include some or all of the following:

- participating in value engineering/value analysis efforts;
- finding and evaluating ethical and sustainable suppliers;
- optimizing the supply base;
- managing and developing local, regional, and global suppliers;
- creating early supplier involvement initiatives;
- creating strategic supplier alliances;
- furthering the integration and development of existing key suppliers;
- contributing to new product development efforts;
- initiating supplier cost reduction programs;
- contributing to the improvement of purchased product and service quality; and
- maintaining and improving internal cooperative relationships.

Since these criteria require both qualitative and quantitative assessments, the performance evaluation tool recommended here would be some form of weighted-factor rating method, as covered in Chapter 3. Because of the tremendous potential value of these activities, supply management staff members should be continuously auditing their capabilities and successes in these areas.

Thus, the skill set requirements of purchasing professionals have been changing as purchasing, sourcing, or supply management has evolved from the tactical, clerical function it was about forty years ago to the highly demanding strategic function it is today. To achieve the type of world-class performance suggested by the preceding assessment criteria, sourcing personnel must today exhibit world-class skills. One recent survey of procurement professionals conducted by *Purchasing* magazine found that their top three responsibilities were negotiating contracts, selecting suppliers, and managing supplier relationships. Given the recent pandemic and economic downturn, controlling costs is also seen as a very important activity of purchasing personnel. Important cost-controlling activities include reducing the supply base, negotiating global agreements with suppliers, and adopting new technologies suited to purchasing activities.[56]

## Summary

Managing supply chains successfully often starts with the sourcing activity. We hope we have provided, in this and previous chapters, evidence of the strategic role played by the sourcing function and the impact of sourcing on supply chain management. Firms that fail to recognize this importance will simply not experience the same level of success in the long run. Two relatively new sourcing topics, ethical and sustainable sourcing, are quickly gaining importance with regards to how firms are choosing to operate. Sourcing personnel are playing an important role today in helping the firm to achieve success in these two areas while maintaining cost, quality, and customer service priorities. The sourcing process thus consists of a number of related activities that, when taken together, provide competitive advantage to the firm. Firms can maximize this advantage by developing effective supply chain strategies and then assessing and revising these strategies periodically as missions, markets, competitors, and technologies change. As we head into the internal operations segment of this text, we hope you will continue to consider the sourcing issues discussed and how they interact with other processes as materials, services, and information move down the supply chain to the firm's immediate customers and, eventually, to end users.

## Key Terms

**strategic sourcing,** 136
**business ethics,** 136
**utilitarianism,** 137
**rights and duties,** 137
**corporate social responsibility,** 137
**ethical sourcing,** 137
**Ethical Trading Initiative,** 139
**fair trade products,** 139
**sustainable sourcing,** 141
**green purchasing,** 141
**sustainability,** 142
**three Ps,** 142
**sustainable sourcing,** 142
**functional products,** 144
**innovative products,** 144
**purchasing spend,** 145
**strategic supplier alliances,** 147
**ethical and environmental certifications,** 148
**supply base rationalization,** 148
**supply base reduction,** 148
**supply base optimization,** 148
**outsource,** 149
**early supplier involvement,** 150
**value engineering,** 150
**co-managed inventories,** 151
**strategic alliance development,** 151
**collaborative negotiations,** 153
**integrative negotiations,** 153
**win–win negotiations,** 153
**distributive negotiations,** 154
**billback penalty,** 155
**benchmarking,** 156

## Discussion Questions

1. What is strategic sourcing?
2. What is the difference between purchasing and strategic sourcing?
3. What is ethical sourcing, and why would firms do it?
4. What do business ethics, utilitarianism, and rights and duties have to do with ethical sourcing?
5. What are some common practices or activities of ethical sourcing?
6. What are some of the risks of ethical sourcing? How about the potential advantages? Do you think ethical sourcing is a good practice? Why?
7. In what ways is corporate social responsibility different from business ethics?

8. How could purchasing goods from suppliers in developing countries be risky? How should firms reduce this risk?
9. What is a fair trade product? Could farmers in the United States. make fair trade products?
10. What is sustainable sourcing, and how does it differ from ethical sourcing and from green purchasing?
11. What are the benefits of sustainable sourcing? Can firms actually make money from sustainable sourcing? Do you think it is a good practice? Why?
12. What are the three Ps? What do they have to do with sustainability?
13. How could you apply sustainability to a supply chain?
14. Describe some sustainable and ethical things your university is doing.
15. How are ethical and sustainable sourcing policies designed in an organization?
16. How is the U.S. government getting involved in sustainability requirements?
17. What are innovative and functional products? Can firms buy functional products in an ethical way? A sustainable way? What about innovative products?
18. What are the benefits of obtaining ethical and sustainable certifications? Why would a buyer want its suppliers to have these certifications?
19. What advantages do company-designed supplier certification programs have over industry certifications like ISO 9000?
20. What is supply base rationalization, and what are its advantages and disadvantages?
21. What is outsourcing? How is it different from purchasing? Would a firm ever want to outsource a core product or process? Why or why not?
22. When would firms want to insource a product or process?
23. Do companies outsource for ethical or sustainable reasons? If so, provide some examples. How might this impact a firm's reputation?
24. What is sourcing's role in value engineering, and what benefits does this give to the firm?
25. Why is early supplier involvement a good way to integrate the supply chain?
26. Why would suppliers want to be involved on a buyer's new product development team?
27. Describe the differences between vendor-managed inventories and co-managed inventories, and when it might be advisable to do either of them.
28. What is the difference between supplier management and strategic alliance development?
29. If your firm had a large number of strategic supplier alliances, what would be the best way to manage them?
30. What makes supplier alliances fail? How can firms reduce the failure rate?
31. Describe the differences between integrative and distributive negotiations, and when each should be used.
32. Why might second- and even third-tier suppliers be important to the focal firm?

33. What is a common method for developing second-tier suppliers?
34. If your firm had 500 suppliers and they each had 100 suppliers, how many second-tier suppliers would your firm have? What if your firm reduced its supply base to twenty?
35. What are some typical supplier rewards and punishments that a buyer could use?
36. If you work for a company, describe how it rewards and punishes its suppliers. Do you think appropriate methods are being used? Why or why not?
37. What is benchmarking? What are some different ways you could use benchmarking to improve your performance at school?
38. Why would a firm want to monitor its own purchasing performance?
39. Describe several successful ethical sourcing practices.
40. How could a company use benchmarking and performance measurement to improve its ethical and sustainable purchasing practices?

## Essay/Project Questions

1. Go to the International Organization for Standardization website (www.iso.org), and write a short description and history of the organization, including some of the various certifications that can be obtained.
2. Go to the CAPS website (www.capsresearch.org), and find the latest cross-industry benchmarking report; then determine the overall purchase dollars as a percentage of sales in the United States. What benchmarking research is CAPS doing now?
3. Go to the Fair Factories Clearinghouse website (www.fairfactories.org), and describe the organization, along with some of the current events underway.
4. Go to the Goldman Environmental Prize website (www.goldmanprize.org), and describe the most recent award winners.
5. What is an ASP? Find some on the Internet that are not listed in the chapter, and describe what they do.
6. Gather information on business ethics and ethical purchasing, and report on several of the most current news items and controversies.

## Cases

### 1. Maryann Franklin Industries*

Connie Fox is chief executive officer of Maryann Franklin Industries (MFI). MFI is feeling the pressure of a declining economy. Connie knows they will weather this storm; however, she believes this is the time to institute better cost controls. MFI has grown very quickly over the last 10 years and Connie realizes that with the growth came some cost issues that were ignored. She feels that the current situation provides an excellent opportunity to have her staff look into approaches to reduce expenses.

*Written by Rick Bonsall, D. Mgt., McKendree University, Lebanon, IL. The people and institution are fictional and any resemblance to any person or any institution is coincidental. This case was prepared solely to provide material for class discussion. The author does not intend to illustrate either effective or ineffective handling of a managerial situation.

Connie knows that every department had opportunities to reduce expenses; however, she believes the buggiest opportunity is in the supply chain management division. Leonard Butler is her vice president of supply chain management. Connie told Leonard that she needed him to find ways to reduce cost without reducing quality. Furthermore, if possible, she would be delighted if he could actually improve quality while still reducing cost.

Leonard brought his staff together to discuss the task. Johnathan Robert, director of supply chain management, suggested a three-pronged approach. The first prong would be to examine the number of suppliers and determine if there were ways to reduce the number. He believed that through supply base optimization, MFI could implement significant reductions in cost. Johnathan believed that a key tool in supply base optimization was to segment the suppliers, based on risk or value.

Johnathan's second idea was to review their current global contracts with their suppliers and determine which ones could be renegotiated. His thought was that if they explained to the suppliers that they were working on reducing their supply base, some would be amenable to negotiations. Leonard chimed in and said that was a good idea. He stated, "We must make sure we do not prose this as a threat. Instead, explain that we hope they see this as an opportunity to strengthen our relationship and to build a stronger strategic alliance."

The third prong was to engage outside sources to help MFI find best practices within the supply chain community. Benchmarking against what other companies are doing would be the most effective and efficient method for improvement.

## Discussion Questions

1. Johnathan Robert suggested that segmenting their suppliers would enable supply base optimization. Use the Internet to research ways to segment suppliers. Find at least three categories of segmentation and explain how these support supply base optimization.
2. Although Leonard agreed with Johnathan's idea about renegotiating contracts with suppliers, he did have a major concern. Was Leonard proposing they engage in collaborative or distributive negotiations? Explain what attributes of the specific type of negotiations you picked. Support your choice and how they relate to Leonard's concern.
3. Go to the APICS SCOR Model:

apics-scc-scor-quick-reference-guide.pdf and download the Quick Reference Guide. Select one item from the Source category and explain in your view how the metrics can lead to benchmark improvements and indicate best practices.

## 2. Fitz-Simmons Consultants*

Fitz-Simmons Consultants is an international company that advises international corporations on ethical and sustainable sourcing. As the world matures in its view of how to treat people and the environment, more companies are focused on ethical and sustainable sourcing. It is evident in the international business community that this is an essential topic to address if one wants to be considered a world class organization.

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Sources:
1. United Nations Development Programme, www.undp.org.

Fitz-Simmons Consultants decided to develop guidelines for assessing a supplier's ethical and sustainable credentials. They determined that the best source to use as a benchmark was the United Nations Development Programme[1] (UNDP). The UNDP has established a set of goals for seventeen different areas, such as clear water and sanitation, climate actions, zero hunger, and others.

Reviewing its clientele list, Fitz-Simmons determined that they needed to divide their clientele's suppliers into several groups. For the first grouping, they focused on responsible consumption and waste reduction. They developed a supplier certification program based on the following areas: decreasing waste through prevention, reduction, recycling, and reuse. Furthermore, they ascertained that a supplier should not only adopt these practices but also incorporate them into their annual reporting metrics.

The challenge Fitz-Simmons discovered as they developed the guidelines for their clients was that many had good supplier relationships, however, not all of these suppliers currently met the requirements Fitz-Simmons proposed. Fitz-Simmons realized that the supplier certification program was the end goal. What they also needed was a method to get the suppliers from their current state through the certification process. Otherwise, Fitz-Simmons' clientele would see no value in the certification process if it upended their current supplier relationships.

## Discussion Questions

1. Clearly, if Fitz-Simmons' clientele have good supplier relationships, they have worked at supplier development. If they want to maintain those relationships with their suppliers, what are some critical first steps that must be taken to ensure suppliers buy-in to the new program?
2. Once the new supplier certification program for ethical and sustainable sourcing is up and running, what would be the process to prune the number of suppliers? Recommend some criteria for enabling this step.
3. Outside of the obvious benefit of a company continuing to do business with its suppliers, how can a company add value to the suppliers adhering to the certification program? Provide specific examples of what the company can do.

## 3. Dean Vanwinkle Enterprises*

Dean Vanwinkle Enterprises is a multi-billion dollar corporation that sources from around the globe. Dean Vanwinkle is the chairman and CEO of the corporation. He has always been a strong advocate for human rights. He believes his company has done a good job of sourcing from suppliers who hold similar values. However, Dean has recently become very uneasy with the way the world seems to be trending. He feels that because of the recent economic conditions throughout the world, its suppliers may be cutting corners. Dean decides to discuss this with his board of directors and his senior staff.

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Dean expresses his concerns to the board and senior staff. He explains that Vanwinkle Enterprises has an enormous amount of clout because of its huge purchasing power. Dean wants to use that buyer power not only to make the best financial deals, but to ensure they are only working with suppliers who are ethical in their dealing with their workforce and communities.

Mr. Vanwinkle tasks Antonia Bentley, senior vice president of human resources, to develop a set of criteria and a process to evaluate how suppliers are performing in this area. Antonia suggests that the best avenue to start this project is to look at corruption and its potential effects on suppliers and their workforce. Antonia begins her task by researching this through Transparency International.[1]

Antonia believes that corruption in government breeds corruption throughout society, including business. Consequently, she decides that if a specific country is rated as highly corrupt, then this is a starting point to identify the company's suppliers from those countries and examine their performance in relation to this topic. Antonia has her staff develop a list of all their suppliers and their home countries. She directs them to input this data into the Supplier Relationship Management (SRM) system. Further, her staff is to utilize the data from the Transparency International Corruption Perception Index[2] and input the data for each country from 2016 through 2020. The latest listing shows a ranking of one to 179. Some countries are ranked the same; for example, Denmark and New Zealand are both ranked number one in 2020, meaning they are the least corrupt. Antonia is surprised to see that the United States is ranked 25$^{th}$; she assumed it would be closer to number one. Using their SRM database will enable Antonia to quickly identify suppliers whose home country is perceived as highly corrupt.

Antonia requested the information from 2016 to 2020 so that she could see the trend. As she reviewed the list of countries and suppliers, she believed it was necessary to ascertain if a country was declining (more corrupt) or rising (less corrupt) in the ratings. Suppliers in countries with declining ratings would be placed at the top of the list for immediate evaluation.

Antonia and her staff brainstormed the types of criteria they should use when examining the ethical values of the suppliers. Since Dean's emphasis was on human rights, they decided to use information from the Ethical Trading Initiative's Base Code.[3] There were nine major items within the code. They decided that although all were very important, the best strategy for the moment was to identify those areas where they could obtain concrete data from either a public source, or from the supplier itself. They chose the following criteria—right to collectively bargain, no child labor used, living wages are paid, and working hours are not excessive.

Antonia provided the following proposal to Dean. They would identify suppliers with potential ethical issues based on their home country's corruption perception index. Those in countries with a declining rating would be evaluated first. They would gather data on each of the four criteria and input that data into the SRM database. This would enable them to effectively analyze it. They would then contact the suppliers whom they were concerned about and explain their concerns.

Sources:

[1]Transparency International, www.transparancy.org

[2]Transparency International Corruption Perception Index, http://www.transparency.org/news/feature/corruption_perceptions_index_2016

[3]Ethical Trading Initiative, www.ethicatrade.org

## Discussion Questions

1. Using Table 4.1, replace two of the four criteria Antonia and her staff decided on. Explain why your two choices are more suitable to use to evaluate the suppliers.
2. Go to: https://www.transparency.org/en/cpi/2020/index/nzl and review the Corruption Perception Index for 2020. Antonia asked you to review the following countries: Djibouti, Laos, Morocco, and Sierra Leone. What is your evaluation of these countries, meaning besides their overall ranking, what concerns if any do you have? What recommendations would you give Antonia based on the data?
3. Is the process developed by Antonia fair? Explain your viewpoint.

# Part 2 Continuing Case

### Vanlandingham Robotics—Ethical and Sustainable Sourcing*

Emogene Edgerton, chief executive officer of Vanlandingham Robotics, has had her team working on supply issues in their supply chain management division. The initiatives they have implemented are critical to Vanlandingham's success. The robotics industry is a rapidly growing market with estimates of it moving from $26 billion in 2020 to $74 billion by 2026. However, the competition is fierce. Consequently, Emogene knows that every effort to reduce expenses within the supply chain is essential. Although growing revenue is another important option, reducing expenses is something they have more control over.

While they have implemented a supplier relationship management program to build trust and evaluate supplier performance there is still more to accomplish. To ensure the efforts they have made so far enable them to accomplish their goals, Emogene wants to ensure they have ethical and sustainable sourcing.

The good news is that ethical and sustainable sourcing can be rolled into the performance metrics they have initiated. Emogene has tasked Candi Cody, vice president of supply chain management, Aaron Lykes, director of supply chain management, Freda Farmer, supply quality manager, and Dori Lenser, purchasing manager, to develop a robust program that guarantees they maintain ethical and sustainable sourcing.

The team decides to build their program utilizing the ethical and sustainable sourcing strategy framework. This framework has six steps. While all are important, step 4, develop a performance measurement system, is one that they can tackle immediately. This step will fit perfectly within the responsiveness metric that is already in place.

Since Vanlandingham Robotics has established a robust supplier performance management system, the team has decided to use it to do benchmarking. They have several suppliers who meet their certified category. Some are stronger in some areas than in others. They will utilize those suppliers as the benchmark for the specific metric they excel in. The team believes this will be more effective than benchmarking against companies outside of their industry.

In addition, as part of the drive to reduce expenses, Vanlandingham Robotics will share cost savings (resulting from the supplier's actions) with the supplier—a true win–win

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scenario. Furthermore, Vanlandingham Robotics will establish an annual award for the supplier that is proactive in supporting corporate social responsibility, a safe environment, and will perfect and monitor current ethical policies to ensure compliance.

The performance categories are based on a range of points from zero to 100. Less than 50 points is unacceptable, 50 to 74 is conditional, 75 to 89 is certified, and greater than 89 is preferred. The following table contains the scores of the top five suppliers.

| METRIC | BAILEY | GOMEZ | KHAN | MCKAY | STAFFORD |
|---|---|---|---|---|---|
| Price | 80 | 72 | 80 | 90 | 78 |
| Quality | 70 | 85 | 65 | 95 | 95 |
| Delivery | 84 | 87 | 82 | 60 | 75 |
| Responsiveness | 85 | 80 | 85 | 65 | 85 |
| Technology | 80 | 92 | 55 | 88 | 90 |
| TCO | 90 | 91 | 80 | 88 | 84 |

Another initiative Vanlandingham Robotics will employ is its 3-Ps Award. This award will focus on what the suppliers are doing to generate a positive impact on people, planet, and profit.

### Discussion Questions

1. Based on the data provided on the performance scores, what vendors appear qualified to act as the benchmark company for specific metrics?
    a. If any vendor is in an unacceptable or conditional category in any area, should they still be a benchmark for the area they excel in? Explain your reasoning.
2. As important as ensuring ethical and sustainable sourcing is, the time to implement actions is often a scarce commodity. Review Table 4.3, Ethical and Sustainable Sourcing Strategy Framework, and select three of the six steps you believe are the most important to implement now. Explain your reasoning.

## Additional Resources

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**52.** See http://www.ascm.org for more information.

**53.** See http://www.ismworld.org for more information.

**54.** See, for instance, Andersen, B., T. Fagerhaug, S. Randmael, J. Schuldmaier, and J. Prenninger, "Benchmarking Supply Chain Management: Finding Best Practices," *Journal of Business and Industrial Marketing* 14(5/6), 1999: 378–389; Carr, A., and L. Smeltzer, "The Relationship Among Purchasing Benchmarking, Strategic Purchasing, Firm Performance, and Firm Size," *Journal of Supply Chain Management* 35(4), 1999: 51–60; Ellram, L., G. Zsidisin, S. Siferd, and M. Stanly, "The Impact of Purchasing and Supply Management on Corporate Success," *Journal of Supply Chain Management* 38(1), 2002: 4–17; and Krause, D., S. Vachon, and R. Klassen, "Special Topic Forum on Sustainable Supply Chain Management," *Journal of Supply Chain Management* 45(4), 2009: 18–25.

**55.** See https://www.cips.org/cips-for-business/supply-assurance/corporate-ethical-procurement-and-supply/corporate-code-of-ethics

**56.** Avery, S., "Today's Travel Procurement Professional Knows How to Manage Supplier Relationships," *Purchasing* 138(2), 2009: 54.

# PART 3

# Operations Issues in Supply Chain Management

# Chapter 5

# Demand Forecasting

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*After all, effective demand forecasting isn't just about technology and algorithms. It's also about teamwork, transparency and trust.*

**—Are Traasdahl, co-founder and CEO, Crisp[1]**

*No software, no matter how powerful, and no analyst, no matter how talented, can guarantee perfect (or even highly accurate) forecasts. The objective should be to deliver forecasts as accurate as can reasonably be expected given the nature of what is being forecast.*

**—Michael Gilliland and Udo Sglavo, Analyticsmagazine.com[2]**

*Accurate forecasting optimizes customer service, minimizes inventory overstocks and lays the groundwork for effective marketing at Nestlé.*

**—Marcel Baumgartner, statistical forecasting head, Nestlé[3]**

*For retailers, making better business decisions depends heavily on the ability to forecast demand accurately. By predicting demand at the store and SKU level, retailers can optimize order quantities, stock levels and store shipment allocations. Most importantly, retailers are better able to compete for shoppers' attention and earn their loyalty.*

**—Tom O'Reilly, president and CEO, Aptaris[4]**

## Learning Objectives

**After completing this chapter, you should be able to**

**LO 1** Explain the role of demand forecasting in a supply chain.

**LO 2** Identify the components of a forecast.

**LO 3** Compare and contrast qualitative and quantitative forecasting techniques.

**LO 4** Assess the accuracy of forecasts.

**LO 5** Explain collaborative planning, forecasting, and replenishment.

## Chapter Outline



## SCM Profile — The ISM Report on Business

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The Institute of Supply Management (ISM), formerly known as the National Association of Purchasing Management (NAPM), surveys supply management professionals participating on the Business Survey Committee comprised of more than 300 purchasing and supply executives, seeking information on "changes in production, new orders, new export orders, imports, employment, inventories, prices, lead times, and the timeliness of supplier deliveries in their companies, comparing the current month to the previous month." The *ISM Report on Business*, available the first business day of each month, is considered to be an accurate indicator of the overall direction of the economy and the health of the manufacturing and nonmanufacturing sectors.

The ISM report provides several indices for the manufacturing sector: New Orders, Production, Employment, Supplier Deliveries, Inventories, Customers' Inventories, Prices, Backlog of

Orders, Exports, and Imports. The most important index is the Purchasing Managers Index (PMI) developed by Theodore Torda, Senior Economist of the U.S. Department of Commerce, and introduced in 1982. The PMI is a composite of five weighted seasonally adjusted indices (weights are shown in parentheses): New Orders (0.20), Production (0.20), Employment (0.20), Supplier Deliveries (0.20), and Inventories (0.20). A reading below 50 represents contraction, and a reading over 50 indicates growth or expansion in the manufacturing sector of the economy compared to the previous month. The purchasing surveys provide comprehensive information for tracking the economy and developing business forecasts.[5] The ISM *Report on Business®*—Manufacturing and Services – "are two of the most reliable economic indicators available, providing guidance to supply management professionals, economists, analysts, and government and business leaders."[6]

In the PMI Match 2021 report, Timothy Fiore, chair of the ISM Manufacturing Business Survey Committee, noted the following: "The manufacturing economy continued its recovery in March. However, Survey Committee Members reported that their companies and suppliers continue to struggle to meet increasing rates of demand due to COVID-19 impacts limiting availability of parts and materials. Extended lead times, wide-scale shortages of critical basic materials, rising commodities prices and difficulties in transporting products are affecting all segments of the manufacturing economy. Worker absenteeism, short-term shutdowns due to part shortages, and difficulties in filling open positions continue to be issues that limit manufacturing-growth potential. . . . Demand expanded, with the (1) New Orders Index growing at a strong level, supported by the New Export Orders Index continuing to expand, (2) Customers' Inventories Index at an all-time low and (3) Backlog of Orders Index growing to an all-time high."[7] The report was a good indicator that the economy was recovering from the COVID-19 pandemic in early 2021.

## Introduction

In today's competitive environment, organizations are moving to a more effective demand-driven supply chain to enable them to respond quickly to shifting demand. The COVID-19 pandemic has shown how demand can fluctuate wildly and wreak havoc on the supply chain. Organizations have to respond to the global economic environment or suffer the consequences. In addition, consumers are also more demanding and discriminating. The market has evolved into a "pull" environment with customers dictating to suppliers what products they desire and when they need them delivered. If a retailer cannot get the product it wants at the right quantity, price, and time from one supplier, it will look for another company that can meet its demands. Any temporary stockout has a tremendous potential downside on sales, profitability, and customer relationships.

There are several ways to closely match supply and demand. One way is for a supplier to hold plenty of stock available for delivery at any time. While this approach maximizes sales revenues, it is also expensive because of the cost of carrying inventory and the possibility of write-downs at the end of the selling season. Use of flexible pricing is another approach. During heavy demand periods, prices can be raised to reduce peak demand. Price discounts can then be used to increase sales during periods with excess inventory or slow demand. This strategy can still result in lost sales, though, as well as stockouts, and thus cannot be considered an ideal or partnership-friendly approach to satisfying demand. In the short term, companies can also use overtime, subcontracting, or temporary workers to increase capacity to meet demand for their products and services. In the interim, however, firms will lose sales as they train workers, and quality may also tend to suffer.

Managing demand is challenging because of the difficulty in forecasting future consumer requirements accurately. In order for supply chains to be successful, suppliers must be able to accurately forecast demand so they can produce and deliver the right quantities demanded by their customers in a timely and cost-effective fashion. Thus, it is imperative that suppliers along the supply chain find ways to better match supply and demand to achieve optimal levels of cost, quality, and customer service to enable them to compete with other supply chains. Any problems that adversely affect the timely delivery of products demanded by consumers will have ramifications throughout the supply chain.

Zara Espana, S.A., a Spanish clothing and accessories retailer, is a giant player in the fashion industry with a major advantage over its competitors due to its fast response time. Zara commits to only 15–20 percent of the season's products six months in advance, but nearly 50 percent of its clothing lines are designed and manufactured during the current season.[8] Product life cycles in the fashion industry are short and so is the selling season. Their tight integration of design, planning, and production enables Zara to respond quickly to market needs. Since its lead time for new product introduction is only two weeks, Zara in effect has to forecast demand just two weeks in advance. The flow of current information among customers, store managers, market specialists, designers, and production staff also mitigates the bullwhip effect (which tends to result in higher safety stock levels). Zara is thus able to avoid the overproduction and heavy discounting so common in the fast fashion industry due to inaccurate forecasting. Zara's approach is considered a reactive one where the retailer is constantly monitoring the market and using sell-out products to determine variety and quantity every few weeks. Some industry experts suggest the use of trend forecasting to reduce overstock, prevent out-of-stock, and respond to consumer desires.[9] Valuable trend information can be gleaned from pictures and videos posted by consumers, their likes, and messages appearing on social media. Such data is invaluable for brands that cater to the younger generation such as Zara.

Several developments have surfaced recently. One is the COVID-19 pandemic and how supply chains adjusted demand forecasts during this turbulent period. The other is the increasing application of artificial intelligence and machine learning in forecasting. Another term you will see more frequently is demand sensing. These topics will be discussed later in this chapter.

## The Importance of Demand Forecasting

Forecasting is an important element of demand management. It provides an estimate of future demand and the basis for planning and sound business decisions. Since all organizations deal with an unknown future, some error between a forecast and actual demand is to be expected. Thus, the goal of a good forecasting technique is to minimize the deviation between actual demand and the forecast. Since a forecast is a prediction of the future, factors that influence demand, the impact of these factors, and whether they will continue to influence future demand must be considered in developing an accurate forecast. In addition, buyers and sellers should share all relevant information to generate a single consensus forecast so that the correct decisions on supply and demand can be made. Improved forecasts benefit not only the focal company but also the trading partners in the supply chain. Having accurate demand forecasts allows the purchasing department to order the right amount of parts and materials, the operations department to produce the right quantity of products, and the logistics department to deliver a correctly sized order. Thus, timely and accurate demand information is a critical component of an effective supply chain. Inaccurate forecasts would lead to imbalances in supply and demand. In today's competitive

business environment, collaboration (or cooperation and information sharing) between buyers and sellers is the rule rather than the exception. The benefits of better forecasts are lower inventories, reduced stock outs, smoother production plans, reduced costs, and improved customer service. Demand forecasting is closely linked to sales and operations planning (S&OP).

As discussed in the chapter-opening SCM Profile, the ISM has been publishing the Manufacturing ISM *Report on Business* monthly since 1931, except for a four-year interruption during World War II. The indices for the manufacturing sector include New Orders, Production, Manufacturing Employment, Supplier Deliveries, Inventories, Customers' Inventories, Prices, Backlog of Orders, Exports, and Imports. Many business executives use these indices to forecast the overall direction of the economy and the health of the manufacturing sector. For example, purchasing and supply managers utilize the Customers' Inventories Index to help forecast future new orders, make production decisions, and measure changes in supply chain activity. The *Wall Street Journal* publishes the ISM *Report on Business*, which includes both the manufacturing and nonmanufacturing sectors.

Many have argued that demand forecasting is both an art and a science. Since there are no accurate crystal balls available, it is impossible to expect 100 percent forecast accuracy at all times. The impact of poor communication and inaccurate forecasts resonates all along the supply chain and results in the *bullwhip effect* (described in Chapter 1) causing stockouts, lost sales, high costs of inventory and obsolescence, material shortages, poor responsiveness to market dynamics, and poor profitability. Numerous examples exist showing the problems that companies faced when their sales forecasts did not match customer demands during new product introductions. For instance, Apple's iPhone has been around for some time, yet forecasting sales of the iPhone 12 with different models is a challenge. Strong iPhone 12 sales prompted Apple to increase 2021 production plans by 20–30 percent. Three of the four iPhone models, iPhone 12, iPhone 12 Pro, and iPhone 12 Pro Max, all exceeded their initial expectations. Investment firm Cowen predicted that iPhone sales could increase almost 50 percent year over year for the first quarter of 2021.[10] iPhone sales have been declining in the past few years due to the popularity of Android phones. However, the recent strong demand for iPhones speaks volumes about the popularity of the current iPhone lineup and the difficulty of accurately forecasting iPhone demand.

**Collaborative planning, forecasting, and replenishment** (CPFR) is a concept first developed by the Voluntary Interindustry Commerce Solutions (VICS) Association, which merged with GS1 US in 2012. According to the Council of Supply Chain Management Professionals, CPFR is:

> *A concept that aims to enhance supply chain integration by supporting and assisting joint practices. CPFR seeks cooperative management of inventory through joint visibility and replenishment of products throughout the supply chain. Information shared between suppliers and retailers aids in planning and satisfying customer demands through a supportive system of shared information. This allows for continuous updating of inventory and upcoming requirements, essentially making the end-to-end supply chain process more efficient. Efficiency is also created through the decrease in expenditures for merchandising, inventory, logistics, and transportation across all trading partners.*[11]

The early adopters of CPFR, Walmart and West Marine, were quite successful implementing the system. However, there were technological, organizational, and cultural challenges which inhibited the implementation of CPFR on a broader scale. One such constraint is the lack of visibility and insight into channel behavior. Without a holistic view of

account pricing, promotion, product mix, and new product introductions the promise of collaborative initiatives are not realized. Change is always difficult; but if top management is committed to the project, then the project is more likely to succeed. Companies will need to educate their employees on the benefits of the process changes and the disadvantages of maintaining the status quo. Trust, a major cultural issue, is considered a big hurdle to widespread implementation of CPFR because many retailers are reluctant to share the type of proprietary information required by CPFR. While the suppliers of Walmart such as Procter & Gamble, for instance, may be willing to share sensitive data with Walmart, they do not want other suppliers to obtain this information. However, experts do not believe that trust is the stumbling block for mass adoption of CPFR. Widespread adoption of CPFR appears to have stalled.

## Demand Forecasting Techniques

Understanding that a forecast is very often inaccurate does not mean that nothing can be done to improve the forecast. Both quantitative and qualitative forecasts can be improved by seeking inputs from trading partners. **Qualitative forecasting methods** are based on opinions and intuition, whereas **quantitative forecasting methods** use mathematical models and relevant historical data to generate forecasts. The quantitative methods can be divided into two groups: time series and associative models.

### Qualitative Methods

Qualitative forecasting methods are based on intuition or judgmental evaluation and are generally used when data is limited, unavailable, or not currently relevant. This approach can vary widely in cost, and accuracies depend to a large extent on the skill and experience of the forecaster(s) and the amount of relevant information, time, and money available. Specifically, qualitative techniques are used to develop long-range projections when current data is no longer very reliable, and for new product introductions when current data simply does not exist. Discussions of four common qualitative forecasting models follow.

#### Jury of Executive Opinion

A group of the firm's senior management executives who are knowledgeable about their markets, their competitors, and the business environment collectively develop the forecast. This technique has the advantage of several individuals with considerable experience working together, but if one member's views dominate the discussion, then the value and reliability of the outcome can be diminished. This technique is applicable for long-range planning and new product introductions, but is also commonly used for general demand forecasting. This type of forecasting is commonly used by commercial banks in the United States for medium-term forecasts.

#### Delphi Method

The Delphi method was first developed by Project RAND in the late 1950s and can be used for a wide range of applications, including forecasting. A group of internal and external experts are surveyed during several rounds in terms of future events and long-term forecasts of demand, in hopes of converging on a consensus forecast. Group members do not physically meet and thus avoid the scenario where one or a few experts could dominate a discussion. The answers from the experts are accumulated after each round of the survey and summarized. The summary of responses is then sent out to all the experts in the

next round, wherein individual experts can modify their responses based on the group's response summary. This iterative process continues until a consensus is reached. The process can be both time-consuming and very expensive. This approach is applicable for high-risk technology forecasting; large, expensive projects; or major new product introductions. Ultimately, the value of a Delphi forecast is dependent upon the qualifications of the expert participants. With the Delphi technique, the number of experts can vary widely, depending on the circumstances, the available time, and the number of experts available.

### Sales Force Composite

The sales force represents a good source of market information. This type of forecast is generated based on the sales force's knowledge of the market and estimates of customer needs. Due to the proximity of the sales personnel to the consumers, the forecast tends to be reliable, but individual biases could negatively impact the effectiveness of this approach. For example, if bonuses are paid when actual sales exceed the forecast, there is a tendency for the sales force to under-forecast.

### Customer Surveys

A forecasting questionnaire can be developed that uses inputs from customers on important issues such as future purchasing needs, new product ideas, and opinions about existing or new products. The survey can be administered through telephone, mail, Internet, or personal interviews. The data collected from these surveys is then analyzed, and forecasts are developed from the results. For example, a 2015 Deloitte consumer study confirmed that smartphones were indispensable for all demographics and locations. In a follow-up 2016 study on consumer attitudes around mobile phones, Deloitte found consumers looked at their smartphones 47 times a day and that number increased to 82 times for 18- to 24-year-olds.[12] Since Google's Android is the dominant smartphone operating system it made strategic sense for Google to get into the fast-growing hardware market with the development of the Pixel smartphone. According to Rick Osterloh, Head of Google's newly formed hardware unit, "Building hardware and software together lets us take full advantage of capabilities like the Google Assistant. It lets us harness years of expertise we've built up in machine learning and AI to deliver the simple, smart and fast experiences that our users expect from us."[13]

## Quantitative Methods

Quantitative forecasting models use mathematical techniques that are based on historical data and can include causal variables to forecast demand. **Time series forecasting** is based on the assumption that the future is an extension of the past; thus, historical data can be used to predict future demand. **Cause-and-effect forecasting** assumes that one or more factors (independent variables) are related to demand and, therefore, can be used to predict future demand.

Since these forecasts rely solely on past demand data, all quantitative methods become less accurate as the forecast's time horizon increases. Thus, for long-time horizon forecasts, it is generally recommended to utilize a combination of both quantitative and qualitative techniques.

### Components of a Time Series

A time series typically has four components: trend, cyclical, seasonal, and random variations:

- *Trend Variations:* Trends represent either increasing or decreasing movements over many years and are due to factors such as population growth, population shifts, cultural changes, and income shifts. Common trend lines are linear, S-curve, exponential, or asymptotic.
- *Cyclical Variations:* Cyclical variations are wavelike movements that are longer than a year and are influenced by macroeconomic and political factors. One example is the **business cycle** (recessions or expansions that tend to occur every eight or ten years). Recent business cycles in the United States have been affected by global events such as the 1991 Mexican financial crisis; the 1997 Asian economic crisis; and the 2008 U.S. financial crisis (considered the worst economic disaster since the U.S. Great Depression of 1929).
- *Seasonal Variations:* Seasonal variations show peaks and valleys that repeat over a consistent interval such as hours, days, weeks, months, years, or seasons. Due to seasonality, many companies do well in certain months and not so well in other months. For example, snow blower sales tend to be higher in the fall and winter but taper off in the spring and summer. A fast-food restaurant will see higher sales during the day around breakfast, lunch, and dinner. U.S. hotels experience large crowds during traditional holidays such as July 4, Labor Day, Thanksgiving, Christmas, and New Year.
- *Random Variations:* Random variations are due to unexpected or unpredictable events such as natural disasters (hurricanes, tornadoes, fire), labor strikes, and wars. These events can completely wreck a good forecast. Examples include the eruption of Iceland's Eyjafjallajökull volcano in 2010, which caused ash clouds to reach mainland Europe. Numerous flights to England and Europe were shut down, which led to the highest air travel disruption since the World War II.[14] Another natural disaster was the earthquake of magnitude 7.0 that hit Haiti in 2010. The Haitian government reported that 250,000 residences and 30,000 commercial buildings were badly damaged; 230,000 people died, 300,000 were injured, and 1,000,000 were made homeless as a result of the earthquake.[15] In 2016, Hurricane Matthew wreaked havoc on property and people across the Western Atlantic, Haiti, Cuba, Dominican Republic and Lucayan Archipelago, southeastern United States, and the Canadian Maritimes. The cost of damages exceeded $10.5 billion.[16]

## Time Series Forecasting Models

As discussed earlier, time series forecasts are dependent on the availability of historical data. Forecasts are estimated by extrapolating the past data into the future. Due to the availability of historical data, time series models are more widely used. For time series models, the more commonly used models are moving averages, simple trend and exponential smoothing. In general, demand forecasts are used in planning for procurement, supply, replenishment, and corporate revenue.

Several of the common time series approaches such as naïve, simple moving average, weighted moving average, and exponential smoothing forecasts are discussed next.

### Naïve Forecast

When using the **naïve forecast**, the estimate for the next period is equal to the actual demand for the immediate past period. The formula is:

$$F_{t+1} = A_t$$

where $F_{t+1}$ = forecast for period $t + 1$

$A_t$ = actual demand for period $t$

For example, if the most recent period's actual demand was 100 units, then the next period's forecast is 100 units. This method is inexpensive to understand, develop, store data for, and operate. However, there is no consideration of causal relationships, and the method may not generate accurate forecasts. Many economic and business series are considered good candidates for using the naïve forecast because the series behave like random walks.

## Simple Moving Average Forecast

The **simple moving average forecast** uses historical data to generate a forecast and works well when the demand is fairly stable over time. The formula for the *n*-period moving average forecast is shown below:

$$F_{t+1} = \frac{\sum_{i=t-n+1}^{t} A_i}{n}$$

where $F_{t+1}$ = forecast for period $t + 1$

$n$ = number of periods used to calculate moving average

$A_i$ = actual demand in period $i$

When $n$ equals 1, the simple moving average forecast reduces to the naïve forecast. The average tends to be more responsive if fewer data points are used to compute the average. However, random events can also impact the average adversely. Thus, the decision maker must balance the cost of responding slowly to changes versus the cost of responding to random variations. The advantage of this technique is that it is simple to use and easy to understand. A weakness of the simple moving average method is its inability to respond to trend changes quickly. Example 5.1 illustrates the simple moving average forecast.

### Example 5.1 Simple Moving Average Forecasting

| PERIOD | ACTUAL DEMAND |
|---|---|
| 1 | 1600 |
| 2 | 2200 |
| 3 | 2000 |
| 4 | 1600 |
| 5 | 2500 |
| 6 | 3500 |
| 7 | 3300 |
| 8 | 3200 |
| 9 | 3900 |
| 10 | 4700 |
| 11 | 4300 |
| 12 | 4400 |

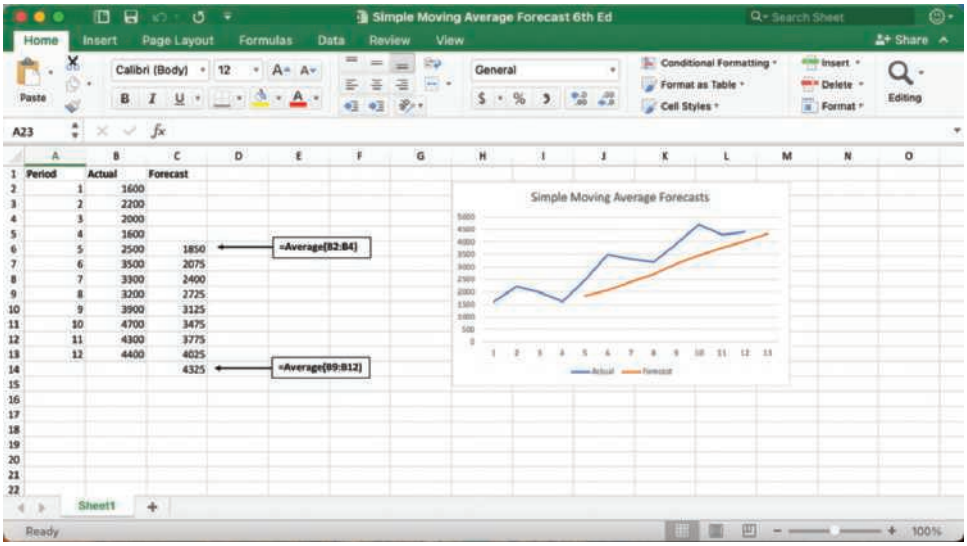
Using the data provided, calculate the forecast for period 5 using a four-period simple moving average.

**SOLUTION**

$$F_5 = \text{forecast for period } 5 = \frac{1600+2200+2000+1600}{4} = 1850$$

An Excel spreadsheet solution is shown in Figure 5.1.

**Figure 5.1** Simple Moving Average Forecasting Using an Excel Spreadsheet




## Weighted Moving Average Forecast

The simple moving average forecast places equal weights ($1/n$) on each of the $n$-period observations. Under some circumstances, a forecaster may decide that equal weighting is undesirable. An $n$-period **weighted moving average forecast** is the weighted average of the $n$-period observations, using unequal weights. The only restriction is that the weights should be nonnegative and sum to 1. The formula for the $n$-period weighted moving average forecast is shown below:

$$F_{t+1} = \sum_{i=t-n+1}^{t} w_i A_i$$

where $F_{t+1}$ = forecast for period $t + 1$;

$n$ = number of periods used in determining the moving average;

$A_i$ = actual demand in period $i$;

$w_i$ = weight assigned to period $i$; $\sum w_i = 1$.

For example, the three-period weighted moving average forecast with weights (0.5, 0.3, 0.2) is: $F_t = 0.5A_{t-1} + 0.3A_{t-2} + 0.2A_{t-3}$. Note that generally a greater emphasis (and thus the highest weight) is placed on the most recent observation and, hence, the forecast would react more rapidly than the three-period simple moving average forecast. However, the forecaster may instead wish to apply the smallest weight to the most recent data such that the forecast would be less affected by abrupt changes in recent data. The weights used thus tend to be based on the experience of the forecaster, and this is one of the advantages of this forecasting method. Although the forecast is more responsive to underlying changes in demand, it still lags demand because of the averaging effect. As such, the weighted moving average method does not do a good job of tracking trend changes in the data. Example 5.2 illustrates the weighted moving average forecast.

### Example 5.2 Weighted Moving Average Forecasting

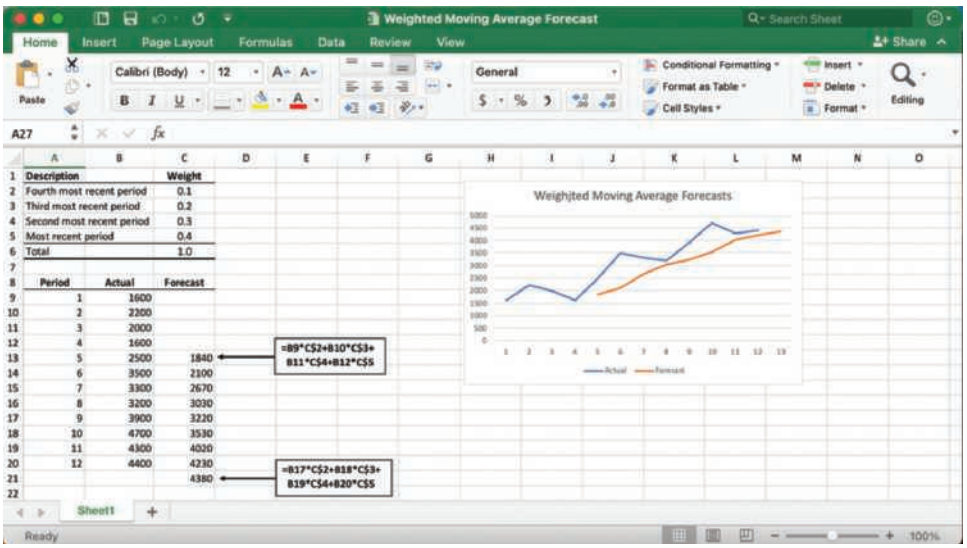
Based on data provided in Example 5.1, calculate the forecast for period 5 using a four-period weighted moving average. The weights of 0.4, 0.3, 0.2, and 0.1 are assigned to the most recent, second most recent, third most recent, and fourth most recent periods, respectively.

**SOLUTION**

$$F_5 = 0.1(1600) + 0.2(2200) + 0.3(2000) + 0.4(1600) = 1840$$

An Excel spreadsheet solution is shown in Figure 5.2.

**Figure 5.2** Weighted Moving Average Forecasting Using Excel Spreadsheet




## Exponential Smoothing Forecast

The **exponential smoothing forecast** is a sophisticated weighted moving average forecasting technique in which the forecast for the next period's demand is the current period's forecast adjusted by a fraction of the difference between the current period's actual demand and forecast. This approach requires less data than the weighted moving average method because only two data points are needed. Due to its simplicity and minimal data requirement, exponential smoothing is one of the more widely used forecasting techniques. This model, like the other time series models, is suitable for data that shows little trend or seasonal patterns. Other higher-order exponential smoothing models (which are not covered here) can be used for data exhibiting trend and seasonality. The exponential smoothing forecasting formula is:

$$F_{t+1} = F_t + \alpha(A_t - F_t) \text{ or } F_{t+1} = \alpha A_t + (1 - \alpha)F_t$$

where $F_{t+1}$ = forecast for period $t + 1$;

$F_t$ = forecast for period $t$;

$A_t$ = actual demand for period $t$;

$\alpha$ = smoothing constant $(0 \leq \alpha \leq 1)$

The exponential smoothing forecast is equivalent to the naïve forecast when $\alpha$ is equal to 1. With an $\alpha$ value closer to 1, there is a greater emphasis on recent data resulting in a major adjustment of the error in the last period's forecast. Thus with a high $\alpha$ value, the model is more responsive to changes in the recent demand. When $\alpha$ has a low value, more weight is placed on past demand (which is contained in the previous forecast), and the model responds slower to changes in demand. The impact of using a small or large value of $\alpha$ is similar to the effect of using a large or small number of observations in calculating the moving average. In general, the forecast will lag any trend in the actual data because only partial adjustment to the most recent forecast error can be made. The initial forecast can be estimated using the naïve method, that is, the forecast for next period is the actual demand for the current period. Example 5.3 illustrates the exponential smoothing forecast.

### Example 5.3 Exponential Smoothing Forecasting

Based on data provided in Example 5.1, calculate the forecast for period 3 using the exponential smoothing method. Assume the forecast for period 2 is 1600. Use a smoothing constant ($\alpha$) value of 0.3.

**SOLUTION**

Given: $F_2 = 1600, \alpha = 0.3$

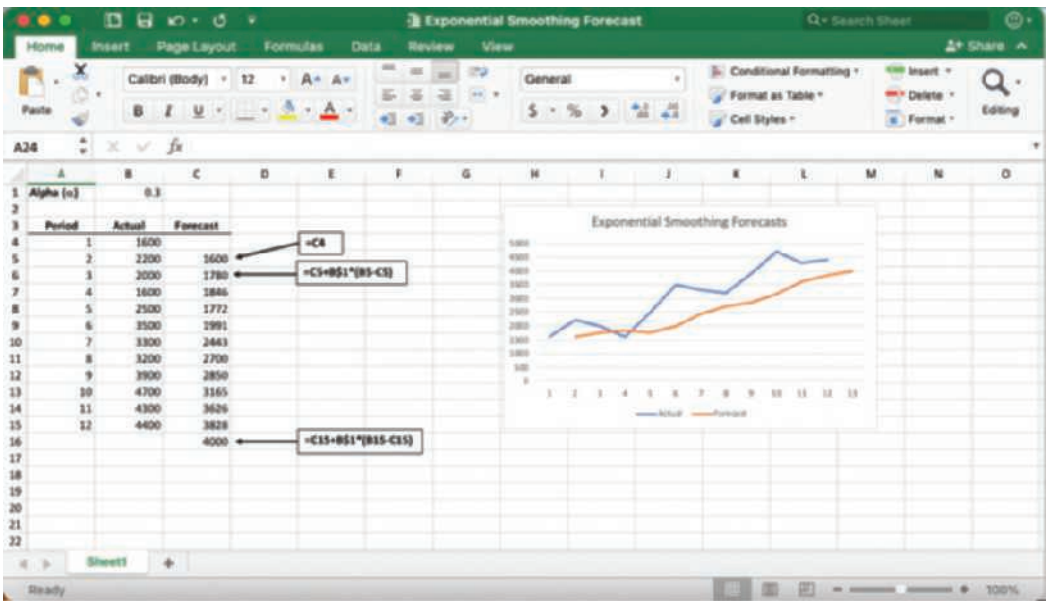
$$F_{t+1} = F_t + \alpha(A_t - F_t)$$

$$F_3 = F_2 + \alpha(A_2 - F_2) = 1600 + 0.3(2200 - 1600) = 1780$$

Thus, the forecast for week 3 is 1780.

An Excel spreadsheet solution is shown in Figure 5.3.

**Figure 5.3** Exponential Smoothing Forecasting Using Excel Spreadsheet



## Linear Trend Forecast

A **linear trend forecast** can be estimated using simple linear regression to fit a line to a series of data occurring over time. This model is also referred to as the simple trend model. The trend line is determined using the least squares method, which minimizes the sum of the squared deviations to determine the characteristics of the linear equation. The trend line equation is expressed as:

$$\hat{Y} = b_0 + b_1 X$$

where $\hat{Y}$ = forecast or dependent variable

$X$ = time variable

$b_0$ = intercept of the vertical axis

$b_1$ = slope of the trend line

The coefficients $b_0$ and $b_1$ are calculated as follows:

$$b_1 = \frac{n\sum(xy) - \sum x \sum y}{n\sum x^2 - (\sum x)^2}$$

$$b_0 = \frac{\sum y - b_1 \sum x}{n}$$

where $x$ = independent variable values

$y$ = dependent variable values

$n$ = number of observations

Example 5.4 illustrates the linear trend forecast.

### Example 5.4 Linear Trend Forecast

The demand for toys produced by the Miki Manufacturing Company is shown in the table below.

| PERIOD | DEMAND | PERIOD | DEMAND | PERIOD | DEMAND |
|---|---|---|---|---|---|
| 1 | 1600 | 5 | 2500 | 9 | 3900 |
| 2 | 2200 | 6 | 3500 | 10 | 4700 |
| 3 | 2000 | 7 | 3300 | 11 | 4300 |
| 4 | 1600 | 8 | 3200 | 12 | 4400 |

The company desires to know the trend line and the forecast for period 13.

**SOLUTION**

| PERIOD ($x$) | DEMAND ($y$) | $x^2$ | $xy$ |
|---|---|---|---|
| 1 | 1600 | 1 | 1600 |
| 2 | 2200 | 4 | 4400 |
| 3 | 2000 | 9 | 6000 |
| 4 | 1600 | 16 | 6400 |
| 5 | 2500 | 25 | 12500 |
| 6 | 3500 | 36 | 21000 |
| 7 | 3300 | 49 | 23100 |
| 8 | 3200 | 64 | 25600 |
| 9 | 3900 | 81 | 35100 |
| 10 | 4700 | 100 | 47000 |
| 11 | 4300 | 121 | 47300 |
| 12 | 4400 | 144 | 52800 |
| $\Sigma x = 78$ | $\Sigma y = 37{,}200$ | $\Sigma x^2 = 650$ | $\Sigma xy = 282{,}800$ |

$$b_1 = \frac{n\sum(xy) - \sum x \sum y}{n\sum x^2 - (\sum x)^2} = \frac{12(282{,}800) - 78(37{,}200)}{12(650) - 78^2} = 286.71$$

$$b_0 = \frac{\sum y - b_1 \sum x}{n} = \frac{37{,}200 - 286.71(78)}{12} = 1236.4$$

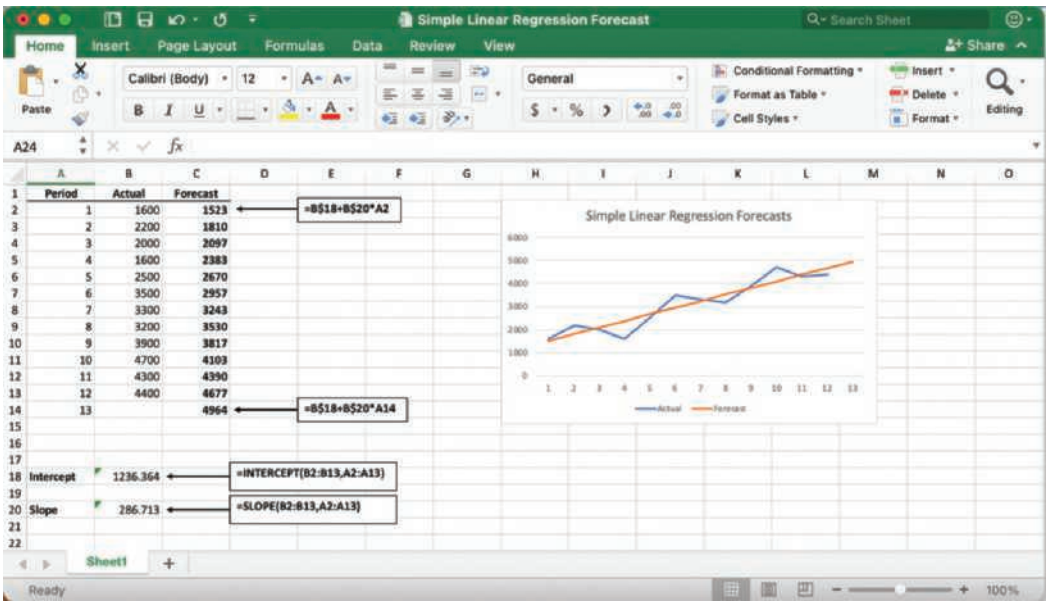
The trend line is then $\hat{Y} = 1236.4 + 286.7x$

To forecast the demand for period 13, we substitute $x = 13$ into the trend equation above.

The linear trend forecast for period 13 = 1236.4 + 286.7(13) = 4963.5 = 4964 toys.

An Excel spreadsheet solution is shown in Figure 5.4.

**Figure 5.4** Forecasting with Simple Linear Regression Using Excel Spreadsheet




## Cause-and-Effect Models

The cause-and-effect models have a cause (independent variable or variables) and an effect (dependent variable). One of the more common models used is regression analysis. In demand forecasting, the external variables that are related to demand are first identified. Once the relationship between the external variable and demand is determined, it can be used as a forecasting tool. Let's review several cause-and-effect models.

### Simple Linear Regression Forecast

When there is only one explanatory variable, we have a simple regression model equivalent to the linear trend model described earlier. The difference is that the $x$ variable is no longer time but instead an explanatory variable of demand. For example, demand could be dependent on the size of the advertising budget. The regression equation is expressed as:

$$\hat{Y} = b_0 + b_1 X$$

where $\hat{Y}$ = forecast or dependent variable

$X$ = explanatory or independent variable

$b_0$ = intercept of the vertical axis

$b_1$ = slope of the regression line

Example 5.5 illustrates the **simple linear regression forecast**.

### Example 5.5 Simple Linear Regression Forecasting

Data on sales and advertising dollars for the past six months are shown below.

| $ SALES ($y$) | $ ADVERTISING ($x$) |
|---|---|
| 100,000 | 2000 |
| 150,000 | 3000 |
| 125,000 | 2500 |
| 50,000 | 1000 |
| 170,000 | 3500 |
| 135,000 | 2750 |

Determine the linear relationship between sales and advertising dollars.

**SOLUTION**

| $ SALES ($y$) | $ ADVERTISING ($x$) | $x^2$ | $xy$ |
|---|---|---|---|
| 100,000 | 2000 | 4,000,000 | 200,000,000 |
| 150,000 | 3000 | 9,000,000 | 450,000,000 |
| 125,000 | 2500 | 6,250,000 | 312,500,000 |
| 50,000 | 1000 | 1,000,000 | 50,000,000 |
| 170,000 | 3500 | 12,250,000 | 595,000,000 |
| 135,000 | 2750 | 7,562,500 | 371,250,000 |
| $\Sigma y = 730{,}000$ | $\Sigma x = 14{,}750$ | $\Sigma x^2 = 40{,}062{,}500$ | $\Sigma xy = 1{,}978{,}750{,}000$ |

$$\hat{Y} = b_0 + b_1X$$

$$b_1 = \frac{n\sum(xy) - \sum x \sum y}{n\sum x^2 - (\sum x)^2} = \frac{6(1{,}978{,}750{,}000) - 14{,}750(730{,}000)}{6(40{,}062{,}500) - 14{,}750^2} = 48.43836$$

$$b_0 = \frac{\sum y - b_1 \sum x}{n} = \frac{730{,}000 - 48.43836(14{,}750)}{6} = 2589.041$$

$$b_0 = 2589.041$$

$$\hat{Y} = 2589.04 + 48.44X$$

The linear regression results indicate that a one-dollar increase in advertising will increase sales by $48.44. Further, a planned monthly advertising expenditure of $4000 would yield a sales forecast of $196,349. Note that a simple linear regression for this example could be performed using an Excel spreadsheet similar to Figure 5.4.

## Multiple Regression Forecast

When several explanatory variables are used to predict the dependent variable, a **multiple regression forecast** is applicable. Multiple regression analysis works well when the relationships between demand (dependent variable) and several other factors (independent or explanatory variables) impacting demand are strong and stable over time. The multiple regression equation is expressed as:

$$\hat{Y} = b_0 + b_1X_1 + b_2X_2 + \ldots + b_kX_k$$

where $\hat{Y}$ = forecast or dependent variable

$X_k$ = $k$th explanatory or independent variable

$b_0$ = constant

$b_k$ = regression coefficient of the independent variable $X_k$

Although the mathematics involved in determining the parameters of the equation is complex, numerous software programs such as Excel, SAS, and SPSS statistical packages can be used to solve the equation. Any statistics textbook should provide the formula for calculating the regression coefficient values and discussion of the assumptions and challenges of using multiple regression techniques. Multiple regression forecasting requires much more data than any of the other techniques discussed earlier, and the additional cost must be balanced against possible improvement in the level of forecast accuracy. Forecast accuracy is discussed next.

## Forecast Performance

The ultimate goal of any forecasting endeavor is to have an accurate and unbiased forecast. The cost associated with prediction error can be substantial and include the costs of lost sales, safety stock, unsatisfied customers, and loss of goodwill. Companies must strive to do a good job of tracking forecast error and taking the necessary steps to improve their forecasting techniques. Typically, forecast error at the disaggregated (stock keeping unit) level is higher than at the aggregated (company as a whole) level. **Forecast error** is the difference between the actual quantity and the forecast. Forecast error can be expressed as:

$$e_t = \mathrm{A}_t - \mathrm{F}_t$$

where $e_t$ = forecast error for period $t$

$\mathrm{A}_t$ = actual demand for period $t$

$\mathrm{F}_t$ = forecast for period $t$

Several measures of forecasting accuracy are shown below:

$$\text{Mean absolute deviation (MAD)} = \frac{\sum_{t=1}^{n} |e_t|}{n}$$

$$\text{Mean absolute percentage error (MAPE)} = \frac{100}{n}\sum_{t=1}^{n}\left|\frac{e_t}{A_t}\right|$$

$$\text{Mean square error} = \frac{\sum_{t=1}^{n} e_t^2}{n}$$

$$\text{Running sum of forecast errors (RSFE)} = \sum_{t=1}^{n} e_t$$

where $e_t$ = forecast error for period $t$

$A_t$ = actual demand for period $t$

$n$ = number of periods of evaluation

The RSFE is an indicator of bias in the forecasts. **Forecast bias** measures the tendency of a forecast to be consistently higher or lower than the actual demand, over time. A positive RSFE indicates that the forecasts are generally lower than actual demand, which can lead to stockouts. A negative RSFE shows that the forecasts are generally higher than actual demand, which can result in excess inventory carrying costs.

The **tracking signal** is used to determine if the forecast bias is within the acceptable control limits. It is expressed as:

$$\text{Tracking signal} = \frac{\text{RSFE}}{\text{MAD}}$$

If the tracking signal falls outside preset control limits, there is a bias problem with the forecasting method, and an evaluation of the way forecasts are generated is warranted. A biased forecast will lead to excessive inventories or stockouts. Some inventory experts suggest using a tracking signal of $\pm 4$ for high-volume items and $\pm 8$ for lower-volume items. Over time when the quality of forecasts improve, it is recommended that the control limits be reduced to $\pm 3$. As tighter limits are instituted, there is a greater probability of finding exceptions that actually require no action, but it also means catching changes in demand earlier, which could lead to further improvement in forecasts. Example 5.6 illustrates the use of these forecast accuracy measures.

## Example 5.6 Forecast Accuracy Measures

The demand and forecast information for the XYZ Company over a twelve-month period is shown in the table below.

| PERIOD | DEMAND | FORECAST | PERIOD | DEMAND | FORECAST |
|---|---|---|---|---|---|
| 1 | 1600 | 1523 | 7 | 3300 | 3243 |
| 2 | 2200 | 1810 | 8 | 3200 | 3530 |
| 3 | 2000 | 2097 | 9 | 3900 | 3817 |
| 4 | 1600 | 2383 | 10 | 4700 | 4103 |
| 5 | 2500 | 2670 | 11 | 4300 | 4390 |
| 6 | 3500 | 2957 | 12 | 4400 | 4677 |

Calculate the MAD, MSE, MAPE, RSFE, and tracking signal. Assume that the control limit for the tracking signal is $\pm 3$. What can be concluded about the quality of the forecasts?

**SOLUTION**

| PERIOD | DEMAND | FORECAST | ERROR (e) | ABSOLUTE ERROR | $e^2$ | ABSOLUTE % ERROR |
|---|---|---|---|---|---|---|
| 1 | 1600 | 1523 | 77 | 77 | 5929 | 4.8 |
| 2 | 2200 | 1810 | 390 | 390 | 152,100 | 17.7 |
| 3 | 2000 | 2097 | −97 | 97 | 9409 | 4.9 |
| 4 | 1600 | 2383 | −783 | 783 | 613,089 | 48.9 |
| 5 | 2500 | 2670 | −170 | 170 | 28,900 | 6.8 |
| 6 | 3500 | 2957 | 543 | 543 | 294,849 | 15.5 |
| 7 | 3300 | 3243 | 57 | 57 | 3249 | 1.7 |
| 8 | 3200 | 3530 | −330 | 330 | 108,900 | 10.3 |
| 9 | 3900 | 3817 | 83 | 83 | 6889 | 2.1 |
| 10 | 4700 | 4103 | 597 | 597 | 356,409 | 12.7 |
| 11 | 4300 | 4390 | −90 | 90 | 8100 | 2.1 |
| 12 | 4400 | 4677 | −277 | 277 | 76,729 | 6.3 |
| | | Total | 0 | 3494 | 1,664,552 | 133.9 |
| | | Average | | 291.17 | 138,712.7 | 11.16 |
| | | | RSFE | MAD | MSE | MAPE |

MAD = 291.2

MSE = 138,712.7

MAPE = 11.2%

RSFE = 0

$$\text{Tracking signal} = \frac{\text{RSFE}}{\text{MAD}} = 0$$

The results indicate no bias in the forecasts, and that the tracking signal is well within the control limits of $\pm 3$. However, the forecasts are on average 291 units or 11.2 percent off from actual demand. This situation might require attention to determine the underlying causes of the variations or to search for a more accurate forecasting technique.

In one study, researchers found that bias in the forecast could be intentional, driven by organizational issues such as motivation of staff and satisfaction of customer demands, influencing the generation of forecasts.[17] For example, sales personnel tend to favor under-forecasting so they can meet or exceed sales quotas, and production people tend to over-forecast because having too much inventory presents less of a problem than the alternative. The key to generating accurate forecasts is collaborative forecasting with different partners inside and outside the company working together to eliminate forecasting error. A collaborative planning, forecasting, and replenishment system provides for free exchange of forecasting data, point-of-sale data, promotions, and other relevant information between trading partners; this collaborative effort, rather than more sophisticated and expensive forecasting algorithms, can account for significant improvements in forecasting accuracy.

### Using Lag in Measuring Forecast Error

Is the lagged approach a new way to measure forecast error? Experts suggest that what is really important for decision makers is not the error at a specific time but the error over the lead time for the particular process. Lag is often confused with lead time. This example illustrates the issue quite well:[18]

> *Let's say you have a three-week frozen schedule, what you are scheduling in week 4 is not the week 4 forecast, but your current inventory minus the next four weeks of forecast and net of safety stock. The quality of your scheduling decision is tied to the accuracy of your entire four week forecast because that is what is driving your projected inventory. For example, if week 1 is over-forecast and week 2 is under-forecast or vice versa, there is no difference. All that matters is the cumulative four-week error.*

While lag and lead time are not the same, this does not prevent companies from using lead time as the lag. A 2019 E2open forecasting and inventory study found that organizations which have adopted this practice have experienced direct benefits and improvements in inventory management performance.[19] It appears that use of forecast error over the exact lead-time as the measure for supply chain decisions is gaining traction. As many will agree, deep-rooted practices may be hard to change.

## Demand Sensing

Another term that is often seen in forecasting is **demand sensing**, which is more applicable to short-term demand forecasting. Manufacturers have shortened delivery times, so demand sensing is important. Demand sensing is a way of identifying short-term trends quickly so companies can better forecast what, when, and where consumers want goods. Instead of depending solely on historical data as the only input for planning purposes, a good demand sensing solution would include the following:[20]

- Real-time inputs from several external sources to generate forecasts of the prevailing market situation.
- Using pattern recognition technologies from artificial intelligence (AI) and machine learning (ML) from sources of big data to generate useful information.
- An automated model with self-adjusting algorithms that can learn from data without human intervention and generate forecasts for execution daily.

The 2019 E2open Forecasting and Inventory Benchmark study (see the nearby SCM Profile) finds that "within the first two weeks a product is on sale, demand sensing creates a step-change in performance that continues to deliver over the life of the product, cutting error by 30 percent."[21] The study also shows that demand sensing improves forecast errors of the top movers by 34 percent and the slow-moving products by 36 percent. It is anticipated that long-term demand sensing will likely cut weekly and monthly forecast errors by greater than 10–20 percent for yearly time horizons. The use of AI/ML and multiple external demand signals as key inputs enable the best forecast to be generated for any time period. Demand sensing provides the building blocks for improving forecasting accuracy and creating a more agile supply chain.

## SCM Profile

## E2open Forecasting and Inventory Benchmark Study[22]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E2open annually carries out a Forecasting and Inventory Benchmark Study on global manufacturers across different industries and presents in-depth analysis of the state of demand forecasting, inventory management and supply performance in North America. "Demand is the heartbeat of the supply chain and companies that get it right have an inherent advantage over their peers," said Michael Farlekas, president and chief executive officer at E2open. "Each year we publish this study as a reliable benchmark to understand the art of the possible and help companies in the pursuit of planning excellence. What separates leaders from the pack is the use of artificial intelligence to systematically create the best forecast at any time horizon and better predict what will sell instead of what they simply hope will sell. This is a game changer in that it provides the agility to serve customers in fast-moving markets and the resiliency to manage uncertainty and disruption."[23]

The following are a few key findings from the study:[24]

- *Innovation is an important source of revenue and represents roughly 20 percent of annual sales but each new product has only half the revenue productivity of existing items. Balance growth through innovation strategies with strong governance to control SKU proliferation that otherwise degrades item productivity, erodes planning, manufacturing and distribution performance, and requires greater investments in inventory to keep the supply chain running.*
- *Don't neglect operational excellence initiatives that increase the sales productivity of existing items. Existing items make up roughly two-thirds of the portfolio and a few percentage point increase in performance can double net growth in sales. Adopt demand sensing capabilities to improve the productivity of existing demand planning programs.*

- *Accelerate the use of AI/ML, and receive more demand signals (including external data) as a key enabler of agility, efficiency, and resiliency. It is proven at scale to provide a consistent step-change in planning performance across any horizon. For short-term horizons, sense demand by using real-time data so that forecasts reflect current realities on the ground. Make sure any investment in AI/ML for planning can encompass your entire business and the solutions you choose automatically publish the forecasts to supply planning without human intervention—otherwise you will fail to realize a meaningful benefit.*

The study also finds that there is a "40 percentage point spread between forecast accuracy used for quarterly C-level planning and that used for weekly operational supply chain decisions." In addition, demand planning forecast error for new items tends to be 40 percent higher than for existing items, mainly attributed to the lack of sales history for new products. Overall demand planning forecast error has remained very similar over the last five years. Another interesting finding is that the tail end intermittent and low-volume items are more difficult to forecast and likely to have errors twice as high as the fast-moving top end items. This suggests that traditional forecasting methods have reached their limits. AI and ML may be what is needed next in forecasting.

## Demand Planning During the COVID-19 Pandemic and Beyond

When the pandemic hit the United States in the spring of 2020, many industries were not well prepared for the disruptive developments that had major impacts on demand planning and the supply chain. The initial lockdown caused many manufacturers such as Ford, GM, and Boeing to shut down many of their operations. Non-essential businesses such as Apple and Ikea had to close their stores. Orders at suppliers went down significantly. As a result of the uncertain environment, many consumers started panic buying and emptying supermarket shelves of canned food, pasta, and eggs. Surprisingly even toilet paper was out of stock due to heavy demand. However, a few weeks later, demand for many of these items was back to normal. The healthcare sector saw demand for products like hand sanitizer and face masks skyrocket and shortages were the norm for months. Manufacturers were hard pressed to meet these astronomical demands in a short period of time.

In the face of this crisis, supply chain managers had to make adjustments to demand planning. The following is a recommended plan of action, according to several supply chain management experts, for the pandemic and beyond:[25]

- Change forecasting models—Switch off from traditional models and manually override forecasts if needed. Implement machine learning algorithms, which can incorporate the latest information and predict future demand.
- Identify future demand drivers—Forecast structural shifts in demand due to changing customer requirements and distribution channels. Implement analytical predictive models using new demand drivers, virus information, and available lock-down information.
- Understand supply chain dynamics—Must fully understand the industry. Predict end consumer demand and capacity in the supply chain, taking into account the effect of lead times and inventories after considering the new environment.

- Increase communication with customers—It is critical to have close direct contact with customers through frequent updates on order forecasts and downstream customer expectations. Hold joint planning meetings with major customers and challenge demand from customers to ensure there is no gaming involved. If possible, neutral independent parties can provide additional information to resolve extreme demand-supply mismatches.
- Restructure S&OP (Sales & Operations Planning) processes—Form a cross-functional team of data analysts, demand planners, and sales to synchronize and update demand and supply changes right up to the S&OP meetings. Organize more regular S&OP meetings to focus on monitoring supply and transportation.
- Plan product portfolio—Planning efforts should be focused on managing fast movers while reducing slow-moving products to better consolidate demand and minimize uncertainty.
- Clean data for the future—Solicit agreement from all functions on a clean baseline data for forecasting and planning after the pandemic recovery. For example, the wild swings in demand for toilet paper in the winter/spring of 2020 would definitely not be relevant data for forecasting seasonal demand in 2021.

## Useful Forecasting Websites

Several forecasting websites that provide a wealth of information on the subject are shown here:

1. Institute for Business Forecasting & Planning (https://ibf.org/)

   *The Institute of Business Forecasting & Planning – IBF is a membership organization recognized worldwide as the premier full-service provider of demand planning, forecasting, business analytics, S&OP/IBP (Integrated Business Planning) education, benchmarking research, corporate training, e-Learning, professional certification, world-class conferences, and advisory services. Since 1981, the IBF has been helping businesses improve their forecasting and planning performance in an effort to enhance growth, optimize supply chains, and improve their bottom line. It has been said that no other organization on the globe has as much depth in its educational content for S&OP, Demand Planning & Forecasting as IBF. The IBF is known for two levels of certification: Certified Professional Forecaster (CPF®) and Advanced Certified Professional Forecaster (ACPF®).*[26] The institute publishes the *Journal of Business Forecasting*.

2. The International Institute of Forecasters (www.forecasters.org/)

   *The International Institute of Forecasters (IIF), a nonprofit organization founded in 1982, is dedicated to developing and furthering the generation, distribution, and use of knowledge on forecasting through the following objectives:*[27]

   - *Develop and unify forecasting as a multidisciplinary field of research* drawing on management, behavioral sciences, social sciences, engineering, and other fields.
   - *Contribute to the professional development* of analysts, managers, and policy makers with responsibilities for making and using forecasts in business and government.
   - *Bridge the gap between theory and practice, with practice helping to set the research agenda and research providing useful results.*

- *Bring together decision makers, forecasters, and researchers from all countries* to improve the quality and usefulness of forecasting.

The Institute also publishes the *International Journal of Forecasting*, *Foresight: The International Journal of Applied Forecasting,* and *The Oracle*.

3. Business Forecasting (www.businessforcastingblog.com)

   Clive Jones, the person responsible for starting this business forecasting blog had this to say on his website: "This blog is about my fascination with forecasting and predictive analytics. I have worked professionally in forecasting and data analytics for enterprise IT (Microsoft, Hewlett Packard, Agilent Technologies) since 1995, and, earlier, for public utilities and government agencies. Started Spring 2012, *businessforecastblog* was re-launched in 2014. My intention is to create greater understanding of the range of techniques – both basic and leading edge – that are crashing like a wave against traditional marketing and forecasting. I think there is a place for writing which ranges from computational and analytical detail to videos and interviews relating to economic forecasts and forecasters." [28]

## Forecasting Software

Forecasts are seldom calculated manually. If a forecaster uses a quantitative method, then a software solution can be used to simplify the process and save the time required to generate a forecast. Several leading forecasting software providers and their products are shown below.

1. *Business Forecast Systems, Inc.* (www.forecastpro.com/)

   Business Forecast Systems, Inc. (BFS) is the maker of Forecast Pro, the leading software solution for business forecasting, and is a premier provider of forecasting education. With more than 40,000 users worldwide, Forecast Pro helps thousands of companies improve planning, cut inventory costs, and decrease stockouts by improving the accuracy of their forecasts. Headquartered in Belmont, Massachusetts, BFS was co-founded by Dr. Robert (Bob) Goodrich and Eric Stellwagen and is privately held.[29] The company offers three editions of Forecast Pro to address the different needs of its customers: Forecast Pro 100, Forecast Pro Unlimited, and Forecast Pro TRAC.

   Several of the forecasting approaches discussed in this chapter such as moving average, trend, and exponential smoothing models are included in the software. Honeywell Safety Products is an example of one of the company's customers that has benefited greatly from use of Forecast Pro software. Their experience with Forecast Pro is discussed in the nearby SCM Profile on Honeywell.

2. *John Galt* (https://johngalt.com/forecastx-new/)

   Founded in 1996, Chicago-based John Galt Solutions "serves mid-market and large global enterprises facing complex supply chain planning challenges helping them make better and faster planning decisions by offering market leading supply chain planning solutions."[31] John Galt's ForecastX is a forecasting tool that is built for growth. The tool gives you unparalleled statistical power along with the infinite flexibility of Excel, while remaining incredibly easy to use. The forecasting software uses the best-fit-algorithm "Procast." Procast is "widely considered the most accurate statistical forecasting solution in the industry and consistently outperforms the competition when tested against other established business forecasting software packages." Companies using ForecastX include Continental, FRAM, Ghirardelli, Interstate Batteries, Mars, Milwaukee, The Container Store, Trek, and UGG.

## SCM Profile Honeywell Improves Customer Service with Better Forecasting

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Honeywell Safety Products (HSP) is a leading supplier of personal protective equipment for the electrical safety and general industrial worker industry. Their products include a wide variety of safety helmets, respirators and first aid kits. HSP has more than $800 million in yearly sales. Their major challenges are lumpy, inconsistent demand and proliferation of SKUs. HSP forecasts on a monthly basis more than 32,000 data series for its U.S. and Canadian market. These challenges led them to use Forecast Pro TRAC. During the implementation period, the management team reviewed forecasts generated from Forecast Pro TRAC in parallel with forecasts from their existing software. HSP also compared how the forecasts would change over a twelve-month period using Forecast Pro TRAC and their current system. After going live with Forecast Pro TRAC, HSP decided that tracking accuracy be at the item/class level. The results show an improving trend for the first three quarters using MAPE from Q1 (24.4 percent) to Q2 (13.6 percent) to Q3 (12.9 percent). According to Lisa Gardner, demand manager, "The analysis showed that since implementing Forecast Pro TRAC, without question, there has been a definite improvement in forecast accuracy across almost every product line." In addition, John Romano, Director, SIOP & Materials Planning, Honeywell Safety Products said, "Forecast Pro has allowed us to have deeper discussions with better information. By coupling the ecast Pro TRAC with the qualitative input from sales and marketing, we are able to create true consensus. The end result is not only buy-in from different parts of the organization, but a crisper view of the market and its needs." [30]

3. *Mi9 Retail* (https://mi9retail.com/retail-demand-management-software/)

   In 2018, Mi9 Retail purchased JustEnough Software, a leader in demand management solutions for retail, wholesale, and direct-to-consumer business worldwide. According to Mi9 Retail, "Analytics and artificial intelligence are woven throughout the Mi9 Retail demand management solutions to help retailers continually improve their business processes and know the best actions to take. By taking a more proactive approach to planning, retailers can keep up with consumer demand and have a positive impact on the future."[32] The company has a global customer base including 24 Fitness, Ackermans, Bare Necessities, BevMo!, Cole Haan, Hard Rock, Levi's, Little Tikes, Tommy Bahamas, Tory Burch, and Tuesday Morning.

4. *SAS* (https://www.sas.com/cs_cz/software/supply-chain/demand-driven-forecasting.html)

   SAS Demand-Driven Forecasting "drives the development of the consensus forecast in conjunction with the S&OP. Combining the power of automation, analytics and workflow, it generates the most unbiased and accurate consensus forecast on a large-scale basis."[33] Features included in their software are: 1) Automated statistical

model selection and optimization; 2) Model repository with predefined models; 3) Event modeling console; 4) What-if analysis and scenario planning; 5) Consensus forecasting workbench; 6) Monitoring, tracking and reporting; and 7) New product forecasting workbench.

The benefits listed on SAS's website are as follows:[34]

- *Improve forecasting accuracy across your product hierarchy.*
  SAS' patented statistical forecasting engine has a complete array of advanced forecasting methods to model and forecast your organization's entire product portfolio.
- *Enhance accuracy with forecast-value-added (FVA) and reporting.*
  The solution automatically generates FVA reports that indicate the differences between the statistical baseline forecast and all individual departmental forecasts with notes indicating reasons. These reports can be reviewed, changed and written back to the data model.
- *Reduce finished goods inventory and stock-outs.*
  SAS provides forecasts that reflect the realities of your business, improving your planning accuracy. With plans that ensure the right products at the right time at the right locations, you can both prevent stock-outs and minimize finished goods inventory – increasing customer satisfaction while reducing costs.

Many Fortune 500 companies use SAS.[35] Nestlé Direct Store Delivery, a division of Nestlé, is an example of a global company that has managed its forecasting function well with the SAS Demand-Driven Forecasting solution (see the nearby SCM Profile on the company).

## SCM Profile: Demand-Driven Forecasting at Nestlé Direct Store Delivery[36]

Nestlé Direct Store Delivery, based in California, is a division of Nestlé USA responsible for distributing its pizza and ice cream products to stores nationwide. Nestlé is the world's biggest food company with more than 273,000 employees and 376 factories in 81 countries and sells to 186 countries worldwide.[37] Nestlé Direct stocks popular brands such as Dreyer's, Edy's Grand ice creams, DiGiorno, and Tombstone pizzas and supplies to thousands of stores nationwide.

Richard Juilliart/Shutterstock.com

The challenge for Nestlé Direct is that products such as pizzas and ice cream are seasonal with plenty of variety. Stores have limited shelf space so these products must be delivered in the right amount to the right store and at the right time. The objective is not only to minimize inventory costs but also to provide customers with the freshest products.

Charles Chase, SAS chief industry consultant for business analytics software, was responsible for selling the demand-driven software to Nestlé Direct. He said: "Using our technology today, when Nestlé's sales and marketing people get together and want to run a sales promotion, say a buy-one-get-one-free that they ran in the past, our system then calculates the unit lift that was associated with that particular promotion in the past and tells them whether it was significant in driving incremental demand, or unit demand. Once it does that it then goes out to the financial system and determines whether or not it actually made any money."[38] There is minimal human interference with the Demand-Driven Forecasting approach and the technology does the heavy number crunching. With the software, 80 percent of Nestlé's forecasts are done with no human judgment at all, and only 20 percent require any kind of human judgment.

According to Bill Grah, senior manager for Strategic Sourcing, "When we switched to SAS, we saw our forecast accuracy improve immediately, we saw service take off in a positive way, and our inventories decreased,"[39] Nestlé Direct found that a 1 percent improvement in forecast accuracy resulted in a 2 percent decrease in safety stock. "We're now able to drill down through customer hierarchies and do things such as integrate the impact of promotions and special offers into the statistical models," said Marcel Baumgartner, head of Global Demand Planning Performance and Statistical Forecasting at Nestlé.

The benefits of using the demand-driven forecasting software are more accurate forecasts, improved service levels, more efficient supply chain, and sales and demand planning are able to plan more profitable promotions.

## Artificial Intelligence and Machine Learning in Demand Forecasting

It is only a matter of time before **artificial intelligence** (AI) and **machine learning** (ML) find their way into the forecasting arena. Improvement using traditional forecasting techniques appear to have reached their limits. Basically, the essence of artificial intelligence is self-learning machines. Many organizations are now using machine learning in demand forecasting methods to see the future of sales. According to McKinsey & Company, reductions in forecasting errors of between 20 and 50 percent are feasible with AI. Other feasible improvements include reduction in lost sales due to out of stock products by up to 65 percent and inventory reductions of 20 to 50 percent.[40]

One of the advantages of AI is speed and the amount of data that can be analyzed quickly. Things that normally take two to three persons to do manually can be done in minutes using AI. However, advanced analytics require good data from different sources. Widespread application of AI has three challenges: access to "right" data, talent scarcity, and trust in AI systems. The first challenge is having access to the right information and whether the data can be trusted. As such you would need domain experts working with data scientists on these data bases. According to Dean Abbott, cofounder and chief data scientist at SmarterHQ, "Teaming data scientists with domain experts and data experts—who understand data sources and how they can be automated—should be a best practice in every analytics operation."[41] Many business leaders consider data to be an important asset, so organizations must commit resources to manage and get the most out of AI and advanced analytics. To get the most value out of advanced analytics and AI, the data collected must be trusted. A study by MIT SMR Connections and SAS finds that although a majority of organizations report increased access to data, only a minority have access to the "right" data for making decisions. They present three major conclusions from their study:[42]

- *Better data governance is needed*
  A minority of respondents have formal activities in data quality assurance, which points to the need for a greater commitment to data governance in support of data analytics.
- *Data privacy emerges as an opportunity*
  Data security is the strongest focus among survey respondents but there are opportunities to increase the maturity of security practices by applying analytics and AI in this area.
- *Fostering an analytics culture improves innovation*
  Leadership and management practices that support a culture of analytics-driven innovation are relatively strong, but the research shows many organizations have an opportunity to do more to spread the necessary skills and mindset throughout the workforce.

Insights gleaned from AI and machine learning also requires trust. According to Chris Donovan, executive director of enterprise information management and analytics at Cleveland Clinic, "Ensure that it's [data and information] governed appropriately, that we have the right processes around accessing it, using it, sharing it, protecting it."[43] Many universities are now offering courses and degrees related to predictive analytics and AI to address the personnel shortage. Companies such as IBM are offering AI learning and certification with online training.

For all the benefits of AI/ML in demand planning, Daniel Fitzpatrick, account manager at Avantalytics Corp., has these words of caution:[44]

> *A reliable algorithm that no one trusts will be of little value to a company. When individuals or teams believe that their view of the future is more accurate than a system's predictions, and they are allowed to game or override the algorithm, most if not all of the value of the algorithm is lost. In my experience, most companies have a significant number of S&OP team members who distrust the systems they use to plan. Unless this is addressed, this underlying lack of confidence in any system will severely limit any algorithm's impact on improving forecast performance. Overrides should be documented and validated by product performance and gaming should be clearly discouraged and called out when it does occur.*

While AI/ML algorithms can provide better demand forecasts, we must also recognize their limitation. No models will be able to represent reality with perfect accuracy. In addition, bad or inaccurate data present risks in the planning process. Once a decision is made then the supply chain must execute the demand plan effectively to meet the customer needs.

## Cloud-Based Forecasting

Instead of investing in the software described above, many companies are choosing instead to use cloud services to track and forecast demand. **Cloud-based forecasting** can be described as using supplier-hosted or software-as-a-service (SaaS) advanced forecasting applications that are provided to companies on a subscription basis. A 2021 Flexera state of the cloud study shows a higher-than-expected cloud usage due to the COVID-19 pandemic restrictions.[45] Today, cloud-based forecasting is accomplished with state-of-the-art time series forecasting algorithms using seasonal and cyclical adjusting models. Some also utilize artificial intelligence-based expert systems to select the forecasting method best suited for a customer's environment.

With cloud-based forecasting, organizations can easily detour around outdated in-house applications, instantly increase data storage and data analysis capabilities as needed, and provide workers with new capabilities without devoting time and resources to software, hardware, and extensive training. Users need only a browser and can be up and running in one day. Firms can reduce their IT costs significantly, improve employee productivity, and improve forecast accuracy, which also reduces stockout costs and inventory carrying costs. Many of these applications are provided as part of larger cloud-based enterprise management applications such as transportation management, customer relationship management, and sales force management systems. A few examples are provided here.

Arizona-based AFS Technologies provides on-demand trade promotion management and other software solutions to the consumer packaged goods industry.[46] Its easy-to-use tools allow users to get a clear-cut picture of sales, from warehouse to customer, and perform sales forecasting along with a number of other applications. Canada-based Angoss Software offers KnowledgeSCORE on-demand predictive sales analytics as part of firms' CRM strategies.[47] Their cloud-based data analysis capabilities combine best-of-breed predictive analytics technologies for big data needs and can improve field sales productivity and sales forecasting. Mailplus, an Australian mail courier service, began using a cloud-based integrated business management system from NetSuite because its in-house system could no longer handle Mailplus's rapid growth. "The more franchises we added to our system, the greater the system stress—to point that it was crashing almost daily and costing us thousands of dollars a month to maintain and service," says Chris Burgess, Mailplus CEO. It uses the NetSuite SuiteCloud system for a wide range of applications including sales and financial forecasting.[48] Halo, a leading provider of data integration and analytics software for supply chain planning, has developed the Halo SkuBrain application to assist beverage suppliers and distributors to combine sales and production forecasting and inventory replenishment planning in a single cloud-based application. According to Keith Peterson, CEO and president, "Many of Halo's beverage customers worldwide have needs for a robust demand supply planning solution at an affordable investment level. The planning needs in the beverage industry are unique – lots of SKUs, heavy seasonality, and rapid introduction of new flavors and packaging make this a challenging area to plan. SkuBrain for Beverage fits a major gap in the market for a powerful solution that fits between spreadsheets and expensive planning systems – offering analytics specific to beverage. With the rapid growth in craft beverages, fast rising players require a clear plan to ensure customer service levels are met. And, with so many SKUs launched seasonally, SkuBrain offers capabilities to support forecasts for new product introductions." [49]

## Summary

Forecasting is an integral part of demand management since it provides an estimate of future demand and the basis for planning and making sound business decisions. A mismatch in supply and demand could result in excessive inventories or stockouts and loss of profits and goodwill. Proper demand forecasting enables better planning and utilization of resources for businesses to be competitive. Both qualitative and quantitative methods are available to help companies forecast demand better. The qualitative methods are based on judgment and intuition, whereas the quantitative methods use mathematical techniques and historical data to predict future demand. The quantitative forecasting methods can be divided into time series and cause-and-effect models. Since forecasts are seldom completely accurate, management must monitor forecast errors and make the necessary improvements to the forecasting process. A forecasting study by E2open finds that the use of lag in forecast error is gaining traction among supply chain organizations.

The computation involved in generating a forecast is seldom done manually. Forecasting software solutions such as Forecast Pro, SAS, and Microsoft Excel are readily available. More recently, cloud-based forecasting solutions have made it possible to have forecasting and other supply chain software on-demand on the Internet. The E2open demand forecasting study suggests that traditional forecasting techniques may have reached their limits to gain incremental improvements. We are likely to see more artificial intelligence and machine learning applied in forecasting to improve demand forecasting accuracy.

## Key Terms

**artificial intelligence,** 197

**business cycle,** 180

**cause-and-effect forecasting,** 179

**cloud-based forecasting,** 198

**collaborative planning, forecasting, and replenishment,** 177

**demand sensing,** 190

**forecast bias,** 188

**forecast error,** 188

**linear trend forecast,** 185

**machine learning,** 197

**multiple regression forecast,** 187

**naïve forecast,** 180

**qualitative forecasting methods,** 178

**quantitative forecasting methods,** 178

**simple moving average forecast,** 181

**time series forecasting,** 179

**tracking signal,** 189

**weighted moving average forecast,** 182

## Discussion Questions

1. Explain demand management.
2. What is demand forecasting? Why is demand forecasting important for effective supply chain management?
3. Explain the impact of a mismatch in supply and demand. What strategies can companies adopt to influence demand?
4. What are qualitative forecasting techniques? When are these methods more suitable?
5. What are the components of a time series? Explain the difference between a time series model and an associative model. Under what conditions would one model be preferred to the other?

6. Explain the impact of the smoothing constant value on the simple exponential smoothing forecast.
7. Explain the impact of forecasting horizon on forecast accuracy.
8. Compare and contrast the jury of executive opinion and the Delphi techniques.
9. What are the key differences between the weighted moving average and the exponential smoothing forecasting methods?
10. Name three measures of forecasting accuracy.
11. How could the MAD be used to generate a better smoothing constant for an exponential smoothing forecast?
12. What is a tracking signal? Explain how the tracking signal can help managers improve the quality of forecasts.
13. Is the use of lag in forecasting performance a measure that companies will adopt in the future?
14. What is demand sensing? Are there any advantages for companies to use demand sensing?
15. Why is widespread adoption of CPFR below expectations?
16. What are the advantages and challenges in using AI/ML in demand planning?
17. Discuss how companies managed demand planning during the COVID-19 pandemic and beyond.
18. What is cloud-based forecasting, and why do companies use this in solving their supply chain forecasting problems? Will cloud services replace the Microsoft desktop?

## Problems

1. Ms. Winnie Lin's company sells computers. Monthly sales for a six-month period are as follows:

| MONTH | SALES |
|---|---|
| Jan | 18,000 |
| Feb | 22,000 |
| Mar | 16,000 |
| Apr | 18,000 |
| May | 20,000 |
| Jun | 24,000 |

   a. Plot the monthly data on a sheet of graph paper.
   b. Compute the sales forecast for July using the following approaches: (1) a three-month moving average; (2) a weighted three-month moving average using .50 for June, .30 for May, and .20 for April; (3) a linear trend equation; (4) exponential smoothing with $\alpha$ (smoothing constant) equal to .40, assuming a February forecast of 18,000.
   c. Which method do you think is the least appropriate? Why?
   d. Calculate the MAD for each of the four techniques in part b. Which is the best? Why?

**2.** The U.S. monthly inflation rate for 2016 is shown below:

| MONTH | INFLATION | MONTH | INFLATION |
|---|---|---|---|
| January | 1.4 | July | 0.8 |
| February | 1.0 | August | 1.1 |
| March | 0.9 | September | 1.5 |
| April | 1.1 | October | 1.6 |
| May | 1.0 | November | 1.7 |
| June | 1.0 | December | 2.1 |

**a.** Compute the inflation rate for January 2017 using the exponential smoothing forecast using $\alpha = .3$ and then using .5. Assume that the forecast for January 2016 is 1.4.
**b.** What is the MAD for the forecasts generated using exponential smoothing method? Which method is better?

**3.** Mron Sheu, the owner of the Chocolate Outlet Store, wants to forecast chocolate demand. Demand for the preceding four years is shown in the following table:

| YEAR | DEMAND (POUNDS) |
|---|---|
| 1 | 68,800 |
| 2 | 71,000 |
| 3 | 75,500 |
| 4 | 71,200 |

Forecast demand for Year 5 using the following approaches: (1) a three-year moving average; (2) a three-year weighted moving average using .40 for Year 4, .20 for Year 3, and .40 for Year 2; (3) exponential smoothing with $\alpha = .30$, and assuming the forecast for Period 1 = 68,000.

**4.** Monthly demand for Accugolf's top rated golf balls in dozens for the last twelve months are shown below.

| MONTH | INFLATION | MONTH | INFLATION |
|---|---|---|---|
| January | 5500 | July | 7500 |
| February | 5700 | August | 7200 |
| March | 6000 | September | 6800 |
| April | 5800 | October | 6300 |
| May | 6300 | November | 6000 |
| June | 7000 | December | 5800 |

**a.** Develop a simple regression model for sales of golf balls.
**b.** What is the forecast for sales of golf balls in January of the upcoming year?

**5.** The forecasts generated by three forecasting methods and actual demand for the Torrance Company are as follows:

| MONTH | DEMAND | FORECAST 1 | FORECAST 2 | FORECAST 3 |
|---|---|---|---|---|
| 1 | 269 | 275 | 268 | 280 |
| 2 | 289 | 266 | 287 | 295 |
| 3 | 294 | 290 | 292 | 290 |
| 4 | 278 | 284 | 298 | 280 |
| 5 | 268 | 270 | 274 | 270 |
| 6 | 269 | 268 | 270 | 260 |

Fisher Ke, the forecasting manager, has been asked to compute the MSE and MAD for each forecasting method. Which forecasting method is the best? Would your decision on which forecasting method performs better depend on which forecasting accuracy measure (MAD or MSE) is selected?

**6.** The Toro Cutlery Company has collected monthly sales information below:

| MONTH | SALES | MONTH | SALES | MONTH | SALES |
|---|---|---|---|---|---|
| January | 20,000 | May | 92,000 | September | 30,000 |
| February | 16,000 | June | 30,000 | October | 90,000 |
| March | 42,000 | July | 90,000 | November | 80,000 |
| April | 100,000 | August | 50,000 | December | 90,000 |

The company is examining two forecasting methods, moving average and exponential smoothing for forecasting sales.

**a.** What will the forecast be for January the following year using a three- , four- , and five-month moving averages?

**b.** What will the forecast be for January the following year using exponential smoothing with an $\alpha = 0.5$ and an initial forecast in August of 50,000?

**7.** The Sun Devils Corporation is deciding which of two forecasting models to use. The forecasts for the two models and actual demand are provided below:

| MONTH | SALES | MODEL 1 FORECAST | MODEL 2 FORECAST |
|---|---|---|---|
| 1 | 170 | 175 | 172 |
| 2 | 190 | 165 | 185 |
| 3 | 195 | 190 | 190 |
| 4 | 180 | 185 | 195 |
| 5 | 170 | 170 | 175 |
| 6 | 170 | 165 | 170 |
| 7 | 160 | 160 | 165 |
| 8 | 175 | 170 | 175 |
| 9 | 180 | 185 | 180 |
| 10 | 175 | 170 | 175 |

Compute the MAD, MAPE, and RSFE for the two forecasting methods. Is RSFE a good forecasting accuracy measure? Which forecast is better? Why?

**8.** The Dominguez Hills Company has the following forecasts generated by two forecasting methods. Actual sales for the same time periods are shown below:

| YEAR | SALES | FORECAST 1 | FORECAST 2 |
|---|---|---|---|
| 1 | 880 | 875 | 850 |
| 2 | 895 | 866 | 890 |
| 3 | 890 | 890 | 895 |
| 4 | 880 | 885 | 890 |
| 5 | 860 | 875 | 875 |
| 6 | 870 | 870 | 880 |
| 7 | 860 | 860 | 860 |
| 8 | 875 | 870 | 875 |

Compute the tracking signal for each forecasting method. Why is tracking signal important in assessing the performance of a forecasting model?

## Essay/Project Questions

1. Find a software company online providing forecasting solutions, and provide a description of the experience of one of its customers' use of the product.
2. Find a company online that is using artificial intelligence (AI) and machine learning (ML), and report on its experiences.
3. Find a company online that is using demand sensing and report on its experiences.
4. Find a software company online providing forecasting solutions, and list the different forecasting techniques that are included in its software.
5. Write a report comparing Apple's demand forecasts of their iPhones and actual sales for each generation of iPhone models since the phone was first introduced in 2007.
6. Find a few companies online that is using lag in their demand forecasting performance and compare their experiences with this approach.
7. Go to one of the forecasting blogs such as Business Forecasting (www.businessforcastingblog.com and) and No Hesitations: A Blog by Francis Diebold (http://fxdiebold.blogspot.com.au) and describe the latest topic of discussion.

## Cases

### 1. Quincy Snodgrass Enterprises – Forecasting*

Quincy Snodgrass is an entrepreneur and a lover of the outdoors. He has worked for various companies since he graduated college with his business administration degree in management. Over the years, he has saved every extra penny and now has the starting capital he needs; consequently, he plans to open his own business. Quincy plans to open a landscaping business. The primary services he'll offer are grass cutting, edging, and bush trimming. Obviously, this will only provide income in the spring, summer, and early fall. Therefore, he plans to offer snow removal in the winter. His goal is to continue to provide those baseline services and expand into actual landscaping work.

Quincy's initial challenge is to develop a forecast of how many customers he'll have each month. This is essential to determine if he needs to hire any additional labor throughout the season, Unfortunately, none of the jobs Quincy has had involved forecasting. Quincy is digging deep into his memory to recall his supply chain management course and the chapter on forecasting. He knows he has two methods to choose from, qualitative and quantitative.

Quincy is a numbers guy and is partial to using a quantitative method if possible, but he doesn't rule out the option of using one of the qualitative methods. He had worked many summers for other yardwork companies. Knowing he wanted to own his own business someday, Quincy took notes on how things went. Since his customer base would be in a series of small towns, Quincy knows he cannot charge as much as the companies that served larger communities. Consequently, volume is necessary to earn the revenue he will need.

Quincy focused on three small towns: Smithburg with a population of 700, Emeryville with 1800, and Golf Creek with 2500. He believes he can get 10 percent of the homes in

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each town to hire him. Quincy used information from the county files to estimate that on average, the number of homes is equal to about 25 percent of the population, meaning in Smithburg (700) the potential number of homes is about 175. Quincy believes his calculations are reasonable and could be the foundation for using a qualitative method to kick off his forecasting.

### Discussion Questions

1. Since Quincy doesn't have any historical data, (only an estimate of the number of customers he'll serve each month), which specific type of qualitative method is he using? What would be the total number of customers based on his assumptions? Is this a realistic number to allow the business to survive? He estimates his average fee will be $25.
2. Because of the type of communities, overtime Smithburg will provide 20 percent of the homes as customers, Emeryville still 10 percent, and Golf Creek only 7 percent. Assuming he was charging $25 per home, what effect does this change in monthly forecast have on his monthly revenue? Should he change his price either up or down? Explain.
3. Quincy has been gathering data for over five years now. He has a record of how many customers he had each month. He also has information on the weather, for example, which month has the most rain. Quincy wants to use these data to improve his forecasting. He has a choice of cause-and-effect models. Based on what data he has and what he wants to do, what would be the best method from the choices he has? Explain the elements of the forecasting equation.

## 2. Alvin Ortega's Social Media Dream*

Alvin Ortega is an avid social media fan. One of his favorite means of communication is Twitter. In addition to being a social media fanatic, Alvin is also a bit of a programming genius. To build his programming skills, Alvin is pursuing a degree in computer science. Although his programming skills are at a much higher level than any of his classmates, Alvin is sticking to his degree program because he plans to create his own social media platform. He is filling all his elective courses with business courses. Not only does he want to understand the ins and outs of managing a company, he believes the credentials will enhance his chance of getting investors for his business.

Alvin is working on a social media platform similar to Twitter; however, his has some unique features that he believes will enable it to compete with Twitter. As he begins working on his business plan he decides he needs some real data to illustrate the potential of his creation. Unfortunately, since he hasn't launched his company yet, he has no data of his own. He searches the Internet and discovers data on Statista,[1] a website that provides statistical information on various industries. He searches for information on Twitter and finds data on the number of users per quarter from 2010 through 2016. He is elated! Alvin decides to use the data from 2010 to 2011 to illustrate the potential he believes his social media platform could have. Although the numbers are Twitter users, he plans to explain that he used their historical user data as a baseline for forecasting his potential user base.

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Alvin decides to test four different forecasting methods—2-quarter moving average, 3-quarter moving average, exponential smoothing with a smoothing constant of 0.2, and exponential smoothing with a smoothing constant of 0.9. Using the Twitter data as his baseline, Alvin wants to see which forecasting method is the most accurate. Alvin creates the table shown below and prepares to calculate the forecasts using each of the four aforementioned methods.

| QUARTER/YEAR | ACTUAL NUMBER OF USERS IN MILLIONS[2] | FORECASTED DEMAND—2-QUARTER MOVING AVERAGE | ABSOLUTE FORECAST ERROR | FORECASTED DEMAND—3-QUARTER MOVING AVERAGE | ABSOLUTE FORECAST ERROR | EXPONENTIAL SMOOTHING WITH SMOOTHING CONSTANT OF .2 | ABSOLUTE FORECAST ERROR | EXPONENTIAL SMOOTHING WITH SMOOTHING CONSTANT OF .9 | ABSOLUTE FORECAST ERROR |
|---|---|---|---|---|---|---|---|---|---|
| Q1/2010 | 30 | | | | | | | | |
| Q2/2010 | 40 | | | | | | | | |
| Q3/2010 | 49 | | | | | | | | |
| Q4/2010 | 54 | | | | | | | | |
| Q1/2011 | 68 | | | | | | | | |
| Q2/2011 | 85 | | | | | | | | |
| Q3/2011 | 101 | | | | | | | | |
| Q4/2011 | 117 | | | | | | | | |
| Q1/2012 | | | | | | | | | |

## Discussion Questions

1. Forecast demand using the 2-quarter moving average and the 3-quarter moving average.
2. Forecast demand using exponential smoothing, one with the smoothing constant of .2 and the other with a smoothing constant of .9. ***Note:*** Set the forecast for Q1/2010 equal to the demand level for Q1/2010.
3. Calculate the mean absolute deviation (MAD) of each forecasting method. Which forecasting method would you recommend Alvin use? Explain why.

[1]Statista, https://www.statista.com

[2]Twitter, www.twitter.com and Statista, https://www.statista.com

## 3. Hammerstein University – Enrollment*

Hammerstein University president Blake Sherman was worried about the survival of his university. The state of Illinois had been having financial troubles for years. For the past two years it was at an impasse in passing a budget. One consequence was that students were not getting the state tuition funds they had received in past years. This issue had multiple results. First, fewer students were enrolling because of the lack of state funds. Second, those students who did enroll were tentative about remaining in school and this generated a high dropout rate. Third, to support the students, Hammerstein University increased its own tuition assistance program. All three results were affecting Hammerstein University's financial well-being.

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The key to survival was simple. Enrollment has to be maintained at a level to support the current level of degree programs, staff, and faculty. In addition, there still are the basic expenses of running Hammerstein University such as building repairs, grounds upkeep, and travel costs for sporting events. If the enrollment could not be maintain at the required level, Blake knew he would have to make some significant cuts. Degree programs that were not paying for themselves may need to be cut. This obviously would affect faculty. Cosmetic repairs for building or the grounds may need to be deferred to later. The potential financial crisis may make it necessary to temporarily shut down some sports. Blake feared that while these types of actions would ease the financial crisis in the short-term, the same actions could further reduce enrollment and result in a slow downward spiral.

Blake had his admissions staff provide the enrollment for the past six semesters. The following table provides the data.

| SEMESTER | ENROLLMENT |
|---|---|
| 2017 fall | |
| 2017 spring | 3120 |
| 2016 fall | 3249 |
| 2016 spring | 3716 |
| 2015 fall | 3520 |
| 2015 spring | 3170 |
| 2014 fall | 3094 |

Blake has the vice president of finance, Leroy Hardy, calculate how many students represented a breakeven point under the current financial situation. He then asked Leroy to calculate what the enrollment breakeven point would be if the state began to provide tuition assistance again to their students. Leroy said for the enrollment breakeven point for no state tuition was 3265. The enrollment breakeven point for state tuition being paid was 3000.

Blake had not yet been told the forecast for fall 2017. However, as he looked over the past enrollments he was not optimistic. Both spring 2017 and fall 2016 enrollments were below the breakeven point for no state tuition. Although he would have to wait for the figures from admissions, he believed he needed to begin looking at options if the state didn't pass a budget that included tuition assistance.

## Discussion Questions

1. Calculate the potential enrollment for Fall 2017 using a three semester weighted moving average, with weights .1, .3, and .6, with .6 for the most recent semester. Start your forecast for the Spring 2016 semester and continue to Fall 2017.
2. Calculate the potential enrollment for Fall 2017 using exponential smoothing with a forecast for Fall 2014 of 3094 and a smoothing constant of .2. Which forecast do you think is the best? Why?
3. Which forecast or forecasts match or exceed the enrollment breakeven point if the state continues to not pay tuition assistance? Which match or exceed the enrollment breakeven point if the state pays tuition assistance? What is the next task Blake should have his staff do, based on these forecasts?

# Part 3 Continuing Case

## Mullenax Automobile Parts Inc., Operational Issues, and Demand Forecasting*

Odis Mullenax is the owner and president of Mullenax Automobile Parts Inc. His company makes various parts for major automobile manufacturers worldwide. They manufacture intake manifold systems, air induction systems, coolant pump modules, oil filtration systems, coil springs, stabilizer bars, precision springs, and other key components within their three business units. Mullenax Automobile Parts Inc. is one link in a very long supply chain. Odis understands that the supply chain isn't a single line of supplier and purchaser. Odis knows that the supply chain is more like a complex web where inputs come from multiple directions, often appearing unrelated to one another.

The automobile industry is extremely competitive no matter where along the supply chain a company is positioned. Therefore, any production slow down, any late delivery, or any quality issues at any point in the supply chain can potentially cause severe problems for those downstream. The consequences for Mullenax Automobile Parts, if they are viewed as the bottleneck, could be a loss of their contract with the major automobile manufacturers.

However, the ramifications can go in both directions. If a major automobile manufacturer shuts down production because another supplier is late delivering a part, such as a semiconductor, Mullenax cannot ship their parts to that manufacturer. Why? Because their agreement is designed around just-in-time (JIT) supplier support. If the major manufacturer's production line is shut down for any reason, they cannot use Mullenax's parts. This is a current issue and has required Mullenax to hold over $2 million in excess inventory. The implications of supply chain problems go even deeper. No matter where along the supply chain a production line is shut down because of missing parts, workers at the shutdown production line don't get paid.

For Mullenax Automobile Parts and its suppliers and customers, the supply chain is similar to the human circulatory system. A blockage or other potential issue can have serious outcomes throughout the supply chain. For example, the price of lumber has risen and now the price of wooden pallets has almost doubled, from $10.82 to $18.50. When a firm uses over 7000 pallets each year like Mullenax, this affects shipping costs. In addition, if they have a late shipment because of a supplier's late delivery, Mullenax must rush the shipment. The additional cost incurred in an expedited shipment comes out of Mullenax's budget—an expense that reduces profit.

Odis sees all the operations issues his company must deal with and develops a plan to address them all. His first target is demand management. Since many of the parts made by Mullenax are used by all major automobile manufacturers, sound demand management could be the key to avoiding problems, such as the current $2 million in excess inventory. For many of the products they manufacture, if one customer shuts down because of a problem unrelated to Mullenax, they may be able to adjust their production by shifting some of the product to another major automobile manufacturer.

Odis tasks Estella Epperson, vice president of operations, to examine their demand forecasting system. The goal is to ensure it is flexible enough to deal with significant disruptions caused by upstream issues. Odis wants to avoid $2 million in excess inventory in the future.

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Estella begins a conversation with Deon Durr, vice president of Marketing. Marketing drives sales; thus, it is the source for customer demand, essential information for demand forecasting. As part of their initiative to improve demand forecasting, they had already moved to cloud-based forecasting solutions. The use of cloud-based forecasting will enable Mullenax Automobile Parts Inc. and its suppliers and customers to provide critical information that will enable Mullenax to know in real time any changes to the flow of parts and materials throughout its extended supply chain.

However, Estella and Deon realize that technology is not always reliable. Although they have tremendous confidence in the cloud-based system, if the system should crash for even a day their ability to meet any changes in demand will be compromised. Consequently, they decided to have a backup system using Excel. Clearly, a manual process is not ideal, but necessary, just in case. As part of their backup plan, the Excel demand forecasting templates will have three demand forecasting methods available: two- and three-month moving averages, a weighted three-month moving average, and exponential smoothing. This will allow Mullenax and its partners to determine which method will provide the most accurate forecast for the specific situation if the backup system must be utilized.

To test this backup system, they use the following historical data from a cloud-based system.

| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10,000 | 11,000 | 9000 | 13,000 | 12,000 | 10,000 | 10,000 | 12,000 | 17,000 | 9000 | 11,000 | 14,000 |

## Discussion Questions

1. Calculate the potential demand for April through December using a simple three-month moving average.
   a. Calculate the potential demand for March through December using a simple two-month moving average.
2. Calculate the potential demand for April through December using a three-month weighted moving average, with weights .1, .3, and .6, with .6 for the most recent month.
   a. Calculate the potential demand for April through December using a three-month weighted moving average, with weights .7, .2, and .1, with .1 for the most recent month.
3. Calculate the potential demand for February through December using exponential smoothing and a smoothing constant of .2. Use a starting forecast of 10,000 for January.
   a. Calculate the potential demand for February through December using exponential smoothing and a smoothing constant of .9. Use a starting forecast of 10,000 for January.
4. Compare the results of each forecast method.
   a. Which forecast method do you think is the best as a backup to the cloud-based system? Why?
5. Which forecast method can you modify to reduce the MAD or MAPE even further?

## Endnotes


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# Chapter 6

# Resource Planning Systems


*There are a lot of different things that we have to balance, a lot of different products that we have to try to fit into a daily schedule. That's like a puzzle that we have to constantly figure out. So, [we're] trying to align a master production schedule that minimizes changeovers, that minimizes water flushes between products, that is as efficient as possible but, at the same time, nimble enough to meet customer demands.*

**– Curt Hyland, Plant Manager, Darigold Inc.**[1]

*Strengthening our businesses begins with building the best team. In 2020, we committed ourselves to the leadership behaviors of humility, transparency, and focus. These are more than just words; they are changing the way we work. Humility helps us recognize what we do not know. Ask questions, then listen carefully. Transparency makes us call it like we see it, highlighting the 'red' and 'green' in equal measure. Focus helps us prioritize what we will and will not do.*

**– H. Lawrence Culp, Jr., Chairman of the Board and CEO, GE.**[2]

*"While the start of a new decade typically brings hope, we quickly saw the world come to a near standstill in 2020, confronted by compounding crises: a public health and economic crisis, persistent issues of systemic racial injustice and inequity, and the devastating effects of climate change. It is easy to fall prey to pessimism, or the sense that we individually or as a company can't make a difference. But helplessness is corrosive to hope, and hope plus work is what is required. Amid this disruption, what's clear is that we have a once-in-a-generation opportunity to harness digital technology to define the world we want to live in. And for that, I am optimistic."*

**– Satya Nadella, Chief Executive Officer, Microsoft.**[3]

## Learning Objectives

**After completing this chapter, you should be able to**

**LO 1** Describe the chase, level, and mixed aggregate production strategies.

**LO 2** Describe the hierarchical operations planning process in terms of materials planning (APP, MPS, MRP) and capacity planning (RRP, RCCP, CRP).

**LO 3** Compute available-to-promise quantities, MRP explosion, and DRP implosion.

**LO 4** Describe the limitations of legacy MRP systems, and why organizations are migrating to integrated ERP systems.

**LO 5** Describe an ERP system, and understand its advantages and disadvantages.

**LO 6** Describe best-of-breed versus single integrator ERP implementations.

## Chapter Outline

## SCM Profile Automated Scheduling Improved Airline Turnaround Efficiency

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Piedmont Airlines, Inc., a regional air carrier headquartered in Salisbury, Maryland, is wholly owned by the American Airlines Group. Piedmont has a fleet of 58 Embraer ERJ-145 regional jets and operates about 400 daily flights to more than 55 cities in the eastern United States. The company employs about 10,000 employees, including 6,000 ground handling personnel who are gate and ramp agents. The other employees are pilots, flight attendants, and aircraft maintenance technicians.

Gate agents are the frontline employees who make boarding announcements, operate the passenger boarding bridge, assist passengers to modify flight itineraries, and change seat assignments, as well as handle special requests, needs, and luggage in the boarding area. Ramp agents work outdoors behind-the-scenes to handle luggage, load/unload, clean, service and marshal aircraft, and operate ground service equipment.[4]

Piedmont did not have a systemwide shift scheduling and reporting system for its ground handling workers. The legacy scheduling method required Piedmont's managers to print and post tentative schedules in break rooms and keep hard copies of the schedules to assist employees to bid on and swap shifts. The managers must also manually track workers' seniority to comply with rules for processing bids and swaps. This labor-intensive manual scheduling system was highly inefficient and onerous for the managers and ground handling workers. Although Excel spreadsheet and Access database were used, scheduling complexity was compounded because managers were scattered across 72 sites with an inconsistent scheduling method.

The need for a systemwide method to schedule ground handling workers across the company and to identify employee dependability to accept assigned shifts led Piedmont to implement an automated rostering software. Also, a systemwide scheduling software could reduce flight delays, improve customer service, enhance profitability, and allow Piedmont to analyze its utilization of equipment and ground handling workers.

After an internal analysis, Piedmont adopted the ARCOS RosterApps software suite for a subset of its 72 sites to schedule ground workers. The software allows Piedmont a near systemwide look at how bidding on work was aligning with flight schedules. A few years later, Piedmont rolled out the software systemwide and integrated it with its flight operations and day-of-operations software. This gave Piedmont a reliable and consistent source of data for decision-making regarding its ground personnel deployment.

Local managers are now able to improve the schedules developed by headquarters to meet their specific needs. The revised schedules from local offices and the requisite workplace rules are entered into ARCOS RosterApps for employees to bid on. The software suite records employees' preferences and analyzes schedules for excesses or shortages in staffing and skills, two to four months in advance. Moreover, the software suite has reduced the complexity of scheduling while ensuring workers aren't working excessive hours or consecutive days but meeting the minimum work hours. The software has eliminated bottlenecks and improved flight turnaround efficiency.[5]

This SCM profile describes the challenge of operations scheduling. Scheduling workers in a service firm is generally easier than scheduling production in a manufacturing company. This chapter describes how manufacturing firms plan and schedule production. Some of the concepts are also relevant to the service industry.

## Introduction

Resource planning is the process of determining the production capacity required to meet demand. In the context of resource planning, *capacity* refers to the maximum workload that an organization can complete in a fixed period. A discrepancy between an organization's capacity and demand results in inefficiencies, either in underutilized resources or unfulfilled orders. The goal of resource planning is to minimize this discrepancy.

One of the most critical activities of an organization is to balance the production plan with capacity; this directly impacts how effectively the organization deploys its resources in producing goods and services. Developing feasible operations schedules and capacity plans to meet delivery due dates and minimize waste in manufacturing or service organizations is a complex problem. The need for better operations scheduling continues to challenge operations managers, especially in today's intensely competitive global marketplace. In an environment fostering collaborative buyer–supplier relationships, the challenge of scheduling operations to meet delivery due dates and eliminate waste is becoming more complex. The problem is compounded in an integrated supply chain, where a missed due date or stockout cascades downstream, magnifying the **bullwhip effect**, and adversely affecting the entire supply chain.

Operations managers are continuously involved in resource and operations planning to balance capacity and output. Capacity may be stated in terms of labor, materials, or equipment. With too much excess capacity, unit production cost is high due to idle workers and machinery. However, if workers and machinery are stressed due to too little capacity, quality levels are likely to deteriorate. Firms generally run their operations at about 85 percent of capacity to allow time for scheduled repairs and maintenance and to meet unexpected surges in demand.

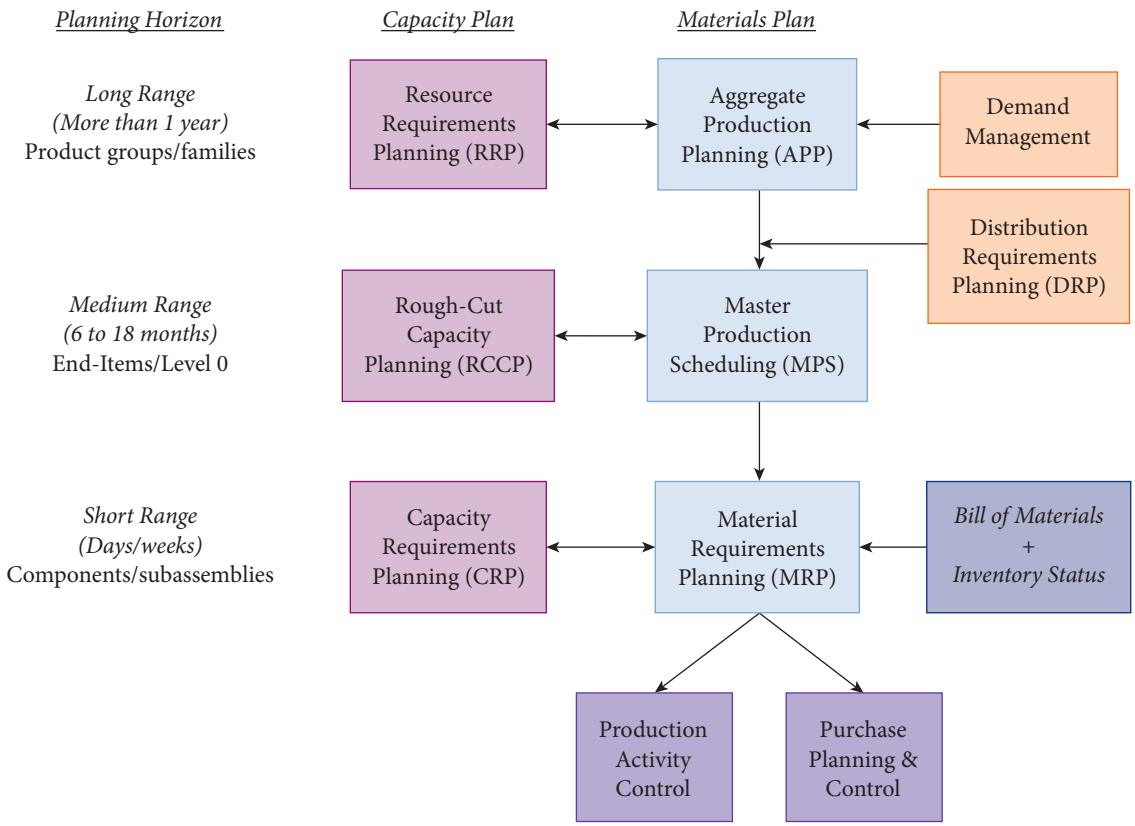
This chapter describes the hierarchical operations planning process in terms of materials and capacity planning. A hypothetical example is used to demonstrate the hierarchical planning process. This chapter also discusses the evolution of the manufacturing planning and control system from the material requirements planning to the enterprise resource planning system.

## Operations Planning

Operations planning is usually hierarchical and can be divided into three broad categories: (1) **long-range**, (2) **intermediate** or **medium-range**, and (3) **short-range planning horizons**. While the distinctions among the three can be vague, long-range plans usually cover a year or more, tend to be more general, and specify resources and outputs in terms of aggregate hours and units. Medium-range plans normally span six to eighteen months, whereas short-range plans usually cover a few days to a few weeks depending on the type and size of the firm. Long-range plans are established first and are then used to guide the medium-range plans, which are subsequently used to guide the short-range plans. Long-range plans usually involve major, strategic decisions in capacity, such as the construction of new facilities and purchase of capital equipment, whereas medium-range plans involve minor changes in capacity such as changes in employment levels. Short-range plans are the most detailed and specify the exact end items and quantities to make on a weekly, daily, or hourly basis.

Figure 6.1 shows the planning horizons and how a business plan cascades into the various hierarchical materials and capacity plans. The **aggregate production plan** (APP)

**Figure 6.1** Manufacturing Planning and Control System




is a long-range materials plan. Since capacity expansion involves the construction of a new facility and major equipment purchases, the aggregate production plan's capacity is usually considered fixed during the planning horizon. The aggregate production plan sets the aggregate output rate, workforce size, utilization and inventory, and/or backlog levels for an entire facility. The **master production schedule (MPS)** is a medium-range plan and is more detailed than the aggregate production plan. It shows the quantity and timing of the end items that will be produced. The **material requirements plan (MRP)** is a short-range materials plan. The MRP is the detailed planning process for the required component parts to support the master production schedule. It is a system of converting the end items from the master production schedule into a set of time-phased component part requirements.

Material requirements planning was first developed in the 1960s. As it gained popularity among manufacturers in the 1980s and as computing technologies emerged, the MRP grew in scope into manufacturing resource planning (MRP-II). MRP-II combined MRP with master production scheduling, rough-cut capacity planning, capacity requirement planning, and other operations planning software modules. Eventually, the MRP-II system evolved into **enterprise resource planning (ERP)** in the 1990s.

**Distribution requirements planning (DRP)** describes the time-phased net requirements from central supply warehouses and regional distribution centers. It links production with distribution planning by providing aggregate time-phased net requirements information to the master production schedule so that the correct finished goods are produced. DRP is a systematic process that helps to produce and deliver the correct finished goods to the central warehouses, regional distributions centers, and customers at the right time and in the right quantity.

## The Aggregate Production Plan

**Aggregate production planning** is a hierarchical planning process that translates annual business plans and demand forecasts into a production plan for all products. As shown in Figure 6.1, *demand management* includes determining the aggregate demand based on forecasts of future demand, customer orders, special promotions, and safety stock requirements. This forecast of demand then sets the aggregate utilization, production rate, workforce levels, and inventory balances or backlogs. Aggregate production plans are typically stated in terms of product families or groups. A **product family** consists of different products that share similar characteristics, components, or manufacturing processes. For example, an all-terrain vehicle (ATV) manufacturer who produces both automatic and manual drive options may group the two different types of ATVs together, since the only difference between them is the drive option. Production processes and material requirements for the two ATVs are likely to be very similar, and thus can be grouped into a family.

The planning horizon covered by the APP is normally at least one year and is usually extended or rolled forward by three months every quarter. This allows the firm to see its capacity requirements at least one year ahead on a continuous basis. The APP *disaggregates* the demand forecast information it receives and links the long-range business plan to the medium-range master production schedule. The objective is to provide sufficient finished goods in each period to meet the sales plan while meeting financial and production constraints. Example 6.1 provides an illustration of an APP.

### Example 6.1 An Aggregate Production Plan for the ATV Corporation

The ATV Corporation makes three models of all-terrain vehicles: Model A, Model B, and Model C. Model A uses a 0.4-liter engine, Model B uses a 0.5-liter engine, and Model C uses a 0.6-liter engine. The aggregate production plan is the twelve-month plan that combines all three models together in total monthly production. The planning horizon is twelve months. The APP determines the size of the workforce, which is the constrained resource. Table 6.1 shows the annual aggregate production plan from January to December, assuming the beginning inventory for January is 100 units (30 units each of Model A and Model B, and 40 units of Model C), and the firm desires to have an ending inventory of 140 units at the end of the year. On average, one unit of ATV requires eight labor hours to produce, and a worker contributes 160 hours (8 hours × 5 days × 4 weeks) per month. Note that the 1,120 labor hours needed in December as shown in Table 6.1 excludes the labor hours (8 hours × 40 units = 320 hours) required to produce the additional 40 units, which is the difference between the January beginning inventory of 100 units and the desired December ending inventory of 140 units.

The last column in Table 6.1 (Planned Capacity) refers to a hypothetical manufacturing workforce situation wherein the firm desires to maintain a minimum core workforce of ten workers while relying on temporary employees, overtime, and subcontracting to handle the forecasted high seasonal demands from March to September. The planned capacities match demands for October and November, but capacities from the ten core workers exceed forecast demands for January, February, and December. The idle times for these three months are 640 (10 workers × 160 hours/worker – 960 hours), 800 (10 workers × 160 hours/worker – 800 hours), and 480 (10 workers × 160 hours/worker – 1,120 hours) hours, respectively. Manufacturers usually use planned idle times to perform preventive maintenance of their machinery and equipment to avert costly unanticipated downtime from equipment failure.

**Table 6.1** ATV Corporation's Aggregate Production Plan

| PERIOD | FORECAST DEMAND | CAPACITY (LABOR HOURS) | |
|---|---|---|---|
| | | NEEDED | PLANNED |
| January | 120 units | 960 hrs | 10 workers (idle time = 640 hrs) |
| February | 100 units | 800 hrs | 10 workers (idle time = 800 hrs) |
| March | 300 units | 2400 hrs | 12 workers + overtime |
| April | 460 units | 3680 hrs | 18 workers + overtime |
| May | 600 units | 4800 hrs | 25 workers + overtime |
| June | 700 units | 5600 hrs | 25 workers + overtime + subcontracting |
| July | 760 units | 6080 hrs | 25 workers + overtime + subcontracting |
| August | 640 units | 5120 hrs | 25 workers + overtime |
| September | 580 units | 4640 hrs | 25 workers + overtime |
| October | 400 units | 3200 hrs | 20 workers (planned capacity matches demand) |
| November | 200 units | 1600 hrs | 10 workers (planned capacity matches demand) |
| December | 140 units | 1120 hrs | 10 workers (idle time = 480 hrs) |
| | 5000 units | 40,000 hrs | |

Costs relevant to the aggregate planning decision include inventory cost, setup cost, machine operating cost, hiring cost, firing cost, training cost, overtime cost, and costs incurred for hiring part-time and temporary workers to meet peak demand. There are three basic production strategies that firms use for completing the aggregate plan: (1) the *chase strategy*, (2) the *level strategy*, and (3) the *mixed strategy*. To simplify the description and computation of chase and level production strategies, it is assumed that the manufacturer does not use overtime or subcontracting for these two strategies.

## The Chase Production Strategy

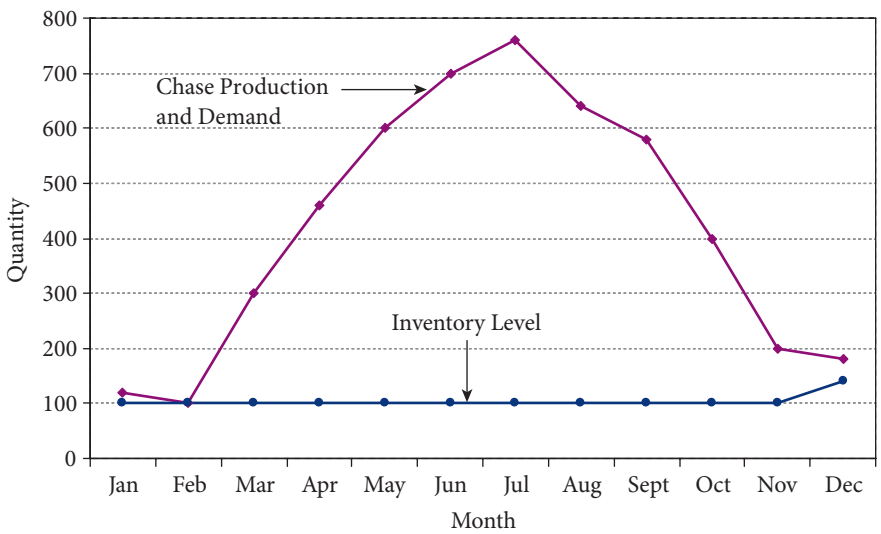
The **chase production strategy** adjusts capacity to match the demand pattern. Using this strategy, the firm will hire and lay off workers to match its production rate to demand. The workforce fluctuates from month to month, but finished goods inventory remains constant. Using Example 6.1, the ATV Corporation would use six workers to make 120 units in January, and then lay off a worker in February to produce 100 units, as shown in Table 6.2. In March, the firm must hire ten additional workers so that it has enough labor to produce 300 units. An additional eight workers must be hired in April. The firm continues its hiring and lay-off policy to ensure its workforce and production capacity matches demand. In December, 180 units would be produced (although the demand is 140) because of the firm's desire to increase its ending inventory by 40 units in December.

The chase strategy obviously has a negative motivational impact on the workers, and it assumes that workers can be hired and trained easily to perform the job. In this strategy, the finished goods inventories always remain constant, but the workforce fluctuates in response to the demand pattern. Figure 6.2 shows that the chase production curve perfectly overlaps on the demand curve. The inventory level remains constant at 100 units until December, when it increases by 40 units. Hiring, training, and termination costs are significant cost components in the chase production strategy.

**Table 6.2** An Example of the Chase Production Strategy

| PERIOD | FORECAST DEMAND (UNITS) | PRODUCTION (UNITS) | CAPACITY NEEDED (LABOR) | | ENDING INVENTORY (UNITS) |
|---|---|---|---|---|---|
| | | | HOURS | WORKERS | |
| January | 120 | 120 | 960 | 6 | 100 |
| February | 100 | 100 | 800 | 5 | 100 |
| March | 300 | 300 | 2400 | 15 | 100 |
| April | 460 | 460 | 3680 | 23 | 100 |
| May | 600 | 600 | 4800 | 30 | 100 |
| June | 700 | 700 | 5600 | 35 | 100 |
| July | 760 | 760 | 6080 | 38 | 100 |
| August | 640 | 640 | 5120 | 32 | 100 |
| September | 580 | 580 | 4640 | 29 | 100 |
| October | 400 | 400 | 3200 | 20 | 100 |
| November | 200 | 200 | 1600 | 10 | 100 |
| December | 140 + 40 | 180 | 1120 + 320 | 9 | 140 |
| | 5040 | 5040 | 40,320 | 252 | |

**Figure 6.2** Constant Inventory Level under the Chase Production Strategy




This strategy works well for **make-to-order** manufacturing firms since they cannot rely on finished goods inventory to satisfy the fluctuating demand pattern. Make-to-order firms generally produce one-of-a-kind, specialty products based on customer specifications. Make-to-order firms cannot build ahead of orders since they do not know the actual specifications of the finished goods. However, make-to-order products generally require

highly skilled labor, capable of producing unique products using general-purpose equipment. Although a chase production strategy works well when unskilled labor is required, the strategy can be problematic when highly skilled workers are needed, especially in a tight labor market.

## The Level Production Strategy

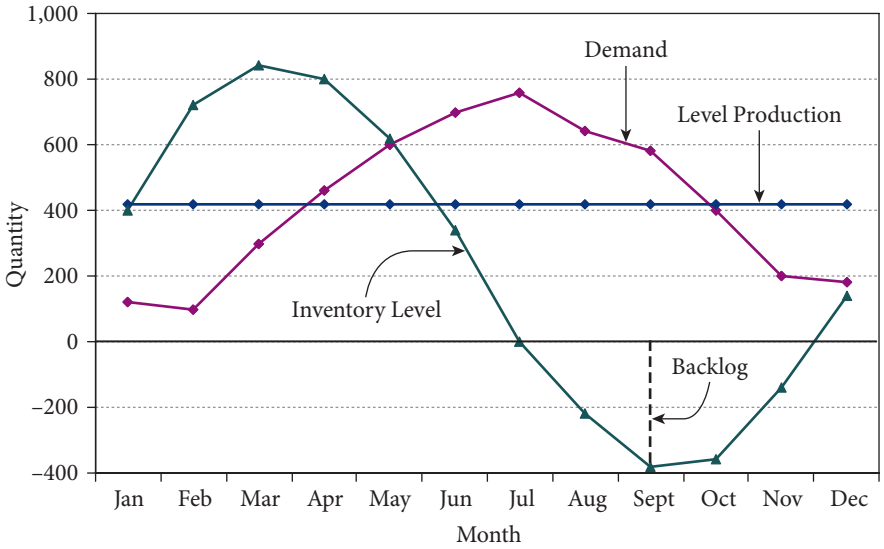
A **level production strategy** relies on a constant output rate and capacity while varying inventory and backlog levels to handle the fluctuating demand pattern. Using this strategy, the firm keeps its workforce levels constant and relies on fluctuating finished goods inventories and backlogs to meet demand. Since the level production strategy keeps a constant output rate and capacity, it is more suited for firms that require highly skilled labor. The workforce is likely to be more effective and their morale is higher when compared to the chase strategy. Using the Example 6.1 forecast information, a level production strategy calls for a monthly production rate of 420 units ([5,000 units annual demand + 40 units additional ending inventory] ÷ 12 months). Thus, this strategy requires a constant workforce of twenty-one workers, as shown in Table 6.3.

The firm allows finished goods inventories to accrue while cumulative demand remains less than cumulative production, and then relies on a series of backlogs to handle the demand from August through November. Figure 6.3 shows that level production is characterized by the fluctuating inventory/backlog level while the workforce and production capacity remain constant. Inventory carrying and stockout costs are major cost concerns in the level production strategy. This strategy works well for **make-to-stock** manufacturing firms, which typically emphasize immediate delivery of off-the-shelf, standard goods at relatively low prices. Firms whose trading partners seek the lowest prices of stock items might select the level production strategy. Additionally, this strategy works well in a situation where highly skilled workers are needed in a tight labor market.

**Table 6.3** An Example of Level Production Strategy

| PERIOD | FORECAST DEMAND (UNITS) | PRODUCTION (UNITS) | CAPACITY NEEDED (LABOR) | | ENDING INV/ (BACKLOG) (UNITS) |
|---|---|---|---|---|---|
| | | | HOURS | WORKERS | |
| January | 120 | 420 | 3360 | 21 | 400 |
| February | 100 | 420 | 3360 | 21 | 720 |
| March | 300 | 420 | 3360 | 21 | 840 |
| April | 460 | 420 | 3360 | 21 | 800 |
| May | 600 | 420 | 3360 | 21 | 620 |
| June | 700 | 420 | 3360 | 21 | 340 |
| July | 760 | 420 | 3360 | 21 | 0 |
| August | 640 | 420 | 3360 | 21 | (220) |
| September | 580 | 420 | 3360 | 21 | (380) |
| October | 400 | 420 | 3360 | 21 | (360) |
| November | 200 | 420 | 3360 | 21 | (140) |
| December | 140 + 40 | 420 | 3360 | 21 | 140 |
| | 5040 | 5040 | 40,320 | 252 | |

**Figure 6.3** Fluctuating Inventory/Backlog Level under the Level Production Strategy




## The Mixed Production Strategy

Instead of using either the chase or level production strategy, many firms use a **mixed production strategy** that strives to maintain a stable core workforce while using other short-term means such as overtime, an additional shift, subcontracting, or the hiring of part-time and temporary workers to manage short-term high demand. Usually, these firms will then schedule preventive maintenance, produce complementary products that require similar resources but different demand cycles, or continue to produce the end items, holding these as finished goods inventory during the off-peak demand periods.

For example, ATV manufacturers can produce snowmobiles to smooth out the seasonal effect of the two products. Table 6.1 shows the mixed strategy (referred to earlier, using the Planned Capacity column) in which the firm strives to maintain a minimum core workforce of ten workers while avoiding hiring above 25 workers during the peak or high demand season. Hiring above 25 workers may strain other capacities, such as machine capacity and the availability of component parts. Instead, the mixed strategy uses overtime and subcontracting to cope with the high demand periods while minimizing fluctuation in finished goods inventory. If labor is the only constrained capacity, it may hire enough workers to run an additional shift to cope with the high demand. We can see here that firms with multiple products and with customers seeking both low-cost and make-to-order items may opt for this type of production strategy to minimize stockouts and cycle time.

## The Master Production Schedule

The **master production schedule** is a time-phased, detailed disaggregation of the aggregate production plan, listing the exact end items to be produced. It is more detailed than the aggregate production plan. The MPS planning horizon is shorter than the aggregate production plan's, but must be longer than a firm's production lead time to ensure the end item can be completed within the MPS planning horizon.

For example, disaggregating ATV Corporation's January and February aggregate production plans may yield the master production schedule shown in Table 6.4. The plan results in time-phased production requirements of the specific model of ATV to produce for every week in January and February. The sum of the weekly MPS matches the quantity of the APP for that same month. For ease of calculation, let us assume that there are four weeks each in January and February, which are shown in the first two rows and are labeled Week 1 to Week 8. The sum of the January MPS quantities for the three models in Table 6.4 equals the January APP quantities of 120 units. Similarly, the sum of the February MPS quantities for the three models equals the February APP quantities of 100 units. The master production schedule provides more detail by breaking down the aggregate production plan into specific weekly demand for Model A, Model B, and Model C.

For the service industry, the master production schedule may just be the appointment book or scheduling software, which is created to ensure that capacity in the form of skilled labor matches demand. Master production schedules in the form of appointments are not overbooked to ensure capacity is not strained. The firm continues to revise and add appointments to the MPS until it obtains the best possible schedule. An example is to schedule patients' appointments in a hospital or dental clinic by means of a medical appointment scheduling software application.

## Master Production Schedule Time Fence

The master production schedule is the production quantity required to meet demand from all sources and is the basis for computing the requirements of all time-phased end items. The material requirements plan uses the MPS to compute component part and subassembly requirements. Frequent changes to the MPS can be costly and may create system nervousness.

**System nervousness** can be defined as a situation wherein a small change in the upper-level production plan causes a major change in the lower-level production plan. For example, in the case of the clinic's schedule, it is much easier for the clinic to book new appointments farther into the future than the current period. The appointment book for current period is more likely to be fully reserved. If an unanticipated patient arrives with an emergency that requires the doctor's immediate attention, it will disrupt and delay all the subsequent appointments for the day. The clinic may need to work overtime to complete the service schedule for the day or reschedule some patients to return on another day.

**Table 6.4 ATV's Master Production Schedule for January and February**

| MONTH | JANUARY | | | | FEBRUARY | | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| WEEK | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| APP QUANTITY | 120 UNITS | | | | 100 UNITS | | | | 220 UNITS |
| MPS—Model A | 10 | 10 | 20 | 0 | 20 | 0 | 0 | 20 | 80 units |
| MPS—Model B | 10 | 10 | 0 | 20 | 0 | 20 | 0 | 20 | 80 units |
| MPS—Model C | 10 | 10 | 10 | 10 | 0 | 0 | 20 | 0 | 60 units |

In the case of manufacturing firms, system nervousness is a more challenging issue because of the long production lead time and availability of materials or component parts. For example, if the January production plan for the ATV Corporation is suddenly doubled during the second week of January due to unanticipated high demand, the firm would be forced to quickly revise purchase orders, component assembly orders, and end-item production orders, causing a ripple effect of change within the firm and up its supply chain to its suppliers. The change would also likely cause missed delivery due dates. The firm needs sufficient lead time to purchase parts and manufacture the end items, especially if manufacturing lead times and lot sizes are large.

Many firms use a **time fence system** to deal with this problem. The time fence system separates the planning horizon into two segments: a *firmed* and a *tentative segment*. A firmed segment is also known as a **demand time fence**, and it usually stretches from the current period to a period several weeks into the future. A firmed segment stipulates that the production plan or MPS cannot be altered except with the authorization of senior management. The tentative segment is also known as the **planning time fence**, and it typically stretches from the end of the firmed segment to several weeks farther into the future. It usually covers a longer period than the firmed segment, and the master scheduler can change production to meet changing conditions. Beyond the planning time fence, the computer can schedule the MPS quantities automatically, based on existing ordering and scheduling policies.

## Available-to-Promise Quantities

In addition to providing time-phased production quantities of specific end items, the MPS also provides vital information on whether additional orders can be accepted for delivery in specific periods. This information is particularly important when customers are relying on the firm to deliver the right quantity of products purchased on the desired delivery date. This information is the **available-to-promise** (ATP) **quantity**, or the uncommitted portion of the firm's planned production (or scheduled MPS). It is the difference between confirmed customer orders and the quantity the firm planned to produce, based on the MPS. The available-to-promise quantity provides a mechanism to allow the master scheduler or sales personnel to quickly negotiate new orders and delivery due dates with customers or to quickly respond to customers' changing demands. The three basic methods of calculating the available-to-promise quantities are (1) *discrete available-to-promise*, (2) *cumulative available-to-promise without look ahead*, and (3) *cumulative available-to-promise with look ahead*. The discrete available-to-promise (ATP:D) computation is discussed next. Readers who are interested in the other two methods are referred to Fogarty, Blackstone, and Hoffmann (1991).[6]

The ATV Corporation's January and February master production schedule for Model A, Model B, and Model C is used in Table 6.5 to demonstrate the ATP:D method for computing the ATP quantities. Again, let us assume there are four weeks each in January and February, which are shown in the first row in the table and are labeled Week 1 to Week 8. The MPS row shows the time-phased production quantities derived from the master production schedule in Table 6.4. These are the quantities to be produced by manufacturing as planned. The number labeled "BI" is the beginning inventory heading into the first week of January. Committed customer orders are orders that have already been booked for specific customers. Finally, the ATP:D quantities are the uncommitted or unpromised units that are available to fulfill new orders.

**Table 6.5** Discrete ATP Calculation for January and February

| WEEK | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| **Model A—0.4 Liter Engine** | | | | | | | | | |
| MPS | BI = 30 | 10 | 10 | 20 | 0 | 20 | 0 | 0 | 20 |
| Committed Customer Orders | | 10 | 0 | 28 | 0 | 0 | 20 | 0 | 10 |
| ATP:D | | 30 | 2 | 0 | 0 | 0 | 0 | 0 | 10 |
| **Model B—0.5 Liter Engine** | | | | | | | | | |
| MPS | BI = 30 | 10 | 10 | 0 | 20 | 0 | 20 | 0 | 20 |
| Committed Customer Orders | | 20 | 10 | 7 | 0 | 0 | 20 | 18 | 0 |
| ATP:D | | 13 | 0 | 0 | 2 | 0 | 0 | 0 | 20 |
| **Model C—0.6 Liter Engine** | | | | | | | | | |
| MPS | BI = 40 | 10 | 10 | 10 | 10 | 0 | 0 | 20 | 0 |
| Committed Customer Orders | | 20 | 10 | 0 | 0 | 0 | 10 | 0 | 15 |
| ATP:D | | 30 | 0 | 10 | 0 | 0 | 0 | 5 | 0 |

## Calculating Discrete Available-to-Promise Quantities

The discrete available-to-promise (ATP:D) is computed as follows:

1. The ATP for the first period is the sum of the beginning inventory and the MPS, minus the sum of all the committed customer orders (CCOs) from period 1 up to but not including the period of the next scheduled MPS.
2. For all subsequent periods, there are two possibilities:
   a. If no MPS has been scheduled for the period, the ATP is zero.
   b. If an MPS has been scheduled for the period, the ATP is the MPS quantity minus the sum of all CCOs from that period up to but not including the period of the next scheduled MPS.
3. If an ATP for any period is negative, the deficit must be subtracted from the most recent positive ATP, and the quantities must be revised to reflect these changes.

As a check, the sum of the BI and MPS quantities for all periods must equal the sum of all CCOs and ATPs. Using these guidelines, the ATP:D quantities in Table 6.5 are computed as follows:

### *Model A*

1. $ATP_1 = BI + MPS_1 - CCO_1 = 30 + 10 - 10 = 30$
2. $ATP_2 = MPS_2 - CCO_2 = 10 - 0 = 10$
3. $ATP_3 = MPS_3 - CCO_3 - CCO_4 = 20 - 28 - 0 = -8$ (need to use 8 units from $ATP_2$)
   Revising: $ATP_2 = 10 - 8 = 2$ and $ATP_3 = -8 + 8 = 0$
4. $ATP_4 = 0$ (no scheduled MPS)
5. $ATP_5 = MPS_5 - CCO_5 - CCO_6 - CCO_7 = 20 - 0 - 20 - 0 = 0$
6. $ATP_6 = 0$ (no scheduled MPS)
7. $ATP_7 = 0$ (no scheduled MPS)
8. $ATP_8 = MPS_8 - CCO_8 = 20 - 10 = 10$

Checking the calculations, the sum of the BI and MPS quantities for the eight periods equals 110 units, which is also the sum of the CCOs and the ATPs for the same periods. Further, the calculation shows that 30 units of the Model A ATV can be promised for

delivery in the first week of January or later, two units can be promised in the second week or later, and another ten units can be promised for delivery in the eighth week or later. The eight-period total ATP of 42 units is the difference between the sum of the beginning inventory and MPS (110 units) and the sum of the committed customer orders (68 units) for the eight weeks. Also note that although no MPS has been scheduled for the sixth week, the committed customer orders of 20 units are still possible, since the units can come from the uncommitted MPS of the previous weeks.

### *Model B*

1. $ATP_1 = BI + MPS_1 - CCO_1 = 30 + 10 - 20 = 20$
2. $ATP_2 = MPS_2 - CCO_2 - CCO_3 = 10 - 10 - 7 = -7$ (need to use 7 units from $ATP_1$)

   Revising: $ATP_1 = 20 - 7 = 13$ and $ATP_2 = -7 + 7 = 0$
3. $ATP_3 = 0$ (no scheduled MPS)
4. $ATP_4 = MPS_4 - CCO_4 - CCO_5 = 20 - 0 - 0 = 20$
5. $ATP_5 = 0$ (no scheduled MPS)
6. $ATP_6 = MPS_6 - CCO_6 - CCO_7 = 20 - 20 - 18 = -18$ (need to use 18 units from $ATP_4$ since $ATP_5 = 0$)

   Revising: $ATP_4 = 20 - 18 = 2$ and $ATP_6 = -18 + 18 = 0$
7. $ATP_7 = 0$ (no scheduled MPS)
8. $ATP_8 = MPS_8 - CCO_8 = 20 - 0 = 20$

Checking, the BI plus the eight MPS weekly quantities equals 110 units and the CCOs plus the ATPs for the eight periods also equals 110 units. The calculation shows that thirteen units of the Model B ATV can be promised for delivery in the first week or later, two units can be promised for delivery in the fourth week or later, and another 20 units can be promised for delivery in the eighth week or later. The eight-period total ATP of 35 units is the difference between the sum of the beginning inventory and MPS (110 units) and the sum of the committed customer orders (75 units) for the eight-week period. Note that although no MPS has been scheduled for the seventh week, the CCO of eighteen units came from the uncommitted MPS quantities of the previous weeks.

### *Model C*

1. $ATP_1 = BI + MPS_1 - CCO_1 = 40 + 10 - 20 = 30$
2. $ATP_2 = MPS_2 - CCO_2 = 10 - 10 = 0$
3. $ATP_3 = MPS_3 - CCO_3 = 10 - 0 = 10$
4. $ATP_4 = MPS_4 - CCO_4 - CCO_5 - CCO_6 = 10 - 0 - 0 - 10 = 0$
5. $ATP_5 = 0$ (no scheduled MPS)
6. $ATP_6 = 0$ (no scheduled MPS)
7. $ATP_7 = MPS_7 - CCO_7 - CCO_8 = 20 - 0 - 15 = 5$
8. $ATP_8 = 0$ (no scheduled MPS)

Checking, the total BI and eight-period MPS is 100 units and the total CCOs and ATPs for the eight periods is also 100 units. The calculation shows that 30 units of Model C ATV can be promised for delivery in the first week of January or later, ten units can be promised in the third week or later, and another five units can be promised in the seventh week or later. The total of

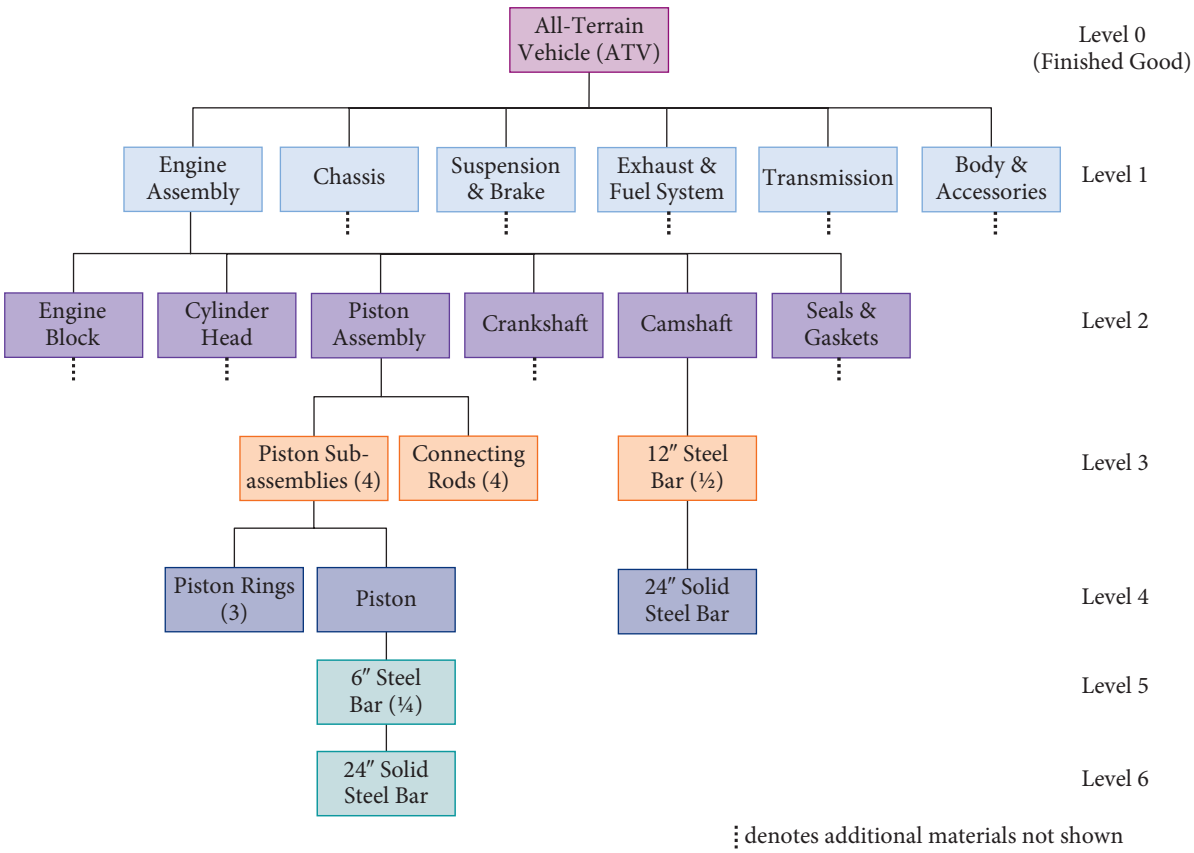
eight-period ATP of 45 units is the difference between the sum of the BI and MPS (100 units) and the sum of the committed customer orders (55 units) for the eight-week period.

Note that while the total uncommitted production quantity can easily be computed by subtracting all CCOs from the sum of the BI and scheduled MPS, it lacks time-phased information. For this reason, the ATP quantities must be determined as shown. This enables the master scheduler or salesperson to quickly book or confirm new sales to be delivered on specific due dates. Reacting quickly to demand changes and delivering orders on time are necessities in high-performing supply chains, and the tools discussed here enable firms to effectively meet customer needs. In supply chain relationships, using the MPS and ATP information effectively is essential to maintaining speed and flexibility (which impacts customer service) throughout the supply chain as products make their way to end users.

## The Bill of Materials

The **bill of materials (BOM)** is an engineering document that shows an inclusive listing of all component parts and subassemblies making up the end item. Figure 6.4 is an example of a *multilevel bill of materials* for the ATV Corporation's all-terrain vehicles. It shows the parent–component relationships and the exact quantity of each component, known as

**Figure 6.4** Bill of Materials for the ATV



the **planning factor**, required for making a higher-level part or assembly. For example, "engine assembly" is the immediate *parent* of "engine block," and conversely "engine block" is an immediate *component* of "engine assembly." The "24-inch solid steel bar" is a *common component part*, because it is a component of the "6-inch steel bar" and the "12-inch steel bar." The *planning factor* of "connecting rods" shows that four connecting rods are needed to make one "piston assembly." Note that twelve "piston rings" (3 × 4) are needed to assemble one ATV since there are three "piston rings" in each "piston subassembly," and there are four "piston subassemblies" in each "piston assembly."

The BOM is shown in various levels, starting from Level 0. The level numbers increase as one moves down on the BOM. Level 0 is the final product, which is the **independent demand** item. In this case, it is the ATV. It has a demand pattern that is subject to trends and seasonal variations, and to general market conditions. Gross requirements of Level 0 items come from the master production schedule (i.e., Table 6.4 in the ATV Corporation example). The next level in the BOM is Level 1, which consists of all components and subassemblies required for the final assembly of one unit of an ATV. The gross requirements of Level 1 components and subassemblies are computed based on the demand for ATVs as specified in Level 0. Therefore, the requirements for all the items in Level 1 and below are called **dependent demand** items. For example, the engine assembly, chassis, suspension and brake, and transmission used to assemble the ATV are dependent demand items. However, if the components or subassemblies are sold as *service parts* to customers for repairing their ATVs, then they are independent demand items.

Correspondingly, the multilevel bill of materials can also be presented as an **indented bill of materials** as shown in Table 6.6. At each level of indentation, the level number increases by one. The indented bill of materials in Table 6.6 can be seen as an illustration of the multilevel bill of materials (Figure 6.4) rotated 90 degrees counterclockwise.

Another type of bill of materials is the **super bill of materials**, which is useful for planning purposes. It is also referred to as a *planning bill of materials*, *pseudo bill of materials*, *phantom bill of materials*, or *family bill of materials*. Using the ATV Corporation's BOM in Figure 6.4 as an example, a simplified product structure diagram can be created for the family of ATVs that consists of different engine sizes (i.e., models) and transmission options. Instead of stating the planning factor, the percentage of each option is used. Figure 6.5 shows that 33⅓ percent of the ATVs are Model A, Model B, and Model C, respectively. Similarly, 75 percent of the ATVs use automatic transmissions, and the remaining 25 percent use manual transmissions. Therefore, the ATV Corporation's January planned production (120 units) consists of 40 units each of Model A, Model B, and Model C (see Table 6.4). Similarly, 90 (75 percent × 120) units of the ATVs will be manufactured with automatic transmissions, and the remaining 30 (25 percent × 120) units will be manufactured with manual transmissions.

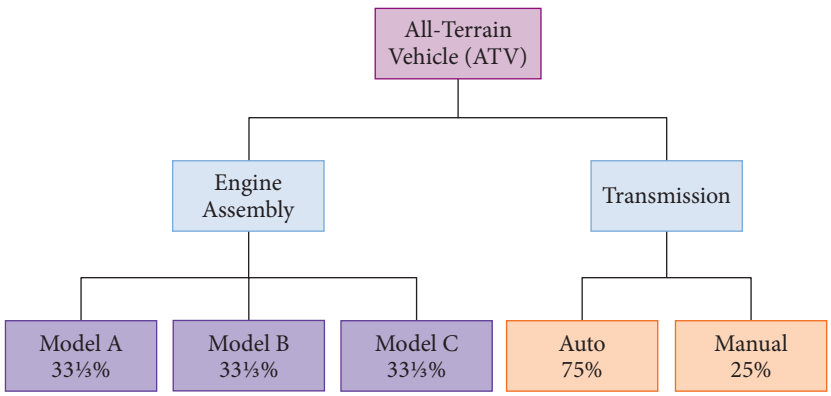
The super bill of materials enables the firm to forecast the total demand of ATVs and then break down the forecast into different models and transmission options using the correct percentage, instead of forecasting the demand for each option individually. It provides quick information on the quantity of components for each option needed for the scheduled production. In addition, it also reduces the number of master production schedules. For the ATV Corporation example, the number of master production schedules was reduced from six (3 models × 2 transmission options) to one.

When the exact proportion of each option is uncertain, the percentage can be increased slightly to cover the uncertainty. For example, the ATV Corporation may increase its automatic transmission option to 78 percent and manual option to

**Table 6.6 Indented Bill of Materials—All-Terrain Vehicles**

| PART DESCRIPTION | LEVEL | PLANNING FACTOR |
|---|---|---|
| Engine Assembly | 1 | 1 |
| Engine Block (components not shown) | 2 | 1 |
| Cylinder Head (components not shown) | 2 | 1 |
| Piston Assembly | 2 | 1 |
| Piston Subassembly | 3 | 4 |
| Piston Rings | 4 | 3 |
| Pistons | 4 | 1 |
| 6″ Steel Bar | 5 | ¼ |
| 24″ Solid Steel Bar | 6 | 1 |
| Connecting Rods | 3 | 4 |
| Crankshaft (components not shown) | 2 | 1 |
| Camshaft | 2 | 1 |
| 12″ Steel Bar | 3 | ½ |
| 24″ Solid Steel Bar | 4 | 1 |
| Seals & Gaskets (components not shown) | 2 | 1 |
| Chassis (components not shown) | 1 | 1 |
| Suspension & Brake (components not shown) | 1 | 1 |
| Exhaust & Fuel System (components not shown) | 1 | 1 |
| Transmission (components not shown) | 1 | 1 |
| Body & Accessories (components not shown) | 1 | 1 |

**Figure 6.5 Super Bill of Materials for the ATV**




27 percent, for a total of 105 percent. The firm raises its total planned production by 5 percent to cover uncertainty. This is known as **option overplanning**. However, when production is raised to cover uncertainly, it increases production cost and the need to hold additional inventory.

## The Material Requirements Plan

As illustrated in the ATV bill of materials in Figure 6.4, **dependent demand** is a term used to describe the internal demand for parts based on the **independent demand** of the final product, for which the parts are used. Subassemblies, components, and raw materials are examples of dependent demand items. Dependent demand may have a pattern of abrupt and dramatic changes because of its dependency on the demand of the final product, especially if the final product is produced in large lot sizes. Once the independent demand of the final product is forecasted or determined in the MPS, the dependent demand item requirements can be exactly calculated using material requirements planning (MRP) software, along with when the items should be assembled or purchased. Dependent demand items are not forecasted.

For example, the ATV Corporation's MPS (Table 6.4) shows that 120 ATVs will be produced in January. The firm thus knows that 120 handlebars and 480 wheel rims will be needed. The demand for handlebars, wheel rims, and all the other dependent demand items can be calculated using the MRP, based on the bill of materials (BOM) and the demand of the final product as stated on the MPS.

The material requirements plan is a software-based production planning and inventory control system that has been used widely by manufacturing firms for computing dependent demand and timing requirements. With the advent of computer and information technologies, the span of MRP evolved to include aggregate production planning, master production scheduling, and capacity requirements planning to become **closed-loop MRP**. It further evolved into manufacturing resource planning (MRP-II) by including other aspects of materials and resource planning. A complete MRP-II system consists of many modules that enable the firm to book orders, schedule production, control inventory, manage distribution, and perform accounting and financial analyses.

While there are vendors still supporting their original MRP systems, most application providers have expanded their systems to enable the users to perform more sophisticated analyses and integrate organization-wide activities, including operations and facilities that are in different countries from the head office.

Material requirements planning is used to calculate the exact quantities, need dates and planned order releases for components and subassemblies needed to manufacture the final products listed on the MPS. MRP begins the computation process by first obtaining the requirements of the final product (the Level 0 item on the BOM) from the MPS to calculate the requirements of Level 1 components and then working its way down to the lowest level components, considering existing inventories and the lead time required for each component part or subassembly. While these manufacturing and delivery lead times are disregarded in the MPS, they are considered in the MRP computation process. For example, if a parent item requires an immediate component with a three-week lead time, the component must be ordered three weeks ahead of the need date.

For MRP, a dependent demand management system, to work effectively, it requires: (1) the independent demand information (the demand for the final product or service part) from the MPS; (2) parent-component relationships from the bill of materials, including the planning factor and lead-time information; and (3) the inventory status of the final product and all of its components. The MRP takes this information to compute the *net requirements* of the final product and components, and then offsets the net requirements with appropriate lead times to ensure orders are released on time to fabricate or purchase the lower-level components. This information, called **planned order releases**, is the most

important output of the MRP. For items manufactured in-house, planned order releases are transmitted to the shop floor, but for purchased items, planned order releases are transmitted to suppliers directly or via the purchasing department.

A key benefit of MRP is that production information—such as scheduled receipts, on-hand inventories, net requirements, and planned order releases—is available for the entire planning horizon; thus, it provides *visibility* for schedulers to plan ahead. However, the need for offsetting net requirements by the lead time to obtain planned order releases causes a *loss of visibility* in the planning horizon of components. This problem is especially acute for products with a deep bill of materials. Another drawback of the MRP is that it ignores capacity and shop floor conditions.

## Terms Used in Material Requirements Planning

Prior to exploring the MRP logic, let us look at some terms as they apply to the MRP:

- *Parent*: The item generating the demand for lower level components. Level 0 is the final product. It is the parent of all Level 1 components. Similarly, each Level 1 item becomes the parent of the Level 2 components used to make that item. For example, Figure 6.4 shows that "piston assembly" is a parent of "piston subassemblies" and "connecting rods."
- *Components:* The parts demanded by a parent. For example, Figure 6.4 shows that "piston assembly" is a component of "engine assembly."
- *Gross requirement:* A time-phased requirement prior to considering on-hand inventory and lead time to obtain the item. It is satisfied from inventory and production.
- *Net requirement:* The unsatisfied item requirement for a specific period. It equals the gross requirement for that period minus the current on-hand inventory and any scheduled receipts. Net requirement must be met from future production or purchase.
- *Scheduled receipt:* A committed order awaiting delivery for a specific period. It is an order released in a past period and due to be received in a specific later period. This information is updated automatically by the MRP software logic system once an order has been placed. For example, an item with a two-week lead time ordered on the first week of the month becomes a scheduled receipt on the third week.
- *Projected on-hand inventory:* The projected inventory at the end of the period. It equals the beginning inventory minus the gross requirement, plus the scheduled receipt and any planned receipt from an earlier planned order release.
- *Planned order receipt:* A projected receipt based on the generation of a planned order release. It is used as a placeholder for the planned order release, prior to offsetting the production and/or delivery lead time.
- *Planned order release:* A specific order to be released to the shop (if the component is made in-house) or to the supplier (if the component is purchased) to ensure that it is available on the need date. A key consideration here is that the *planned order releases of the parent determine the gross requirements of the components*.

- *Time bucket:* The time period used on the MRP. It is usually expressed in days or weeks. The current period is the action time bucket.
- *Explosion:* The common term used to describe the process of converting a parent item's planned order releases into component gross requirements.
- *Planning factor:* The number of components needed to make a unit of the parent item. For example, Figure 6.4 shows that three "piston rings" are needed to make a "piston subassembly."
- *Firmed planned order:* A planned order that the MRP software logic system cannot automatically change when conditions change. The primary purpose of a firmed planned order is to prevent *system nervousness*, like the time fence system explained earlier in the master production schedule discussion.
- *Pegging:* Relates gross requirements for a component to the planned order releases that created the requirements.
- *Low-level coding:* Assigns the lowest level on the bill of materials to all common components to avoid duplicate MRP computations. For example, Figure 6.4 shows that "24-inch solid steel bar" is a common component in Level 4 and Level 6. Instead of computing its planned order releases at Level 4 and Level 6 separately, a low-level code of 6 is assigned to the item. Its net requirements at Level 4 are added to those at Level 6, and the MRP explosion logic is performed at Level 6 only.
- *Lot size:* The order size for MRP logic. Lot size may be determined by various lot-sizing techniques, such as the EOQ (a fixed order quantity) or lot-for-lot (order whatever amount is needed each period). A lot size of 50 calls for orders to be placed in multiples of 50. With a net requirement of 85 units, using lot-for-lot (LFL) order sizing will result in an order of 85 units; however, an order of 100 units would be placed when using a fixed order quantity of 50 (order sizes are multiples of 50).
- *Safety stock*: Protects against uncertainties in demand, supply, quality, and lead time. Its implication in MRP logic is that the minimum projected on-hand inventory should not fall below the safety stock level.

## An Example of MRP Computation without Net Requirements and Planned Order Receipts

An MRP computation is provided in Example 6.2. This example and all the answer keys in this chapter do not use net requirements or planned order receipts in the MRP computation.

### Level 0 MRP Computation—Model A ATV

The first row is the planning horizon for the eight weeks in January and February. The gross requirements are derived directly from the MPS. The scheduled receipt of ten units in Week 2 is due to an order placed last week, or earlier but scheduled to be delivered on Week 2. The order size for the Model A ATV is in multiples of ten units, the lead time is two weeks, and the desired safety stock is fifteen units. MRP computation focuses on calculating the projected on-hand inventory and planned order releases for each period by using the beginning inventory, gross requirements, scheduled receipts, order size, lead time, and safety stock. The projected on-hand inventory of twenty units for the first week is computed by taking the beginning inventory of thirty units and subtracting the gross

## Example 6.2 An MRP Example at the ATV Corporation

Model A's production schedule for the ATV Corporation is used to illustrate the MRP logic. Its level 0 gross requirements are first obtained from the master production schedule in Table 6.4, and the inventory status shows that 30 units of Model A are available at the start of the year. The parent–component relationships and planning factors are available from the BOM in Figure 6.4. Assuming the following lot sizes (Q), lead times (LT), and safety stocks (SS) are used, the MRP computations of the Model A ATV and some of its components are as follows:

| **MODEL A ATV—LEVEL 0** | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
|---|---|---|---|---|---|---|---|---|---|
| Gross Requirements | | 10 | 10 | 20 | 0 | 20 | 0 | 0 | 20 |
| Scheduled Receipts | | | 10 | | | | | | |
| Projected On-Hand Inventory | 30 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| Planned Order Releases | | 20 | | 20 | | | 20 | | |

Q = 10; LT = 2; SS = 15

×1 ×1 ×1

| **ENGINE ASSEMBLY—LEVEL 1** | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
|---|---|---|---|---|---|---|---|---|---|
| Gross Requirements | | 20 | | 20 | | | 20 | | |
| Scheduled Receipts | | 20 | | | | | | | |
| Projected On-Hand Inventory | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Planned Order Releases | | 18 | | | 20 | | | | |

Q = LFL; LT = 2; SS = 0

×1 ×1

| **PISTON ASSEMBLY—LEVEL 2** | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
|---|---|---|---|---|---|---|---|---|---|
| Gross Requirements | | 18 | | | 20 | | | | |
| Scheduled Receipts | | 20 | | | | | | | |
| Projected On-Hand Inventory | 10 | 12 | 12 | 12 | 22 | 22 | 22 | 22 | 22 |
| Planned Order Releases | | | | 30 | | | | | |

Q = 30; LT = 1; SS = 10

×4

| **CONNECTING RODS—LEVEL 3** | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
|---|---|---|---|---|---|---|---|---|---|
| Gross Requirements | | | | 120 | | | | | |
| Scheduled Receipts | | | | | | | | | |
| Projected On-Hand Inventory | 22 | 22 | 22 | 52 | 52 | 52 | 52 | 52 | 52 |
| Planned Order Releases | | | 150 | | | | | | |

Q = 50; LT = 1; SS = 20

requirement of ten units in that week. The projected on-hand inventory of twenty units in Week 2 is the total of the previous balance of twenty units, plus the scheduled receipt of ten units, and subtract the gross requirement of ten units.

In Week 3, additional Model A ATVs must be completed to ensure the on-hand balance is above the safety stock level of fifteen units. Since the opening inventory of twenty units is entirely consumed to meet the gross requirement for Week 3, the net requirement here is fifteen units (the safety stock). Given that orders must be in multiples of ten, twenty units must be ordered in the first week to satisfy both the lead time and the safety stock requirements.

Simply stated, if twenty units are needed in the third week, the two-week lead time requires the order to be placed two weeks earlier, which explains why there is a planned order release of twenty units in the first week. The projected on-hand inventory of twenty units at the end of the third week is computed by taking the previous balance of twenty units from Week 2, adding the planned order receipt of twenty units (due to the planned order release in the first week), and subtracting the gross requirement of twenty units.

Similarly, the gross requirements of twenty units each in the fifth and eighth week consumed the beginning inventory, triggering a net requirement of fifteen units for those periods and a planned order release of twenty units each during the third and sixth week, respectively. The level 0 MRP computation of projected on-hand inventory is summarized below.

Note: [BI = beginning inventory, SR = scheduled receipt, GR = gross requirement, POR = planned order release]

Projected On-Hand Inventory Calculation

Week 1: 30 BI − 10 GR = 20 units

Week 2: 20 BI + 10 SR − 10 GR = 20 units

Week 3: 20 BI − 20 GR + 20 $POR_{Week1}$ = 20 units (triggered POR of 20 units in Week 1)

Week 4: 20 BI − 0 GR = 20 units

Week 5: 20 BI − 20 GR + 20 $POR_{Week3}$ = 20 units (triggered POR of 20 units in Week 3)

Week 6: 20 BI − 0 GR = 20 units

Week 7: 20 BI − 0 GR = 20 units

Week 8: 20 BI − 20 GR + 20 $POR_{Week6}$ = 20 units (triggered POR of 20 units in Week 6)

## Level 1 MRP Computation—Engine Assembly

The BOM in Figure 6.4 indicates that the gross requirements for the engine assembly are derived from the planned order releases of the Model A ATV. Since the planning factor is one unit, the Model A ATV's planned order releases translate directly into gross requirements for engine assembly in the first, third, and sixth week (as indicated by the arrows in Example 6.2). The scheduled receipt of twenty units in the first week is due to a committed order placed previously. The gross requirements of twenty units each for the third and sixth week triggered net requirements of eighteen and twenty units, which turn into planned order releases for the first and fourth week, respectively (note here that no safety stock is required, and the lot size is lot-for-lot [LFL], thus order sizes vary according to whatever quantities are needed to have end-of-period inventories of zero). The level 1 MRP computation of projected on-hand inventory is summarized below.

Projected On-Hand Inventory Calculation

Week 1: 2 BI + 20 SR − 20 GR = 2 units

Week 2: 2 BI − 0 GR = 2 units

Week 3: 2 BI − 20 GR + 18 $POR_{Week1}$ = 0 unit (triggered POR of 18 units in Week 1)

Week 4: 0 BI − 0 GR = 0 unit

Week 5: 0 BI − 0 GR = 0 unit

Week 6: 0 BI − 20 GR + 20 $POR_{Week4}$ = 0 unit (triggered POR of 20 units in Week 4)

Week 7: 0 BI − 0 GR = 0 unit

Week 8: 0 BI − 0 GR = 0 unit

## Level 2 MRP Computation—Piston Assembly

The gross requirements for the piston assembly are derived directly from the planned order releases of engine assembly (recall that based on the BOM in Figure 6.4, the engine assembly is the immediate parent of the piston assembly and the planning factor is one). Therefore, the gross requirements of piston assembly are eighteen and twenty units, respectively, for the first and fourth weeks. Computations of its projected on-hand inventory and planned order releases are similar to earlier examples (note here that inventories must not drop below the safety stock requirement of ten and order quantities must be made in multiples of 30). The level 2 MRP computation of projected on-hand inventory is summarized below.

Projected On-Hand Inventory Calculation

Week 1: 10 BI + 20 SR − 18 GR = 12 units

Week 2: 12 BI − 0 GR = 12 units

Week 3: 12 BI − 0 GR = 12 units

Week 4: 12 BI − 20 GR + 30 $POR_{Week3}$ = 22 units (triggered POR of 30 units in Week 3)

Week 5: 22 BI − 0 GR = 22 units

Week 6: 22 BI − 0 GR = 22 units

Week 7: 22 BI − 0 GR = 22 units

Week 8: 22 BI − 0 GR = 22 units

## Level 3 MRP Computation—Connecting Rods

The BOM in Figure 6.4 indicates that four connecting rods are required for each piston assembly. Thus, the gross requirement for connecting rods in the third week is obtained by multiplying the planned order releases for piston assemblies by four. Due to the requirement to offset the lead times in each MRP computation, the planned order release for connecting rods can be determined only up to the second period, although the gross requirements of the Model A ATV are known for the first eight weeks. This is known as *loss of visibility*, as discussed earlier. The level 3 MRP computation of projected on-hand inventory is summarized below.

Projected On-Hand Inventory Calculation

Week 1: 22 BI − 0 GR = 22 units

Week 2: 22 BI − 0 GR = 22 units

Week 3: 22 BI − 120 GR + 150 $POR_{Week2}$ = 52 units (triggered POR of 150 units in Week 2)

Week 4: 52 BI − 0 GR = 52 units

Week 5: 52 BI − 0 GR = 52 units

Week 6: 52 BI − 0 GR = 52 units

Week 7: 52 BI − 0 GR = 52 units

Week 8: 52 BI – 0 GR = 52 units

Since there are no lower-level components shown for the connecting rods, we can assume that the ATV Corporation purchases this component. Thus, the planned order releases would be used by the purchasing department (as shown by the purchase planning and control function in Figure 6.1) to communicate order quantities and delivery requirements to its connecting rod supplier. Production activity control involves all aspects of shop floor scheduling, dispatching, routing, and other control activities. In supply chain settings, manufacturing firms share their planned order release information with their strategic suppliers through electronic data interchange (EDI), their ERP system, or other forms of communication. Since the firm manufactures its own piston assemblies, the planned order release for this part is communicated to shop floor operators and used to trigger production in that week. We can see, then, that planned order releases for purchased items eventually become the independent demand gross requirements for the firm's suppliers. Communicating this information accurately and quickly to strategic suppliers is a necessary element in an effective supply chain information system.

## An Example of MRP Computation with Net Requirements and Planned Order Receipts

Example 6.3 shows the use of net requirements and planned order receipts in the MRP computation. Note that the computation of projected on-hand inventory differs slightly from Example 6.2. It is now possible to have negative projected on-hand inventory.

A general sequence to compute the MRP for an item is to (1) fill in the gross requirements for all time periods using its planning factor and parent's planned order releases; (2) compute the projected on-hand inventory, net requirement, and planned order receipt for the period; (3) if there is a planned order receipt, use the lead time to offset planned order release for the period; and (4) repeat steps 2, 3 and 4 until all the periods have been evaluated.

### Level 0 MRP Computation—Model A ATV

The projected on-hand inventory of twenty units for the first and second weeks are computed as in Example 6.2. During the third week, the projected on-hand inventory is the beginning inventory of twenty units minus the gross requirement of twenty units, which equals to zero. However, additional Model A ATVs must be assembled to ensure the on-hand balance is above the safety stock level of fifteen units. Thus, the net requirement is fifteen units. Given that orders must be in multiples of ten, the planned order receipt is twenty units. To ensure that the twenty units of Model A ATV are received on week 3, the firm must place the order in the first week to meet the two-week lead time requirement.

Similarly, the gross requirements of twenty units each in the fifth and eighth week consumed the beginning of period inventory, triggering a net requirement of fifteen units and planned order receipt of twenty units for those periods. Therefore, planned order releases of twenty units each must be placed during the third and sixth week to ensure the items are received on the fifth and eighth week, respectively.

### Level 1 MRP Computation—Engine Assembly

Like Example 6.2, the gross requirements for the engine assembly came from the planned order releases of the Model A ATV. Since the planning factor is one unit, the planned order releases of Model A ATV translated to gross requirements for engine assembly of twenty units each in the first, third, and sixth week. Again, the scheduled receipt of twenty units in the first week is due to a committed order placed previously. The gross requirements of twenty units

## Example 6.3 An MRP Example at the ATV Corporation with Net Requirements and Planned Order Receipts

The same master production schedule in Table 6.4, BOM in Figure 6.4, order lot sizes, and delivery lead times for the ATV Corporation are used to demonstrate net requirements and planned order receipts in the MRP computation.

| MODEL A ATV—LEVEL 0 | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Gross Requirements | | 10 | 10 | 20 | 0 | 20 | 0 | 0 | 20 |
| Scheduled Receipts | | | 10 | | | | | | |
| Projected On-Hand Inventory | 30 | 20 | 20 | 0<br>(20) | 20 | 0<br>(20) | 20 | 20 | 0<br>(20) |
| Net Requirements | | | | 15 | | 15 | | | 15 |
| Planned Order Receipts | | | | 20 | | 20 | | | 20 |
| Planned Order Releases | | 20 | | 20 | | | 20 | | |

Q = 10; LT = 2; SS = 15

× 1 × 1 × 1

| ENGINE ASSEMBLY—LEVEL 1 | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Gross Requirements | | 20 | | 20 | | | 20 | | |
| Scheduled Receipts | | 20 | | | | | | | |
| Projected On-Hand Inventory | 2 | 2 | 2 | –18<br>(0) | 0 | 0 | –20<br>(0) | 0 | 0 |
| Net Requirements | | | | 18 | | | 20 | | |
| Planned Order Receipts | | | | 18 | | | 20 | | |
| Planned Order Releases | | 18 | | | 20 | | | | |

Q = LFL; LT = 2; SS = 0

× 1 × 1

| PISTON ASSEMBLY—LEVEL 2 | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Gross Requirements | | 18 | | | 20 | | | | |
| Scheduled Receipts | | 20 | | | | | | | |
| Projected On-hand Inventory | 10 | 12 | 12 | 12 | –8<br>(22) | 22 | 22 | 22 | 22 |
| Net Requirements | | | | | 18 | | | | |
| Planned Order Receipts | | | | | 30 | | | | |
| Planned Order Releases | | | | 30 | | | | | |

Q = 30; LT = 1; SS = 10

× 4

| CONNECTING RODS—LEVEL 3 | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Gross Requirements | | | | 120 | | | | | |
| Scheduled Receipts | | | | | | | | | |
| Projected On-Hand Inventory | 22 | 22 | 22 | –98<br>(52) | 52 | 52 | 52 | 52 | 52 |
| Net Requirements | | | | 118 | | | | | |
| Planned Order Receipts | | | | 150 | | | | | |
| Planned Order Releases | | | 150 | | | | | | |

Q = 50; LT = 1; SS = 20

each for the third and sixth week resulted in negative eighteen and negative twenty projected on-hand inventory for Week 3 and 6, respectively. Therefore, the net requirements for Week 3 and 6 are eighteen and twenty units, respectively. Since the order lot size is lot-for-lot and there is no safety stock requirement, the planned order receipts are identical to the net requirements. As the lead time is two weeks, the planned order receipts turn into planned order releases of eighteen and twenty units for the first and fourth week, respectively.

### Level 2 MRP Computation—Piston Assembly

The gross requirements for the piston assembly came from the planned order releases of engine assembly. Therefore, the gross requirements of piston assembly are eighteen and twenty units, respectively, for the first and fourth weeks. In Week 4, the projected on-hand inventory is negative eight units (beginning inventory of twelve units minus gross requirement of twenty units). Therefore, the net requirement is eighteen units to cover the shortage of eight units in projected on-hand inventory and safety stock requirement of ten units. Since the order lot size is thirty unit and lead time is one week, the planned order receipt and planned order release are thirty units in Week 4 and 3, respectively.

### Level 3 MRP Computation—Connecting Rods

Since the BOM in Figure 6.4 shows that four connecting rods are required for each piston assembly, the gross requirement for connecting rods in the third week is one hundred and twenty units ($30 \times 4 = 120$). In week 3, the projected on-hand inventory is the beginning inventory of twenty-two units minus the gross requirement of one hundred and twenty units, which equals to negative ninety-eight units. Since the safety stock is twenty units, the net requirement is one hundred and eighteen units ($98 + 20 = 118$). Since the order lot size is fifty units and lead time is one week, the planned order receipt and planned order release are one hundred and fifty units in Week 3 and 2, respectively.

## Capacity Planning

The material plans (the aggregate production plan, the master production schedule, and the material requirements plan) discussed so far have focused exclusively on production and materials management, but organizations must also address capacity constraints. Excess capacity wastes valuable resources such as idle labor, equipment, and facilities, while inadequate capacity adversely affects quality levels and customer service. Thus, a set of capacity plans is used in conjunction with the materials plan to ensure capacity is not over- or underutilized.

In the context of capacity planning, **capacity** refers to a firm's labor and machine resources. It is the maximum amount of output that an organization can complete in each period. Capacity planning follows the basic hierarchy of the materials planning system as shown in Figure 6.1. At the aggregate level, **resource requirements planning** (RRP), a long-range capacity planning module, is used to check whether aggregate resources can meet the aggregate production plan. Typical resources considered at this stage include gross labor hours and machine hours. Generally, capacity expansion decisions at this level involve a long-range commitment, such as new machines or facilities. If existing resources are unable to meet the aggregate production plan, then the plan must be revised. The revised aggregate production plan is reevaluated using the resource requirements plan until a feasible production plan is obtained.

Once the aggregate production plan is determined to be feasible, the aggregate production information is disaggregated into a more detailed medium-range production plan, the master production schedule. Although RRP has already determined that aggregate

capacity is sufficient to meet the aggregate production plan, medium-range capacity may not be able to satisfy the master production plan. For example, the master production schedule may call for normal production quantities when much of the workforce typically takes vacation or when machines are shut down for preventive maintenance. Therefore, the medium-range capacity plan, or **rough-cut capacity plan** (RCCP), is used to check the feasibility of the master production schedule.

The RCCP takes the master production schedule and converts it from production to capacity required, then compares it to capacity available during each production period. If the medium-range capacity and production schedule are feasible, the master production schedule is firmed up. Otherwise, it is revised, or the capacity is adjusted accordingly. Options for increasing medium-range capacity include overtime, subcontracting, adding resources, and an alternate routing of the production sequence.

**Capacity requirements planning** (CRP) is a short-range capacity planning technique that is used to check the feasibility of the material requirements plan. The time-phased material requirements plan is used to compute the detailed capacity requirements for each workstation during specific periods to manufacture the items specified in the material requirements plan. Although the RCCP may show that sufficient capacity exists to execute the master production schedule, the CRP may indicate that production capacity is inadequate during specific periods. The nearby SCM Profile describes long-term capacity planning at Taiwan Semiconductor Manufacturing.

## Capacity Strategies

Capacity expansion or contraction is an integral part of an organization's manufacturing strategy. Effectively balancing capacity with demand is an intricate management decision as it directly affects a firm's competitiveness. Short- to medium-term capacity can be increased by using overtime, additional shifts, and subcontracting, whereas long-term capacity can be increased by introducing new manufacturing techniques, hiring additional workers, and adding new machines and facilities. Conversely, capacity contraction can be attained by reducing the workforce, and disposing idle machines and facilities. The nearby SCM Profile describes long-term capacity planning at Taiwan Semiconductor Manufacturing.

The three commonly recognized capacity strategies are lead, lag, and match capacity strategies. A **lead capacity strategy** is a proactive approach that adds or subtracts capacity in anticipation of future market conditions and demand, whereas a **lag capacity strategy** is a reactive approach that adjusts its capacity in response to demand. In favorable market conditions, the lag strategy generally does not add capacity until the firm is operating at full capacity. The lag capacity strategy is a conservative approach that may result in a lost opportunity when demand increases rapidly, whereas the lead strategy is more aggressive and can often result in excess inventory and idle capacity. Leaders in the electronics industry usually favor the lead capacity strategy because of the short product life cycles. A **match** or **tracking capacity strategy** is a moderate strategy that adjusts capacity in small amounts in response to demand and changing market conditions.

# The Distribution Requirements Plan

The **distribution requirements plan** (DRP) is a time-phased finished-goods inventory replenishment plan in a distribution network. Distribution requirements planning is a logical extension of the MRP system, and its logic is analogous to MRP. Distribution requirements planning ties the physical distribution system to the manufacturing

## SCM Profile Long-Term Capacity Planning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Taiwan Semiconductor Manufacturing Company Limited (TSM) was founded in 1987 and headquartered in Hsin Chu, Taiwan. TSM is the world's largest and most advanced contract semiconductor and integrated circuit manufacturer with roughly fifty percent of the global market share. It serves more than 500 customers including Advanced Micro Devices, Apple, Broadcom, Intel, Nvidia, and Qualcomm. Most of TSM's production capacity is in Taiwan but it also has factories in the United States and China. Its total revenue for the fiscal year 12/31/2020 was about US $44.6 billion of which roughly sixty percent came from customers in the United States. More than 85 percent of TSM's revenue came from semiconductor wafer manufacturing.[7]

The COVID-19 pandemic has had far-reaching economic and social consequences beyond the spread of the highly contagious disease itself. It also caused a global semiconductor microchip shortage that has affected automobile, home appliance, smartphone, and other consumer electronics production. Social distancing guidelines have radically inflated the demand of personal computers, laptops, gaming consoles, and other electronic devices which led to a severe global shortage of microchips. On the supply side, the pandemic has hindered full scale production of microchips and the sanctions against Chinese technology companies have further exacerbated the crisis. The microchip shortage has forced Ford Motor Company to shut down or reduce production at its Oakville, Dearborn, Louisville, Kansas City, Chicago, and Ohio plants.[8] Similarly, General Motors in the United States, Jaguar Land Rover in England, Daimler Mercedes in Germany, and Renault in France, were also affected. Semiconductor shortages are projected to cost the automobile industry roughly $60 billion in lost revenue in 2021.

As the pandemic continued to push the world further into the digital realm, TSM could not meet the surging demand of its customers despite that its fabs were running at 100 percent capacity. In late March 2021, TSM announced that it would invest $100 billion over the next three years to scale up its manufacturing operations and fund the development of new chip technologies. This is in addition to the $12 billion proposed microchip plant in Phoenix, Arizona. TSM has purchased 1,128 acres of state land for $89 million in north Phoenix for this plant and raised the investment to $35 billion.[9] TSM plans to use the advanced 5-nanometer technology to produce 20,000 wafers per month at the Arizona plant. Its home base plants in Taiwan can produce hundreds of thousands wafers per month.[10]

Despite its aggressive long-term capacity expansion plans, TSM cautioned that the pandemic-fueled global microchip shortage across industries from consumer electronics to automobile may extend into 2022. The company plans to invest $30 billion on capacity expansions and upgrades in 2021 and predicts an annual total revenue growth of twenty percent. With its aggressive capacity expansion strategy over the next few years, TSM hopes to build sufficient capacity to support customers' demands by 2023.[11]

This SCM Profile shows that long-term capacity planning is complex and difficult to predict. Even the industry leader who generally favored a lead capacity strategy could end up reacting to unexpected surge in demand. Who could predict that a pandemic would cause a global microchip shortage?

planning and control system by determining the aggregate time-phased net requirements of the finished goods and provides demand information for adjusting the MPS. A major difference between MRP and DRP is that while MRP is driven by the production schedule specified in the MPS to compute the time-phased requirements of components, the DRP is driven by customer demand for the finished goods. Hence, the MRP operates in a dependent demand situation, whereas the DRP operates in an independent demand setting. The result of MRP execution is the production of finished-goods inventory at the manufacturing site, whereas DRP time-phases the movements of finished goods inventory from the manufacturing site to the central supply warehouse and distribution centers.

A clear benefit of the DRP system is that it extends manufacturing planning and control visibility into the distribution system to allow the firm to adjust its production plans and to avoid stocking excessive finished goods inventory. By now it should be clear that excessive inventory is a major cause of the bullwhip effect. Distribution requirements planning provides time-phased demand information needed for the manufacturing and distribution systems to effectively allocate finished goods inventory and production capacity to improve customer service and inventory investment. A distribution requirements planning example is provided in Example 6.4.

### Example 6.4 A DRP Example at the ATV Corporation

The ATV Corporation's January and February distribution schedule for its Model A ATV is used to illustrate the DRP replenishment schedules from the firm's central supply warehouse to its two distribution centers. The time buckets used in the DRP are the same weekly time buckets used in the MRP system. DRP uses the order quantity, delivery lead time, on-hand balance and safety stock information to determine the planned order releases necessary to meet anticipated market demand.

Gross requirements from the two distribution centers in Las Vegas and East Lansing are first obtained from the demand management system. The same MRP logic is used to compute the planned order releases of the two distribution centers. The gross requirements of the central supply warehouse reflect the cascading demand of Las Vegas and East Lansing distribution centers. The gross requirements of fourteen units in the first week for the central supply warehouse are the sum of the planned order releases of the two distribution centers. The planned order releases of the central supply warehouse are passed on to the manufacturing facility, where they are absorbed into the MPS. This process is commonly referred to as **implosion**, where demand information is gathered from several field distribution centers and aggregated in the central warehouse, and eventually passed onto the manufacturing facility. While both the processes are similar, the *implosion* DRP logic is different from the *explosion* notion in MRP, where a Level 0 finished good is broken into its component requirements.

**Scheduled Receipts and Projected On-Hand Inventory**

Las Vegas Distribution Center (Q = 2; LT = 2; SS = 0)

| Model A ATV | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Gross Requirements | | 0 | 1 | 1 | 0 | 1 | 0 | 6 | 0 |
| Scheduled Receipts | | | | | | | | | |
| Projected On-Hand | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| Planned Order Releases | | 2 | 0 | 0 | 0 | 6 | 0 | 0 | 0 |

East Lansing Distribution Center (Q = 2; LT = 1; SS = 0)

| Model A ATV | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Gross Requirements | | 3 | 11 | 0 | 1 | 0 | 2 | 0 | 15 |
| Scheduled Receipts | | | | | | | | | |
| Projected On-Hand | 3 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 |
| Planned Order Releases | | 12 | 0 | 0 | 0 | 2 | 0 | 16 | 0 |

2 + 12 = 14

6 + 2 = 8

| Central Supply Warehouse | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Gross Requirements | | 14 | 0 | 0 | 0 | 8 | 0 | 16 | 0 |
| Scheduled Receipts | | | | | | | | | |
| Projected On-Hand Inventory | 16 | 2 | 2 | 2 | 2 | 4 | 4 | 3 | 3 |
| Planned Order Releases | | 0 | 0 | 10 | 0 | 15 | 0 | 0 | 0 |

Q = 5; LT = 2; SS = 2

## The Legacy Material Requirements Planning Systems

The MRP time-phased netting algorithm was developed by an IBM engineer, Joseph Orlicky, in 1964. After Orlicky published his second book entitled "Material Requirements Planning: The New Way of Life in Production and Inventory Management"[12] in 1975, the principles of MRP gained wide acceptance among manufacturing firms and IBM developed the MRP algorithm into database programs. MRP systems during this period were either homegrown or based on the IBM platform. From there, MRP systems proliferated and spread across multiple platforms and eventually evolved into the MRP-II system.

For decades, an MRP system was the first choice among manufacturing firms in the United States for planning and managing their purchasing, production, and inventories. To improve the efficiency and effectiveness of the manufacturing planning and control system, manufacturers have utilized **electronic data interchange** (EDI) to relay planned order releases to their suppliers. This information system has worked well for coordinating internal production and purchasing.

By the end of the twentieth century, however, the global business environment had changed. Many savvy manufacturers and service providers were building multiplant international sites, either to take advantage of cheaper raw materials and labor or to expand their markets. Business executives found themselves spending more time dealing with international subcontractors using different currencies and languages among varying political environments. The need to access real-time information on customers' requirements, production levels and available capacities, company-wide inventory levels and plants capable of meeting current order requirements increased. The existing MRP systems simply could not handle these added tasks.

To fully coordinate the information requirements for purchasing, planning, scheduling and distribution of an organization operating in a complex multi unit global environment, an enterprise-wide information system was needed. Thus, ERP systems that operated from a single, centralized database were engineered to replace the legacy MRP systems.

The term **legacy MRP system** is a broad label used to describe an older information system that usually works at an operational level to schedule production within an organization. Many legacy systems were implemented in the 1960s, 1970s, and 1980s and subjected to extensive modifications as requirements changed over the years. Today, these systems have lasted beyond their originally intended life spans. The continuous modifications of these systems made them complex and cumbersome to work with, especially when considering they were not designed to be user-friendly in the first place. Legacy systems were designed to perform a very specific operational function and were programmed as independent entities with little regard for meeting requirements or coordinating with other functional areas. Communication between legacy systems is often limited, and visibility across functional areas is severely restricted. Legacy systems were implemented to gather data for transactional purposes and, thus, lacked any of the analytical capabilities required for today's complex global environment.

## Manufacturing Resource Planning

The development of the legacy system can be traced back to the evolution of the MRP system, the closed-loop MRP system, and the **manufacturing resource planning (**MRP-II) system. The development of closed-loop MRP was a natural extension of the MRP system. It was an attempt to further develop the MRP into a formal and explicit manufacturing planning and control system by adding capacity requirements planning and feedback to

describe the progress of orders being manufactured. The originally developed MRP is a part of the closed-loop MRP system.

Manufacturing resource planning was an outgrowth of the closed-loop MRP system. Business and sales plans were incorporated, and a financial function was added to link financial management to operations, marketing, and other functional areas. The concept of manufacturing resource planning was that the information system should link internal operations to the financial function to provide management with current data, including sales, purchasing, production, inventory, and cash flow. It should also be able to perform "what-if" analyses as internal and external conditions change. For example, MRP-II enables the firm to determine the impact on profit and cash flow if the firm is only able to fill 85 percent of its orders due to late deliveries of raw materials. MRP-II is an explicit and formal manufacturing information system that integrates the internal functions of an organization, enabling it to coordinate manufacturing plans with sales, while providing management with essential accounting and financial information.

Manufacturing resource planning has further evolved to include other functional areas of the organization. Although it synchronizes an organization's information systems and provides insight into the implications of aggregate production plans, master production schedules, capacities, materials plans, and sales, it primarily focuses on one unit's internal operations. It lacks the capability to link the many operations of an organization's foreign branches with its headquarters. It also lacks the capability to directly interface with external supply chain members. For this reason, enterprise-wide information systems began to be developed.

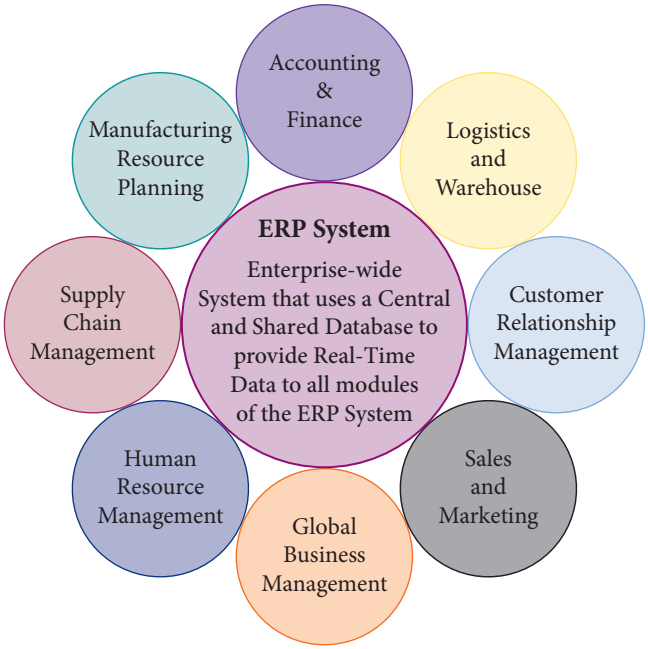
## The Development of Enterprise Resource Planning Systems

While legacy MRP systems continue to be used and modified to include other functional areas of an organization, the growth of supply chain management, e-commerce, and global operations have created the need to exchange information directly with suppliers, customers, and foreign branches of organizations. The concept of the manufacturing information system thus evolved to directly connect all functional areas and operations of an organization and, in some cases, its suppliers and customers via a common software infrastructure and database. This type of information system is referred to as an **enterprise resource planning** (ERP) system.

The typical ERP system is an umbrella system that ties together a variety of specialized systems, such as manufacturing resource planning, logistics and warehousing, accounting and finance, human resource management, customer relationship management, and supply chain management using a common, shared, centralized database. However, exactly what is tied together varies on a case-by-case basis, based on the ERP system capabilities and the needs of the organization. Figure 6.6 illustrates a generic ERP system, where a centralized database and software application infrastructure are used to drive a firm's information systems and to link the operations of its branches, suppliers, and customers with the firm's headquarters.

Enterprise resource planning is a broadly used industrial term to describe the multi module application software for managing an enterprise's internal functional activities, as well as its suppliers and customers. Initially, ERP software focused on integrating the internal business activities of a multi facility organization, or enterprise, to ensure that it was operating under the same information system. With the onset of supply chain management,

**Figure 6.6** A Generic ERP System




ERP vendors today are designing their products to include modules for managing suppliers and customers. For example, ERP enables an organization to deal directly with key suppliers to assess the availability of their resources, as if they are an extended unit of the firm. Similarly, ERP also allows key customers to directly access the firm's inventory information and manufacturing and delivery schedules.

ERP is an enterprise-wide information system that utilizes a centralized and shared database system to tie an organization across business units and departments together, as opposed to the legacy MRP system that uses multiple databases and interfaces that frequently result in duplicate and inconsistent information across different branches or even departments within an organization. With ERP, information is entered once at the source and made available to all users in real-time. It eliminates the inconsistency and incompatibility created when different functional areas use different systems with overlapping data.

The legacy MRP system typically utilizes multiple software packages and databases for different functional areas. Usually, each functional area implements its own information system based on its unique needs, with very little input or coordination from the other functional areas. The different packages within an organization often are incompatible with each other and prevent transactions from taking place directly between systems. The multiple databases also cause the same information to be stored in multiple locations; thus, multiple entries of the same data are required. This need to enter the same data repeatedly is a major cause of inconsistency in database management. For example, a customer, ATV Inc., may be entered as ATV Inc. in one database and ATV Incorporated in another database. From an information system's perspective, ATV Inc. and ATV Incorporated are two distinct customers.

With a shared, centralized database system, ERP is capable of automating business processes rapidly and accurately. For example, when taking a sales order, a sales agent has all the

necessary information of the customer (the credit history, rating, and limit from the accounting and finance module), the company's production and inventory levels (from the manufacturing resource planning module), and the delivery schedule (from the sales and marketing module) to complete the sale. After the sale is confirmed and entered into the centralized database, other supply chain partners affected by the transaction can directly utilize the same information system to take appropriate proactive actions. Suppliers can also find out the production schedules planned by upstream supply chain members so that raw materials and components can be produced accordingly to support sales. Similarly, downstream companies can utilize the same information system and database to access delivery schedules of raw materials and components ordered from their upstream supply chain members.

Thus, ERP integrates the internal operations of an enterprise with a common software platform and centralized database system. It also ties together the processes of supply chain members using the same information system. ERP provides the mechanism for supply chain members to share information so that scarce resources can be fully utilized to meet demand, while minimizing the bullwhip effect and supply chain inventories. Production changes and other modifications can also be executed quickly and efficiently to minimize delivery lead times. Example 6.5 illustrates a typical ERP transaction.

## The Rapid Growth of Enterprise Resource Planning Systems

The use of ERP systems has rapidly spread from manufacturing to the service sector and has become widely used in many university classrooms. Many universities in the United States, for instance, have cooperated with major ERP software providers to integrate ERP

### Example 6.5 A Hypothetical ERP Transaction

The following example demonstrates a hypothetical ERP transaction for the ATV Corporation. The ATV Corporation makes three models of all-terrain vehicles: Model A, Model B, and Model C. The corporation is headquartered in the United States with manufacturing facilities in the United States and Mexico. ATV sells its products in the United States, Canada, and Mexico. Its sales representatives make quarterly visits to customers to take sales orders and provide necessary customer services. The following steps describe a sales transaction by a sales representative during a typical visit to a retail customer in Canada.

We assume here that a dealer ordered 100 units of Model A and 150 units of Model B, to be delivered within 30 days.

1. *Ordering* The field sales representative takes the order of 100 units of Model A and 150 units of Model B. Using the Internet, the sales rep accesses the sales and marketing module of the ERP system at the ATV Corporation headquarters in the United States to check the price and other related information, such as quantity discounts, guarantees and rebates. The sales rep also accesses the customer's credit history and rating from the customer relationship management, and accounting and finance modules.

2. *Availability* Simultaneously, the ERP system checks the inventory status and the available-to-promise quantities of its manufacturing facilities in the United States and Mexico and notifies the sales rep whether the order can be filled on time. The sales rep finds that the Mexico factory has sufficient inventory to fill the Model A order immediately, while the Model B order can be manufactured in ten days from the U.S. factory. Logistics information shows that shipping from Mexico to Canada takes two weeks, and delivery from the U.S. factory takes one week. Thus, the order is accepted, and the factory in Mexico receives instructions to ship 100 units of Model A to Canada immediately. The inventory status is updated accordingly. An invoice will be printed, and the accounting and finance module will be updated to reflect the partial delivery upon shipment of the goods from Mexico.

3. *Manufacturing* The manufacturing resource planning module immediately schedules the production of 150 units of Model B at the U.S. factory. All dependent demand items and labor necessary to produce 150 units of Model B are scheduled to meet the due date. For components manufactured in-house, planned order releases are transmitted to the shop floor. For purchased items, the information is sent to the suppliers. The ERP system also checks whether there are sufficient workers in the U.S. factory or additional short-term capacity is needed to complete the order.

4. *Order Tracking* An advance shipping notice (ASN) that provides delivery information to the dealer's receiving operations is transmitted. The customer relationship management module allows the customer to track the status of its order.

training into their business curricula. Many universities have also migrated their human resources and student information systems such as course registrations, transcripts, and financial aid management to the ERP platform. There are many reasons, some of which are discussed in the following paragraph, for the rapid growth of ERP since the early 1990s.

At the turn of the twenty-first century, many firms were uncertain as to how the Year 2000 Millennium Bug or Y2K bug (conversion of the year from 1999 to 2000) would affect their information systems. Most information systems installed were programmed to use the last two digits of the year (e.g., the year 1998 would be shown as 98). Using the same logic, the year 2000 would be recorded as 00, which might also be interpreted as the year 1900, or 98 years prior to 1998. This could adversely affect time-sensitive programming logic (e.g., interest calculations). In addition, the legacy MRP systems had been modified so extensively over the years that the many layers of program codes made it too complex and redundant to correctly assess the true impact of Y2K. The extensive modifications to the legacy systems had also made them too expensive to maintain. Thus, many savvy business managers took a proactive approach to set aside sufficient budgetary funds to replace their legacy MRP systems with the more efficient ERP systems to reduce costs and deal with the Y2K problem as well.

The rapid development of computer and information technology over the last three decades has also contributed positively to the growth of ERP. Enterprise resource planning is the key building block of global business management information systems. As the global business environment continues to change, ERP has evolved to become more flexible to adapt to mergers and acquisitions and to provide more real-time monitoring and response. Tasks that were previously limited to mainframe computers are now easily implemented on servers and desktop computers that cost only a fraction of the capital investment previously needed. Information systems that were previously off-limits are now accessible to many smaller organizations.

A recent development in ERP is **cloud computing**. Software vendors such as Oracle Cloud, Microsoft Azure, and SAP Business Technology Platform offer cloud-based services where end-users can simply log on to remote servers without installing any software or storing data on local hard drives. The cloud is a metaphor for the internet. In its simplest terms, cloud computing means accessing programs or storing data over the internet (on some other company's server) instead of the user's local hard drive. With a high-speed online connection, cloud computing can be done anywhere and anytime. The popular Microsoft Office product, Microsoft 365, for example is now available in the cloud.

Cloud computing can also be done by accessing the application software from a local computer and storing the data in the cloud. The data in the cloud can be synchronized on one or more local hard drives. This allows data to be accessed offline via the local hard drive when an internet connection is unavailable. However, the downside is that the user must ensure the latest data is synchronized in the cloud and local hard drive before accessing it. Also, storing, accessing, and synchronizing data in the cloud causes a noticeable delay in the storage and retrieval process compared to using a local hard drive. Despite these minor drawbacks, it is hard to imagine any technologically savvy business or university student not utilizing the cloud to store, retrieve, and share data in this digital age.

## Implementing Enterprise Resource Planning Systems

ERP systems have continued to evolve, and integration of e-commerce, customer relationship management, and supply chain management applications are now considered

ERP requirements by most organizations. While many firms believe a well-designed and implemented ERP system can translate into a substantial competitive advantage, research analysts and industrial practitioners are still debating the usefulness of ERP, and the advantages and disadvantages of using a **best-of-breed solution** versus a **single integrator solution**. It is important to understand that ERP is not a panacea for poor business decisions, but in the right hands it can be a valuable tool to enhance competitiveness.

The *best-of-breed* solution picks the best application or module for each individual function required for the supply chain (thus, best of breed). Although best-of-breed vendors fill a void in the ERP market with specialized applications that mainstream ERP vendors may not provide, the resulting system can include several different applications that must be integrated to work as a single coordinated system to achieve the global scope required of the ERP. A major criticism of the best-of-breed solution is that multiple software infrastructures and databases may have to be used to link the multiple applications obtained from different vendors. This may severely affect the ability of the system to update the databases rapidly and efficiently—a similar problem of the legacy MRP systems.

The *single integrator* approach picks all the desired applications from a single vendor for the ERP system. The obvious advantages are that all of the applications should work well together, and getting the system up and running should be easier. As companies become more global, and as firms desire to expand their systems with other compatible modules later on, the notion of using a single integrator solution becomes more attractive. On the other hand, as information technology continues to evolve and as competition increases in the ERP software market, ERP vendors are designing their products to be more compatible with each other.

Choosing whether to utilize a single integrator ERP solution or combine niche software is a challenge facing many companies today. If the firm's IT department has its way, the company will choose a single integrator solution for their ERP implementation; if people overseeing other business processes have their way, a company is likely to choose the best-of-breed solution.

The emergence of the single integrator ERP solution over the last two decades does not signal the extinction of best-of-breed software vendors. While it is rare now, to find major companies using best-of-breed ERP packages, best-of-breed vendors will continue to fill the niches left by the large ERP vendors. Some businesses such as small and medium-sized enterprises require unique best-of-breed software to do advanced or big data analytical decision-making. Businesses are often interested in tasks that extend beyond core ERP functions, into areas like sales and operations planning or analyses using ERP data. Many best-of-breed ERP vendors have thrived by creating early software innovations around the "edges of ERP," exploiting gaps left by ERP product suites. Many of these surviving vendors for example, are in inventory management systems.[14] Finally, businesses often turn to best-of-breed system vendors when the cost savings expected from their ERP implementations fail to materialize. In general, best-of-breeds are better suited to more intricate workplaces, while single integrator ERP solutions fit the less complex business environments.[15]

Implementing an ERP system has proven to be a real challenge for many companies. Most ERP systems are written based on the best practices of selected firms. Thus, a condition required for implementation of the system is that the user's business processes must conform to the approaches used in the software logic. These processes can be significantly different from those currently used within the company. Having to adapt a company's business processes to conform to a software program is a radical departure from the conventional business practice of requiring the software to be designed around the business processes.

Two primary requirements of successful implementation of ERP are computer support and accurate, realistic inputs. Instead of implementing the entire system at once, some organizations choose to implement only those applications or modules that are absolutely critical to operations at that time. New modules are then added in later phases. This ensures that the system can be implemented as quickly as possible while minimizing interruption of the existing system. However, many implementations have failed due to a variety of reasons, as follows:

- *Lack of top management commitment*: While management may be willing to set aside sufficient funds to implement a new ERP system, they may not take an active role in the implementation process. Often, this leads users to revert to the old processes or systems because of their lack of interest in learning the capabilities of the new ERP system.
- *Lack of adequate resources:* Implementing a new ERP system is a long-term commitment requiring substantial capital investment. Although the cost has become more affordable due to the rapid advent of computer technology, full implementation may still be out of reach for many small organizations. In addition, small firms may not have the necessary workforce and expertise to implement the complex system.
- *Lack of proper training:* Many employees may already be familiar with their legacy MRP systems. Thus, when a new ERP system is implemented, top management may assume that users are already adequately prepared and underestimate the training required to get the new system up and running. Lack of financial resources can also reduce the amount of training available for its workforce.
- *Lack of communication:* Lack of communication within an organization, or between the firm and its ERP vendor can be a barrier for successful implementation. Lack of communication usually results in the wrong specifications and requirements being implemented.
- *Incompatible system environment*: In certain cases, the firm's environment does not give ERP a distinct advantage over other systems. For example, there is no advantage for a small, family-owned used-car dealer in a small town to implement an expensive new ERP system. The nearby SCM Profile describes a successful ERP implementation.

## SCM Profile — An ERP System Success Story

Brunswick Steel is a second-generation, family-owned full-service steel production job shop situated in Winnipeg, Manitoba, Canada. The company produces sheet, plate, and long steel products used by manufacturing, construction, agricultural, mining, forestry, farming, and oil and gas companies across Western Canada. The company was founded in 1971 by three Copp brothers as a salvage firm but changed to selling new steel in the 1980s. Brunswick Steel recently celebrated its 50th year in business.

As Brunswick Steel continued to grow, its outdated ERP system struggled to link the production schedules of its modern steel cutting and processing equipment with demand, labor, financial analysis, and other facets of the organization. The company was forced to work around its outdated ERP system by using manual procedures to handle many aspects of its operations. Although the old ERP system could fill orders from inventory adequately, it lacked real-time

visibility of its actual capacity or committed orders from its master production schedules. It was difficult to revise a released production schedule and system nervousness was a common occurrence because short-term capacity was easily over committed. It was not uncommon for the production team to spend 25 percent of their time on non value adding administrative activities like manually recording the start time, end time, processing time, and materials used for each batch of jobs. Besides, the company's financial data was kept in a separate standalone software.

Mikko Lemola/Shutterstock.com

It was time for Brunswick Steel to upgrade to a new ERP system that could schedule production, provide real-time data, perform meaningful financial analyses, and fully integrate all facets of the company's operations. After thorough and exhaustive research to identify the features and capabilities of a new ERP system that matched the company's needs, Brunswick Steel chose the Global Shop Solutions' advanced planning and scheduling software module.

The new Global Shop Solutions' ERP system allowed Brunswick Steel to schedule jobs, automate planned order releases and purchases, manage demand, track capacity, provide real-time load visibility and financial data, and perform what-if analysis. After the new ERP system was implemented, Brunswick Steel's top management commented that the new software was simple and easy to use, allowing the production team to quickly schedule, reschedule, or reroute jobs and increase productivity on the shop floor. The management team also noted that they saw immediate improvements in their business operations. The new system was very intuitive in that many employees were using it without additional training. Barely a month after switching to the new system, the chief financial officer noted that it was much easier to run financial reports because data was real-time and integrated with other facets of the business.

On the production side, the redundant manual scheduling activities were eliminated, thus allowing the team to focus on production. Moreover, the new ERP system merged and automated all facets of the company's processes, including those that were done manually in the past like tracking laser cutting. By eliminating the manual processes, the new system prevented errors from manual data entry. The new ERP system allowed production, sales, purchasing, and finance to coordinate and work off the same real-time data. The new master production schedule reduced system nervousness and overbooking to improve on-time delivery. Brunswick Steel is now able to track its operations and financial status on a real-time basis. The company has gotten everything it had hoped for from the new ERP system, and yet allowed it to run its business the way it wanted.[16]

This SCM profile describes the successful implementation of an ERP system and how it can enhance a company's operations. Scheduling production in a manufacturing firm is complex, but an appropriate ERP system can help a company to seamlessly integrate its production and other facets of the company's operations.

## Advantages and Disadvantages of Enterprise Resource Planning Systems

When properly installed and operating, an ERP system can provide a firm and its supply chain partners with a significant competitive advantage, which can fully justify the investments of time and money in ERP. A fully functional ERP system can enhance the firm's capability to fully utilize capacity, accurately schedule production, reduce inventory, meet delivery due dates, and improve the efficiency and effectiveness of the supply chain. Let us look at some specific advantages and disadvantages.

### Enterprise Resource Planning System Advantages

As mentioned earlier, the primary advantage of ERP over the legacy MRP systems is that ERP uses a single database and a common software infrastructure to provide a broader scope and up-to-date information, enabling management to make better decisions swiftly. ERP is also robust in providing real-time information and, thus, can communicate information about operational changes to supply chain members quickly. ERP systems are also designed to take advantage of Internet and Cloud computing technologies. Thus, users can access the system through any Internet-connected devices like computers, smartphones, and tablets.

ERP helps organizations reduce supply chain inventories due to added visibility throughout the entire supply chain. It enables the supply, manufacturing, and logistics processes to flow smoothly by providing visibility of the order fulfillment process throughout the supply chain. Supply chain visibility leads to reductions of the bullwhip effect and helps supply chain members to better plan production and end-product deliveries to customers.

ERP systems also help organizations to standardize manufacturing processes. Manufacturing firms often find that multiple business units across the company make the same product using different processes and information systems. ERP systems enable the firm to automate some of the steps of a manufacturing process. Process standardization eliminates redundant resources and increases productivity.

ERP enables an organization, especially a multi business-unit enterprise, to efficiently track employees' time and performance and to communicate with them via a standardized method. Performance can be monitored across the entire organization using the same measurements and standards. The use of a single software platform and database also allows the ERP system to integrate financial, production, supply, and customer order information. By having this information in one software system rather than scattered among many different systems that cannot communicate with one another, companies can keep track of materials, orders and financial status efficiently and coordinate manufacturing, inventory, and shipping among many different locations and business units at the same time.

### Enterprise Resource Planning System Disadvantages

While the benefits of ERP systems can be impressive, ERP is not without shortcomings. For example, a substantial capital investment is needed to purchase and implement the system. Considerable time and money must be set aside to evaluate the available ERP applications, to purchase the necessary hardware and software, and then to train employees to operate the new system. Total cost of ERP ownership includes hardware, software, professional and software customization services, training, and other internal staff costs.

ERP systems are very complex and have proven difficult to implement, particularly in large multi business unit organizations.

However, the primary criticism of ERP is that the software is designed around a specific business model based on specific business processes. Although business processes are usually adopted based on best practices in the industry, the adopting firm must change its business model and associated processes to fit the built-in business model designed into the ERP system. Thus as mentioned earlier, the adopting firm must restructure its processes to be compatible with the new ERP system. This has resulted in a very unusual situation where a software system determines the business practices and processes a firm should implement, instead of designing the software to support existing business practices and processes.

Despite the widespread adoption of costly ERP systems by large firms since the Y2K scramble, many implementation challenges remain unsolved, and scores of ERP systems today are grossly underutilized.[17, 18, 19] Intricate business process reengineering challenges arise when business processes are adapted to the software. Consequently, firms struggle to justify their investment and find ways to better utilize their ERP systems. This raises the question of whether large firms can effectively manage their operations and supply chain activities without sophisticated information technology.

## Enterprise Resource Planning Software Applications

ERP systems typically consist of many modules that are linked together to access and share a common database in real-time. Each module performs distinct functions within the organization and is designed so that it can be installed on its own or with a combination of other modules. Most ERP software providers design their products to be compatible with their competitors' products, so that modules from different providers can be combined. Integration of customer relationship management, supply chain management, and e-procurement modules into the ERP system is now becoming relatively commonplace.

Today, there are scores of ERP software providers, each targeting a specific market segment and industry type. In terms of market share, SAP and Oracle are the two prominent ERP providers, followed by Microsoft and Infor. Though each software company configures its products differently from its competitors, some common modules of ERP systems are described here:

- *Accounting and finance*: This module assists an organization in maintaining financial control and accountability. It tracks accounting and financial information such as revenues, costs, assets, liabilities, and other accounting and financial information of the company. It is also capable of generating routine and advanced accounting and financial reports, product costing, budgeting, and analyses.
- *Customer relationship management:* This module manages customer relationships. It enables collaboration between the organization and its customers by providing relevant, personalized, and up-to-date information. It also enables customers to track sales orders. The customer relationship management module allows the user to communicate with existing customers and acquire new customers through sales automation and partner relationship management. This module allows the firm to segment customers and track their purchase activities, and then design customized promotions appealing to each customer segment.

- *Human resource management:* It helps an organization plan, develop, manage, and control its human resources. It allows the firm to deploy the right people to support its overall strategic goals and to plan the optimal workforce levels based on production levels.
- *Manufacturing resource planning:* It schedules materials and tracks production, capacity, and the flow of goods through the manufacturing process. It may even include the capability for quality planning, inspection, and certifications. This is probably the most important module for manufacturing companies.
- *Supply chain management*: This module handles the planning, execution, and control of activities involved in a supply chain. It helps to strengthen a firm's supply chain networks to improve delivery performance. Major functions of this module include sourcing, purchase order processing, goods receipt, supplier management, and customer requirement processing. It may also include various logistics functions such as transportation, warehousing, and inventory management. The supply chain management module creates value by allowing the user to optimize its internal and external supply chains.

ERP systems have continued to evolve in the twenty-first century. The industry has differentiated between very large enterprises and the small and medium-sized enterprise (SME) sectors. New best-of-breed vendors continued to emerge rapidly in the SME sector. Another development in the ERP industry is the advent of cloud computing solutions that require lower startup cost and total cost of ownership. SMEs are now able to experiment with cloud-based ERP solutions. As information technology continues to become more sophisticated, ERP software providers will continue to add new functions and capabilities to their systems.

## Summary

While both manufacturing and service organizations rely on effective production and capacity planning to balance demand and capacity, manufacturers have the added advantage of being able to build up inventory as stored capacity. Service firms are unable to inventory their services, so they rely upon backlogs or reservations, cross-training, or queues to match supply with demand. However, excess capacity results in underutilized equipment and workforce and eventually leads to unnecessary costs, adversely impacting all firms along the supply chain.

This chapter covers materials planning, capacity planning, and enterprise resource planning, which are all widely used for balancing demand with supply. An example was used to demonstrate how the aggregate production plan, master production schedule, material requirements plan, and distribution requirements plan are related to each other. This chapter also briefly discusses how the various materials plans are related to the capacity plans. A central piece of the materials plan is the material requirements plan, which takes information from the master production schedule, the bill of materials, and inventory status to compute planned order releases. For items that are produced in-house, planned order releases are released to the shop floor to trigger production. For purchased items, planned order releases are released to suppliers.

Finally, this chapter discusses the enterprise resource planning system, including its relationships with the traditional MRP and MRP-II systems, its advantages and disadvantages, implementation issues, and ERP modules. The goal of ERP development was to build a single software application that runs off a common shared database to serve the needs of an entire organization, regardless of its units' geographical locations and the currency used. Despite its complexity and considerable costs, ERP provides a way to integrate different business functions of different businesses, on different continents. The integrated approach can have a tremendous payback if companies select the right applications and implement the software correctly. Unfortunately, many companies that have installed these systems have failed to realize the benefits expected.

Implementing ERP should be viewed as a long-term, ongoing project. No matter what resources a firm has initially committed to replacing legacy systems, selecting and implementing ERP applications and training users, ERP requires ongoing management commitment and resources. As needs and technologies change and new applications are designed, new functionality and business processes will need to be continuously revisited and improved.

## Key Terms

**aggregate production plan,** 216

**available-to-promise (ATP) quantity,** 224

**best-of-breed solution,** 247

**bill of materials (BOM),** 227

**bullwhip effect,** 216

**capacity,** 238

**capacity requirements planning,** 239

**chase production strategy,** 219

**closed-loop MRP,** 230

**cloud computing,** 246

**demand time fence,** 224

**dependent demand,** 228

**distribution requirements plan,** 239

**distribution requirements planning (DRP),** 218

**electronic data interchange,** 242

**enterprise resource planning (ERP),** 217

**implosion,** 241

**indented bill of materials,** 228

**independent demand,** 230

**intermediate planning horizon,** 216

**lag capacity strategy,** 239

**lead capacity strategy,** 265

**legacy MRP system,** 242

**level production strategy,** 221

**long-range planning horizon,** 216

**make-to-order,** 220

**make-to-stock,** 221

**manufacturing resource planning,** 242

**master production schedule (MPS),** 217

**match capacity strategy,** 239

**material requirements plan (MRP),** 217

**medium-range planning horizon,** 216

**option overplanning,** 229

**planned order releases,** 230

**planning factor,** 228

**planning time fence,** 224

**product family,** 218

**mixed production strategy,** 222

**resource requirements planning,** 238

**rough-cut capacity plan,** 239

**short-range planning horizon,** 216

**single integrator solution,** 247

**super bill of materials,** 228

**system nervousness,** 223

**time fence system,** 224

**tracking capacity strategy,** 239

## Discussion Questions

1. Why is it important to balance production capacity with market demand?
2. Describe long-range, medium-range, and short-range planning in the context of a materials plan and a capacity plan. How are they related?
3. Describe aggregate production planning, master production planning, material requirements planning, and distribution requirements planning. How are these plans related?
4. Describe how MRP evolved into closed-loop MRP, MRP-II, and eventually into ERP.
5. Compare and contrast chase versus level production strategies. Which is more appropriate for an industry where highly skilled laborers are needed? Why?
6. Is a level production strategy suitable for a pure service industry, such as professional accounting and tax services or law firms? Can these firms inventory their outputs?
7. What is the purpose of low-level coding?
8. What is the purpose of the available-to-promise quantity, and how is it different from on-hand inventory?
9. What is system nervousness? Discuss how it can be minimized or avoided.
10. List and describe the two segments of a time fence system.
11. The available-to-promise quantity and on-hand inventory are used to fill orders. What is the difference between them?
12. What are the crucial inputs for material requirements planning?
13. What is a BOM, and how is it different from the super BOM?
14. What is the planning factor in MRP?
15. Are manufacturing or purchasing lead times considered in the MPS and the MRP?
16. What is the difference between scheduled receipts and planned order releases?
17. In MRP computation, do the gross requirements of level 3 items come from the gross requirements or planned order releases of the level 2 items? Explain how this works.
18. Where do the gross requirements of a level 0 item in the MRP come from?
19. Where do the gross requirements of a level 5 item in the MRP come from?
20. Are the gross requirements of level 0 item in the MRP an independent or dependent demand? How about items below level 0 (i.e., level 1, 2, 3, and below)?

21. What is the difference between an MRP explosion and a DRP implosion?
22. Describe lead capacity strategy and lag capacity strategy. Which strategy is more widely used in the electronics manufacturing industry, especially in the semiconductor and integrated circuit sectors? Why?
23. Briefly describe resource requirements planning, rough-cut capacity planning and capacity requirements planning. How are these plans related?
24. How are the various capacity plans (RRP, RCCP, CRP) related to the material plans (APP, MPS, MRP)?
25. Why are production planning and capacity planning important to SCM?
26. Why have so many firms rushed to implement ERP systems over the past twenty years?
27. Describe the limitations of a legacy MRP system.
28. Why is it important to learn the fundamentals of the traditional MRP system, even if it is considered an outdated, legacy system?
29. What are the advantages of an ERP system over the legacy MRP system?
30. Explain best-of-breed and single integrator ERP implementations. What are the advantages and disadvantages of the best-of-breed implementation?
31. Explain why many ERP implementations have failed to yield the expected benefits over the last ten years.
32. Describe how a cloud-based ERP system works. When might a firm use a cloud-based ERP?

## Essay/Project Questions

1. It is inevitable that cloud computing will significantly affect how businesses and students use information technology in the next few years. If you have not done so, search on the Internet to sign up for free cloud storage on OneDrive and/or Google Drive. Do not forget to sync your files to your local hard drives. Describe your experience.
2. Visit the websites of SAP, Oracle, and Microsoft, and use the information to write a brief report of each company and its ERP software. Do their products offer the same configurations or functionalities?
3. Use the Internet to search for relevant information to prepare a brief report on how SAP and Oracle expanded their product lines. Which of the two firms is known for its aggressive strategy of acquiring smaller best-of-breed providers?
4. Use the Internet to search for information to write a report on whether the trend is toward a single integrator or best-of-breed ERP implementation.
5. Use resources available on the Internet to prepare a report on the current and projected ERP market total revenue and the rate of growth over the next five years.
6. Use resources available on the Internet to prepare a report about a firm that has successfully implemented an ERP system.
7. Use resources available on the Internet to prepare a report that describes a failed ERP implementation. What can be learned from this company?

8. Explore the websites of SAP and Oracle, and use the information to write a report to discuss their (a) supply chain management, (b) supplier relationship management, (c) customer relationship management, and (d) advanced planning and scheduling software applications.
9. Use resources on the Internet to write a report describing Microsoft's strategy and competitive position in the ERP market.
10. Use resources on the Internet to write a report on the current stage of ERP implementation in the United States, Europe, and China.

## Spreadsheet Problems

1. The beginning January inventory and the desired ending inventory on June 30 are zero. Given the following demand information from January to June, what are the monthly chase and level production quantities?

| MONTH | JAN | FEB | MAR | APR | MAY | JUN |
|---|---|---|---|---|---|---|
| Demand | 250 | 300 | 540 | 660 | 700 | 250 |
| Chase Production Quantity | | | | | | |
| Level Production Quantity | | | | | | |

2. Given the following demand information, use (a) a chase production strategy and (b) a level production strategy to compute the monthly production, ending inventory/(backlog) and workforce levels. A worker can produce 100 units per month. Assume the beginning inventory as of January is zero, and the firm desires to have zero inventory at the end of June.

| MONTH | JAN | FEB | MAR | APR | MAY | JUN |
|---|---|---|---|---|---|---|
| Demand | 2000 | 3000 | 5000 | 6000 | 6000 | 2000 |
| Production | | | | | | |
| Ending Inventory | | | | | | |
| Workforce | | | | | | |

3. Given the following demand information, use (a) a chase production strategy and (b) a level production strategy to compute the monthly production, ending inventory/(backlog) and workforce levels. A worker can produce 50 units per month. Assume that the beginning inventory in January is 500 units, and the firm desires to have 200 units of inventory at the end of June.

| MONTH | JAN | FEB | MAR | APR | MAY | JUN |
|---|---|---|---|---|---|---|
| Demand | 2000 | 3000 | 5000 | 6000 | 6000 | 2000 |
| Production | | | | | | |
| Ending Inventory | | | | | | |
| Workforce | | | | | | |

**4.** Given the following production schedule, compute the available-to-promise quantities.

| WEEK | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Model A | | | | | | | | | |
| MPS | BI = 60 | 20 | 30 | 20 | 20 | 20 | 50 | 0 | 20 |
| Committed Customer Orders | | 50 | 10 | 30 | 10 | 20 | 20 | 10 | 0 |
| ATP:D | | | | | | | | | |

**5.** Given the following production schedule, compute the available-to-promise quantities.

| WEEK | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Model B | | | | | | | | | |
| MPS | BI = 20 | 20 | 0 | 20 | 20 | 0 | 20 | 20 | 20 |
| Committed Customer Orders | | 10 | 10 | 10 | 10 | 10 | 0 | 0 | 10 |
| ATP:D | | | | | | | | | |

**6.** Given the following production schedule, compute the available-to-promise quantities.

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Model C | | | | | | | | | |
| MPS | BI = 15 | 20 | 0 | 0 | 15 | 0 | 0 | 20 | 20 |
| Committed Customer Orders | | 5 | 10 | 0 | 0 | 12 | 0 | 0 | 12 |
| ATP:D | | | | | | | | | |

**7.** Given the following production schedule, compute the available-to-promise quantities.

| WEEK | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Model A | | | | | | | | | |
| MPS | BI = 10 | 20 | 0 | 10 | 15 | 0 | 0 | 20 | 20 |
| Committed Customer Orders | | 5 | 10 | 0 | 0 | 18 | 0 | 0 | 22 |
| ATP:D | | | | | | | | | |

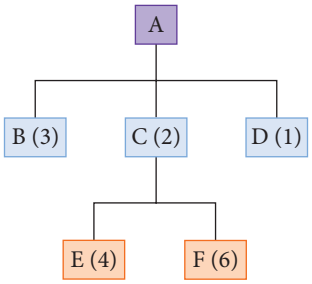
**8.** Given the following production schedule, compute the available-to-promise quantities.

| WEEK | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Model B | | | | | | | | | |
| MPS | BI = 8 | 20 | 0 | 20 | 0 | 12 | 0 | 28 | 20 |
| Committed Customer Orders | | 12 | 8 | 16 | 2 | 8 | 0 | 30 | 18 |
| ATP:D | | | | | | | | | |

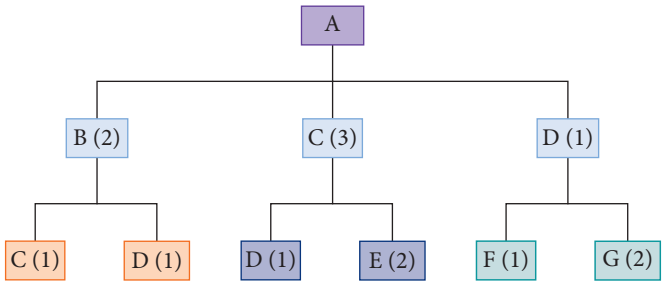
**9.** Given the following production schedule, compute the available-to-promise quantities.

| WEEK | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Model C | | | | | | | | | |
| MPS | BI = 22 | 0 | 30 | 25 | 0 | 0 | 0 | 28 | 8 |
| Committed Customer Orders | | 2 | 48 | 10 | 9 | 2 | 2 | 25 | 0 |
| ATP:D | | | | | | | | | |

**10.** Given the following bill of materials for product A with the associated component parts and planning factors (in parenthesis), how many units of each of the dependent demand items are required to produce one unit of product A?




**11.** The bill of materials for product A with the associated component parts and planning factors (in parenthesis) are shown below. How many units of the component parts are required to make one unit of the product A (combine all component C's and D's)?




**12.** Given the following information, compute the planned order releases and projected on-hand inventory for component part X.

| PART X | WEEK | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Gross Requirements | | 80 | 0 | 90 | 0 | 90 |
| Scheduled Receipts | | 60 | | | | |
| Projected On-Hand Inventory | 120 | | | | | |
| Planned Order Releases | | | | | | |

Q = 60; LT = 3 weeks; Safety Stock = 5

**13.** Given the following information, compute the planned order releases and projected on-hand inventory for component part Y.

| PART Y | WEEK | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Gross Requirements | | 80 | 50 | 90 | 0 | 80 |
| Scheduled Receipts | | 160 | | | | |
| Projected On-Hand Inventory | 120 | | | | | |
| Planned Order Releases | | | | | | |

Q = 20, LT = 2 weeks, Safety Stock = 10

**14.** Given the following information, compute the planned order releases and projected on-hand inventory for component part Z.

| PART Z | WEEK | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | 24 | 80 | 160 | 20 | 125 | 280 |
| Scheduled Receipts | | 12 | | | | | |
| Projected On-Hand Inventory | 20 | | | | | | |
| Planned Order Releases | | | | | | | |

Q = 12, LT = 1 weeks, Safety Stock = 6

**15.** Given the following information, compute the planned order releases and projected on-hand inventory for component part Z.

| PART A | WEEK | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | 150 | 252 | 240 | 320 | 280 | 450 |
| Scheduled Receipts | | 150 | 250 | | | | |
| Projected On-Hand Inventory | 22 | | | | | | |
| Planned Order Releases | | | | | | | |

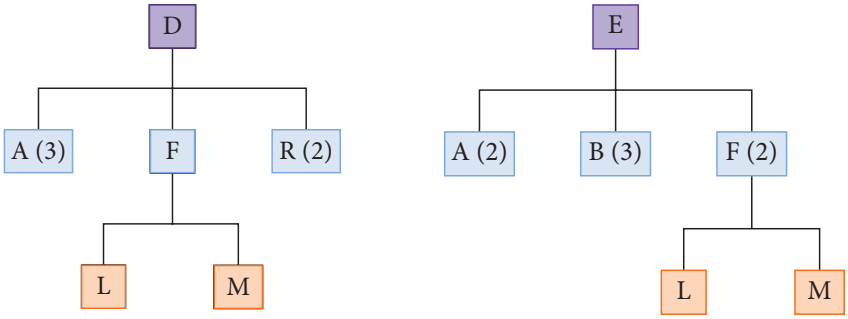
Q = 50, LT = 2 weeks, Safety Stock = 20

**16.** Given the MPS of an independent demand item, Model A ATV, compute the gross requirements, projected on-hand inventory, and planned order releases of this level 0 item.

| WEEK | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| MPS for Model A | | 30 | 40 | 80 | 15 | 75 | 85 | 95 | 158 |
| **MODEL A (LEVEL 0 ITEM)** | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| Gross Requirements | | | | | | | | | |
| Scheduled Receipts | | 50 | | | | | | | |
| Projected On-Hand Inventory | 10 | | | | | | | | |
| Planned Order Releases | | | | | | | | | |

Q = 50; LT = 1; SS = 12

**17.** The bills of materials for two finished products (D and E), inventory status, and other relevant information are given below. Compute the planned order releases and projected on-hand balances for finished goods D and E, and component part F.




| PART D | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | 7 | 11 | 9 | 5 | 8 | 6 |
| Scheduled Receipts | | | | | | | |
| Projected On-Hand Inventory | 10 | | | | | | |
| Planned Order Releases | | | | | | | |

Q = 30; LT = 1; SS = 0

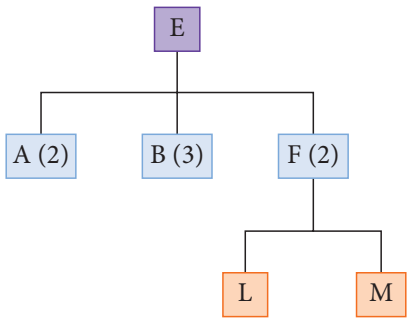
| PART E | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | 10 | 12 | 15 | 11 | 6 | 8 |
| Scheduled Receipts | | | 11 | | | | |
| Projected On-Hand Inventory | 15 | | | | | | |
| Planned Order Releases | | | | | | | |

Q = LFL; LT = 2; SS = 3

| PART F | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | | | | | | |
| Scheduled Receipts | | 60 | | | | | |
| Projected On-Hand Inventory | 20 | | | | | | |
| Planned Order Releases | | | | | | | |

Q = 60; LT = 1; SS = 0

**18.** The bill of materials for a finished product E, inventory status, and other relevant information are given below. Compute the planned order releases and projected on-hand balances for the independent demand item E, and dependent demand items F and M.



| PART E | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | 20 | 0 | 0 | 20 | 0 | 40 |
| Scheduled Receipts | | | | | | | |
| Projected On-Hand Inventory | 20 | | | | | | |
| Planned Order Releases | | | | | | | |

Q = 50; LT = 2; SS = 0

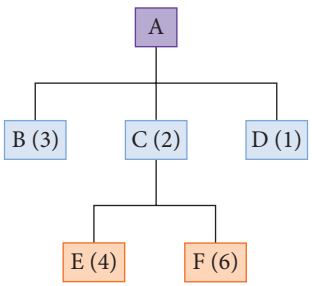
| PART F | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | | | | | | |
| Scheduled Receipts | | | | 50 | | | |
| Projected On-Hand Inventory | 120 | | | | | | |
| Planned Order Releases | | | | | | | |

Q = 50; LT = 2; SS = 20

| PART M | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | | | | | | |
| Scheduled Receipts | | 60 | | | | | |
| Projected On-Hand Inventory | 10 | | | | | | |
| Planned Order Releases | | | | | | | |

Q = 60; LT = 1; SS = 30

**19.** The bill of materials for a finished product A, inventory status, and other relevant information are given below. Compute the planned order releases and projected on-hand balances for the independent demand item A, and its dependent demand items C, E, and F.




| PART A | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | 58 | 44 | 38 | 65 | 88 | 168 |
| Scheduled Receipts | | 60 | | | | | |
| Projected On-Hand Inventory | 10 | | | | | | |
| Planned Order Releases | | | | | | | |

Q = 60; LT = 1; SS = 8

| PART C | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | | | | | | |
| Scheduled Receipts | | 90 | 120 | | | | |
| Projected On-Hand Inventory | 45 | | | | | | |
| Planned Order Releases | | | | | | | |

Q = 30; LT = 2; SS = 10

| PART E | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | | | | | | |
| Scheduled Receipts | | 500 | | | | | |
| Projected On-Hand Inventory | 50 | | | | | | |
| Planned Order Releases | | | | | | | |

Q = 250; LT = 1; SS = 40

| PART F | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | | | | | | |
| Scheduled Receipts | | 700 | | | | | |
| Projected On-Hand Inventory | 80 | | | | | | |
| Planned Order Releases | | | | | | | |

Q = 100; LT = 1; SS = 50

**20.** Eat-More-Chicken Inc. replenishes its two distribution centers in Emeryville and Seattle from its St. Louis central supply warehouse. The distribution schedule for one of its products for the next six weeks is shown below. Use proper distribution requirements planning logic to complete the replenishment schedules of its distribution centers and central warehouse.

| EMERYVILLE DISTRIBUTION CENTER | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | 40 | 70 | 65 | 85 | 120 | 90 |
| Scheduled Receipts | | 35 | | | | | |
| Projected On-Hand Inventory | 10 | | | | | | |
| Planned Order Releases | | | | | | | |

Q = LFL; LT = 1; SS = 5

| SEATTLE DISTRIBUTION CENTER | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | 120 | 230 | 180 | 286 | 145 | 268 |
| Scheduled Receipts | | 150 | | | | | |
| Projected On-Hand Inventory | 15 | | | | | | |
| Planned Order Releases | | | | | | | |

Q = 50; LT = 1; SS = 2

| ST. LOUIS CENTRAL WAREHOUSE | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | | | | | | |
| Scheduled Receipts | | 240 | 240 | | | | |
| Projected On-Hand Inventory | 50 | | | | | | |
| Planned Order Releases | | | | | | | |

Q = 40; LT = 2; SS = 0

**21.** Crop-Quick Inc. replenishes its three distribution centers in Boston, Denver, and Houston from its Las Vegas central supply warehouse. The distribution schedule for one of its products for the next six weeks is shown below. Use proper distribution requirements planning logic to complete the replenishment schedules of the three distribution centers and the central supply warehouse.

| BOSTON DISTRIBUTION CENTER | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | 0 | 20 | 0 | 55 | 0 | 0 |
| Scheduled Receipts | | | | | | | |
| Projected On-Hand Inventory | 10 | | | | | | |
| Planned Order Releases | | | | | | | |

Q = 30; LT = 1; SS = 5

| DENVER DISTRIBUTION CENTER | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | 0 | 20 | 10 | 0 | 0 | 20 |
| Scheduled Receipts | | | 11 | | | | |
| Projected On-Hand Inventory | 15 | | | | | | |
| Planned Order Releases | | | | | | | |

Q = LFL; LT = 2; SS = 2

| HOUSTON DISTRIBUTION CENTER | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | 10 | 0 | 0 | 45 | 0 | 0 |
| Scheduled Receipts | | | | | | | |
| Projected On-Hand Inventory | 20 | | | | | | |
| Planned Order Releases | | | | | | | |

Q = 60; LT = 1; SS = 0

| LAS VEGAS CENTRAL WAREHOUSE | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | | | | | | |
| Scheduled Receipts | | | | | | | |
| Projected On-Hand Inventory | 50 | | | | | | |
| Planned Order Releases | | | | | | | |

Q = 20; LT = 1; SS = 0

# Cases

## 1. Teen's Scene*

Myrtle Mendez is an entrepreneur. She started a clothing manufacturing business and established a store a few years ago that focused on teens. Her brand and store are called Teen's Scene. Initially, Myrtle worried about just getting the business running and keeping the financials above water. As her success grew, Myrtle realized that she needed to think more about the big picture. What was the direction she wanted her company to go? Did she want her business to stay as a single store? Did she want to get her brand sold in other clothing stores? Did she want to expand locally within the city of Chicago, or was there another avenue of growth she should pursue?

Although her company was relatively small, Myrtle had a senior staff, a director of operations (DO), a director of finance (DF), and a director of supply chain management (DS). Myrtle was a very hands-on owner and president of her company. Myrtle knew that each of her senior staff were experts in their areas; therefore, she decided the best course of action was to engage them in the planning of her company's future.

Myrtle and her staff spent many weeks discussing the situation. Rolando Curry (DF) was concerned about the financial effect of expansion. Rolando supported expansion; however, he emphasized that the specific strategy selected should be based on its financial impact. For example, how would it affect labor costs? What about inventory costs?

Essie Floyd (DO) agreed with Rolando that the selection of a specific strategy was a crucial first step. Essie explained that the type of production strategy the company chose to utilize would be one that they would be "stuck" with for at least a year, maybe more. The production strategy would dictate such things as capacity, scheduling, and training. Therefore, while she understood Rolando's concerns, she disagreed that the financials were the primary consideration. Essie believed that they should instead look at it primarily from the perspective of production. What strategy would enable them to run the production smoothly? Essie preferred a strategy where she would have a stable workforce she could count on.

Andy Allen (DS) said that in theory both Essie and Rolando were correct. However, as director of supply chain management, Andy's perspective was different. If they planned to sell their clothing line to other stores, they must focus on ensuring that the availability of the product was constant and consistent. If they didn't have the inventory to provide to local stores, then those stores may eventually drop them as a supplier. Andy's argument to Rolando was that if they were too cautious about the financials, they may be putting the company in a position where they would fall short of meeting customer expectations.

Myrtle listened to their views and realized that each one had valid points. Selecting the wrong strategy could result in her company failing financially in the long term. Furthermore, technically, her store was her manufacturing company's customer, although the teens were the ultimate end users. If she added other intermediate suppliers between her manufacturing company and the teens, that is, other clothing stores, they would be her manufacturing company's critical customers. Obviously, as her own customer she knew about any problems that would cause a disruption in supply; however, other stores wouldn't care about the reasons. Consequently, a disruption in supply would be a major cause of

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customer dissatisfaction. Finally, she understood Essie's point of view very clearly. A stable trained workforce was essential to the quality of their product. A strategy that may seem more attractive from a financial perspective, that is, keeping labor costs low, could affect their ability to maintain the level of quality they currently had.

Ms. Mendez met again with her senior staff. She shared that she had thought a lot about their individual views. While the discussions had provided a lot of food for thought, Myrtle said she needed each director to formally present their case in writing. Once she had those documents, they would meet and discuss the merits of each case. The desired outcome of that meeting would be to decide on an approach that minimized the negative effects each of them had identified and maximized the Teen's Scene's opportunity for success.

## Discussion Questions

1. If Myrtle and her staff decided to expand the business by selling the Teen's Scene brand to other clothing stores, which **production strategy** would be the best? Explain why your choice would be the best by addressing how the concerns of each director are resolved or at least minimized.
2. One of the options that Myrtle is considering is the **lead capacity strategy**. Based on the case and the issues all three directors voiced, do you agree that this is the best capacity strategy? Explain why or why not. If you don't agree, describe what would be a better capacity strategy.
3. Essie Floyd (DO) and Andy Allen (DS) have different concerns. What system or systems can Teen's Scene procure and implement that would provide a resolution for both directors? Identify the system or systems and explain why they would alleviate the specific concerns of each director. Be specific.

## 2. Fox's Furniture Division*

Beulah Burton is the vice president of Fox's furniture division. Fox is a corporation with businesses in many different industries. The furniture division has always been profitable; however, many years have passed since any overhaul of systems, equipment, or processes has been done. Jo Simon, chief executive officer of Fox, believed the time was right to give the furniture division a face lift. That was one reason she hired Beulah. Beulah has a reputation within the furniture industry of modernizing furniture companies.

As Beulah reviewed the current systems, equipment, and processes, she was shocked at how outdated things were. Fox was at least two decades behind the rest of the industry. Beulah was further amazed that it was a profitable division. Beulah wondered how much waste was going unnoticed because of antiquated systems. She was convinced that a lot of data were missing and this made any analysis ineffective.

Beulah met with Jo and explained that Fox needed an enterprise resource planning system. She believed that the furniture division had continued to make a profit only because most of the workers had been there for years. However, as they retired, she was convinced that their knowledge could not be easily replaced by new employees. Fox needed better data collection and data management. Clearly, this would be a huge undertaking.

Once the ERP system was installed and operational the first reports began to flow, Beulah realized that there was a lot of excess inventory. It was more than just too many of a

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certain part, for example, wood spindles. It was a case of having inventory that was not used for any of their current product line. They had tens of thousands of dollars of obsolete inventory sitting in their warehouses.

## Discussion Questions

1. You work for Beulah Burton. She directs you to determine what specific actions the furniture division needs to take in order to clean up the inventory system and to have the new system implemented effectively. What will you report?
2. You are part of a team tasked by Beulah to anticipate what problems may occur in the planning and implementation of an ERP system. Think about the scenario presented in the case. What specific problems may they encounter? What common problems (i.e., ones happening in many companies) may they encounter? What solutions or contingencies do you recommend?
3. Do you agree with Beulah's plan to jump all the way in, concerning an ERP system? Why? Shouldn't Jo have slowed things down and said they would implement it more piecemeal? Explain your thoughts.

## 3. Owen Poole CPA*

The first quarter of the year is Owen's favorite time. Owen Poole is a certified public accountant (CPA) and he loves the tax season. Although he understands that tax reform would be best for everyone if it simplified the process, he is glad that the idea of reform has been just talk. Owen enjoys the challenge of figuring out what deductions clients can take and how to maximize his clients' tax refunds. Owen sees it as a battle between himself and the Internal Revenue Service. The only thing Owen likes more than the challenge itself is winning!

When Owen was earning his degree in accounting, he took several electives in other business topics. One of his favorite ones was supply chain management. Owen enjoyed the big picture perspective this course emphasized. Understanding business from a broad perspective is crucial to Owen's own business because many of his clients are businesses, not individuals. As part of his services, Owen gives advice to his business clients on how to improve their bottom line. He explains to them that he will search out every penny possible in deductions to enhance their bottom line. However, he explains that they can help themselves by implementing more effective and efficient processes within their business. Although Owen isn't an expert in many of these processes, he understands enough to point his clients in the right direction. Since a significant portion of Owen's clients are small businesses, often just a few years old, his advice is helpful and very welcomed.

Today Owen is meeting with Van Ward. Van's business has been growing very rapidly. As Owen reviews Van's financial statements, he notices that Van's profit has been decreasing slightly despite his company's growth. Van's financial statements tell Owen a lot. He knows that there has not been much invested in resource planning systems. Consequently, as Van's business has grown, so have the inefficiencies. Owen decided that will be the topic for today—to help Van understand the need for investment in this area.

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## Discussion Questions

1. Put yourself in Owen's position. What questions would you ask Van to better understand his needs concerning resource planning?
2. Enterprise resource planning software is expensive. As Owen, you know that Van cannot afford to buy and implement a complete ERP system. In your opinion, what two common modules of an ERP system do you believe are the most crucial to any business? Provide a recommendation to Van, justifying your choice of the two modules for his business. How does the investment potentially benefit him?
3. Currently, Van is using a chase production strategy. Owen believes that this is an inefficient strategy. Do you agree with Owen? If so, what option would you recommend to Van? If you disagree with Owen, explain why Van is on the right track with his strategy.

# Part 3 Continuing Case

## Mullenax Automobile Parts Inc., Operational Issues and Resource Planning Systems*

Odis Mullenax is the owner and president of Mullenax Automobile Parts Inc. His company makes various parts for major automobile manufacturers worldwide. They manufacture intake manifold systems, air induction systems, coolant pump modules, oil filtration systems, coil springs, stabilizer bars, precision springs, and other key components within their three business units. Mullenax is one link in a very long supply chain. Odis understands that the supply chain is not a single line of suppliers and purchasers. Odis knows that the supply chain is more like a complex web where inputs come from multiple directions, often appearing unrelated to one another.

Estella Epperson, vice president of operations at Mullenax, has had her team reviewing the company's demand forecasting system. Estella realizes that demand forecasting is not the only area the company must review to ensure the most efficient and effective operations. Estella discusses Mullenax Automobile Parts' resource planning systems with Joel Kirkwood, director of operations. Resource planning is critical to ascertaining the production capacity required to meet demand. Therefore, it follows Estella's recent initiative concerning demand forecasting.

The challenge in terms of resource planning systems is that Mullenax has three business units. Each unit has different customer requirements and expectations. Although Mullenax works to maximize synergies between the three business units, there are still certain processes that work better in one business unit that the other business units.

Although all the products they produce are important to their customers, some are more important than others. For example, the filtration devices they manufacture are one of the parts of an automobile that requires routine replacement. Filtration devices such as oil, gasoline, diesel, and air filters are part of a vehicle's routine maintenance. However, products related to suspension systems such as springs, coils, and stabilizer bars generally last the life of the vehicle, depending on their use. Therefore, the amount of production capacity is significantly different depending on the product.

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The business unit manufacturing diverse filtration devices must guarantee that their products are available in the marketplace all the time. Not only are they required during the initial manufacture of a vehicle, but there must also be a sufficient supply to meet the varying demand that results from different maintenance schedules. The frequency of vehicle usage, the environment the vehicle is used in, and the stress put on the vehicle will dictate how often filtration devices must be replaced. Thus, the demand needs to be considered level or constant over the short-term.

While one may think the same could apply to suspension systems, that is, frequency, environment, and stress could dictate a significant variation, studies have shown that this is not true. These products are more robustly designed than filtering devices and can take a beating. Therefore, the production strategy needed for these products is different than the one needed for the filtering devices. In this situation, the products are more suited for make-to-order since the need is less frequent, and the demand is much lower.

A factor that Joel Kirkwood must consider is his workforce. Labor is a large expense and is tied to the resource planning system utilized. Therefore, Joel needs to select a production method that will ensure capacity meets the specific business unit demand and its labor requirement. Joel is scheduled to meet with Estella on Monday to share his findings.

The following are the details for labor cost per hour, number of hours worked per day per worker, number of days worked per month, and assembly time per unit in hours:

- Labor cost per hour = $15.75
- Number of hours worked per day per worker = 8
- Number of days worked per month = 20
- Assembly time per unit in hours = 7

## Discussion Questions

1. Based on the information provided in the case, which production strategy would be best for the filtering devices?
    a. Why? What is the distinguishing element?
2. Based on the information provided in the case, which production strategy would be best for the suspension parts?
    a. Why? What is the distinguishing element?
3. Using the information provided on labor cost per hour, number of hours worked per day per worker, number of days worked per month, and assembly time per unit in hours, use the online student worksheet and determine the numbers for both the level and chase production strategies. In addition, answer the questions listed below.
    a. What is the annual demand for the filtering devices?
    b. What is the total annual labor cost for the filtering device workforce?
    c. What is the average number of employees per month for the filtering device business unit?
    d. What is the annual demand for the suspension parts?
    e. What is the total annual labor cost for the suspension parts workforce?
    f. What is the average number of employees per month for the suspension business unit?

Below is the monthly demand for the products.

### Filtering Devices

| JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEPT | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10,000 | 11,000 | 9,000 | 13,000 | 12,000 | 10,000 | 10,000 | 12,000 | 17,000 | 9,000 | 11,000 | 14,000 |

### Suspension Parts

| JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEPT | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9,000 | 9,000 | 13,000 | 10,000 | 10,000 | 17,000 | 8,000 | 7,000 | 12,000 | 8,500 | 7,000 | 10,000 |

## Additional Resources


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# Chapter 7

# Inventory Management


General photographer/Shutterstock.com

*Don't sweat the small stuff. Manage all disposables by the box or package. Don't waste your inventory manager's time counting needles, for example.*

**—Dr. Eric Rooker, Dairy Doctors Veterinary Services[1]**

*Bar codes are good for transactional visibility, but RFID provides for real-time visibility. That's a whole different level of visibility that an execution system can make use of.*

**—Mark Wheeler, Director of Supply Chain Solutions, Zebra[2]**

*Inventory management can drive efficiency in retail pharmacies by optimizing the entire process from the ordering stage through expired pharmaceutical returns for credit. This is a great efficiency improvement goal. Analyzing sales and demand data next to inventory records is a good way to uncover efficiencies—both in ordering and in stocking to have what customers need, while also reducing waste.*

**—Daniela Weiszhar, Head of Marketing and Communications, Pharma Logistics[3]**

## Learning Objectives

**After completing this chapter, you should be able to**

**LO 1** Distinguish dependent from independent demand inventories.

**LO 2** Describe the four basic types of inventories and their functions.

**LO 3** Describe the costs of inventory and inventory turnovers.

**LO 4** Describe ABC classification, the ABC inventory matrix, and cycle counting.

**LO 5** Describe RFID and how it can be used in inventory management.

**LO 6** Describe the EOQ model and its underlying assumptions.

**LO 7** Describe the Quantity Discount and the EMQ models and their relationships with the basic EOQ model.

**LO 8** Describe the various statistical ROP models.

**LO 9** Describe the continuous review and periodic review systems.

## Chapter Outline



## SCM Profile — Inventory Management to Support Omnichannel Retailing


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Bed Bath & Beyond Inc., headquartered in Union, New Jersey, was founded by Warren Eisenberg and Leonard Feinstein in 1971. The retailer was originally called Bed 'n Bath but was renamed in 1987. Bed Bath & Beyond is an omnichannel retailer that operates 1,020 retail stores under the names Bed Bath & Beyond, buybuy BABY, Harmon Health and Beauty, and Decorist in the United States, Canada, and Mexico. For the fiscal year ending February 28, 2021, Bed Bath & Beyond had a total revenue of $9.233 billion and employed more than 38,000 workers. Its cost of goods sold was $6.115 billion and ending inventory was $1.672 billion, yielding an inventory turnover ratio of 3.66.[4] Bed Bath & Beyond is a Fortune 500 company.

Omnichannel is a recent multichannel retail concept that integrates the physical inventory in stores with digital channels to allow customers to shop in a physical store, or online via a mobile device, laptop, or personal computer. Customers can pick up the purchased items in a store or curbside, or have the items shipped directly from the company's stores, distribution

centers, or vendors. The COVID-19 pandemic accelerated the growth of omnichannel in the retail industry, to provide a safer and seamless shopping experience. Store purchases are mostly fulfilled from a store's inventory whereas online purchases can be shipped from stores, distribution centers, warehouses, or directly from vendors.

Bed Bath & Beyond started as a traditional brick and mortar retailer but began to transition to omnichannel in late 2019. In late March 2020, the COVID-19 pandemic forced the retailer to close all its retail stores, except some stand-alone BABY and Harmon stores across the United States and Canada. In May 2020, Bed Bath & Beyond began to reopen its stores. By July 2020, almost all its stores were reopened.

The pandemic accelerated the retailer's transition to omnichannel retailing. To bolster the transition effort, Bed Bath & Beyond hired a new CEO, shuffled its executive leadership team to streamline decision-making, revamped its dated website for an easier online shopping experience, and established new services in its omnichannel platform for contactless curbside pickup or same-day delivery. The retailer also strengthened its inventory management capability and moved to a centralized ordering and replenishment system to improve in-stock levels. To support its new growth strategy that prioritized digital omnichannel retailing and to optimize a store network to support a physical and digital presence, the retailer closed 144 stores during the last fiscal year and planned to close another 56 stores in the next two years.

To improve inventory management, Bed Bath & Beyond replaced its legacy ERP with a new Oracle system. The new ERP system provides real-time data and allows the retailer to analyze its inventory and product life cycles to discover significant patterns in its inventory deployment. This analytics capability allows the retailer to see insights and meaningful data that it might not otherwise reveal. Moreover, the new ERP system provides ABC classifications and inventory turnovers to help its managers focus on the high-value items.

The retailer plans to work with a third-party logistics provider to add four regional distribution centers to support its omnichannel strategy. It would ditch its network of cross docks that consolidate vendor shipments in favor of regional warehouses to replenish stores and fulfill online orders. The retailer believes that its investment in leading-edge technology and strategically located physical infrastructure will help to reduce stockouts and store replenishment times from 35 to 10 days. In addition to its partnership with Google, the retailer also invested $250 million to partner with a cloud-based system provider to setup an automated forecasting, planning, and replenishment system to improve its inventory turnovers and in-stock performance.[5]

This SCM profile describes the importance and challenges of inventory management, especially in a rapidly changing business environment. Inventory management in the manufacturing sector or retail industry is generally more complex than in the service sector because of the large amount of inventory required in the former sector. Inventory management is one of the most critical tasks of an organization. This chapter describes several inventory models, and the tools and concepts of inventory management.

## Introduction

Inventory can be one of the most expensive assets of an organization. It may account for more than 10 percent of total revenue or total assets for some organizations. Although companies in the manufacturing sector usually carry more inventory than service firms, effective inventory management is nonetheless important to both manufacturers and service organizations. Table 7.1 shows the amount of inventory and the ratio of inventory

to total revenue and total assets, of a few large globally recognized manufacturing and service firms. While the inventory to total assets ratio for service organizations (such as the first two casino hotel companies shown in Table 7.1) is relatively low compared to most manufacturers, inventory management for service firms poses a different challenge. Casino hotels for example carry a wide range of perishable food items to stock the diverse restaurants operating within their properties. Managing perishable inventory presents a unique challenge to operations managers.

Inventory management policy affects how efficiently a firm deploys its assets in producing goods and services. Developing effective inventory control systems to reduce waste and stockouts in manufacturing or service organizations is a complex problem. The right amount of inventory supports manufacturing, logistics, and other functions, but excessive inventory is a sign of poor inventory management that creates an unnecessary waste of scarce resources. In addition, excessive inventory adversely affects financial performance. The need for better inventory management systems continues to challenge operations managers.

This chapter first explains the difference between dependent demand and independent demand items. Then it focuses on the independent demand items to describe the basic concepts and tools of inventory management, including the ABC inventory control system, inventory costs, and radio frequency identification. The chapter also discusses the three fundamental deterministic inventory models and the two major types of stochastic inventory models.

**Table 7.1** Inventory Investment Compared to Total Revenue and Total Assets

| COMPANY | FINANCIAL YEAR END | TOTAL REVENUE ($) | TOTAL ASSETS ($) | YEAR END INVENTORY ($) | INVENTORY / TOTAL REVENUE (%) | INVENTORY / TOTAL ASSETS (%) |
|---|---|---|---|---|---|---|
| **Las Vegas Sands Corp.** | Dec 31, 2020 | 3612 | 20,807 | 32 | 0.89 | 0.15 |
| **MGM Resorts International** | Dec 31, 2020 | 5162 | 36,495 | 88 | 1.70 | 0.24 |
| **Microsoft Corporation** | Jun 30, 2020 | 143,015 | 301,311 | 1895 | 1.33 | 0.63 |
| **Apple Inc.** | Sep 30, 2020 | 274,515 | 323,888 | 4061 | 1.48 | 1.25 |
| **Ford Motor Company** | Dec 31, 2020 | 127,144 | 267,261 | 10,808 | 8.50 | 4.04 |
| **General Motors Company** | Dec 31, 2020 | 122,485 | 235,194 | 10,235 | 8.36 | 4.35 |
| **Tesla Inc.** | Dec 31, 2020 | 31,536 | 52,148 | 4101 | 13.00 | 7.86 |
| **Walmart Inc.** | Jan 31, 2021 | 559,151 | 252,496 | 44,949 | 8.04 | 17.80 |
| **Target Corporation** | Jan 31, 2021 | 93,561 | 51,248 | 10,653 | 11.39 | 20.79 |
| **Pfizer Inc.** | Dec 31, 2020 | 41,908 | 154,229 | 8046 | 19.20 | 5.22 |
| **Intel Corporation** | Dec 31, 2020 | 77,867 | 153,091 | 8427 | 10.82 | 5.50 |
| **Advanced Micro Devices, Inc.** | Dec 31, 2020 | 9763 | 8962 | 1399 | 14.33 | 15.61 |

*Source:* Annual Reports on Form 10-K; All numbers in millions, except ratios.

## Dependent Demand and Independent Demand

Inventory management models are generally separated by the nature and types of the inventory being considered and can be classified as dependent demand and independent demand models.

**Dependent demand** is the internal demand for parts based on the demand of the final product in which the parts are used. Subassemblies, components, and raw materials are examples of dependent demand items. Dependent demand may have a pattern of abrupt and dramatic change because of its dependency on the demand of the final product, particularly if the final product is produced in large lot sizes. Dependent demand can be calculated once the demand of the final product is known. Hence, material requirements planning (MRP) software is often used to compute exact material requirements.

The dependent demand inventory system was discussed in Chapter 6. For example, the ATV Corporation's master production schedule discussed in Table 6.4 in Chapter 6 shows that 120 all-terrain vehicles will be produced in January. The firm thus knows that 120 handlebars and 480 wheel rims will be needed. The demand for handlebars, wheel rims, and other dependent demand items can be calculated based on the bill of materials and the demand of the final product as stated on the master production schedule.

**Independent demand** is the demand for a firm's end products and has a demand pattern affected by trends, seasonal patterns, and general market conditions. For example, the customer demand for all-terrain vehicles is independent demand. Batteries, headlights, seals, and gaskets originally used in assembling the all-terrain vehicles are dependent demand examples; however, the replacement batteries, headlights, seals, and gaskets sold as *service parts* to the repair shops or end users are independent demand items. Similarly, the original battery used in assembling your new car is a dependent demand item for the automobile manufacturer, but the new battery that you bought to replace the original battery is an independent demand item for the car parts store. Independent demand items cannot be derived using the material requirements planning logic from the demand for other items and, thus, must be forecasted based on market conditions.

## Concepts and Tools of Inventory Management

Savvy operations managers are concerned with controlling inventories not only within their organizations, but also throughout their many supply chains. An effective independent demand inventory system ensures smooth operations and allows manufacturing firms to store up production capacity in the form of work-in-process and finished goods inventories. While some service firms are unable to inventory their output, such organizations may rely on appointment backlogs, labor scheduling, and cross-training to balance supply and demand.

All manufacturing and service organizations are concerned with effective inventory planning and control. Inventory requires capital investment, handling and storage space, and it is also subject to deterioration and shrinkage. Although a firm's operating costs and financial performance can be improved by reducing inventory, the risk of stockouts can be devastating to customer service. Therefore, companies must strike a delicate balance between inventory investment and customer service. This section discusses some important concepts and tools of inventory management. Vendor-managed inventory and co-managed inventory, discussed in Chapter 4, will not be explored here.

## The Functions and Basic Types of Inventories

Inventory includes all the materials and goods that are purchased, partially completed materials and component parts, and the finished goods produced. The primary functions of inventory are to *buffer* uncertainty in the marketplace and to *decouple*, or break the dependencies between stages in the supply chain. For example, an appropriate amount of inventory, known as *safety stock* or *buffer stock*, can be used to cushion uncertainties due to fluctuations in supply, demand, and/or delivery lead time. Similarly, the right amount of inventory enables a work center to operate without interruption when other work centers in the same production process are offline for maintenance or repair. Keeping the correct amount of inventory at each work center also allows a faster work center to operate smoothly when it is constrained by slower upstream work centers.

In this global business environment, it is not unusual that organizations use the concept of *geographical specialization* to manufacture their products in developing countries. In this scenario, the developing countries specialize in cheap labor and abundant raw materials, whereas the manufacturing firms provide the technology and capital to produce the goods. The ability to geographically separate the consumption of the finished goods from production is a key function of inventory. For manufacturers, inventory also acts as *stored capacity*. For instance, snowmobile manufacturers can build up inventory by producing snowmobiles year-round in anticipation of peak demand during the busy winter season.

There are four broad categories of inventories: raw materials; work-in-process; finished goods; and maintenance, repair, and operating (MRO) supplies.

- *Raw materials* are unprocessed purchased inputs or materials for manufacturing the finished goods. Raw materials become part of finished goods after the manufacturing process is completed. There are many reasons for keeping raw material inventories, including volume purchases to create transportation economies or to take advantage of quantity discounts; stockpiling in anticipation of future price increases or to avoid a potential short supply; or keeping safety stock to guard against supplier delivery or quality problems.
- *Work-in-process* (WIP) describes materials that are partially processed but not yet ready for sales. One reason to keep WIP inventories is to decouple processing stages or to break the dependencies between work centers.
- *Finished goods* are completed products ready for shipment. Finished goods inventories are often kept to buffer against unexpected demand changes and in anticipation of production process downtime; to ensure production economies when the setup cost is very high; or to stabilize production rates, especially for seasonal products.
- *Maintenance, repair, and operating* (*MRO*) *supplies* are materials and supplies used in-house when producing the products but are not parts of the products. Solvents, cutting tools, and lubricants for machines are examples of MRO supplies. The two main reasons for storing MRO supplies are to gain purchase economies and to avoid material shortages that may shut down production.

## Inventory Costs

The bottom line of effective inventory management is to control inventory costs and minimize stockouts. Inventory costs can be categorized in many ways: as direct and indirect costs; fixed and variable costs; and order (or setup) and holding (or carrying) costs.

**Direct costs** are those that are directly traceable to the unit produced, such as the amount of materials and labor used to produce a unit of the finished good. **Indirect costs** are those that cannot be traced directly to the unit produced, and they are synonymous with manufacturing overhead. Maintenance, repair, and operating supplies; heating; lighting; buildings; equipment; and plant security are examples of indirect costs. **Fixed costs** are independent of the output quantity, but **variable costs** change as a function of the output level. Buildings, equipment, plant security, heating, and lighting are examples of fixed costs, whereas direct materials and labor costs are variable costs. A key focus of inventory management is to control variable costs since fixed costs are generally considered *sunk costs*. Sunk costs such as capital investment and lease expense on warehouses and distribution centers are costs that have already been incurred and cannot be recovered or reversed.

**Order costs** are the direct variable costs associated with placing an order with the supplier, whereas **holding** or **carrying costs** are the costs incurred for holding inventory in storage. Order costs include managerial and clerical costs for preparing the purchase, as well as other incidental expenses that can be traced directly to the purchase. Examples of holding costs include handling charges, warehousing expenses, insurance, pilferage, shrinkage, taxes, and the cost of capital. In a manufacturing context, **setup costs** are used in place of order costs to describe the costs associated with setting up machines and equipment to produce a batch of product. However, in inventory management discussions, *order costs* and *setup costs* are often used interchangeably.

## Inventory Investment

Inventory serves many important functions for manufacturing and service firms; however, excessive inventory is detrimental to a firm's financial health and competitive edge. Whether inventory is an asset that contributes to organizational objectives or a liability depends on its management.

Inventory is expensive and it ties up a firm's working capital. Moreover, inventory requires storage space and incurs other carrying costs. Some products such as perishable food items and hazardous materials require special handling and storage that add to the cost of holding inventory. Inventory can also deteriorate quickly while it is in storage. In addition, inventory can become obsolete very quickly as new materials and technologies are introduced. Most importantly, large piles of inventory delay a firm's ability to respond swiftly to production problems and changes in technologies and market conditions.

Inventory investment can be measured in several ways. The typical annual physical stock counts to determine the total dollars invested in inventory provides an absolute measure of inventory investment. The inventory value is then reported in a firm's balance sheet. This value can be compared to the budget and past inventory investments. However, the absolute dollars invested in inventory does not provide sufficient evidence about whether the company is using its inventory wisely. A widely used measure to determine how efficiently a firm uses its inventory to generate revenue is the **inventory turnover ratio** or **inventory turnovers**. This ratio shows how many times a company turns over its inventory in an accounting period. Higher turnovers are desirable because it indicates the company generates more revenue per dollar in inventory investment. Moreover, higher turnovers allow the company to increase cash flow and reduce warehousing and carrying costs. Conversely, a low inventory turnover may point to overstocking or deficiencies in the product line or marketing effort. Table 7.2 shows recent inventory turnover ratios for

**Table 7.2 Inventory Turnover Ratios**

| COMPANY | FINANCIAL YEAR END | TOTAL REVENUE ($) | COST OF REVENUE ($) | YEAR END INVENTORY ($) | INVENTORY TURNOVER RATIO |
|---|---|---|---|---|---|
| **Las Vegas Sands Corp.** | Dec 31, 2020 | 3612 | 2608 | 32 | 81.50 |
| **MGM Resorts International** | Dec 31, 2020 | 5162 | 3453 | 88 | 39.24 |
| **Microsoft Corporation** | Jun 30, 2020 | 143,015 | 46,078 | 1895 | 24.32 |
| **Apple Inc.** | Sep 30, 2020 | 274,515 | 169,559 | 4061 | 41.75 |
| **Ford Motor Company** | Dec 31, 2020 | 127,144 | 112,752 | 10,808 | 10.43 |
| **General Motors Company** | Dec 31, 2020 | 122,485 | 108,813 | 10,235 | 10.63 |
| **Tesla Inc.** | Dec 31, 2020 | 31,536 | 24,906 | 4101 | 6.07 |
| **Walmart Inc.** | Jan 31, 2021 | 559,151 | 420,315 | 44,949 | 9.35 |
| **Target Corporation** | Jan 31, 2021 | 93,561 | 66,177 | 10,653 | 6.21 |
| **Pfizer Inc.** | Dec 31, 2020 | 41,908 | 8692 | 8046 | 1.08 |
| **Intel Corporation** | Dec 31, 2020 | 77,867 | 34,255 | 8427 | 4.06 |
| **Advanced Micro Devices, Inc.** | Dec 31, 2020 | 9763 | 5416 | 1399 | 3.87 |

*Source*: Annual Reports on Form 10-K; All numbers in millions, except ratios.

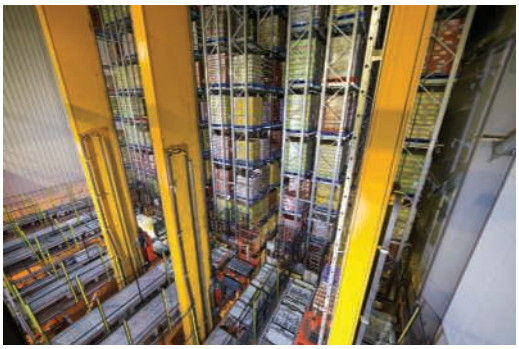
the same twelve firms shown in Table 7.1. The formula for the inventory turnover ratio can be stated as:

$$\text{Inventory turnover ratio} = \frac{\text{Cost of Revenue}}{\text{Average Inventory}}$$

The inventory turnover ratio can be computed for any accounting period—monthly, quarterly, or annually. Cost of revenue is also the cost of goods sold, which is readily available from a firm's income statement. The average inventory is the mean of the beginning and ending inventory for a period. However, a firm's inventory may fluctuate widely in a financial year; thus, the average of the beginning and ending inventory may be a poor indicator of the firm's actual average inventory for the year. In this case, the average of the twelve monthly ending inventories can be used as the average inventory when computing the annual inventory turnover ratio. In Table 7.2, since the average of the monthly inventories was not available in the *annual reports*, the financial year-end closing inventory was used to compute the ratio.

In 2020, for instance, Las Vegas Sands Corp. (LVS) for example, turned over its inventory a staggering 81.50 times. However, the nature of LVS's business may suggest that a major portion of its revenue came from hotel room and gaming sales, with the inventory consisting mostly of goods for the restaurants. Thus, the revenue generated by hotel room and gaming sales could be excluded from the calculation of the turnover ratio. Firms put a significant emphasis on improving their turnovers. It is not uncommon for firms, especially manufacturers and retailers to run promotions and clearance sales to reduce year-end inventories. The nearby SCM profile describes how a warehouse equipped with an automated storage and retrieval system can improve inventory turnover.

## SCM Profile Inventory Management with Automated Storage and Retrieval Systems



Juice Flair/Shutterstock.com

Stemilt Growers, founded by Tom Mathison in 1964, is a family-owned, fruit and tree nut farming business based in Wenatchee, Washington. It is one of the largest tree fruit grower-packer-shippers of apples, pears, cherries, and drupes such as peaches, nectarines and apricots in the U.S. Stemilt Growers is now managed and run by the fourth and fifth generations of the Mathison family. Its estimated annual revenue for the fiscal year ended June 30, 2021, was $500 million.[6] The company managed, 1480 acres of organic fruit trees and sells about 106 million pounds of apples, 13.3 million pounds of drupes, 9.3 million pounds of pears, and 3 million pounds of sweet cherries annually. In addition to growing its own fruit trees, the company also buys fruit from small, medium, and large growers around the Washington state area.[7]

Stemilt Growers previously used three warehouses to store and distribute its products. It was very inefficient and required a lot of unnecessary product movements to consolidate goods at a specific warehouse to allow truckers to pick up loads from one location. Spreading highly perishable inventory across three warehouses also complicated inventory management and incurred redundant fixed costs that prevented the company from exploiting economies of scale with its warehousing systems. A pallet of fresh fruit can weigh up to a ton, thus requiring heavy lifting equipment. Moreover, different types of fresh fruit require different storage temperatures, and some temperature-sensitive products must be stored in a special storage facility. Duplicating the needs across three warehouses was not an efficient option, hence the company decided to transform its three warehouses into a single state-of-the-art warehouse.

The new warehouse is equipped with an automated storage and retrieval system and is fully integrated with the company's ERP systems to provide real-time visibility of its inventory status. This allows Stemilt Growers to better manage the freshness of its products and increase inventory turnover. According to Stemilt Growers' inventory manager, the newly installed automated storage and retrieval system is a high-density shuttle system for pallet warehousing that can store 60 percent more pallets per unit space compared to a traditional warehouse.

Stemilt Growers' new warehouse can hold up to 13,000 pallets. Its inbound throughput is 287 pallets per hour and outbound throughput is 207 pallets per hour. The new warehouse system consists of three quality control stations where quality inspectors can retrieve pallets for inspection by using the automated retrieval system instead of relying on forklift drivers, thus considerably increasing productivity and retrieval accuracy. The new warehouse system has reduced truck load times by roughly 67 percent and warehouse labor costs by 40 percent. The new system has also improved productivity and customer service.[8]

This SCM profile describes how a warehouse that is equipped with an automated storage and retrieval system can improve inventory turnover, productivity, and customer service. Today's automated storage and retrieval systems are designed to provide real-time visualization of the inventory stored in the system, optimize storage space, and handle high volume flow quickly. Although a network of strategically located warehouses can help to shorten delivery time on many occasions, an advanced centralized warehouse may be the better option for some businesses.

## The ABC Inventory Control System

A common problem with inventory management systems is the challenge to maintain accurate inventory records. Many organizations use **cycle counting** to reconcile discrepancies between their physical inventory and inventory record on a monthly or quarterly basis. Cycle counting, or physically counting inventory on a periodic basis, also helps to identify obsolete stocks and inventory problems so that remedial action can be taken in a reasonable amount of time. However, cycle counting can be costly and time-consuming and can disrupt operations.

The **ABC inventory control system** is a useful tool to determine which inventories should be counted more frequently and managed more closely and which others should not. ABC analysis is often combined with the **80/20 rule** or **Pareto analysis**. The 80/20 rule suggests that 80 percent of the objective can be achieved by doing 20 percent of the tasks, but the remaining 20 percent of the objective will take up 80 percent of the tasks. The Pareto analysis recommends that tasks falling into the first category be assigned the highest priority and managed closely.

The ABC inventory control system prioritizes inventory items into Groups A, B, and C. However, it is not uncommon that some firms choose to use more than three categories. The *A items* are given the highest priority, while *C items* have the lowest priority and are typically the most numerous (the *B items* fall somewhere in between). Greater attention, safety stocks, and resources are devoted to the high-priority or *A items*. The priority is most often determined by annual dollar usage. However, priority may also be determined by product shelf life, sales volume, whether the materials are critical components, or some other criteria. A summary of the classification is provided in Table 7.3.

When prioritizing inventories by annual dollar usage, the ABC system suggests that approximately 20 percent of the items make up about 80 percent of the total annual dollar usage, and these items are classified as the *A items*. The *B items* make up roughly 40 percent of the items and account for about 15 percent of the total annual dollar usage, while the *C items* are the remaining 40 percent of the items, making up about 5 percent of the total annual dollar usage of inventory. Since the *A items* are the highest annual dollar usage items, they should be monitored more frequently and may have higher safety stock levels to guard against stockouts, particularly if these items are used in products sold to supply chain partners. The *C items* would then be counted less often, and stockouts may be allowed to save inventory space and carrying costs.

ABC inventory classification can be done monthly, quarterly, annually, or any fixed period. For the fast-moving consumer market, an *A item* may become a *C item* within months or even weeks. For these cases, the ABC inventory classification based on annual dollar usage might not be useful to management. An illustration of an ABC inventory classification using annual dollar usage is shown in Example 7.1.

**Table 7.3** ABC Inventory Classification

| CLASSIFICATIONS | PERCENT OF TOTAL ANNUAL DOLLAR USAGE | PERCENT OF TOTAL INVENTORY ITEMS |
|---|---|---|
| A Items | 80 | 20 |
| B Items | 15 | 40 |
| C Items | 5 | 40 |

**Example 7.1 ABC Inventory Classification Based on Annual Dollar Usage**

Note that in this example, the *A items* only account for about 67 percent of the total annual dollar volume, while the *B items* account for about 28 percent. This illustrates that judgment must also be applied when using the ABC classification method, and the 80/20 rule should only be used as a general guideline.

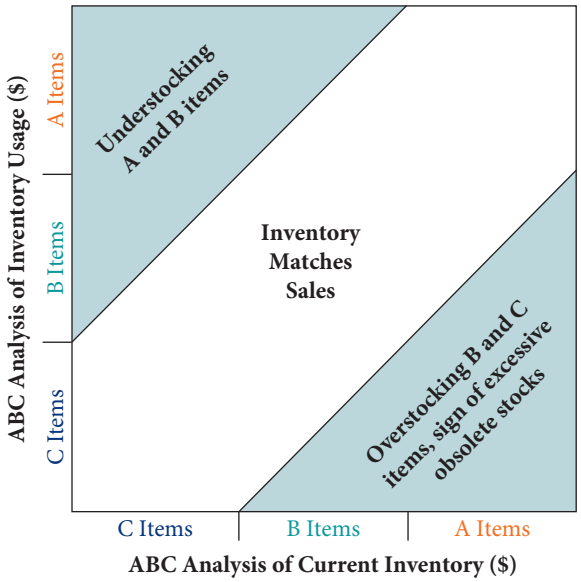
| INVENTORY ITEM NUMBER | ITEM COST($) | ANNUAL USAGE (UNITS) | ANNUAL USAGE ($) | PERCENT OF TOTAL ANNUAL DOLLAR USAGE | CLASSIFICATION BY ANNUAL DOLLAR USAGE |
|---|---|---|---|---|---|
| A246 | 1.00 | 22,000 | 22,000 | 35.2 | A |
| N376 | 0.50 | 40,000 | 20,000 | 32.0 | A |
| C024 | 4.25 | 1468 | 6239 | 10.0 | B |
| R221 | 12.00 | 410 | 4920 | 7.8 | B |
| P112 | 2.25 | 1600 | 3600 | 5.8 | B |
| R116 | 0.12 | 25,000 | 3000 | 4.8 | B |
| T049 | 8.50 | 124 | 1054 | 1.7 | C |
| B615 | 0.25 | 3500 | 875 | 1.4 | C |
| L227 | 1.25 | 440 | 550 | 0.9 | C |
| T519 | 26.00 | 10 | 260 | 0.4 | C |
| | **Total Annual Dollar Usage: $62,498** | | | **100%** | |

## The ABC Inventory Matrix

The ABC Inventory analysis can be expanded to assist in identifying obsolete stocks and to analyze whether a company is stocking the correct inventory by comparing two ABC analyses. First, an ABC analysis is done based on annual inventory dollar usage (as shown in Example 7.1) to classify inventories into A, B, and C groups. Next, a second ABC analysis is done based on current or on-hand inventory dollar value (as shown in Example 7.2) to classify inventories again into A, B, and C groups. Finally, the two ABC analyses are combined to form an **ABC inventory matrix** as shown in Figure 7.1. The *A items* based on current inventory value should match the *A items* based on annual inventory dollar usage, falling within the unshaded diagonal region of the figure. Similarly, the *B* and *C items* should match when comparing the two ABC analyses. Otherwise, the company is stocking the wrong items. The ABC inventory matrix also suggests that some overlaps are expected between two borderline classifications (as indicated by the wide diagonal region). For instance, some marginal *B items* based on annual inventory dollar usage might appear as *C items* based on the current inventory value classification and vice versa.

Referring to Figure 7.1, plots in the upper-left shaded triangle of the ABC inventory matrix indicate that some *A items* based on annual inventory dollar usage are showing up as *B* or *C items* based on the current inventory value classification and that some *B items* have similarly been classified as *C items*. This suggests that the company has current inventories for its *A* and *B items* that are too low, and is risking stockouts of their higher dollar usage items. Conversely, plots in the lower-right shaded triangle show that some *C items* based on annual inventory dollar usage are showing up as *A* and *B items* based on current inventory value, and some *B items* are similarly showing up as *A items*, thus indicating that the company has current inventories for its *B* and *C items* that are too high, and is incurring excess inventory carrying costs. This may also point to the presence of excessive *obsolete stock* if the inventory turnover ratios are very low. Obsolete stocks should be disposed of so that valuable inventory investment and warehouse space can be used for productive inventory. When used in conjunction with inventory turnovers, the ABC inventory matrix is a powerful tool for managing inventory investment. Example 7.2 shows the classifications based on current inventory value for the same ten items shown in Example 7.1, and it also shows the annual dollar usage classifications.

**Figure 7.1** Generic ABC Inventory Matrix




**Example 7.2 ABC Inventory Classification Based on Current Inventory Value**

| INVENTORY ITEM NUMBER | ITEM COST ($) | CURRENT INVENTORY (UNITS) | CURRENT INVENTORY VALUE ($) | PERCENT OF TOTAL CURRENT INVENTORY | CLASSIFICATION BY CURRENT INVENTORY VALUE | CLASSIFICATION BY ANNUAL DOLLAR USAGE |
|---|---|---|---|---|---|---|
| T519 | 26.00 | 300 | 7800 | 40.5 | A | C |
| A246 | 1.00 | 5600 | 5600 | 29.1 | A | A |
| L227 | 1.25 | 1200 | 1500 | 7.8 | B | C |
| C024 | 4.25 | 348 | 1479 | 7.7 | B | B |
| R221 | 12.00 | 80 | 960 | 5.0 | B | B |
| P112 | 2.25 | 352 | 792 | 4.1 | B | B |
| T049 | 8.50 | 50 | 425 | 2.2 | C | C |
| N376 | 0.50 | 800 | 400 | 2.1 | C | A |
| R116 | 0.12 | 2100 | 252 | 1.3 | C | B |
| B615 | 0.25 | 120 | 30 | 0.2 | C | C |
| **Total Physical Inventory: $19,238** | | | | **100%** | | |

The two ABC analyses from Examples 7.1 and 7.2 are combined and plotted on the ABC inventory matrix shown in Figure 7.2. Each inventory item is plotted on the matrix using the "percent of total current inventory" on the horizontal or x-axis and the "percent of total annual dollar usage" on the vertical or y-axis. Note that the largest value on the horizontal axis, "percent of total current inventory," is 40.5 (from the 5th column in Example 7.2), and the largest value on the vertical axis, "percent of total annual dollar usage," is 35.2 (from the 5th column in Example 7.1). It is easier to plot the ABC inventory matrix by converting both axes to a 10-point scale. Thus, the coordinates of the ten inventory items in Examples 7.1 and 7.2 can be computed as,

A246: (29.1, 35.2) $\Rightarrow$ (29.1/40.5 $\times$ 10, 35.2/35.2 $\times$ 10) = (7.2, 10.0)

N376: (2.1, 32.0) $\Rightarrow$ (2.1/40.5 $\times$ 10, 32.0/35.2 $\times$ 10) = (0.5, 9.1)

C024: (7.7, 10.0) $\Rightarrow$ (7.7/40.5 $\times$ 10, 10.0/35.2 $\times$ 10) = (1.9, 2.8)

R221: (5.0, 7.8) $\Rightarrow$ (5.0/40.5 $\times$ 10, 7.8/35.2 $\times$ 10) = (1.2, 2.2)

P112: (4.1, 5.8) $\Rightarrow$ (4.1/40.5 $\times$ 10, 5.8/35.2 $\times$ 10) = (1.0, 1.6)

R116: (1.3, 4.8) $\Rightarrow$ (1.3/40.5 $\times$ 10, 4.8/35.2 $\times$ 10) = (0.3, 1.4)

T049: (2.2, 1.7) $\Rightarrow$ (2.2/40.5 $\times$ 10, 1.7/35.2 $\times$ 10) = (0.5, 0.5)

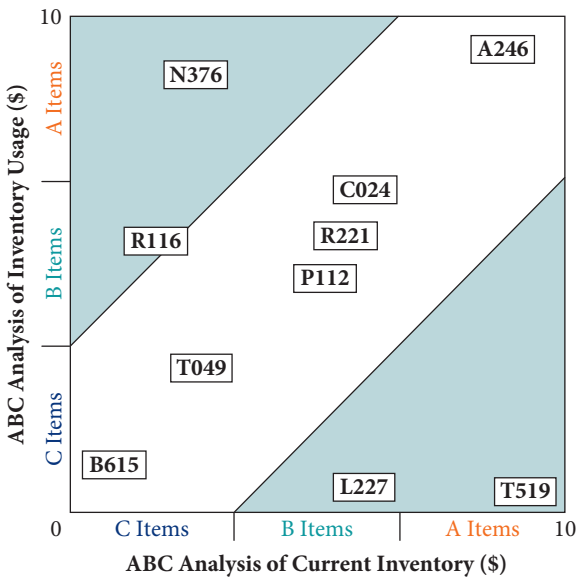
B615: (0.2, 1.4) $\Rightarrow$ (0.2/40.5 $\times$ 10, 1.4/35.2 $\times$ 10) = (0.0, 0.4)

L227: (7.8, 0.9) $\Rightarrow$ (7.8/40.5 $\times$ 10, 0.9/35.2 $\times$ 10) = (1.9, 0.3)

T519: (40.5, 0.4) $\Rightarrow$ (40.5/40.5 $\times$ 10, 0.4/35.2 $\times$ 10) = (10.0, 0.1)

Using a 10-point scale for both the horizontal and vertical axes, the coordinate of the item "A246" would be (7.2, 10.0). Similarly, the coordinate of the item "T519" would be (10.0, 0.1). Therefore, "A246" falls on the upper-right corner, whereas "T519" falls on the extreme lower-right corner of the matrix. The plots in Figure 7.2 show that six of the inventory items fell along the diagonal, suggesting the appropriate stocking levels. The company has probably overstocked items "T519" and "L227" and understocked "N376" and possibly "R116." It is important however, that the inventory turnover ratios for each item be used in conjunction with the ABC inventory matrix to get a sense of how fast or slow inventories are turning over.

**Figure 7.2** ABC Inventory Matrix for Example 7.2



## Radio Frequency Identification

The barcode has been used to identify the manufacturer and contents of a package or container for decades. However, it cannot store enough information to distinguish goods at the item level. Direct line of sight is also required to read a barcode, and the information stored on it is static and not updatable. **Radio frequency identification** (RFID) has been used as an eventual successor to the barcode for tracking an individual unit of goods. RFID tags do not require direct line of sight or physical contact with the reader to transmit data, and information on the tag is updatable. RFID technology is used in libraries, for passport identification, animal tracking, medical disciplines, toll payments, and in many other fields. There is a related technology called **Near Field Communication** (NFC) that was designed for short-range secured data exchange between NFC-enabled smart devices such as cell phones, tablets, wearables, and payment cards. NFC is a specialized subset of RFID technology. The nearby SCM Profile describes use of RFID tags in an oilfield operation.

### SCM Profile — RFID and Inventory Management

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U.S. Well Services, Inc., headquartered in Houston, Texas, was founded in February 2012. The company's revenues for the fiscal year ending December 31, 2020, were $244 million. It employs more than 600 full-time employees. U.S. Well Services provides well stimulation and development services through high-pressure hydraulic fracturing processes to oil and natural gas exploration and production companies in the United States. Since its inception in 2012, U.S. Wells Services' customer base, operating areas, production capacity and development grew rapidly.

The oil and gas industry has been relying on a labor-intensive manual process that is prone to errors to manage its extensive amount of iron assets and inventory such as industrial valves, pipes, slurry blenders, high-pressure fracking pumps, and storage tanks. The iron assets and equipment are used to connect the fracking pumps to the boreholes to inject high-pressure liquid into subterranean rocks or boreholes to extract oil or gas. Using the manual process, U.S. Well Services required three employees to work for three to four days to count its iron assets and inventory at each job site. Due to the size and weight of the iron equipment, one employee would read the serial numbers while another employee would record the information. The serial numbers of the equipment could be buried in mud, rusted, ripped, facing the ground, or stacked under other equipment, thus complicating the process.

In addition to keeping track of onsite iron assets and inventory, U.S. Well Services must also maintain an accurate record and be able to retrieve all the safety certificates of the equipment quickly to meet OSHA's safety standards. Keeping and maintaining hardcopies of the certificates using a manual process is highly inefficient.

To improve its inventory management and reduce cost, U.S. Well Services adopted a modern iron inventory management system using RFID technology to manage its iron assets and inventory.

This new RFID system that can be loaded onto a smart device like a cell phone transformed the company's iron assets and inventory management capabilities. An employee uses a handheld reader to read the serial number of an iron equipment without the need to flip it over or dig it up from the mud or a stack of heavy equipment. It also allows the employee to retrieve the relevant certificates or edit any information via the smart device in the field. This new RFID system reduced the company's operating cost while simultaneously improving efficiency and accuracy.

With the new RFID system, one employee can complete an onsite iron assets and inventory count in two to three hours compared to three employees who needed three to four days with the manual system. Moreover, the new system is much more accurate and provides more useful information for each piece of equipment. This new system allows the company to conduct iron assets and inventory counts more frequently, thus reducing discrepancies between physical inventory and stock records, and the need to stock unnecessary expensive assets or equipment. The real-time visibility of its iron assets and inventory allows U.S. Well Services to see its production capability instantly to help determine whether it can commit to new jobs quickly.[9]

This SCM Profile shows an important application of RFID in inventory management. RFID continues to gain widespread acceptance in many aspects of our life and the business sectors. We are also seeing a rapid deployment of NFC technology in payment systems. For example, many credit cards today have an NFC enabled chip built-in to allow contactless payments at retail outlets and gas stations.

The Electronic Product Code (EPC) was designed as a universal identifier that can uniquely identify a physical object. The current Gen2v2 RFID standard, EPC Radio Frequency Identification Protocols Class 1 Generation 2 UHF RFID,[10] was developed by EPCglobal, Inc. in 2004 and was approved by the International Organization for Standardization (ISO)[11] as ISO 18000-6C in a July 2006 standard. The RFID standard defines air interface parameters for tags operating within the frequency range of 860–960 Mhz. The standard has been revised several times by both organizations. The current ISO standard is the ISO/IEC 18000-6:2013.[12] EPCglobal, Inc. is now known as GS1.[13]

Like barcode technology, a reader is used to read the information stored in RFID tags. However, the reader does not have to be placed directly in the line of sight of the tag to read the radio signal—a very significant advantage of RFID over barcodes. The original RFID tag classes were first developed by the MIT Auto-ID Center. The oldest class 0 and 1 later passed onto EPCglobal as a basis to create the newer EPC Gen 2 standard. The EPC standards call for six classes of tags as shown in Table 7.4. Class 0 tags are read-only tags, but class 1 tags can be programmed once to update the information stored on the tags. Like a rewritable CD, class 2 tags are enhanced Generation 2 class 1 tags that can be rewritten multiple times. Classes 0, 1, and 2 are **passive RFID tags** that do not store power on the tags, and classes 3 and 4 are **active RFID tags** that contain a power source to boost their range. Class 5 tags can communicate with other class 5 tags and other devices.

The current EPC standard is the 96-bit ultra-high-frequency (UHF) class 1, Gen 2 write-once-read-many (WORM) tag. The management board of GS1, which oversees the EPC standards, ratified the new EPC Gen2v2.0.1 in 2015.[14] Gen2v2, a fully backward-compatible EPC standard operating in the 860 to 960 MHz UHF range, is a major update since 2008. This generation of tags is expected to pave the way to the class 2 high memory full read/write tags. A 256-bit version of the tag is being created, but full details are not yet available. Class 3 tags have not yet been fully defined whereas class 4 and 5 tags are in the early definition stage.

**Table 7.4 EPCglobal's Tag Classes**

| CLASS TYPE | FEATURES | TAG TYPE |
|---|---|---|
| Class 0 | Read only | Passive (64 bits only)<br>Generation 1, factory preprogramed read-only passive tag |
| Class 1* | Write once, read many | Passive (minimum 96 bits)<br>Generation 1 and 2, read-only passive tag like class 0 and has one-time filed programmability |
| Class 2 | Read/write | Passive (minimum 96 bits)<br>Passive tag with read-wrote capability |
| Class 3 | Read/write with battery power to enhance range | Semi-active tag with read-write memory, onboard sensor, and an incorporated battery to provide increased coverage |
| Class 4 | Read/write active transmitter | Read-write active tag with integrated transmitter for communication using the battery onboard |
| Class 5 | Read/write active transmitter | Active tag that can communicate with other class 5 tags |

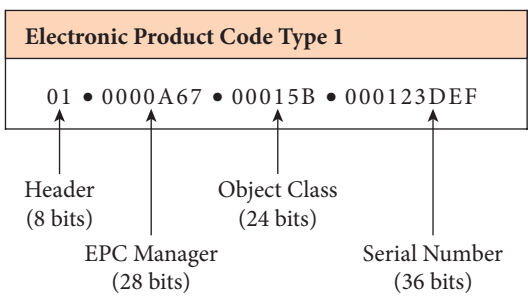
* Current EPC standard

The current 96-bit EPC is a number made up of a header and three sets of data as shown in Figure 7.3. The 8-bit *header* identifies the version of the EPC being used; the 28-bit *EPC manager* identifies the manufacturer (and even plant) of the product; the 24-bit *object class* identifies the unique product family; and the 36-bit *serial number* uniquely identifies the individual physical item being read. The 8-bit header can identify 256 ($2^8$) versions of EPC; the 28-bit EPC manager can classify 268,435,456 ($2^{28}$) companies; the 24-bit object class can identify 16,777,216 ($2^{24}$) product families per company; and the 36-bit serial number can differentiate 68,719,476,736 ($2^{36}$) specific items per product family. Using this mammoth combination (which is unmatched by the barcode), it is not difficult to envisage that RFID can revolutionize inventory management in the supply chain.

## Components of a Radio Frequency Identification System

An RFID system consists of four parts: the tag, reader, communication network, and RFID software. The tag consists of a computer chip and an antenna for wireless communication with the handheld or fixed-position RFID reader, and the communication network

**Figure 7.3 Structure of the Electronic Product Code**



connects the readers to transmit inventory information to the enterprise information system. The RFID software manages the collection, synchronization, and communication of the data with warehouse management, ERP and supply chain planning systems, and stores the information in a database. Figure 7.4 shows a generic RFID system.

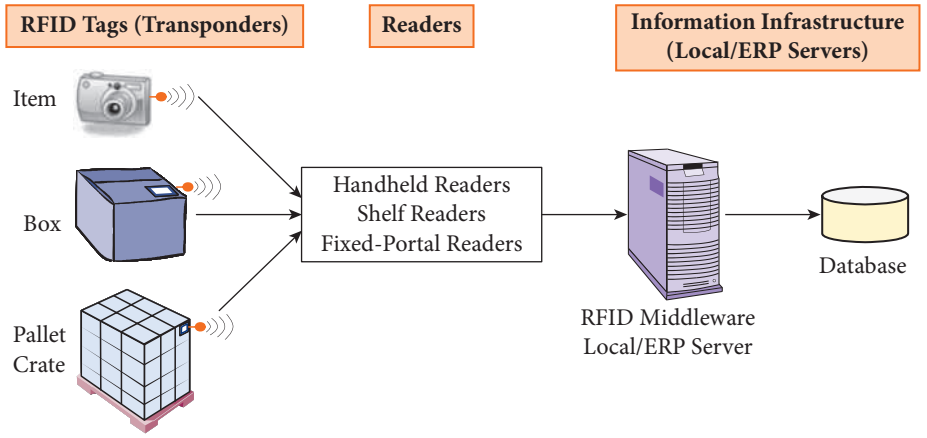
Though RFID was designed for use at the item level to identify individual items, current implementation focuses on the aggregate level where tags are placed on cases, crates, pallets, or containers due to the high cost of the tags. A passive 96-bit RFID tag costs approximately 7 to 15 cents today compared to $2 in 1999,[15,16] but it is still not financially feasible to tag individual low-price ticket items. Thus, the existing focus is at the aggregate level focusing on cases or pallets of items, although some retailers have started to place RFID tags on individual high-price ticket items like cameras and electronic products to deter theft and closely manage the expensive inventories.

## How Radio Frequency Identification Automates the Supply Chain

RFID is a valuable technology for tracking inventory in the supply chain. It can synchronize information and physical flow of goods across the supply chain from manufacturers to retail outlets and to the consumers at the right place at the right time. Likewise, RFID can track returned goods through the supply chain and prevent counterfeiting. It also helps to reduce out-of-stock items. There is no doubt that RFID is an invaluable tool for improving inventory management and supply chain efficiencies. The steps by which the RFID can automate the supply chain follow.

1. *Materials Management*: As a supply vehicle enters the warehouse, the fixed-portal RFID reader positioned at the entrance reads the tags on the pallets or individual items to provide handling, routing, and storage information of the incoming goods. Inventory status can be updated automatically.
2. *Manufacturing*: An RFID tag can be placed on the unit being produced so that specific customer configurations can be incorporated automatically during the production process. This is invaluable in a make-to-order environment.
3. *Distribution Center*: As the logistics vehicle arrives at the loading dock, the fixed-portal RFID reader communicates with the tag on the vehicle to confirm

**Figure 7.4** RFID System



that it is approved to pick up goods. When the loaded vehicle leaves the dock and crosses the portal, the reader picks up the signals from the tags to alert the RFID software and ERP system to update the inventory automatically and initiate an advance shipping notice (ASN), proof of pickup, and invoices.

4. *Retail Store*: As the delivery vehicle enters the unloading dock, the fixed-portal reader picks up the signals from the tags, and the RFID software application processes the signals to provide specific handling instructions and initiate automatic routing of the goods. The RFID reader can also be placed on the store shelf to trigger automatic replenishments when an item reaches its reorder point. Moreover, inventory status can be updated in real time automatically at any stage of the supply chain, and handheld readers can be used to assist in cycle counting. Item-level tagging can be used to recommend complementary products. For instance, a computer screen and a reader can be placed in the changing room, so when a consumer tests a tagged suit in the changing room, the reader picks up the signal to suggest matching shirts and shoes on an LCD screen. When RFID is fully implemented at the item level, it is not difficult to envisage that instead of waiting for a cashier, a consumer could simply walk out the door of a store while simultaneously making a purchase. A reader built into the door would be able to recognize the items in the consumer's cart and charge the consumer's pre-approved credit card automatically.

## Global RFID Implementation and Challenges[17,18,19]

Radio frequency identification is one of the latest developments in inventory management. RFID technology has also been adopted by major retailers worldwide, including Marks & Spencer and Tesco in the United Kingdom, and Metro Group in Germany. In the United States, Walmart has mandated its suppliers to tag all shipments to its warehouses with RFID. Likewise, the U.S. Department of Defense has also required that pallets delivered to its warehouses from its largest suppliers be tagged with RFID.

Tagging strategies differ considerably by region. In the United States, the focus is on case- or pallet-level tagging, whereas European retailers focus on item-level tagging. U.S. retailers focus on case- and pallet-level tagging for inventory management to help reduce inventory and stockouts while simultaneously improving customer service. Consumer-privacy issues and high implementation costs for hardware and tags deter American retailers from moving into item-level tagging. In Europe, the cultural climate has made it easier to deploy RFID, and retailers are using the technology at the item-level for category management and garment sorting, and are looking at RFID for smart shelves such as automatic replenishment. While most retailers in Asia expect to gain from integrating RFID technology along their supply chains, China is skeptical about sharing potentially confidential information with foreign businesses and lags behind other nations in RFID technology use. In Japan, the RFID market focuses on government applications, logistics usage, and asset tagging.

Rapid industry adoption has proved more challenging than initially believed and, as in the case of Walmart, has had mixed success. Tag and RFID system costs are among the major impediments to a faster adoption of the technology. RFID tags can cost ten to twenty times more than simple barcode tags. Globally, the RFID industry still does not have its own UHF spectrum allocation though the new Gen2v2.0.1 standard uses 860 to 960 MHz. Differences between radio frequencies in various parts of the world are another major hurdle to broader adoption. While the United States favors the 915 MHz UHF, the Europeans prefer the 868 MHz UHF. The Chinese use frequencies from 840.25–844.75 MHz to 920.25–924.75MHz; while in Japan, 125–134 kHz, 13.56 MHz, 2.4–2.5 GHz, and 5.8 GHz are used, with the 950–956 MHz UHF allocated for unlicensed, low-power use. Another challenge of RFID is that UHF signals are reflected by metal and absorbed by

water. Finally, with limited benefit information from a few RFID pilot projects, it is difficult for a company to calculate returns.

While considerable progress has been made on code standardization over the last few years, much work remains to be done. The United States and Europe have jointly worked on a common standard based on the modified GS1 UHF Gen 2 standard, but China and Japan have decided to develop their own. China supports its own EPC classification system for domestic product labeling, whereas Japan uses its Ubiquitous ID standard. Using competing RFID standards is likely to eventually lead to the need for costly multiprotocol readers that can handle tags that comply with the different standards. Despite all the challenges, RFID continues to replace barcode technology in inventory management.

### Big Data Decision-Making

Another recent development that may change inventory management and combine with RFID to enable better business decision-making is big data. **Big data** broadly refers to collections of data sets that are too large and complex to be processed by traditional database management tools or data processing software applications. Instead, massive parallel software applications running on hundreds or even thousands of servers simultaneously are often required to store and process the data. RFID generates a huge amount of data as inventory moves through the supply chain. Big data technology helps to process the data in real time to take advantage of the information captured by RFID.

An example of how big data can enhance competitive advantage is Google's search engine. Google's core business is targeted marketing and advertising. To excel in this business, Google captures and exploits two types of big data—a comprehensive index and library of all the contents on the web and the behavior of Google users worldwide as they interact with its products and services. Google stores and indexes all the information on the web. On a big data perspective, Google processes about 12 billion searches each month. The company estimated that the web consists of 60 trillion pages that are stored in an index that exceeds 100 million gigabytes. Having a comprehensive index of the web and consumer behavior in real time allow Google to serve highly relevant searches and ads that closely mirror the user's intent.[20]

## Inventory Models

A variety of inventory models for independent demand items are reviewed in this section by classifying the models into two broad categories. First, the deterministic inventory models are discussed that assume demand, delivery lead time, and other parameters are deterministic. These models use fixed parameters to derive the optimum *order quantity* to minimize *total inventory costs*. Thus, these models are also known as the **fixed order quantity models**. The economic order quantity, quantity discount, and economic manufacturing quantity models are the three most widely used fixed order quantity models. Following this, the statistical reorder point is discussed, where demand and/or lead time are not constant but can be estimated by means of a normal distribution. Finally, the continuous review and periodic review systems are discussed.

## The Economic Order Quantity Model

The **economic order quantity** (**EOQ**) **model** is a classic independent demand inventory system that provides many useful ordering decisions. The basic order decision is to determine the optimal order size that minimizes two annual inventory costs—that is, the

sum of the annual order cost and the annual inventory holding cost. The issue revolves around the trade-off between annual inventory holding cost and annual order cost: when the order size for an item is small, orders have to be placed on a frequent basis, causing high annual order costs; however, the firm then has a low average inventory level for this item, resulting in low annual inventory holding costs. When the order size for an item is large, orders are placed less frequently, causing lower annual order costs, but high average inventory levels for this item, resulting in higher annual expenses to hold the inventory. The EOQ model thus seeks to find an optimal order size that minimizes the sum of the two annual costs. In EOQ computations, the term *carrying cost* is often used in place of holding cost and *setup cost* is used in place of order cost.

## Assumptions of the Economic Order Quantity Model

Users must carefully consider the following assumptions when determining the economic order quantity:

1. *The demand is known and constant*. For example, if there are 365 days per year and the annual demand is known to be 730 units, then the daily usage must be exactly two units throughout the entire year.
2. *Order lead time is known and constant*. For example, if the delivery lead time is known to be ten days, every delivery will arrive exactly ten days after the order is placed.
3. *Replenishment is instantaneous*. The entire order is delivered at one time and partial shipments are not allowed.
4. *Price is constant*. Quantity or price discounts are not allowed.
5. *The holding cost is known and constant*. The cost or rate to hold inventory must be known and constant.
6. *Order cost is known and constant*. The cost of placing an order must be known and remains constant for all orders.
7. *Stockouts are not allowed*. Inventory must be available at all times.

## Deriving the Economic Order Quantity

The economic order quantity can be derived easily from the total annual inventory cost formula using basic calculus. The total annual inventory cost is the sum of the annual purchase cost, the annual holding cost and the annual order cost. The formula can be shown as:

$$\text{TAIC} = \text{Annual purchase cost} + \text{Annual holding cost} + \text{Annual order cost}$$
$$\text{TAIC} = \text{APC} + \text{AHC} + \text{AOC} = (R \times C) + (Q/2 \times k \times C) + (R/Q \times S)$$

where:

TAIC = total annual inventory cost
APC = annual purchase cost
AHC = annual holding cost
AOC = annual order cost
$R$ = annual requirement or demand
$C$ = purchase cost per unit
$S$ = cost of placing one order
$k$ = holding rate, where annual holding cost per unit = $k \times C$, and
$Q$ = order quantity

Since $R$, $C$, $k$, and $S$ are deterministic (i.e., assumed to be constant terms), $Q$ is the only unknown variable in the TAIC equation. The optimum $Q$ (the EOQ) can be obtained by taking the first derivative of TAIC with respect to $Q$ and then setting it equal to zero. A second derivative of TAIC can also be taken with respect to $Q$ to prove that the TAIC is a concave function, and thus $\frac{d\text{TAIC}}{dQ} = 0$ is at the lowest point (i.e., minimum) of the total annual inventory cost curve. Thus:

$$\frac{d\text{TAIC}}{dQ} = 0 + (½ \times k \times C) + (-1 \times R \times S \times 1/Q^2)$$
$$= \frac{kC}{2} - \frac{RS}{Q^2}$$

then setting $\frac{d\text{TAIC}}{dQ}$ equal to zero,

$$\frac{kC}{2} - \frac{RS}{Q^2} = 0$$
$$\Rightarrow \frac{kC}{2} = \frac{RS}{Q^2}$$
$$\Rightarrow Q^2 = \frac{2RS}{kC}$$
$$\Rightarrow \text{EOQ} = \sqrt{\frac{2RS}{kC}}$$

The second derivative of TAIC is:

$$\frac{d^2\text{TAIC}}{dQ^2} = 0 - \left(-2 \times \frac{RS}{Q^3}\right) = \left(\frac{2RS}{Q^3}\right) \geq 0,$$

implying that the TAIC is at its minimum when $\frac{d\text{TAIC}}{dQ} = 0$.

The annual purchase cost drops off after the first derivative is taken. The managerial implication here is that purchase cost does not affect the order decision if there is no quantity discount (the annual purchase cost remains constant regardless of the order size, as long as the same annual quantity is purchased). Thus, the annual purchase cost is ignored in the classic EOQ model. Example 7.3 provides an illustration of calculating the EOQ. It should be noted that all demand must be converted to the annual requirement, and holding cost is the product of the holding rate and unit cost of the item. For example, if the annual holding rate, $k$, is 12 percent and the item cost, $C$, is \$10 per unit, the holding cost, $kC$, is \$1.20 per unit per year.

Figure 7.5 shows the relationships between annual holding cost, annual order cost, and total annual holding plus order cost. Using the data in Example 7.3, at the EOQ (600 units), annual holding cost (\$1,200) equals annual order cost (\$1,200). At or close to the EOQ, the annual total cost curve is rather flat, indicating that it is not very sensitive to small variations in the economic order quantity. Therefore, the classic EOQ model is said to be very *robust* to minor errors in estimating cost parameters, such as holding rate, order cost, or annual usage. Table 7.5 for example, compares the annual total cost at an EOQ of 600 units and at 10 percent below and above the EOQ. The analysis shows that the cost variations range from only 0.01 percent to 0.56 percent above the minimum total cost.

Figure 7.5 and Table 7.5 show that if the order size is smaller than the EOQ, the annual holding cost is slightly lower, whereas the annual order cost is slightly higher. The net effect is a slightly higher annual total cost. Similarly, if the order quantity is slightly larger than the EOQ, the annual holding cost is slightly higher, whereas the annual order cost is slightly lower. The net effect is again a slightly higher annual total cost.

### Example 7.3 Calculating the EOQ at the Las Vegas Corporation

The Las Vegas Corporation purchases a critical component from one of its key suppliers. The operations manager, Dr. Suhaiza Zailani, wants to determine the economic order quantity, along with when to reorder, to ensure the annual inventory cost is minimized. The following information was obtained from historical data.

| | |
|---|---|
| Annual requirements ($R$) | = 7200 units |
| Order cost ($S$) | = \$100 per order |
| Holding rate ($k$) | = 20% |
| Unit cost ($C$) | = \$20 per unit |
| Order lead time ($LT$) | = 6 days |
| Number of days per year | = 360 days |

Thus,

$$EOQ = \sqrt{\frac{2RS}{kC}} = \sqrt{\frac{2 \times 7200 \text{ units} \times \$100}{0.20 \times \$20}} = 600 \text{ units}$$

1. The annual purchase cost = $R \times C$ = 7200 units × \$20 = \$144,000.
2. The annual holding cost = $Q/2 \times k \times C$ = (600/2) × 0.20 × \$20 = \$1200.
3. The annual order cost = $R/Q \times S$ = (7200/600) × \$100 = \$1200.
   (Note that when using the EOQ, the annual holding cost equals the annual order cost.)
4. The total annual inventory cost = \$144,000 + \$1200 + \$1200 = \$146,400.
5. For an order lead time of six days, the reorder point (ROP) would be:
   ROP = (7200/360) × 6 = 120 units
   Thus, the purchasing manager should reorder the part from the supplier whenever the physical stock is down to 120 units, and 600 units should be ordered each time. The order cycle can also be computed as follows:
6. Number of orders placed per year = 7200/600 = 12 orders.
7. Time between orders = 360/12 = 30 days.

### Figure 7.5 The Economic Order Quantity and Total Costs

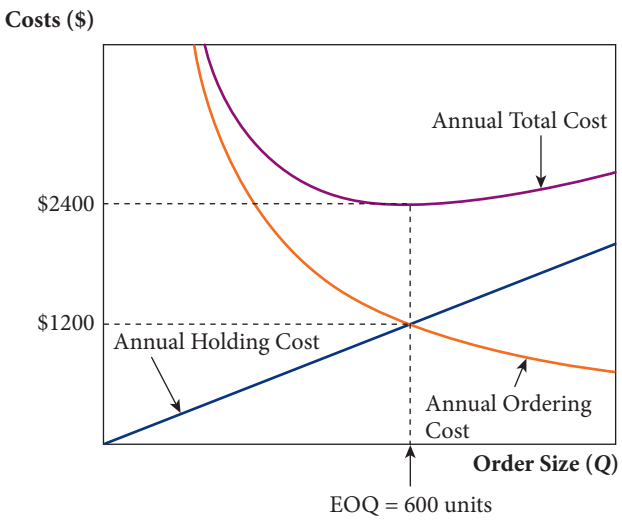


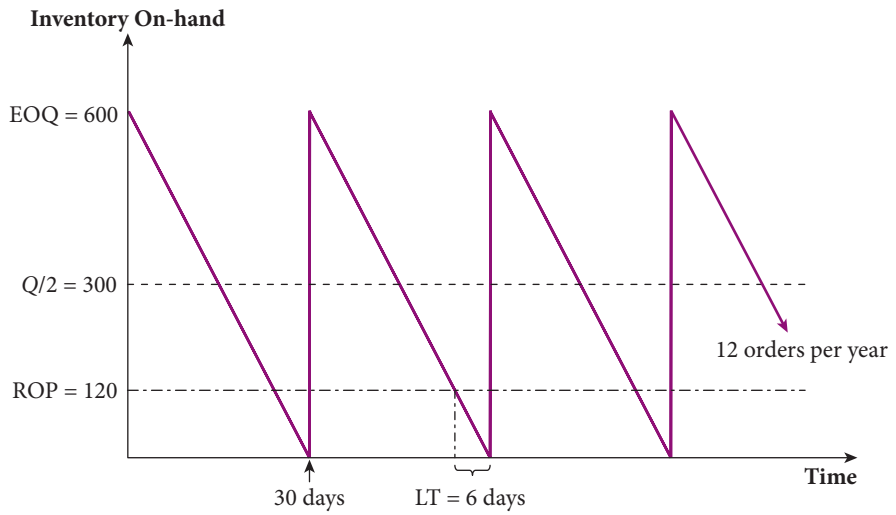
**Table 7.5 Percent Variation in Total Annual Cost**

| *Q* (UNITS) | AHC ($) | AOC ($) | ATC ($) | VARIATION (%) |
|---|---|---|---|---|
| 540 | 1080.00 | 1333.33 | 2413.33 | 0.56 |
| 550 | 1100.00 | 1309.09 | 2409.09 | 0.38 |
| 560 | 1120.00 | 1285.71 | 2405.71 | 0.24 |
| 570 | 1140.00 | 1263.16 | 2403.16 | 0.13 |
| 580 | 1160.00 | 1241.38 | 2401.38 | 0.06 |
| 590 | 1180.00 | 1220.34 | 2400.34 | 0.01 |
| EOQ = 600 | 1200.00 | 1200.00 | 2400.00* | 0.00 |
| 610 | 1220.00 | 1180.33 | 2400.33 | 0.01 |
| 620 | 1240.00 | 1161.29 | 2401.29 | 0.05 |
| 630 | 1260.00 | 1142.86 | 2402.86 | 0.12 |
| 640 | 1280.00 | 1125.00 | 2405.00 | 0.21 |
| 650 | 1300.00 | 1107.69 | 2407.69 | 0.32 |
| 660 | 1320.00 | 1090.91 | 2410.91 | 0.45 |

* Indicates minimum total cost at the EOQ.

Figure 7.6 shows the movement of physical inventory and the relationships of the EOQ, average inventory, lead time, reorder point and order cycle. Continuing with the use of the data in Example 7.3, at Time 0, the firm is assumed to start with a complete order of 600 units. The inventory is consumed at a steady rate of 20 units per day. On the 24th day, the ROP of 120 is reached and the firm places its first order of 600 units. It arrives 6 days later (on the 30th day). The 120 units of inventory will be totally consumed immediately prior to the arrival of the first order. The vertical line on the 30th day shows that all 600 units are

**Figure 7.6 Physical Inventory with the EOQ Model**



received (this is the instantaneous replenishment assumption of the EOQ model). A total of 12 orders (including the initial 600 units) will be placed during the year to satisfy the annual requirement of 7,200 units.

## The Quantity Discount Model

The **quantity discount model** or **price-break model** is one variation of the classic EOQ model. It relaxes the constant unit price assumption by allowing purchase quantity discounts. In this case, the unit price of an item is allowed to vary with the order size. For example, a supplier may offer a price of $5 per unit for orders up to 200 units, $4.50 per unit for orders between 201 and 500 units, and $4 per unit for orders of more than 500 units. This creates an incentive for the buyer to purchase in larger quantities to take advantage of the quantity discount, provided the savings is greater than the extra cost of holding larger inventory levels. Unlike the EOQ model, the annual purchase cost now becomes an important factor in determining the optimal order size and the corresponding total annual inventory cost. The quantity discount model must consider the trade-off between purchasing in larger quantities to take advantage of the price discount (while also reducing the number of orders required per year) and the higher costs of holding inventory. With the quantity discount model, there are thus two variables in the TAIC equation (the purchase price, $C$, and the order quantity, $Q$). Hence a new approach is needed to find the optimal order quantity.

The purchase price per unit, $C$, is no longer fixed, as assumed in the classical EOQ model derivations. Consequently, the total annual inventory cost must now include the annual purchase cost, which varies depending on the order quantity. The new total annual inventory cost formula can now be stated as:

$$\text{Total annual inventory cost} = \text{Annual purchase cost} + \text{Annual holding cost} + \text{Annual order cost},$$

or

$$\text{TAIC} = \text{APC} + \text{AHC} + \text{AOC} = (R \times C) + [(Q/2) \times (k \times C)] + [(R/Q) \times S]$$

The quantity discount model yields a total annual inventory cost curve for each price level; hence, no single curve is relevant to all purchase quantities. The relevant total annual inventory cost curve is a combination of the cost curves for each price level, starting with the top curve where the price is the highest, and dropping down curve by curve at the price break point. A **price break point** is the minimum quantity required to get a price discount. There is an EOQ associated with each price level, however the EOQ may not be *feasible* at that particular price level because the order quantity may not lie in the given quantity range for that unit price. Due to the stepwise shape of the total inventory cost curve, the optimal order quantity lies at either a *feasible EOQ* or at a *price break point*.

A fairly straightforward two-step procedure can be used to solve the quantity discount problem. Briefly, the two steps can be stated as follows:

1. Starting with the lowest purchase price, compute the EOQ for each price level until a feasible EOQ is found. If the feasible EOQ found is for the lowest purchase price, this is the optimal order quantity. The reason is that the EOQ for the lowest price level is the lowest point on the total annual inventory cost curve (see Figure 7.7). If the feasible EOQ is not associated with the lowest price level, proceed to step 2.
2. Compute the total annual inventory cost for the feasible EOQ found in step 1, and for all the price break points at each *lower* price level. Price break points *above* the feasible EOQ will result in higher total annual inventory cost, thus need not be evaluated. The order quantity that yields the lowest total annual inventory cost is the optimal order quantity.

Examples 7.4 and 7.5 illustrate the quantity discount model.

### Example 7.4 Finding the Optimal Order Quantity with Quantity Discounts at the Kuantan Corporation

The Kuantan Corporation purchases a component from a supplier who offers quantity discounts to encourage larger order quantities. The supply chain manager of the company, Dr. Hadiyan Wijaya Ibrahim, wants to determine the optimal order quantity to ensure the total annual inventory cost is minimized. The company's annual demand forecast for the item is 7,290 units, the order cost is $20 per order, and the annual holding rate is 25 percent. The price schedule for the item is:

| ORDER QUANTITY | PRICE PER UNIT |
|---|---|
| 1–200 | $5.00 |
| 201–500 | $4.50 |
| 501 and above | $4.00 |

The two questions of interest here are: 1) what is the optimal order quantity that will minimize the total annual inventory cost for this component? And 2) what is the minimum total annual inventory cost?

**Solution:**

**Step 1:** Find the first feasible EOQ starting with the lowest price level:

$$EOQ_{C=\$4.00} = \sqrt{\frac{2 \times 7290 \text{ units} \times \$20}{0.25 \times \$4}} = 540 \text{ units}$$

This is a *feasible* EOQ because order size of 540 units falls within the order quantity range for the price level of $4.00 per unit. Thus, 540 units is the optimal order quantity. In this case, the optimal order size falls on a feasible EOQ.

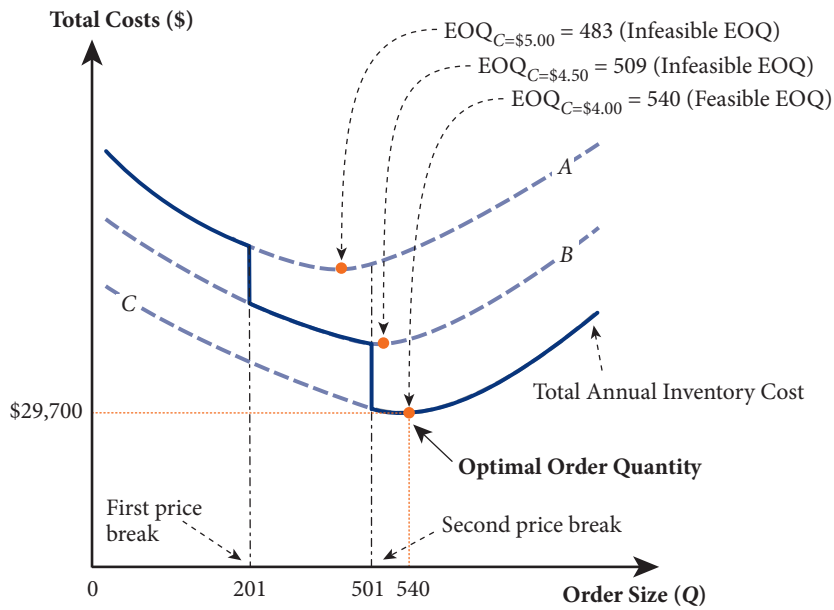
**Step 2:** The minimum total annual inventory cost is then:

$$\begin{aligned} TAIC &= APC + AHC + AOC = (R \times C) + (Q/2 \times k \times C) + (R/Q \times S) \\ &= (7290 \times \$4) + (540/2 \times 0.25 \times \$4) + (7290/540 \times \$20) \\ &= \$29{,}160 + \$270 + \$270 = \$29{,}700 \end{aligned}$$

The annual holding cost equals the annual order cost because the optimal order quantity falls on an EOQ.

Cost curves A, B, and C in Figure 7.7 are the annual inventory costs at price levels of $5, $4.50, and $4 respectively. Since each cost curve is only applicable for its price range, the relevant total annual inventory cost is the combination of these three cost curves where the total cost drops vertically at each price break point, curve by curve, to the next lower cost curve. Figure 7.7 shows that the feasible EOQ for the lowest price level is the lowest point on the total annual inventory cost curve; thus, it is the optimal order quantity. The two infeasible EOQs for the price levels of $4.50 and $5 are also shown in Figure 7.7 to reiterate that if an EOQ falls outside of its price range, it is irrelevant to the total annual inventory cost.

**Figure 7.7** Total Annual Inventory Cost Where the EOQ at the Lowest Price Level Is the Optimal Order Quantity




*Note:* The TAIC of $29,700 corresponds to the EOQ of 540, not the price break quantity of 501.

### Example 7.5 Finding the Optimal Order Quantity with Quantity Discounts at the Soon Corporation

The Soon Corporation is a multinational company that purchases one of its crucial components from a supplier who offers quantity discounts to encourage larger order quantities. The supply chain manager of the company, Dr. Mohd Rizaimy Shaharudin, wants to determine the optimal order quantity to minimize the total annual inventory cost. The company's annual demand forecast for the item is 1,000 units, its order cost is $20 per order, and its annual holding rate is 25 percent. The price schedule is:

| ORDER QUANTITY | PRICE PER UNIT |
|---|---|
| 1–200 | $5.00 |
| 201–500 | $4.50 |
| 501 and above | $4.00 |

The first price break point is 201 units and the second is 501 units. What is the optimal order quantity that will minimize the total annual inventory cost for this component and what is the total annual inventory cost?

**Solution:**

**Step 1:** Find the first feasible EOQ starting with the lowest price level of $4.00:

A. $EOQ_{C=\$4.00} = \sqrt{\frac{2 \times 1000 \text{ units} \times \$20}{0.25 \times \$4}} = 200 \text{ units}$

B. This quantity is *infeasible* because an order quantity of 200 units does not fall within the required order quantity range to qualify for the $4 price level (the unit price for an order quantity of 200 units is $5). Next, we evaluate the EOQ at the next higher price level of $4.50:

C. $EOQ_{C=\$4.50} = \sqrt{\frac{2 \times 1000 \text{ units} \times \$20}{0.25 \times \$4.50}} = 189 \text{ units}$

D. This quantity is also *infeasible* because it fails to qualify for the $4.50 price level. Moving on to the next higher price level of $5:

E. $EOQ_{C=\$5.00} = \sqrt{\frac{2 \times 1000 \text{ units} \times \$20}{0.25 \times \$5}} = 179 \text{ units}$

This order quantity is the *first feasible EOQ* because a 179-unit order quantity corresponds to the correct price level of $5 per unit.

**Step 2:** Find the total annual inventory costs for the first feasible EOQ found in step 1 and for the price break points at each lower price level (201 units at $4.50 and 501 units at $4).

$$TAIC = APC + AHC + AOC = (R \times C) + (Q/2 \times k \times C) + (R/Q \times S)$$

A. $TAIC_{EOQ=179,\ C=\$5} = (1000 \times \$5) = (179/2 \times 0.25 \times \$5) + (1000/179 \times \$20)$
$= \$5000 + \$111.88 + \$111.73 = \$5223.61$

B. $TAIC_{Q=201,\ C=\$4.50} = (1000 \times \$4.50) + (201/2 \times 0.25 \times \$4.50) + (1000/201 \times \$20)$
$= \$4500 + \$113.06 + \$99.50 = \$4712.56$

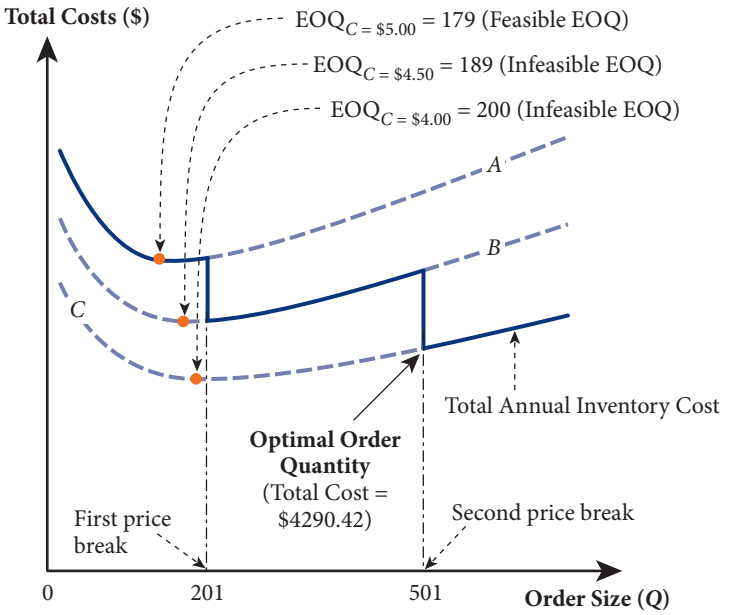
C. $TAIC_{Q=501,\ C=\$4} = (1000 \times \$4) + (501/2 \times 0.25 \times \$4) + (1000/501 \times \$20)$
$= \$4000 + \$250.50 + \$39.92 = \$4290.42$

Comparing the total annual inventory costs in A, B, and C, the optimal order quantity is 501 units, which qualifies for the deepest discount. In this case, the optimal order size falls on a *price break point*; hence, the annual holding cost ($250.50) does not equal the annual order cost ($39.92). When the quantity discount is large compared to the holding cost, it makes sense to purchase in large quantities and hold more inventory. However, this ignores the fact that excessive inventory hides production problems and can become obsolete very quickly. In the attempt to find the optimal order quantity to minimize inventory cost, a manager should also consider the impact of excessive inventory on firm performance. Figure 7.8 demonstrates the characteristics of the cost curves for this example. Cost curves A, B, and C are the annual inventory costs at price levels of $5, $4.50, and $4 respectively. The relevant total annual inventory cost is derived from these three cost curves by joining the relevant portion of each cost curve vertically at the price break points.

## The Economic Manufacturing Quantity Model

The **Economic Manufacturing Quantity** (**EMQ**) or **Production Order Quantity** (**POQ**) **model** is another variation of the classic EOQ model. It relaxes the *instantaneous replenishment* assumption by allowing usage or partial delivery during production. The EMQ model is especially appropriate for a manufacturing environment where items are

**Figure 7.8** Total Annual Inventory Cost Where the Optimal Order Quantity Is at the Price Break Point

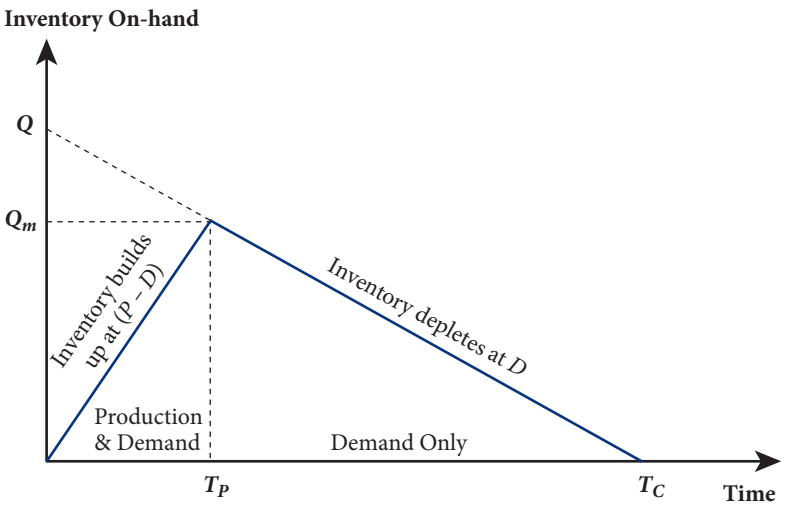



being manufactured and consumed simultaneously; hence the name economic manufacturing quantity. Inventory builds up gradually during the production period rather than all at once as in the EOQ model.

For instance, let us assume that the production lot size for a manufactured product is 600 units, the manufacturer's production rate is 100 units per day, and its demand is 40 units per day. The manufacturer thus needs six days (600/100) to produce a batch of 600 units. While being produced, the items are also consumed simultaneously; hence inventory builds up at the rate of 60 units (100−40) per day for six days. The maximum inventory is 360 units (60 × 6 days), which is less than the lot size of 600 units as would have been in the case of the classic EOQ model. The lower inventory level implies that the holding cost of the EMQ model is less than the EOQ model given the same cost parameters. It is also clear that the production rate must be greater than the demand rate; otherwise, there would not be any inventory buildups. On the seventh day, the production of the first batch stops and the inventory starts to deplete at the demand rate of 40 units for the next 9 days (360/40). The first production lot and the subsequent usage of the inventory take 15 days (6 + 9) to complete, and then the second cycle repeats.

Figure 7.9 depicts the inventory versus time for the EMQ model. The item is produced in lot sizes of $Q$, at the production rate of $P$, and consumed at the demand rate of $D$. Hence, inventory builds up at the rate of $(P-D)$ during the production period, $T_P$. At the end of the production period ($T_P$), inventory begins to deplete at the demand rate of $D$ until it is exhausted at the end of the inventory cycle, $T_C$.

**Figure 7.9** Physical Inventory with the Economic Manufacturing Quantity Model




The production rate, $P$, which can be expressed as $Q/T_P$, is the production lot size divided by the time required to produce the lot. The maximum inventory, $Q_M$, can be obtained by multiplying the inventory build-up rate with the production period, and can be expressed as $(P - D) \times T_P$. These relationships can be stated as:

$$P = \frac{Q}{T_p} \quad \text{and} \quad Q_M = (P - D) \times T_P$$

Therefore, $T_P = \frac{Q}{P}$ and substituting $\frac{Q}{P}$ for $T_P$ in $Q_M$ gives,

$$\begin{aligned} Q_M &= (P - D) \times \frac{Q}{P} \\ &= \frac{PQ}{P} - \frac{DQ}{P} \\ &= Q\left(1 - \frac{D}{P}\right) \end{aligned}$$

Hence, the average inventory, $\frac{Q_M}{2} = \frac{Q}{2}\left(1 - \frac{D}{P}\right)$.

The total annual inventory cost can be stated as:

Total annual inventory cost = Annual product cost + Annual holding cost + Annual setup cost,

or

$$\text{TAIC} = \text{APC} + \text{AHC} + \text{ASC} = [R \times C] + \left[\left(\frac{Q}{2}\left(1 - \frac{D}{P}\right)\right) \times k \times C\right] + [R/Q \times S]$$

where:

TAIC = total annual inventory cost
APC = annual product cost
AHC = annual holding cost

ASC = annual setup cost
$R$ = annual requirement or demand
$C$ = total cost of one unit of the finished product
$S$ = cost of setting up the equipment to process one batch of the product
$k$ = holding rate, where annual holding cost per unit = $k \times C$
$Q$ = order quantity.

Like the EOQ model where $Q$ is the only unknown variable in the TAIC equation, the optimum $Q$ (the EMQ) can be obtained by taking the first derivative of TAIC with respect to $Q$ and then setting it equal to zero. A second derivative of TAIC can also be taken with respect to $Q$ to prove that the TAIC is a concave function, and thus $\frac{d\text{TAIC}}{dQ} = 0$ is at the lowest point of the cost curve. Thus:

$$\frac{d\text{TAIC}}{dQ} = 0 + \left[ \tfrac{1}{2}\left(1 - \frac{D}{P}\right) \times k \times C \right] + \left[ -1 \times R \times S \times 1/Q^2 \right]$$

$$= \left[ \frac{kC}{2}\left(1 - \frac{D}{P}\right) \right] - \frac{RS}{Q^2}$$

Then setting $\frac{d\text{TAIC}}{dQ}$ equal to zero and solving for the *EMQ*,

$$\left[ \frac{kC}{2}\left(1 - \frac{D}{P}\right) \right] - \frac{RS}{Q^2} = 0$$

$$\Rightarrow \left[ \frac{kC}{2}\left(1 - \frac{D}{P}\right) \right] = \frac{RS}{Q^2}$$

$$\Rightarrow Q^2 = \frac{2RS}{kC\left(1 - \frac{D}{P}\right)} = \frac{2RS}{kC\left(\frac{P-D}{P}\right)} = \frac{2RS}{kC}\left(\frac{P}{P-D}\right)$$

And the $EMQ = \sqrt{\left(\frac{2RS}{kC}\right)\left(\frac{P}{P - D}\right)}$

The second derivative of the TAIC is

$$\frac{d^2\text{TAIC}}{dQ^2} = 0 - \left( -2 \times \frac{RS}{Q^3} \right) = \left( \frac{2RS}{Q^3} \right) \geq 0,$$

implying that the TAIC is at its minimum when $\frac{d\text{TAIC}}{dQ} = 0$.

Similar to the EOQ model, the annual product cost drops off after the first derivative is taken, indicating that product cost does not affect the order decision if the unit cost of each product produced is constant; thus, the annual product cost is also ignored in the EMQ model. Example 7.6 provides an illustration of calculating the EMQ for a manufacturing company.

### Example 7.6 Calculating the EMQ at the Lone Wild Boar Corporation

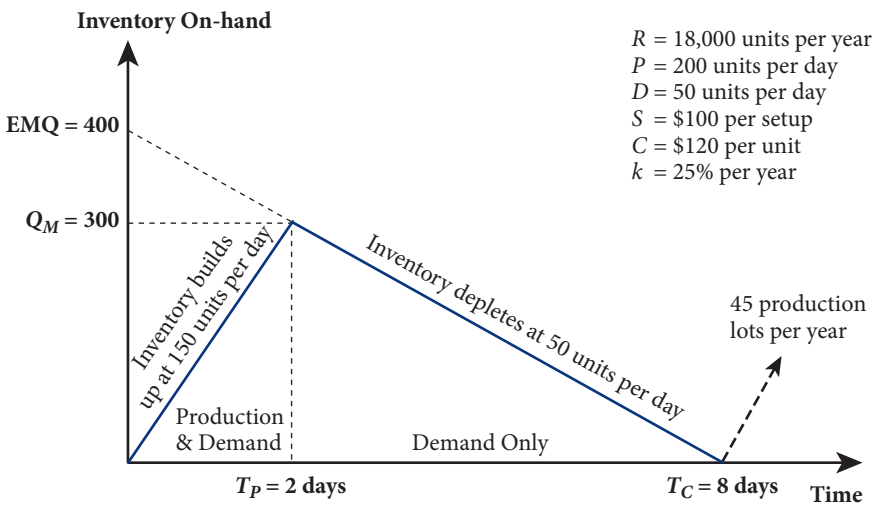
The Lone Wild Boar Corporation manufactures a crucial component internally using the most advanced technology. The operations manager wants to determine the economic manufacturing quantity to ensure that the total annual inventory cost is minimized. The daily production rate ($P$) for the component is 200 units, annual demand ($R$) is 18,000 units, setup cost ($S$) is \$100 per setup, and the annual holding rate ($k$) is 25 percent. The manager estimates that the total cost ($C$) of a finished component is \$120. It is assumed that the plant operates year-round and there are 360 days per year.

**Solution:**

1. The daily demand rate, $D = 18{,}000/360 = 50$ units per day.
2. $EMQ = \sqrt{\left(\frac{2RS}{kC}\right)\left(\frac{P}{P-D}\right)} = \sqrt{\left(\frac{2 \times 18{,}000 \times 100}{0.25 \times 120}\right)\left(\frac{200}{200-50}\right)} = 400$ units.
3. The highest inventory level, $Q_M = Q\left(1-\frac{D}{P}\right) = 400\left(1-\frac{50}{200}\right) = 300$ units.
4. The annual product cost $= R \times C = 18{,}000$ units $\times$ \$120 = \$2,160,000.
5. The annual holding cost $\frac{Q_M}{2} \times k \times C = \frac{300}{2} \times 0.25 \times \$120 = \$4500$.
6. The annual setup cost $= R/Q \times S = (18{,}000/400) \times \$100 = \$4500$.
   (Note that at the EMQ, the annual holding cost equals the annual setup cost.)
7. The TAIC = \$2,160,000 + \$4500 + \$4500 = \$2,169,000.
8. The length of a production period, $T_P = \frac{EMQ}{P} = 400/200 = 2$ days.
9. The length of each inventory cycle, $T_C = \frac{EMQ}{D} = 400/50 = 8$ days.
10. The rate of inventory buildup during production, $(P - D) = 200 - 50 = 150$ units per day.
11. The number of inventory cycles per year = 360 days/8 days = 45 cycles.

Figure 7.10 illustrates the EMQ model for this example. A unique observation regarding the classic EOQ, quantity discount, and the EMQ models is that when ordering at the EOQ or EMQ, the annual order or setup cost equals the annual holding cost, except in the quantity discount model when the optimal order quantity falls on a price break point.

**Figure 7.10** Lone Wild Boar Corporation's EMQ Model



## The Statistical Reorder Point

The two major inventory management decisions are to determine 1) the right order quantity or lot size and 2) when to release an order. Three basic independent demand lot-sizing techniques have been discussed, but as of yet, the question of when to order has not been fully discussed. The **reorder point** (ROP) is the lowest inventory level at which a new order must be placed to avoid a stockout. In a deterministic setting where both the demand and delivery lead time are known and constant, Example 7.3 showed that the reorder point was equal to the demand during the order's delivery lead time. In reality, the demand and delivery lead time tend to vary. Uncertain demand or lead time raises the possibility of stockouts, thus requiring *safety stock* to be held to safeguard against variations in demand or lead time. Next, we discuss how the probabilistic demand pattern and lead time affect the ROP.

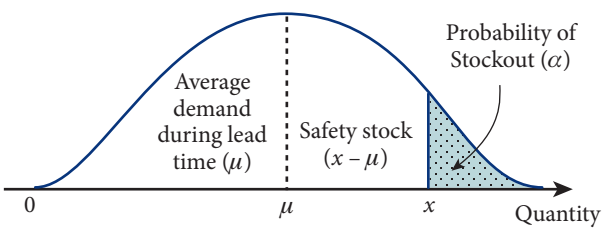
### The Statistical Reorder Point with Probabilistic Demand and Constant Lead Time

This model assumes the lead time of a product is constant while the demand during the delivery lead time is unknown but can be specified using a normal distribution. Since the statistical reorder point is to determine the lowest inventory level at which a new order should be placed, demand prior to a purchase order does not directly affect the ROP. Figure 7.11 illustrates the relationship between safety stock and the probability of a stockout. If the average demand during the lead time is represented by $\mu$, and the ROP is represented by $x$, then the safety stock is $(x - \mu)$, which can be derived from the standard deviation formula $\left(Z = \frac{x - \mu}{\sigma}\right)$. Then, if the probability of stockout is represented by $\alpha$, the probability that inventory is sufficient to cover demand or the *in-stock probability* is $(1 - \alpha)$. The in-stock probability is commonly referred to as the **service level** (actually, the calculation of the true service level requires use of a loss function for a stockout, which is beyond the scope of this text). Next, the $Z$-value can be determined from the standardized normal curve and a desire to achieve a specific service level (see the $Z$-table in the Appendix). For example, a 97.5 percent service level ($\alpha = 2.5\%$) corresponds to the $Z$-value of 1.96. Note that at the middle of the normal curve, where the reorder point equals the average demand, the required safety stock is zero and the probability of stockout would be 50 percent.

The statistical reorder point ($x$) can be calculated as the average demand during the order's delivery lead time plus the desired safety stock, or:

$$\text{ROP} = \bar{d}_{\text{LT}} + Z\sigma_{\text{dLT}}$$

**Figure 7.11** The Relationship of Safety Stock to the Probability of a Stockout



**Example 7.7 Calculating the Statistical Reorder Point Using Probabilistic Demand and Constant Delivery Lead Times at London, Inc.**

London, Inc., stocks a crucial part that has a normally distributed demand pattern during the reorder period. Past demand shows that the average demand during lead time ($\mu$) for the part is 550 units, and the standard deviation of demand during lead time ($\sigma_{dLT}$) is 40 units. The supply chain manager wants to determine the safety stock and statistical reorder point that result in 5 percent stockouts or a service level of 95 percent. Alternately, the manager wants to know the additional safety stock required to attain a 99 percent service level.

**Solution:**

The normal distribution Z-table in Appendix 1 shows that a 95 percent service level (5 percent stockouts allowed) corresponds to a *Z*-value of 1.65 standard deviations above the mean.
The required safety stock is

$$(x-\mu) = Z\sigma_{dLT} = 1.65 \times 40 = 66 \text{ units.}$$

The ROP $= \bar{d}_{LT} + Z\sigma_{dLT} = 550 + 66$ units $= 616$ units. This means the manager must reorder the part from their supplier when their current stock level reaches 616 units.

Alternately, the required safety stock at a 99 percent service level $= Z\sigma_{dLT} = 2.33 \times 40 = 93$ units. The additional safety stock compared to the 95 percent service level is 27 units.

The safety stock $Z\sigma_{dLT}$ or $(x - \mu)$ can be derived from the standard deviation formula of the normal curve as shown earlier, and $\sigma_{dLT}$ is the standard deviation of demand during the delivery lead time period. Example 7.7 illustrates the calculation of the ROP with probabilistic demand and constant delivery lead time.

The safety stock computation as shown in Example 7.7 needs to be modified if the standard deviation is available for daily demand and not lead time demand. In this situation, if the delivery lead time is greater than one day, the standard deviation of daily demand ($\sigma_d$) must be converted to the standard deviation of lead time demand ($\sigma_{dLT}$). If the daily demand is identically distributed, we can use the statistical premise that the variance of a series of independent occurrences is equal to the sum of the variances. That is, the variance of demand during the lead time equals the sum of the variances of all the identical daily demand that covers the lead time period. This can be expressed as:

$$\sigma_{dLT}^2 = \sigma_d^2 + \sigma_d^2 + \sigma_d^2 + \cdots = \sigma_d^2(LT)$$

where:

$\sigma_{dLT}^2$ = variance of demand during the lead time
$\sigma_d^2$ = variance of the identically and independently distributed daily demand
LT = lead time in days

Thus, the standard deviation of demand during the lead time is $\sigma_{dLT} = \sigma_d\sqrt{LT}$.
Hence, the safety stock and the statistical reorder point can be stated as:

$$\text{Safety stock} = Z\sigma_d\sqrt{LT}$$
$$\text{and ROP} = \bar{d}_{LT} + Z\sigma_d\sqrt{LT}.$$

Example 7.8 illustrates this calculation.

## The Statistical Reorder Point with Constant Demand and Probabilistic Lead Time

When the demand of a product is constant and the lead time is unknown but can be specified by means of a normal distribution, the safety stock is used to buffer against variations

### Example 7.8 Calculating the Statistical Reorder Point at Brussels, Inc., Using the Standard Deviation of Daily Demand and Constant Delivery Lead Times

Brussels, Inc., is a local liquor retailer specializing in selling beer at big discounts. Historical data shows that the demand for beer has a normal distribution. The average daily demand for beer at Brussels is 150 cases, and its standard deviation for daily demand is 30 cases. Brussels' supplier maintains a very reliable and constant lead time of six days. The manager desires to determine the standard deviation of demand during lead time, the safety stock and statistical reorder point that results in a 97.5 percent service level and the safety stock reduction if the manager decides to attain a 90 percent service level.

**Solution:**

Average daily demand, $\bar{d} = 150$ cases

Standard deviation of daily demand, $\sigma_d = 30$ cases

Lead time, LT = 6 days

$$\text{The standard deviation of demand during lead time, } \sigma_{dLT} = \sigma_d \sqrt{\text{LT}}$$
$$= 30\sqrt{6} \text{ cases} = 73.5 \text{ cases}$$

The $Z$-table shows that a 97.5 percent service level (2.5 percent stockouts allowed) corresponds to the $Z$-value of 1.96 standard deviations above the mean.

The corresponding safety stock, $Z\sigma_d\sqrt{\text{LT}} = 1.96 \times 30\sqrt{6} = 144$ cases.

The ROP $= \bar{d}_{\text{LT}} + Z\sigma_d\sqrt{\text{LT}} = (150 \times 6) + 144 = 1044$ cases. Thus, ordering more beer when they have a current inventory of 1044 cases will result in a 97.5 percent service level.

For the lower service level of 90 percent, safety stock $= Z\sigma_d\sqrt{\text{LT}} = 1.28 \times 30\sqrt{6} = 94$ cases. The safety stock reduction would be 50 cases.

in the lead time instead of demand. The safety stock is then (daily demand $\times Z\sigma_{\text{LT}}$), and the reorder point is:

$$\text{ROP} = (\text{daily demand} \times \text{average lead time in days}) + (\text{daily demand} \times Z\sigma_{\text{LT}})$$

where

$\sigma_{\text{LT}}$ = the standard deviation of lead time in days.

The calculation is demonstrated in Example 7.9.

### Example 7.9 Calculating the Statistical Reorder Point at the Harpert Store Using Constant Demand and Probabilistic Lead Time

The Harpert Store has an exclusive contract with Brussums Electronics to sell their most popular mp4 player. The demand of this mp4 player is very stable at 120 units per day. However, the delivery lead times vary and can be specified by a normal distribution with a mean lead time of eight days and a standard deviation of two days. The supply chain manager at Brussums desires to calculate the safety stock and reorder point for a 95 percent service level (in-stock probability).

**Solution:**

Daily demand ($d$) = 120 units.

Mean lead time ($\overline{\text{LT}}$) = 8 days.

Standard deviation of lead time ($\sigma_{\text{LT}}$) = 2 days.

A service level of 95 percent yields a $Z = 1.65$ from the Z-table.

$$\text{Required safety stock} = d \times Z\sigma_{LT} = 120 \text{ units} \times 1.65 \times 2 = 396 \text{ units.}$$
$$\text{ROP} = (d \times \overline{LT}) + (d \times Z\sigma_{LT}) = (120 \times 8) + 396 = 1356 \text{ units.}$$

Brussums must reorder mp4 players from Harpert when their current inventory reaches 1356 units.

### The Statistical Reorder Point with Probabilistic Demand and Lead Time

When both the demand and lead time of a product are unknown but can be specified by means of a normal distribution, safety stock must be held to cover the variations in both demand and lead time, resulting in higher safety stocks when compared to variations in the demand or lead time only. The reorder point can be computed as follows:[21]

$$\text{ROP} = (\overline{d} \times \overline{LT}) + Z\sigma_{dLT}$$

where:

$\sigma_{dLT}$ = Standard deviation of demand during the lead time
$= \sqrt{\sigma_{LT}^2(\overline{d})^2 + \sigma_{\overline{d}}^2(\overline{LT})}$

and where:

$\sigma_{LT}$ = Standard deviation of lead time days, and
$\sigma_{d}$ = Standard deviation of daily demand.

Note that this standard deviation formula ($\sigma_{dLT}$) can be applied to all the previous reorder point examples by observing the following fact: "constant" or "no variation" means zero standard deviation. Therefore:

1. When the lead time and demand are constant, then $\sigma_{LT}$ and $\sigma_{d}$ are zero, and the average daily demand and average lead time would be the deterministic demand and lead time. Thus, the reorder point is the demand during lead time period.
2. When the daily demand is probabilistic and lead time is constant, then ($\sigma_{LT}$) is zero and the average lead time would be the deterministic lead time. Using this guideline, the reorder point in Example 7.8 can also be computed as:

   $\text{ROP} = (150 \times 6) + 1.96\sqrt{0^2(150)^2 + 30^2(6)} = 900 + 1.96 \times 30\sqrt{6} = 1044$ cases.
3. When the daily demand is constant and the lead time is probabilistic, then $\sigma_{d}$ is zero and the average daily demand would be the deterministic daily demand. Using this guideline, the reorder point in Example 7.9 can also be computed as:

   $\text{ROP} = (120 \times 8) + 1.65\sqrt{2^2(120)^2 + 0^2(8)} = 960 + 1.65 \times 2(120) = 1356$ units.

Example 7.10 demonstrates the safety stock and reorder point computation when both the daily demand and lead time are probabilistic.

## The Continuous Review and the Periodic Review Inventory Systems

The order quantity and reorder point inventory models discussed thus far assume that the physical inventory levels are precisely known at every point in time. This implies that stock movements must be updated in real time, and that there are no discrepancies between physical inventory and the stock record. In other words, a *continuous review* of the physical inventory is required to make sure that orders are initiated when physical inventories reach their reorder points. In practice, a **continuous review system** can be difficult to achieve and very expensive to implement. Inventory review costs can be lowered by using a **periodic review system** instead, where physical inventory is reviewed at regular intervals, such as weekly or monthly. However, more safety stock would be required for the periodic review system to buffer the added variation due to the longer review period.

### Example 7.10 Calculating the Statistical Reorder Point at the Dosseldorf Store Using Probabilistic Demand and Delivery Lead Time

The Dosseldorf Store is the sole distributor of a popular cell phone. The demand of this cell phone is normally distributed with an average daily demand of 120 units and a standard deviation of 18 units per day. The cell phones are ordered and shipped directly from the manufacturer. Past delivery records for the manufacturer show that delivery lead times are normally distributed with an average of 8 days and a standard deviation of two days. The supply chain manager at Dosseldorf desires to determine the safety stock required and the reorder point for a 95 percent service level.

**Solution:**

Average daily demand, $\bar{d} = 120$ units.
Standard deviation of daily demand, $\sigma_d = 18$ units.
Average lead time, $\overline{LT} = 8$ days.
Standard deviation of lead time, $\sigma_{LT} = 2$ days.
A desired service level of 95 percent yields $Z = 1.65$ from the Z-table.

$$\text{The required safety stock} = Z\sigma_{dLT}$$
$$= 1.65 \times \sqrt{\sigma_{LT}^2(\bar{d})^2 + \sigma_d^2(\overline{LT})}$$
$$= 1.65 \times \sqrt{2^2(120)^2 + 18^2(8)} = 1.65 \times 245.34 = 405 \text{ units.}$$

$$\text{The ROP} = (\bar{d} \times \overline{LT}) + Z\sigma_{dLT} = (120 \times 8) + 405 = 1365 \text{ units.}$$

Dosseldorf must reorder cell phones from their supplier when their current stock reaches 1365 units to ensure a 95 percent service level.

When analyzing the continuous review and the periodic review systems, the following symbols are used:

$s$ = order point
$S$ = maximum inventory level
$Q$ = order quantity
$R$ = periodic review, and
$n$ = 1, 2, 3 . . .

## The Continuous Review System

The continuous review system implies that physical inventory is known at all times, so it is more expensive to administer. However, the only uncertainty is the magnitude of demand during the delivery lead time; thus, the only safety stock required is for potential stockouts during this time period. There are two continuous review systems, described below.

1. *(s, Q) continuous review policy*: This policy orders the same quantity, $Q$, when physical inventory reaches the reorder point, $s$. The quantity, $Q$, can be determined by one of the fixed order quantity methods (such as the EOQ). This policy works properly only if the quantity demanded is one unit at a time. Otherwise, the inventory level may fall below the reorder point, $s$.
2. *(s, S) continuous review policy*: When current inventory reaches or falls below the reorder point, $s$, sufficient units are ordered to bring the inventory up to a predetermined level, $S$. If the quantity demanded is one unit at a time, this system is similar to the *(s, Q)* policy. However, if the quantity demand is larger than one unit and when physical inventory falls below the reorder point, then the order size is larger than $Q$. For instance, suppose $s = 10$, $S = 120$, and current inventory is 11 units.

If the next demand is 3 units, then on-hand inventory will be reduced to 8 units. Consequently, an order size of 112 units would be released ($S-8$).

## The Periodic Review System

The periodic review system reviews physical inventory at specific intervals of time. Although this system is cheaper to administer, a higher level of safety stock is needed to buffer against uncertainty in demand over a longer planning horizon. There are three periodic review systems, described below.

1. *(nQ, s, R) periodic review policy*: If at the time of inventory review, the physical inventory is equal to or less than the reorder point, $s$, the quantity, $nQ$, is ordered to bring the inventory up to the level between $s$ and $(s + Q)$. Recall that $n = 1, 2, 3, \ldots$, and the order size is then some multiple of $Q$. No order is placed if the current inventory is higher than the reorder point. For example, let $s = 100$ and $Q = 50$. If the current inventory is 20 units at the time of the review, then $2Q$ quantities ($2 \times 50 = 100$) are ordered to bring the inventory level up to 120 units.
2. *(S, R) periodic review policy*: At each review time, a sufficient quantity is ordered to bring the inventory up to a pre-determined maximum inventory level, $S$. This policy places a variable-sized order as long as the physical inventory is less than the maximum inventory level, $S$. If order cost is high, this is obviously not a preferred system. However, it may work well if a large variety of items are ordered from the same supplier.
3. *(s, S, R) policy:* If at the time of inventory review, the physical inventory is equal to or less than the reorder point, $s$, a sufficient quantity is ordered to bring the inventory level up to the maximum inventory level, $S$. However, if the physical inventory is higher than the reorder point, $s$, no order is placed. This policy addresses the major deficiency of the *(S, R)* policy.

## Summary

Organizations rely on inventory to balance supply and demand, and to buffer uncertainties in the supply chain. However, inventory can be one of the most expensive assets of an organization; hence it must be managed closely. The right amount of inventory supports business operations, but too little of it can adversely affect customer service. Conversely, excess inventory not only leads to unnecessary inventory carrying cost, but hides production problems and other flaws in a company.

This chapter covered the crucial roles of inventory and various inventory management techniques that are widely used for balancing demand with supply. The classic ABC inventory classification was discussed along with the ABC inventory matrix as a means to monitor if a firm is stocking the right inventories. Ample examples were used to demonstrate the order size and order period inventory models. This chapter also covered two of the latest developments in inventory management—RFID and big data. Radio frequency identification certainly has the potential to drastically change the way inventories are managed in the future, and big data analysis allows firms to gain a competitive advantage through better decision-making.

## Key Terms

**80/20 rule,** 280
**ABC inventory control system,** 280
**ABC inventory matrix,** 281
**active RFID tags,** 285
**big data,** 289
**carrying costs,** 277
**continuous review system,** 304
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**quantity discount model,** 294
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**reorder point (ROP),** 301
**service level,** 301
**setup costs,** 277
**variable costs,** 277

## Discussion Questions

1. Describe and provide examples of dependent and independent demand.
2. Describe the four basic types of inventory.
3. What is the ABC inventory system, and how is it used to manage inventory?
4. What is the ABC inventory matrix, and how is it used to manage inventory?
5. Describe inventory turnover and how it can be used to manage inventory.
6. Explain whether it is desirable to have a low or high inventory turnover ratio.
7. Why is it important to conduct cycle counting?

8. What is the electronic product code (EPC)?
9. Briefly describe how RFID can be used to manage inventory.
10. Explain why item-level tagging is more expensive than case-level tagging in RFID.
11. What is big data?
12. How can firms use big data to make better decisions?
13. What is the purpose of the EOQ and the ROP? How can they be used together?
14. What are the assumptions of the EOQ model? Why do you think these assumptions are used for the EOQ model?
15. What are the two major costs considered in the EOQ model? Why is the total purchase price not a factor affecting the order quantity?
16. How is the quantity discount model related to the EOQ model?
17. How is the EMQ model related to the EOQ model?
18. Discuss whether the EOQ model is still useful if a small error was made while estimating one of the cost parameters used in the EOQ computation.
19. Assume that you used the EOQ model to compute the order quantity for an item, and the answer was twenty units. Unfortunately, the minimum lot size for the item is twenty-four units. Discuss how this is going to impact your annual holding cost, annual order cost, and annual total inventory cost.
20. Suppose in an EOM model, the optimum order quantity of an item is 310 units. However, the item is only sold in a lot size of 300 units. Explain what the impacts are on the annual carrying cost, annual ordering cost, and annual total inventory cost.
21. Explain whether the continuous review or periodic review inventory system is likely to result in higher safety stock. Which is likely to require more time and effort to administer? Why?
22. Use the inventory turnover ratios in Table 7.2 to comment on which firm is the most efficient in deploying its inventory to generate sales.
23. What is the order quantity when the annual order or setup cost equals the annual holding cost in the (a) EOQ model, (b) quantity discount model, and (c) EMQ model?
24. Why is inventory management important to SCM?
25. Describe the difference between annual physical inventory count and cycle counting.
26. Describe Near Field Communication (NFC), its relationship with RFID, and its applications.
27. What is omnichannel and how does it affect inventory management?

## Essay/Project Questions

1. Visit the website of GS1 and use the information to write a brief report on RFID technology and the state of RFID implementation.
2. Use the Internet to search for relevant information to prepare a brief report on the state of RFID implementation in North America, Europe, and Asia.

3. Use resources available on the Internet to prepare a report on the RFID implementation at Walmart Stores, Inc.

4. Use resources available on the Internet to prepare a brief report on big data and business analytics.

5. Use resources available on the Internet (e.g., https://finance.yahoo.com/ or http://www.cnbc.com/) to access the annual reports (financial statements and balance sheets) of three of your favorite listed companies to (a) extract their latest total revenue, cost of revenue, total assets, and year-end or average inventory, and use these numbers to (b) prepare their inventory/total revenue ratio, inventory/total assets ratio, and the inventory turnover ratio. Comment on how they performed based on these ratios. (Hint: See Tables 7.1 and 7.2.)

## Computation/Spreadsheet Problems

1. The revenue for a firm is $2,500,000. Its cost of revenue is $850,000, and its average inventory for the year is $62,000. What is the inventory turnover?

2. The revenue for a firm that has incurred an operating loss of $800,000 is $1,350,000. Its cost of revenue is $1,500,000, and its average inventory for the year is $150,000. What is the inventory turnover?

3. Given the following information, what is the annual inventory turnover ratio?

| | |
|---|---|
| Revenue | $2,2000,000 |
| Cost of Revenue | $1,250,000 |
| Quarter 1 Ending Inventory | $85,000 |
| Quarter 2 Ending Inventory | $98,000 |
| Quarter 3 Ending Inventory | $125,000 |
| Quarter 4 Ending Inventory | $68,000 |

4. Given the following information, compute the economic order quantity, annual holding cost, annual order cost, and total annual inventory cost.

| | |
|---|---|
| Annual requirements ($R$) | = 50,000 units |
| Order cost ($S$) | = $150 per order |
| Holding rate ($k$) | = 15% |
| Unit cost ($C$) | = $100 per unit |

5. The annual requirement of a part is 360,000 units. The order cost is $120 per order, the holding rate is 12 percent and the part cost is $2,500 per unit. What are the (a) EOQ, (b) annual holding cost, (c) annual order cost, and (d) total annual inventory cost?

6. In Question 5 above, if the company decided to order at a lot size of 2,500 units instead of the EOQ quantity, what are the (a) annual holding cost, (b) annual order cost, and (c) total annual inventory cost? What can you conclude about these costs compared to ordering the EOQ quantity?

7. In Question 5 above, if the company decided to order at a lot size of 2,800 units instead of the EOQ quantity, what are the (a) annual holding cost, (b) annual order cost, and (c) total annual inventory cost? What can you conclude about these costs compared to ordering the EOQ quantity?

8. The weekly requirement of a part is 950 units. The order cost is $85 per order, the holding cost is $5 per unit per year, and the part cost is $250 per unit. The firm operates fifty-two weeks per year. Compute the (a) EOQ, (b) annual holding cost, (c) annual order cost, and (d) total annual inventory cost.

9. In Question 8 above, if the company decided to order at a lot size of 1000 units instead of the EOQ quantity, what are the (a) annual holding cost, (b) annual order cost, and (c) total annual inventory cost? What can you conclude about these costs compared to ordering the EOQ quantity?

10. In Question 8 above, if the company decided to order at a lot size of 1400 units instead of the EOQ quantity, what are the (a) annual holding cost, (b) annual order cost, and (c) total annual inventory cost? What can you conclude about these costs compared to ordering the EOQ quantity?

11. The monthly demand for a part is 1500 units. The order cost is $285 per order, the holding cost is $56 per unit per year, and the part cost is $850 per unit. The firm operates twelve months per year. Compute the (a) EOQ, (b) annual holding cost, (c) annual order cost, and (d) total annual inventory cost.

12. Icy Snowmobile, Inc., has an annual demand of 1200 snowmobiles. Their purchase cost for each snowmobile is $2500. It costs about $250 to place an order, and the holding rate is 35 percent of the unit cost. Compute the (a) EOQ, (b) annual holding cost, (c) annual order cost, and (d) total annual inventory cost.

13. In Question 12 above, if the company decided to order at a lot size of 24 units instead of the EOQ quantity, what are the (a) annual holding cost, (b) annual order cost, and (c) total annual inventory cost? When compared to ordering the EOQ quantity, what is the percent difference of each cost?

14. In Question 12 above, if the company decided to order at a lot size of 30 units instead of the EOQ quantity, what are the (a) annual holding cost, (b) annual order cost, and (c) total annual inventory cost? When compared to ordering the EOQ quantity, what is the percent difference of each cost?

15. Steamy Speedboats has an annual demand for 1500 speedboats. Its supplier offers quantity discounts to promote larger order quantities. The cost to place an order is $300, and the holding rate is 32 percent of the purchase cost. The purchase cost for each speedboat is based on the price schedule given below. Compute the (a) optimal order quantity, (b) annual purchase cost, (c) annual holding cost, (d) annual order cost, and (e) total annual inventory cost.

| ORDER QUANTITY | PRICE PER UNIT |
|---|---|
| 1–50 | $18,500 |
| 51–100 | $18,000 |
| 101–150 | $17,400 |
| 151 and above | $16,800 |

16. Using the Steamy Speedboats problem above, assume that the order cost has dropped from $300 to $50. What are the (a) optimal order quantity, (b) annual purchase cost, (c) annual holding cost, (d) annual order cost, and (e) total annual inventory cost?

17. Using the Steamy Speedboats problem above, assume that the holding rate has dropped from 32 percent to 15 percent. What are the (a) optimal order quantity, (b) annual purchase cost, (c) annual holding cost, (d) annual order cost, and (e) total annual inventory cost?

18. Frankfurt Electronics produces a component internally using a state-of-the-art technology. The operations manager wants to determine the optimal lot size to ensure that the total annual inventory cost is minimized. The daily production rate for the component is 500 units, annual demand is 36,000 units, setup cost is $150 per setup, and the annual holding rate is 30 percent. The manager estimates that the total cost of a

finished component is $80. If we assume that the plant operates year-round, and there are 360 days per year, what are the (a) daily demand, (b) optimal lot size, (c) highest inventory, (d) annual product cost, (e) annual holding cost, (f) annual setup cost, (g) total annual inventory cost, (h) length of a production period, (i) length of each inventory cycle, (j) rate of inventory buildup during the production cycle, and (k) the number of inventory cycles per year? Plot the movement of the inventory during one production cycle using time on the horizontal axis and on-hand inventory on the vertical axis (see Figure 7.10).

**19.** A manufacturing firm produces a product in its factory. The operations manager wants to determine the EMQ to ensure that the total annual inventory cost is minimized. The daily production rate for the product is 120 units, annual demand is 14,400 units, setup cost is $400 per setup, and the annual holding rate is 20 percent. The cost of the product is $95. If we assume that the plant operates year-round, and there are 360 days per year, what are the (a) daily demand, (b) EMQ, (c) highest inventory, (d) annual product cost, (e) annual holding cost, (f) annual setup cost, (g) total annual inventory cost, (h) length of a production period, (i) length of each inventory cycle, (j) rate of inventory buildup during the production cycle, and (k) the number of inventory cycles per year?

**20.** Paris Store stocks a part that has a normal distribution demand pattern during the reorder period. Its average demand during lead time is 650 units, and the standard deviation of demand during lead time is 60 units. What are the safety stock and statistical reorder point that result in a 97.5 percent service level?

**21.** Lindner Congress Bookstore sells a unique calculator to college students. The demand for this calculator has a normal distribution with an average daily demand of fifteen units and a standard deviation of four units per day. The lead time for this calculator is very stable at five days. Compute the standard deviation of demand during lead time, and determine the safety stock and statistical reorder point that result in 5 percent stockouts.

**22.** The daily demand of a product is very stable at 250 units per day. However, its delivery lead time varies and can be specified by a normal distribution with a mean lead time of twelve days and standard deviation of three days. What are the safety stock and reorder point for a 97.5 percent service level?

**23.** The daily demand of a product can be specified by a normal distribution. Its average daily demand is 250 units with a standard deviation of 40 units. The delivery lead time of this product is also normally distributed with an average of ten days and a standard deviation of three days. What are the safety stock and reorder point for a 95 percent service level?

**24.** Given the following inventory information, perform an ABC analysis.

| ITEM NUMBER | UNIT COST ($) | ANNUAL USAGE |
|---|---|---|
| B8867 | 6.00 | 100 |
| J1252 | 5.25 | 6500 |
| K9667 | 0.25 | 4000 |
| L2425 | 1.00 | 1500 |
| M4554 | 5.50 | 2000 |
| T6334 | 70.00 | 500 |
| W9856 | 0.75 | 800 |
| X2215 | 1.50 | 8000 |
| Y3214 | 32.00 | 1000 |
| Y6339 | 4.00 | 3500 |

**25.** Given the following inventory information, construct an (a) ABC analysis by annual dollar usage, (b) ABC analysis by current inventory value, and (c) an ABC inventory matrix. Is the firm stocking the correct inventories?

| ITEM NUMBER | UNIT COST ($) | ANNUAL USAGE (UNITS) | CURRENT INVENTORY (UNITS) |
|---|---|---|---|
| B8867 | 6.00 | 100 | 8000 |
| J1252 | 5.25 | 6500 | 120 |
| K9667 | 0.25 | 4000 | 1000 |
| L2425 | 1.00 | 1500 | 375 |
| M4554 | 5.50 | 2000 | 500 |
| T6334 | 70.00 | 500 | 800 |
| W9856 | 0.75 | 800 | 20,000 |
| X2215 | 1.50 | 8000 | 2000 |
| Y3214 | 32.00 | 1000 | 500 |
| Y6339 | 4.00 | 3500 | 125 |

**26.** Given the following inventory information, construct an (a) ABC analysis by annual dollar usage, (b) ABC analysis by current inventory value, and (c) an ABC inventory matrix. Is the firm stocking the correct inventories?

| ITEM NUMBER | UNIT COST ($) | ANNUAL USAGE (UNITS) | CURRENT INVENTORY (UNITS) |
|---|---|---|---|
| A967 | 32.00 | 1 | 4500 |
| B886 | 6.00 | 100 | 8000 |
| C314 | 5.25 | 32 | 115 |
| D879 | 12.50 | 54 | 254 |
| E536 | 0.05 | 125 | 120 |
| F876 | 0.07 | 423 | 500 |
| G112 | 0.12 | 500 | 1008 |
| H098 | 1.22 | 235 | 750 |
| J125 | 5.25 | 6500 | 120 |
| K966 | 0.25 | 4000 | 1000 |
| L242 | 1.00 | 1500 | 375 |
| M455 | 5.50 | 2000 | 500 |
| N007 | 7.21 | 54 | 525 |
| P231 | 5.25 | 32 | 300 |
| Q954 | 3.25 | 25 | 240 |
| T633 | 70.00 | 500 | 800 |
| W985 | 0.75 | 800 | 20,000 |
| X221 | 1.50 | 8000 | 2000 |
| Y321 | 32.00 | 1000 | 500 |
| Z633 | 4.00 | 3500 | 125 |

**27.** Given the following information for an important purchased part, compute the (a) EOQ, (b) total purchase cost, (c) annual holding cost, (d) annual order cost, (e) annual total cost, (f) reorder point, (g) number of orders placed per year, and

(h) time between orders. Use Microsoft Excel to plot the cost curves (annual holding cost, annual order cost, and total annual cost) on the vertical axis, and the order quantity on the horizontal axis.

| | |
|---|---|
| Annual requirements (*R*) | = 5000 units |
| Order cost (*S*) | = $100 per order |
| Holding rate (*k*) | = 20% |
| Unit cost (*C*) | = $20 per unit |
| Lead time (*LT*) | = 6 days |
| Number of days per year | = 360 days |

**28.** Given the following information for a purchased part, compute the (a) EOQ, (b) total purchase cost, (c) annual holding cost, (d) annual order cost, (e) total annual cost, (f) reorder point, (g) number of orders placed per year, and (h) time between orders. Use Microsoft Excel to plot the cost curves (annual holding cost, annual order cost, and total annual inventory cost) on the vertical axis, and the order quantity on the horizontal axis.

| | |
|---|---|
| Monthly demand | = 3500 units |
| Order cost (*S*) | = $250 per order |
| Holding cost (*kC*) | = $8.65 per unit per year |
| Unit cost (*C*) | = $85 per unit |
| Lead time (*LT*) | = 12 days |
| Number of days per year | = 365 days |

**29.** Kopi Luwak produces the world's most expensive coffee by using coffee beans that have been digested by a wild civet cat. The coffee beans, widely known as "cat poop coffee" can be packaged in one pound bags at a daily production rate of 700 bags. The coffees are shipped to retailers at a constant rate of 120 bags every day of the year. Due to the scarcity of partly-digested coffee beans from civet cat feces, the senior operations manager, Dr. Hadiyan Wijaya Ibrahim, uses the economic manufacturing quantity (EMQ) to produce the coffee. The setup cost is $250 per setup, and the annual holding rate is 25 percent. The manager estimates that the total cost of a bag of coffee is $85. If we assume that there are 360 days per year, what are the (a) annual demand, (b) EMQ, (c) highest inventory, (d) annual product cost, (e) annual holding cost, (f) annual setup cost, (g) total annual inventory cost, (h) length of a production period, (i) length of each inventory cycle, (j) rate of inventory buildup during the production cycle, and (k) the number of inventory cycles per year? Plot the movement of the inventory during one production cycle using time on the horizontal axis and on-hand inventory on the vertical axis (see Figure 7.10).

**30.** Given the following information for a part manufactured in-house, can you compute the economic manufacturing quantity? Provide a brief explanation to support your answer.

| | |
|---|---|
| Annual demand | = 500,000 units |
| Daily production rate | = 1000 units |
| Setup cost | = $250 per order |
| Holding rate | = 40 percent per year |
| Value of finished part | = $120 per unit |
| Number of days per year | = 360 days |

# Cases

## 1. Sharp's Sandwich Shop—Inventory Management*

Dawn Sharp is the owner of Sharp's Sandwich Shop. Her shop is open 24/7 and serves many different types of sandwiches, from classic breakfast sandwiches to more exotic burgers and other sandwiches usually consumed at lunch and dinner. Not all of the menu items are available all day. Dawn has divided her menu into four timeframes—breakfast, lunch, dinner, and after hours. Breakfast runs from 5 a.m. to 11 a.m. Lunch begins at 11 a.m. and ends at 3 p.m. Dinner begins early, at 3 p.m., and continues until 9 p.m. Between 9 p.m. and 5 a.m., customers can select sandwiches from the after hour's section of the menu.

Sharp's Sandwich Shop is in the heart of downtown New York City. Some periods are more brisk than others; however overall, because it is the city that never sleeps, business is reasonably steady most days. New Yorkers are fast moving and always in a rush. Consequently, no one wants to wait very long for their sandwich, no matter how unique or complicated it may be. Because of this, Dawn has set up a system where the kitchen produces specific sandwiches in bulk. For example, a basic ham and cheese on rye bread can be made in advance, wrapped, and placed in the ready bin. This way, when a customer orders a ham and cheese on rye, they get it quickly.

One challenge to this system is warm sandwiches. Depending on the complexity, for example, is it a plain cheese burger, or one with specific toppings selected by the customer? A premade warm sandwich can be made and placed in the warmer.

Another challenge to this system is that Sharp's sandwiches are very popular because of the quality of the sandwiches. Part of the quality is their freshness. Therefore, whether it is a cold sandwich or a warm sandwich, neither can stay in the premade bins too long. After a set period of time, if a sandwich is still in the bin it is removed and placed in the charity bin. The charity bin contains food that is still edible; however, won't be sold to Sharp's customers. The food in the charity bin is donated to a local homeless shelter twice a day.

Dawn strongly believes in giving back to the community. Her company sponsors runs for several causes throughout the year. Therefore, although it would be easier to throw out the food whose freshness life has reached its limit according to her standard of quality, giving it to the homeless shelter is an important outreach program for her. However, obviously, Dawn's business model is based on selling the food, not giving it away. She realizes she cannot completely prevent items from sitting in the bins past her standard of freshness quality time. However, as she reviews her monthly financial statements, Dawn sees a trend of increasing waste, i.e., more going into the charity bin.

As Dawn examines her financials she notices that her sandwich shop is going through certain inventory items faster than usual. From the ingredients listed, Dawn suspects that more of the high end sandwiches are reaching her freshness quality time limit. Furthermore, as she compares the point of sale data to her inventory expense data, she concludes that there are spikes in the day where more sandwiches are reaching the charity bin.

Dawn speculates on what could be the issue. She reflects back on her class in Supply Chain Management, specifically the inventory management chapter. She realizes that her primary focus had been on freshness, a key quality metric. She also recognized that timely service was another key quality metric that enabled her to get high customer satisfaction

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ratings. In hindsight, Dawn grasps that she had ignored basic inventory requirements while focusing on quality. Because of the freshness issue, more and more, her staff was making two sandwiches and only charging for one. Dawn firmly believes she cannot compromise on the quality; however, she needs to improve her inventory management in order to eliminate the growing waste.

## Discussion Questions

1. Dawn understand her customers very well. She knows that they want two things—1) speed in getting the sandwich, no matter what type, and 2) the sandwich must taste fresh. As Dawn works out how to improve her inventory management process, how can she utilize the ABC inventory classification system as part of the remedy for this situation?
    - Think outside the box. Consider which type of inventory she really needs to classify using the ABC classification system.
2. As we examine this case, we know that the basic issue is low inventory turnover. Consequently, the bins are overstocked during specific times and items must be discarded because they exceed the freshness quality time limit. As she considers this point, Dawn is debating if she needs to use the EOQ model or the EMQ model. Provide a recommendation to Dawn on which model would be the most effective for her situation. Explain why your choice is better than the one you did not select.
3. Considering Sharp's Sandwich Shop's inventory issue, justify to Dawn what type of inventory review system she should establish. Go one step further, explain how this supports your previous answers to the above questions.

## 2. Lamb's Automotive Supplies*

Molly Lamb has been a car aficionado since she was a teenager. This passion led her to open an automotive supply store. Her primary customers are small car repair shops. Many of these shops service a variety of makes and models. The other customer base is car buffs such as herself. These customers are car hobbyists and they own "classic" cars. They often buy an older clunker and rebuild it. They prefer to rebuild it as much as they can to the original specifications. Consequently, finding parts for these older makes/models is a challenge and building an inventory is even more difficult.

Because Molly is such an old car enthusiast, she has often scoured the Internet, junk yards, and other places for usable old car parts. Molly has a section of her warehouse set aside for "classic" car parts, from starters, to hub caps, to door handles. There is no real competitor in this segment of her business. While a few places may have the odd part or two for older models, Molly has a significant inventory for most makes and models going back to the 1940's. Because of the generation of the customers she is serving, the newest make/model is from the early 1970's.

The remainder of Lamb's Automotive Supplies' inventory is for more recent makes and models, those built within the last 10 years. This section of the inventory is much larger than the one for the "classic" cars; however, despite its size, its dollar value isn't much higher. One challenge Ms. Lamb has is warehouse space. Inventory capacity is basically directly related to space. Therefore, in order to serve both customer segments as best she can, Molly must maximize her warehouse space.

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Although Molly is aware of what inventory she has on hand, she has never actually used a specific inventory system. Now that her warehouse is reaching capacity, Molly realizes she must have a better inventory management process. Adding more warehouse space isn't an option. She must use the space she has more efficiently. Molly begins to ponder how she can do this without creating a potential inventory shortage for either customer segment.

### Discussion Questions

1. Since the parts for the "classic" cars are difficult to obtain, Molly has decided that she must set aside a certain percentage of the warehouse for these parts. When she locates a specific part for this customer segment, Molly has to buy it and place it in her inventory because once the opportunity passes, it may never return. How does this affect the inventory management of the parts for newer cars? What systems or processes do you recommend to Molly to ensure she does not develop shortages for the parts for the car repair shops? Explain how your recommendation helps Molly.
2. Considering Molly's situation and her two distinct customer bases, do you think the ABC classification system would benefit her? If so or if not, explain why.
3. Explain whether the EOQ or statistical reorder point methods can enable Molly to better manage her "classic" car parts inventory.

## 3. Crabtree Electronics*

Sylvester Bush owns Crabtree Electronics. His business has been going very well since he opened a few years ago. Most of his customers are other small businesses that need electronic parts such as circuit boards, transistors, resistors, capacitors, etc. A small percentage of his customers are hobbyists who enjoy building their own home sound systems and other items.

As with many businesses today, Crabtree Electronics is feeling a bit of a pinch because the overall economy isn't doing well. Sylvester is confident that business will eventually pick up; however, until then he needs to tighten his belt a bit. One area that he hasn't monitored as closely as he should is inventory. Sylvester knows that excess inventory is just money sitting on the shelf. In the past he has used his gut as the driver of what and how much he should purchase. His understanding of his customers and their needs has been sufficient so far.

Sylvester wants to do more than just save some money now during the lean times. He wants to establish an inventory system that enables him to capture continuous savings through effective inventory control. His inventory doesn't contain many high priced items. Most of the items his customers require are relatively low-cost items such as transistors, resisters, integrated circuit boards, wire, etc. If they need some item that is high priced, Sylvester orders it for them. Since he can get these items within two days, often within one, this process works well for the expensive parts. Sometimes customers cannot wait even one day; in those cases Sylvester directs them to another source. This seldom happens so neither Sylvester nor his customers have any concern about him not carrying those very expensive parts. Also, since the requests for such parts are rare, Sylvester doesn't want to have them sitting in his inventory gathering dust. Sylvester wants to ensure his inventory turns over frequently. Sylvester begins to consider all his options.

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## Discussion Questions

1. Sylvester Bush is a good businessman; however, he isn't familiar with inventory control systems. Develop a chart for Mr. Bush with pros on one side and cons on the other. Help him make the choice between the ABC classification system and the EOQ. Based on the inventory he carries and his general process, which approach is best for him? Or, should he employ both, why?
2. Crabtree Electronics deals in relatively low-cost parts. However, they also deal in large volumes of those parts. Some of the businesses he supplies often get large contracts that require them to buy electronic parts in bulk. Is there a way for Mr. Bush to turn this into an advantage for his business? What would you recommend he do and why? How would your recommendation benefit him and his customers?
3. Many electronic parts are physically small. Sylvester's warehouse is brimming with rows upon rows of bins with hundreds and sometimes thousands of parts in them. Although some of the inventory models assume that the physical inventory levels are precise at any point in time, in reality they are not. Consider Sylvester's situation. Sell Mr. Bush on a specific inventory review system. Explain why it is the best for his situation and what benefit he will receive by using the system you suggest.

# Part 3 Continuing Case

## Mullenax Automobile Parts Inc., Inventory Management*

Odis Mullenax is the owner and President of Mullenax Automobile Parts Inc. His company makes various parts for major automobile manufacturers worldwide. They manufacture intake manifold systems, air induction systems, coolant pump modules, oil filtration systems, coil springs, stabilizer bars, precision springs, and other key components within their three business units. Mullenax Automobile Parts is one link in a very long supply chain. Odis understands that the supply chain is not a single line of suppliers and buyers. Odis knows that the supply chain is more like a complex web where inputs come from multiple directions, often appearing unrelated to one another.

Odis has been working with Estella Epperson, Vice President of Operations, to ensure their supply chain management techniques are as robust as possible. To date, they have tackled demand forecasting and resource planning systems. They are ready to look at their inventory management capabilities. Inventory is extremely important because it is money sitting on the shelf. Consequently, they want to produce sufficient inventory to meet the customers' demands while ensuring the inventory turns over.

Inventory is managed by Madie Mcconke, Director of Inventory Management. Madie is well known throughout the automotive industry as a top inventory specialist. Madie takes several approaches to ensure they have sufficient inventory while always focusing on generating high inventory turnover. As mentioned previously, inventory is money sitting on the shelf. Madie understands that frequent turnover is a big positive because it enables Mullenax Automobile Parts to increase cash flow and reduce warehousing and carrying costs.

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Odis and Estella schedule a meeting with Madie. They request that she present the current status of Mullenax's inventories. For example, they want to know if their inventory turnover ratio is good compared to other companies in the automotive industry. Furthermore, what system is Mullenax using to guarantee the lowest possible annual inventory cost?

As Madie pulls together information for the presentation, she focuses on two main items: Economic Order Quantity (EOQ) and Inventory Turnover Ratio. Madie uses the following data to build her illustrations to support her explanations concerning how Mullenax inventories are managed: the weekly requirement of one part is 2,000 units, the order cost is $55 per order, the holding cost is $5 per unit per year, and the part cost is $350 per unit. The firm operates fifty-two weeks per year. Madie has her assistant use the data to compute various inventory statistics. Other data Madie had available were the cost of revenue or cost of goods sold ($525,750) and the average inventory level (43,812 units); therefore, she has the data required for the inventory turnover ratio. Madie also had last year's inventory turnover ratio for Ford (15.23), General Motors (10.53), and Toyota (16.95). Since Mullenax Automobile Parts was dependent on the production and sales of the major automobile manufacturers, Madie used these results as a means of determining how Mullenax was doing.

## Questions

1. Calculate the following:
   a. EOQ
   b. Annual holding cost
   c. Annual order cost
   d. Total annual inventory cost
2. Calculate the inventory turnover ratio for Mullenax.
   a. Discuss Mullenax's inventory turnover compared to that of the automobile companies.
3. Select which type of review of inventory you believe would be most effective for Mullenax Automobile Parts—Continuous review or Periodic review.
   a. Justify your choice. Explain the benefits of the system you selected.

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Chapter 8

# Process Management—Lean and Six Sigma in the Supply Chain

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*Mitigating risk is definitely a good thing, but it's always going to cost more than just having one plant. Having two plants costs more. Having to dual-source costs more. People have, I wouldn't say 'forgotten,' but shifted the focus more towards cost than risk mitigation. There's a lot more that can be done, but it's a balance.*

**—Genki Uemura, product director at Sharp Electronics**[1]

*Get out your phone and video the process you want to improve. Then all you have to do is review it with the person doing that job. This allows them the opportunity to observe the process and not be thinking about doing it. Their creative genius will kick in!*

**—Brad Cairns, senior principal at The Center for Lean Learning**[2]

*Six Sigma has been around for more than 30 years in the United States already. I think Six Sigma and now lean Six Sigma will continue on and evolve for many years to come. The results of the past 40 years have shown the effectiveness of disciplined, customer-focused, project definition, project selection and prioritization, followed by data-based, structured problem solving, with attention to ongoing process management.*

**—Tedd Snyder, lean Six Sigma Master Black Belt at Snyder Consulting**[3]

## Learning Objectives

**After completing this chapter, you should be able to**

**LO 1** Discuss and compare the major elements of lean and Six Sigma.

**LO 2** Describe why lean and Six Sigma are integral parts of SCM.

**LO 3** Discuss the Toyota Production System and its association with lean production.

**LO 4** Discuss the linkage between lean programs and environmental protection.

**LO 5** Describe the historical developments of lean and Six Sigma.

**LO 6** Describe and use the various tools of Six Sigma.

**LO 7** Understand the importance of statistical process control for improving quality.

## Chapter Outline



### SCM Profile — Keiretsu Brings Autonomous Vehicles to Life

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With the help of Keiretsu relationships, Japan-based Denso Corp. is emerging as a global force in autonomous vehicles. Denso has invested more than $3 billion through 2020, while beefing up its advanced engineering staff to become a lynchpin in a number of new joint ventures. It is bringing together Toyota with its supplier network, and other Japanese automakers to tackle autonomous driving, electrification, and connectivity.

Denso is Toyota's top supplier and is also 24 percent owned by Toyota. By leveraging Toyota's keiretsu system to recruit new startups, Denso hopes it can quickly emerge at the head of the pack in autonomous driving and other futuristic automotive fields. "The keiretsu suppliers, if they successfully join forces, can be a mighty weapon," said Tatsuo Yoshida, senior auto analyst at Sawakami Asset Management.

In one example, Denso is joining Toyota's transmission maker Aisin Seiki to develop electrified driving modules. In another, Denso and Aisin Seiki are partnering with brake manufacturer Advics and steering supplier JTEKT, two other Toyota suppliers, to develop the software that acts as the brains for automated driving. "We are now in a life-or-death situation," said Denso President Koji Arima after announcing the ventures." We will bring together our strengths and take a new step. Even though we have high levels of technology, whether you can create a system is what matters."

Denso is also a partner in EV Common Architecture Spirit Co., an alliance with Toyota, Mazda, Subaru, Suzuki, Daihatsu, and Hino, to develop the architecture and components of electric cars. Denso has also been busy investing in startups that might prove useful. For example, Denso invested in U.S.-based Metawave, which develops radar for detecting vehicles and pedestrians, and it bought in to U.S.-based Dellfer, which produces cybersecurity for autonomous cars. This approach highlights the resilience of the keiretsu system.[4]

## Introduction

As discussed in earlier chapters, supply chain management goals are concerned with achieving process integration, low cost, and high levels of quality and responsiveness throughout the supply chain. Customer expectations make it necessary for firms to adopt strategic initiatives emphasizing speed, innovation, cooperation, quality, and efficiency. Lean thinking and Six Sigma quality, two important operating philosophies that are central to the success of supply chain management, seek to achieve these strategic initiatives, while at the same time resolve the trade-offs that can exist when simultaneously pursuing the goals of high quality, fast response, and low cost.

In the 1990s, supply chain management emerged as a strategy combining several practices already in use—**quick response (QR)**, **efficient consumer response (ECR)**, Just-in-Time (JIT), and Japanese **keiretsu relationships**. The first two are concerned with speed and flexibility, while keiretsu involves partnership arrangements. The QR program was developed by the U.S. textile industry in the mid-1980s as an offshoot of JIT and was based on merchandisers and suppliers working together to cope with the demand for large numbers of SKU's with short product life cycles and high seasonalities. QR allowed garment manufacturers to respond more quickly to consumer needs by sharing information, resulting in better customer service and less inventory and waste.[5] In the early 1990s, ECR was developed by a U.S. grocery industry task force charged with making grocery supply chains more competitive. Point-of-sale transactions at grocery stores were forwarded via computer to upstream distributors and manufacturers, allowing the grocery stores to keep stocks replenished while minimizing the need for safety stock inventories.[6] As described in the chapter-opening profile, Keiretsu networks are cooperative memberships between Japanese manufacturing firms and their suppliers. In some cases, the stronger suppliers are prevented from doing too well, while the weaker suppliers are prevented from failing, due to a web of constraints that keiretsu networks place on their member firms. Group members might even pay an insurance premium for the safety net that insulates each of them.[7]

Supply chain management is thus closely associated with all of these concepts. However, relying too exclusively on a few suppliers can land companies in trouble during unexpected problems such as the recent pandemic outbreak. A study by the Institute for Supply

Management of U.S. auto industry manufacturers found that nearly three-quarters of the respondents experienced supply chain disruptions in the first months of the COVID-19 outbreak in China. It is estimated that the global automotive industry purchases approximately $34 billion in components from China every year.[8]

While many argue that Henry Ford and his company invented JIT practices (although not called JIT at the time), the term **Just-In-Time** was originally associated with Toyota managers like Mr. Taiichi Ohno along with his kanban system, encompassing continuous problem solving in order to eliminate waste. Use of the term *lean* has today largely replaced use of the term JIT, and is associated with the Toyota Production System. **Lean thinking** is broader, although closely related to JIT, and describes a philosophy incorporating tools that seek to economically optimize time, human resources, assets, and productivity, while improving product and service quality. In the early 1980s, these practices started making their way to the Western world, first as JIT and then today, as **lean production**, **lean manufacturing**, or simply **lean**. Lean thinking has evolved into a way of doing business for many organizations.

Quality assessment and improvement is a necessary element of lean production. First, as the process of waste elimination begins to shrink inventories (primarily safety stocks and lot sizes), problems with human resource requirements, queuing, lead times, quality, and delivery timing are typically uncovered both in the production process and with inbound and outbound materials. Eventually, these problems are remedied, resulting in higher levels of quality and customer service (consider that quality must improve since safety stocks are reduced, and items are produced more quickly since lot sizes are reduced). Second, as the drive to continuously reduce throughput times and inventories continues, the need for a continuing emphasis on improving quality throughout the productive system results in the need for an overall quality improvement or Six Sigma program.

**Six Sigma** stresses a commitment by the firm's top management to help the firm identify customer expectations and excel in meeting and exceeding those expectations. Since global economic changes (such as the most recent pandemic and global recession) along with changes in technology and competition cause customer expectations to change, firms must then commit to a program of continual reassessment and improvement; this, too, is an integral part of Six Sigma. Thus, to achieve the primary objectives of low cost, high quality, and fast response, supply chain management requires the use of lean and Six Sigma throughout the supply chain. These topics are discussed in this chapter.

## Lean Production and the Toyota Production System

The term lean production essentially refers to the **Toyota Production System** in its entirety, which was created and refined by several of Toyota's key executives over a number of decades. In 2010, Toyota came under fire for a number of recalls involving over 8 million vehicles worldwide for several quality and safety problems. While these problems were indeed serious, they do not diminish the value of lean production or the Toyota Production System. In fact, in 2010, Toyota promised a return to their "customer first" principles.[9] In 2020, Toyota once again earned the title of the most valuable automotive brand in the world, according to Interbrand's 2020 "Best Global Brands" annual report. Interbrand estimated Toyota's 2020 brand value at $51.5 billion. "Leadership, engagement and relevance are three consistent themes we are seeing as brands try to navigate the rapidly changing business landscape," said Interbrand Global CEO Charles Trevail. "They are the keys to unlock results in the current crisis, building customer confidence and

business resilience. By setting out powerful ambitions and pursuing them with courage and conscience, brands can help us lift our heads, make sense of chaos, and see beyond it, championing a new decade of possibility."[10] Several of the important events in the creation of the Toyota Production System are described next.

Mr. Sakichi Toyoda invented the power loom in 1902 and in 1926 founded the Toyoda Automatic Loom Works. In 1937, they sold their loom patents to finance an automobile manufacturing plant to compete with Ford and General Motors, both of which accounted for over 90 percent of the vehicles sold in Japan at the time. Sakichi's son Kiichiro Toyoda was named managing director of the new facility.[11]

Kiichiro spent a year in Detroit studying Ford's manufacturing system and others, and then returned to Japan, where he adapted what he learned to the production of small quantities of automobiles, using smaller, more frequently delivered batches of materials. This later was referred to as the Just-In-Time system within Toyoda. At Ford, their system was designed such that parts were fabricated, delivered directly to the assembly line, and then assembled onto a vehicle within just a few minutes. Henry Ford had called this *flow production*, the precursor to JIT.[12]

Mr. Eiji Toyoda, nephew of Sakichi, began working at Toyoda in 1936 and was named managing director of the renamed and reorganized Toyoda Automotive Works in 1950. Eiji too, traveled to Detroit to study Ford's automobile manufacturing system and was particularly impressed with their quality improvement activities, most notably their employee suggestion system. He was also impressed with Ford's daily automobile output of 7,000 cars, compared to Toyoda's comparatively miniscule *13-year total output* of just 2,700 cars. Back in Japan, he implemented the concepts he had seen in the United States and this became the foundation of what was later referred to as the Toyota Production System.

In 1957, the company was again renamed and became the Toyota Company. They introduced their first U.S. car that year—the Toyopet Crown. While popular in Japan, the car's quality, speed, and styling problems resulted in sales of only 288 units in 14 months in the United States. Consequently, Toyota withdrew from the U.S. market to further analyze U.S. consumers and their demands for reliability. "No detail was unimportant, and they paid very close attention to customers," says Dave Cole, chairman of Michigan-based Centre for Automotive Research. In 1965, the Corona was introduced in the United States and by 1972 U.S. sales had reached 1 million units.[13] In 1982, Eiji established Toyota Motor Sales USA, and finally in 1983, Eiji renamed the firm the Toyota Motor Corporation.

Taiichi Ohno began his career at the Toyoda Automatic Loom Works in 1932. He eventually expanded on the concepts established by Kiichiro and Eiji, by developing and refining methods to produce items only as they were needed for assembly. Detroit was visited several times to observe auto manufacturing techniques. After World War II, the Toyoda production facilities were rebuilt, with Taiichi playing a major role in establishing the low-batch production principles that were developed earlier. These principles proved very valuable at the time, since postwar Japan was experiencing severe materials shortages. What Taiichi and Eiji had both realized during their trips to the United States was the tremendous waste everywhere (referred to as **muda** in Japan). These wastes of labor, inventories, space, time, and processing were certainly things Toyoda could not afford. From this realization came the idea that parts should be produced only as needed by the next step in an entire production process. When a type of signal or card (called a **kanban**) was used, the system became much more effective. This began to be called the kanban or JIT system within Toyoda.

Refinements to the JIT concepts continued under Taiichi's tutelage, and he later attributed the system to two things—Henry Ford's autobiography wherein he explained the Ford manufacturing system, and U.S. supermarket operations characterized by daily supply deliveries, which Ohno observed during a visit to the United States in 1956. The final two notable people in the development of the Toyota Production System were Shigeo Shingo, a quality consultant hired by Toyota, and W. Edwards Deming who happened to be in Japan after World War II, helping to conduct the census. Deming became known to Ohno and others at Toyota when he began attending professional manufacturing meetings in Japan to discuss statistical quality control techniques. By the 1950s in Japan, Deming had created and was discussing his 14-point quality management guidelines and his ideas for continuous improvement with many Japanese manufacturing engineers and managers.

Shingo developed the concept of **poka-yoke** in 1961, when he was employed at Toyota. Poka-yoke means error- or mistake-proofing. The idea is to design processes such that mistakes or defects are prevented from occurring in the first place, and if they do occur, further errors are also prevented. These fail-safe mechanisms can be electrical, mechanical, visual, procedural, or any other method that prevents problems, errors, or defects, and they can be implemented anywhere in the organization. Poka-yoke thus leads to higher levels of quality and customer service.[14]

In the latter part of the 1950s as mentioned earlier, Toyota was experiencing quality problems which were impacting potential sales in the United States. To remedy this, Toyota implemented what they referred to as total quality control (TQC) in concert with their JIT system. This then became the final piece of the Toyota Production System and was later refined and renamed total quality management (TQM). Interestingly, in the first quarter of 2007, Toyota sold more vehicles worldwide than General Motors, ending GM's 76-year reign as the world's largest auto maker.[15] Recently, Volkswagen and Toyota have been virtually tied each year in total vehicle output—about 10 million units each. GM has remained in third or fourth place with about 9 million units produced per year.[16]

Actually, the term *lean production* did not originate at Toyota. It was first used in a benchmarking study conducted by the International Motor Vehicle Program (IMVP) at the Massachusetts Institute of Technology. The IMVP conducted a global automobile quality and productivity benchmarking study which eventually culminated in the book, *The Machine that Changed the World* wherein the elements of lean production and the benchmarking results were presented.[17] The word "lean" was suggested because the Japanese facilities in the benchmarking study, when compared to their U.S. counterparts, used half the manufacturing labor, half the space, and half the engineering hours to produce a new automobile model in about half the time. They also used much less than half the average inventory levels to produce the same number of vehicles, and had far fewer defects. The term *lean* seemed appropriate, and as they say, the term went viral.

The use of lean thinking has spread rapidly over the years among many manufacturers, services, and small businesses in numerous industries. For example, what can an oil company do when oil prices drop rapidly, as was seen in 2014 to 2015? Turn to lean production. The New York-based Hess Corp. cut about $400,000 from the cost of drilling each North Dakota well over the first half of 2015, along with sharply reducing the time it took to drill a well. Company officials said that applying lean manufacturing principles kept its 1,200 Bakken field oil wells profitable. "This stuff really does work when you have a culture that is behind it," Hess President Greg Hill said. "We haven't even scratched the surface."[18] Major tire manufacturer Goodyear, once considered a stodgy bureaucratic company, has even implemented lean thinking in its product development process, throughout its global operations. The company has reduced lead time by more than half and increased their success rate in introducing new profitable goods to near perfection.[19]

## Lean Thinking and Supply Chain Management

Simply put, the objective of supply chain management is to balance the flow or supply of materials with downstream customer requirements throughout the supply chain, such that costs, quality, and customer service are at optimal levels. Lean production emphasizes reduction of waste, continuous improvement, and the synchronization or integration of material flows within the organization and eventually including the organization's first-tier suppliers and customers. In many respects, then, supply chain management seeks to incorporate lean thinking along entire supply chains. Supply chain management encourages cross-training, satisfying internal customer demand, moving goods or people through the production system quickly, and communicating end-customer demand forecasts and production schedules up the supply chains. In addition, it seeks to optimize inventory levels along entire supply chains. Thus, when implemented within the focal firm and its trading partners, the realized benefits of lean are much more significant.

Firms are increasingly implementing and sharing lean strategies along their supply chains. As a matter of fact, one of the newest terms in the lean lexicon is **yokoten**. Yokoten is a Japanese term meaning "across everywhere." In lean terminology, it is used to mean the sharing of best practices. Lean firms are using yokoten to reach out to closely-linked suppliers and customers to make their supply chains leaner. For example, a joint venture between Toyota and Pakistan's Indus Motor Company (IMC) adopted yokoten which has led to significant quality control gains and fewer production errors at IMC facilities, where the company manufactures Toyota brand vehicles.[20]

For manufacturers, most of their goods' final costs derive from supply chains. Consequently, supply chains represent the best opportunities for results from lean implementations. When *Logistics Management* magazine conducted a lean survey among hundreds of their subscribers, they found that use of lean improvements to their supply chains had grown significantly—from just 30 percent in 2007 to 46 percent in 2011, a growth of over 50 percent.[21] That trend continues today.

Many firms successfully implement a few lean activities at a time, based on resources, product characteristics, customer needs, and supplier capabilities. Coffeehouse giant Starbucks has a V.P. of lean thinking who travels from region to region with their lean team, looking for ways to reduce the wasted movements of its baristas. This in turn gives baristas more time to interact with customers and improve the Starbucks experience. The results are streamlined operations, happier customers, and a better bottom line.[22] Noted lecturer and author of many books on lean and associated topics, Norman Bodek suggests that maybe half of U.S. manufacturing companies are into some aspect of lean.[23] The following section is a discussion of the lean elements.

## The Elements of Lean

Table 8.1 presents the major lean elements that are discussed in this section of the chapter, along with a short description of each element. As noted above, lean programs can vary significantly, based on a company's resource capabilities, product and process orientation, and past failures or successes with other improvement projects. Firms with a mature lean program will most likely be practicing a significant number of these elements.

**Table 8.1 The Elements of Lean**

| ELEMENTS | DESCRIPTIONS |
|---|---|
| 1. Waste elimination | Eliminating waste is the primary concern of lean thinking. This includes reducing excess inventories, material movements, production steps, scrap losses, rejects, and rework. |
| 2. Lean supply chain relationships | Firms work with suppliers and customers with the mutual goal of eliminating waste, improving speed, and improving quality. Key suppliers and customers are considered partners. |
| 3. Lean layouts | WIP inventories are positioned close to each process, and layouts are designed to reduce movements of people and materials. Processes are positioned to allow smooth and level flows of work through the facility. |
| 4. Inventory and setup time reduction | Inventories are reduced by reducing production batch sizes, setup times, and safety stocks. This tends to create or uncover processing problems which are then controlled. |
| 5. Small batch production scheduling | Firms produce frequent small batches of product, with frequent product changes to enable a level production schedule. Smaller, more frequent purchase orders are communicated to suppliers, and more frequent deliveries are offered to customers. Kanbans are used to pull WIP through the system. |
| 6. Continuous improvement | As queues and lead times are reduced, problems surface more quickly, causing the need for continual attention to problem solving and process improvement. With lower safety stocks, quality levels must be high to avoid process shut downs. Attention to supplier, WIP, and finished goods quality levels are high. |
| 7. Workforce empowerment | Employees are cross-trained to add processing flexibility and to increase the workforce's ability to solve problems. Employees are trained to provide quality inspections as parts enter a process area. Employee roles are expanded and they are given top management support and resources to identify and fix problems. |

Sources: Lamming, R. (1993), *Beyond Partnership: Strategies for Innovation and Lean Supply*, Prentice Hall, London; Ohno, T. (1988), *The Toyota Production System: Beyond Large-Scale Production, Productivity Press*, Portland, OR; Schonberger, R.J. (1982), *Japanese Manufacturing Techniques*, The Free Press, New York, NY.; Womack, J. and Jones, D. (1996), *Lean Thinking: Banish Waste and Create Wealth for Your Corporation*, Simon and Schuster, New York, NY.

## Waste Elimination

One of the primary and long-term goals of all lean endeavors is **waste elimination**. The desired outcome is value enhancement. Firms reduce costs and add value to their goods and services, by eliminating waste from their productive systems. For example, California-based e-grocer Imperfect Foods plans to become a net-zero carbon company by 2030. As part of this plan, Imperfect Foods will certify its first certified zero-waste-to-landfill facility in 2022, and will certify five more over the following three years. Imperfect Foods will boost its regional sourcing by 15 percent to reduce truck emissions. Last year, the company converted its largest fulfillment center in Los Angeles to solar power, beginning a process that will see the company shift all of its six fulfillment centers to 100 percent renewable power by 2026. In 2020, the company bought 7,921 tons of post-consumer recycled packaging and saved more than 52 million pounds of food. By composting and turning food into animal food, Imperfect Foods diverted more than 75 percent of its waste from landfills in 2020.[24]

Waste is a catch-all term encompassing things such as excess wait times and inventories, wasted or unneeded material and people movements, too many processing steps, variabilities in processing, and *any other nonvalue-adding activity.* Taiichi Ohno of Toyota, described what he termed the **seven wastes**, which have since been applied across many industries around the world, to identify and reduce waste. The seven wastes are shown and described in Table 8.2. The common term across the seven wastes is *excess*.

**Table 8.2 The Seven Wastes**

| WASTES | DESCRIPTION |
|---|---|
| Overproducing | Production of unnecessary items to maintain high utilization. |
| Waiting | Excess idle machine and operator time; materials experiencing excess wait time for processing. |
| Transportation | Excess movement of materials between processing steps; transporting items long distances using multiple handling steps. |
| Overprocessing | Nonvalue-adding manufacturing, handling, packaging, or inspection activities. |
| Excess inventory | Storage of excess raw materials, work-in-process, and finished goods. |
| Excess movement | Unnecessary movements of employees to complete a task. |
| Scrap and rework | Scrap materials and product rework activities due to poor-quality materials or processing. |

Source: Ohno, T. (1988), *Toyota Production System*. Portland, OR: Productivity Press, 1988.

Obviously, firms require some level of inventories, material and worker movements, and processing times, but the idea is to determine the *right* levels of these things and then decide how best to achieve them.

Unfortunately, many companies and their trading partners view waste as simply a cost of doing business. To identify and eliminate waste, workers and managers must be continually assessing processes, methods, and materials for their value contributions to the firm's salable goods and services. This is accomplished through worker–management interactions and commitment to the continued elimination of waste, and frequent solicitation of feedback from customers. Significant waste reduction results in a number of positive outcomes including lower costs, shorter lead times, better quality, and greater competitiveness. During the economic downturn beginning in 2009, eliminating waste enabled firms to stay profitable while sales levels were declining. The use of lean programs increased in popularity during those years.

## Using the Five-Ss to Reduce Waste

Another technique for waste reduction has been termed the **Five-Ss**. The original Five-Ss came from Toyota and were Japanese words related to industrial housekeeping. The idea is that by implementing the Five-Ss, the workplace will be cleaner, more organized and safer, thereby reducing processing waste and injury accidents, and improving productivity. A Five-S system, though, is not only a housekeeping program; it is a problem identification and prevention system. When something is found to be missing or out of place, the problem solution should be to repeatedly ask "why?" until the root (or most basic) cause is found and corrected. Toyota's Taiichi Ohno once commented that until why is asked five times, the root cause has probably not been identified. This is called the **Five-Why** (or 5Y) root cause process.[25] Table 8.3 lists and describes each of the S-terms, and presents the equivalent terms used in the English version of the Five-S system.

The goals of the first two (sorting and setting in order) are to eliminate searching for parts and tools, avoid unnecessary movements, and avoid using the wrong tools or parts. Work area tools and materials are evaluated for their appropriateness, and approved items are arranged and stored near their place of use. Seiso/sweep refers to proper workplace cleaning and maintenance, while Seiketsu/standardize seeks to reduce processing variabilities by eliminating nonstandard activities and resources. Shitsuke/self-discipline or sustain means using effective work habits through use of the first four terms.

**Table 8.3 The Five-Ss**

| JAPANESE S-TERM | ENGLISH TRANSLATION | ENGLISH S-TERM IN USE |
|---|---|---|
| 1. Seiri | Organization | Sort |
| 2. Seiton | Tidiness | Set in order |
| 3. Seiso | Purity | Sweep or shine |
| 4. Seiketsu | Cleanliness | Standardize |
| 5. Shitsuke | Discipline | Self-discipline or sustain |

Source: Becker, J. "Implementing 5S: To Promote Safety & Housekeeping." *Professional Safety* 46, no. 8 (2001): 29–31; Rooney, S. and Rooney, J., "Lean Glossary," *Quality Progress* 38, 9(6), (2005): 41-47.

The Five-S system can be employed in any service or manufacturing environment. Many lean efforts begin with implementation of the Five-Ss. Firms can conduct a "waste hunt" using the Five-Ss, then follow up with a "red-tag event" to remove or further evaluate all nonessential, red-tagged items. Some companies have also added their own "sixth-S," for surprises or for safety, to assess the safety of work conditions.[26]

## Lean Supply Chain Relationships

Quite commonly, firms hold safety stocks of purchased goods because their suppliers' delivery times are inconsistent or the quality of the goods may not always meet specifications. Internally, extra work-in-process (WIP) inventories are stored as a way to deal with temperamental processing equipment or other variabilities causing processing problems. On the distribution side, firms hold stocks of finished goods in warehouses prior to shipment to customers, in some cases for months at a time, to avoid stockouts and to maintain high customer service levels. Holding high levels of these inbound, internal, and outbound inventories costs the firm money while not adding much, if any value to the goods or the firm; thus, they are considered wastes.

The pandemic in 2020, though, changed some minds about the risks involved in carrying low safety stock levels along a supply chain. According to a survey conducted by the Council of Supply Chain Management Professionals, Infosys Consulting, Penn State University, and Penske Logistics, 42 percent of the supply chain professionals thought that supply chains were too lean based on their experience during the pandemic, but 49 percent disagreed. When toilet paper and hand sanitizer ran out at retailers for example, it meant manufacturers and retailers were missing sales, which is one problem with a lean supply chain. If a company wants to maintain the cost savings of lean while still being prepared for an increase in demand, one strategy would be to have a contract in place for additional manufacturing capacity close to the point of use, which could be executed when needed. The agreement would be at a higher cost, but it would be there if the company needed it. "So, there isn't a single right answer," says Andrew Manikas, an associate professor of management and lean researcher at the University of Louisville. "You don't want to be at either extreme: super lean or super fat. And a lot of it is related to the profitability of your product."[27]

During more normal times, when the focal firm, its suppliers, and its customers begin to work together to identify customer requirements, remove wastes and reduce costs, while improving quality and customer service, it marks the beginning of lean supply chain relationships. Companies like Kansas-based Cox Machine, an aerospace component manufacturer, have been doing this successfully for years. Cox uses mutually beneficial shipping methods, advance shipping notices, and barcoding to help their customers reduce

their lead times and inventories. Cox shares their forecasts with their suppliers so they can deliver just when the materials are needed. When materials arrive, they are delivered directly to the machine cell, which reduces inventories.[28]

Using lean thinking with suppliers includes having them deliver smaller quantities, more frequently, to the point of use at the focal firm. While this reduces average inventory levels, it also means higher inbound transportation costs—to reduce these costs, suppliers might consider locating warehouses or production facilities close to the buyer. To entice suppliers to make these investments, buyers use fewer suppliers in order to give the remaining suppliers a greater share of buyer's total purchasing spend.

Making small, frequent purchases from just a few suppliers puts the focal firm in a position of greater dependence on these suppliers. It is therefore extremely important that deliveries always be on time, delivered to the right location, in the right quantities, and be of high quality, since existing inventories will be lower. In the automobile industry, Honda and Toyota have been the top two auto companies with regards to building supplier relationships since 2002, according to the Automotive Supplier Working Relations Index (WRI) published annually by Planning Perspectives. According to the study, Ford, General Motors, and Nissan would have earned between $144 and $285 more profit per vehicle if they matched the supplier relationships of the leaders Toyota and Honda.[29]

Firms can also use lean thinking with their key customers. As these relationships develop, the focal firm reserves more of its capacity for these large, steady customers. They locate production or warehousing facilities close to these customers and make frequent small deliveries of finished goods to their customers' points of use, thus reducing transportation delivery times and average inventory levels. Lean thinking with customers means determining how to give them exactly what they want when they want it, while minimizing waste as much as possible. New York-based printed circuit board manufacturer IEC Electronics uses a new product introduction ambassador to hand-deliver prototypes to customers and answer any questions they might have, to build better customer relationships.[30]

It can be seen, then, that mutual dependencies and mutual benefits occur among all of these **lean supply chain relationships**, resulting in increased product value and competitiveness for all of the trading partners.

## Lean Layouts

The primary design objective with **lean layouts** is to reduce wasted movements of workers, customers, and/or WIP inventories, while achieving smooth product (or customer) flow through the facility. Moving inventory and people around a facility does not add value. Lean layouts allow people and materials to move only when and where they are needed, as quickly as possible. Thus, whenever possible, processing centers, offices, or departments that frequently transfer parts, customers, or workers between them should be located close together, to minimize the times for these movements. In this way, layouts can add value, by reducing processing times. The nearby SCM Profile of Warner Electric provides a good discussion of lean layouts.

Lean layouts are very visual, meaning that lines of visibility are unobstructed, making it easy for operators at one processing center to monitor work occurring at other centers. In lean manufacturing facilities, all purchased and WIP inventories are located on the production floor at their points of use, and the good visibility makes it easy to spot inventory buildups and potential bottlenecks. When these and other production problems occur, they are spotted and rectified quickly. The relative closeness of the processing centers facilitates teamwork and joint problem solving and requires less floor space than conventional production layouts.

## SCM Profile: Warner Electric's World-Class Lean Production Plant

Illinois-based Warner Electric recently completed a 96,000 square-foot plant near Columbia City, IN. The world-class facility allowed Warner Electric to consolidate production activities from three different locations. The consolidation gave Warner Electric the opportunity to develop a state-of-the-art operation using lean principles.

Gorodenkoff/Shutterstock.com

The new plant provided an opportunity for a "blank sheet" layout. Several kaizen events were held to establish the optimal equipment layout and material flow. The goal was to eliminate the wasted movements, wait times and inventory throughout the entire production process. "Teams of up to 15 members each were formed, representing all levels of employees, from production associates, material handlers and engineers to corporate executives," says Stan Owens, Warner Electric's General Manager.

Each team began by mapping the current production processes of all goods. Cardboard cutouts of machines were used to experiment with plant layouts. Each proposed layout was evaluated using lean techniques. "We also had a separate team evaluate raw material, finished goods inventory, and material flow," says Owens.

Optimized productivity begins immediately when raw materials are delivered to the plant receiving dock. All material receipts are initiated by an order to the supplier triggered by a kanban card from an empty container. Receiving and quality personnel, along with material handlers, all own and drive the process. Lean accounting techniques require inventory be at the lowest possible level. This is achieved through a very responsive supply chain that provides smaller, more frequent deliveries tracked electronically with minimal intervention.

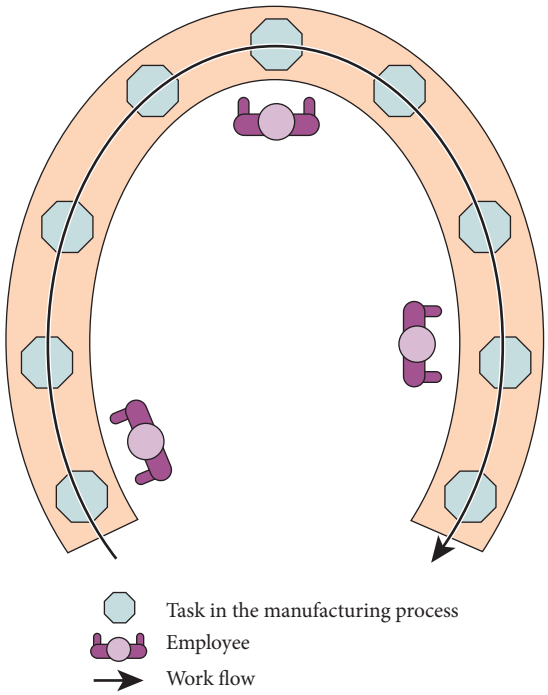
All raw material and finished goods at the plant are delivered and retrieved utilizing a unique system that cycles through the plant every two hours. Material handling associates are devoted to keeping production lines supplied with components. In order to reduce travel times, most materials are stored at the point-of-use, rather than a central location. "One of the most significant measures of our success can be found in our production 'up-time' and 'productivity,' both of which are up over 15 percent year over year," says Owens.[31]

Lean layouts allow problems to be tracked to their source more quickly as well. As processed items flow from one processing center to the next, a quality problem, when found, can generally be traced to the previous work center, provided inspections are performed at each processing stage.

## Manufacturing Cells

**Manufacturing cells** or **work cells** are designed to process any parts, components or jobs requiring the same or similar processing steps, saving duplication of equipment and labor. These similarly processed parts are termed **part families**. In many cases these manufacturing cells are U-shaped to facilitate easier operator and material movements within the cell, as shown in Figure 8.1. In assembly line facilities, manufacturing cells are positioned close to the line, feeding finished components directly to the line instead

**Figure 8.1** A U-Shaped Work Cell Layout



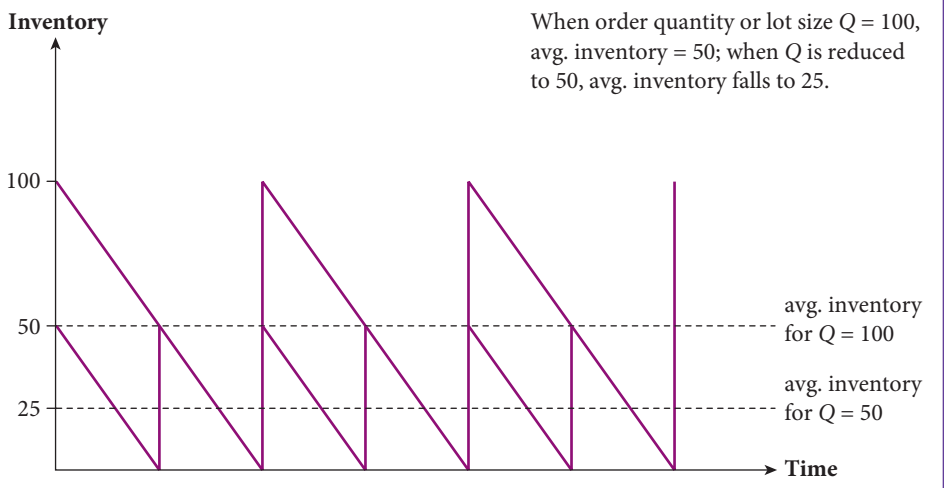

of delivering them to a stock area where they would be brought back out when needed. Manufacturing cells are themselves actually small assembly lines and are designed to be flexible, allowing machine configurations to change as processing requirements dictate.

## Inventory and Setup Time Reduction

In lean thinking, excess inventories are considered a waste, since they can hide a number of purchasing, production, and distribution problems within the organization. Just as water in a lake hides boat-damaging rocks beneath its surface, so excess inventories hide value-damaging problems along a supply chain. And, just as reducing the water levels causes rocks to become detectable, so too the reduction of inventory levels causes problems to surface in the organization and among its trading partners. Once these problems are detected, they can be resolved, allowing the system to run more effectively with a lower inventory investment. For example, reducing safety stocks of purchased materials will cause stockouts and potential manufacturing disruptions when late supplier deliveries occur. Firms must then either find a way to help solve the supplier's delivery problem or find a more reliable supplier. Either way, the end result is a smoother running supply chain with less inventory investment. The same story can be applied to production machinery. Properly maintained equipment breaks down less often, so less safety stock is needed to keep downstream processing areas supplied with parts to be further processed.

Another way to reduce inventory levels is to reduce purchase order quantities and production lot sizes. Figure 8.2 illustrates this point. When order quantities and lot sizes are cut

**Figure 8.2** Relationship between Order Quantity, Lot Size, and Average Inventory




in half, average inventories are also cut in half, assuming usage remains constant. Unfortunately, this means that the firm must make more purchase orders (potentially increasing annual order costs). Suppliers must also make more deliveries, potentially increasing delivery costs or purchase costs. Thus, ordering costs and delivery costs must be reduced. This can be accomplished by automating or simplifying the purchasing process, and by giving the supplier more of the firm's business to gain negotiating leverage.

Reducing manufacturing lot sizes also means increasing the number of **equipment setups**. Since setting up production equipment for the next production run takes valuable time, increasing the number of setups means the firm must find ways to reduce these setup times. Setup times can be reduced in a number of ways including doing setup preparation work while the previous production lot is still being processed, moving machine tools closer to the machines, improving tooling or die couplings, standardizing setup procedures, practicing various methods to reduce setup times, and purchasing automated machines that require less setup time.

For example, Charlie Mitchell, a machinist for Indiana-based Andretti Autosport, saw an opportunity to consolidate a time-consuming part of a machining center setup—the handling of fixtures like vises, chucks, and collets that had to be bolted onto the tables of their five-axis and three-axis machines with T-slots, studs, and nuts. This required fully disassembling multiple components from the table, finding the right studs or nuts and squaring the part before assembling it all back onto the machine. The process took several hours. Using Unilock's pallet clamping system uses spring pressure or manual actuation to clamp knobs in fixed locations for rapid unloading, loading, and locating of fixtures and workpieces. Standard knobs can be clamped and mounted in a blind location hole from the bottom or fastened from the top of a fixture. "Because my fixtures are all bolted onto the Unilock pallets, in less than five minutes I can throw the air switch, pull a pallet off the machine, drop another on, throw the switch again, and it's ready to go," Mr. Mitchell explains. Now, setup times are 70 to 80 percent shorter.[32]

Finally, once inventories have been reduced and the flow problems detected and resolved, the firm can reduce inventories still further, uncovering yet another set of problems to be addressed. With each inventory reduction iteration, the firm runs leaner, cheaper, faster, and with higher levels of product quality.

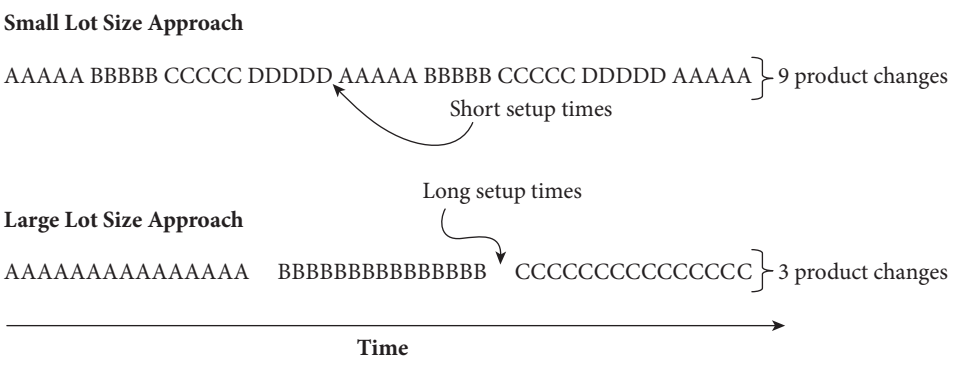
## Small Batch Production Scheduling

Continuing with the elements of lean, saying that a manufacturer should purchase in small quantities more frequently, and produce items using small lot sizes with more setups is one thing, but actually accomplishing this feat is something else. Many firms have tried and failed, eventually returning to carrying high levels of inventory and producing with large lot sizes, rather than dealing with the many problems accompanying lean production. Use of level production schedules of small batches though, communicated throughout the production processes and to outside suppliers, is a primary strategy of lean production.

Small batch scheduling drives down costs by reducing purchased, WIP, and finished goods inventories, and it also makes the firm more flexible to meet varying customer demand. Figure 8.3 illustrates this point. In the same period of time, the firm with small lot sizes and short setup times can change product lines nine times, while the firm with large lot sizes and long setup times can only change product lines three times (and has yet to produce product D). Maintaining a set, level, small batch production schedule will allow suppliers to anticipate and schedule deliveries also, resulting in fewer late deliveries. The nearby SCM Profile describes Toyota's small batch manufacturing facility.

Moving small production batches through a lean production facility is often accomplished with the use of **kanbans**. The Japanese word "kanban" has several meanings in Japan—it can refer to a billboard, as in "The Donut Shoppe," or more historically, to a uniform worn by servants of the samurai to indicate they acted on the authority of their clan or lord. Mr. Chihiro Nakao, a former Toyota manager who worked directly with Taiichi Ohno recalls a story about the origins of the word kanban at Toyota—Mr. Ohno supposedly caught a worker trying to pull materials too early from an upstream work center and

**Figure 8.3** Small Lot Sizes Increase Flexibility



## SCM Profile: Toyota's New Small Batch Production Facility


Wes Liangsutthisakon/Shutterstock.com

The thinking behind Toyota's new GR factory near their global headquarters is to produce small batch, high-performance vehicles for the Gazoo Racing line. The factory makes the GR Yaris, a high horsepower subcompact, which will be sold in Japan, Australia, and several European countries. The factory employs numerous manufacturing techniques for small batch vehicle outputs. It relies on a mix of highly skilled labor and high-tech automation. "We have a mission to make excellent specialized vehicles," said president Akio Toyoda.

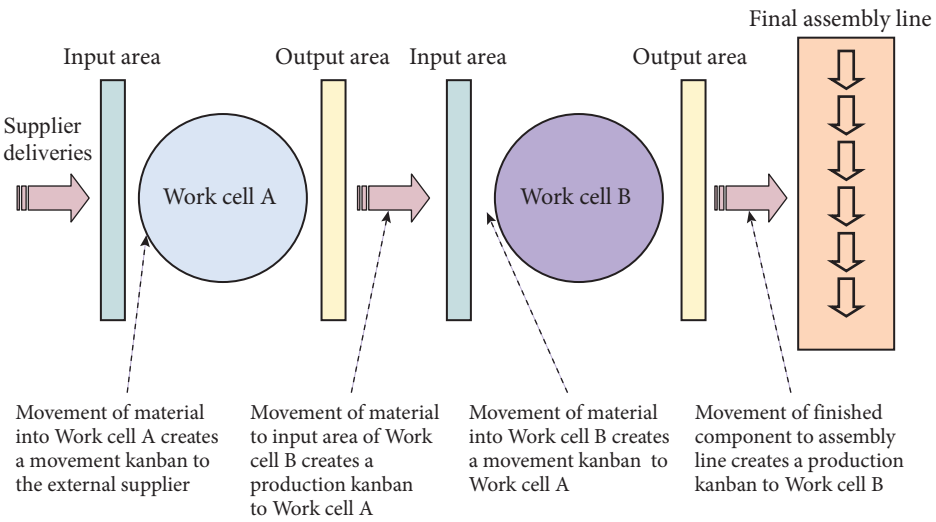
The key to small batch production is the use of work cells, instead of a conveyor-driven assembly line. The cell volume can be increased or decreased as demand fluctuates. Veteran workers assigned to each cell handle multiple processes in quick succession more efficiently than on a typical assembly line. Cars are moved between work cells by workers or automated guided vehicles pulling them on dollies. Production focuses on delivering ultra-rigid bodies with exacting precision—glue is added to stiffen the body, while an additional 250 spot welds are made by hand. Over 300 workers swarm the pint-size factory. (The GR Yaris has about 7,000 preorders, but was deemed too small for the U.S. market).[33]

he yelled, "Who are you and where did you come from?! What makes you think you have any right to this material?! Show me your kanban!"[34] Thus, the origin of the more modern "permission slip" or "authority" definition of the word kanban. In most lean facilities it simply refers to a signal.

When manufacturing cells need parts or materials, they use a kanban to signal their need for the items from the upstream manufacturing cell, processing unit, or external supplier providing the needed material. In this way, nothing is provided until a downstream demand occurs. That is why a lean system is also known as a **pull system**. Ideally, parts are placed in standardized containers, and kanbans exist for each container. Figure 8.4 illustrates how a kanban pull system works. When finished components are moved from Work cell B to the final assembly line, the following things occur:

1. The container holding finished parts in Work cell B's output area is emptied and a **production kanban** (a light, flag, or sign) is used to tell Work cell B to begin processing more components to restock the empty container in its output area.
2. During this stage, when parts are moved from Work cell B's input area to its processing area, the container holding these parts is emptied and a movement kanban (a light, flag, or sign) is used to indicate to Work cell A that more parts are needed. This authorizes a full container of parts to move from Work cell A's output area to Work cell B's input area, and the empty container is moved to Work cell A's output area.

**Figure 8.4** A Kanban Pull System




3. As this movement occurs, a production kanban is used to authorize Work cell A to begin processing parts to restock its empty container in the output area.
4. Finally, as full containers of parts are emptied and used in Work cell A's processing area, the emptied containers in Work cell A's input area create a movement kanban seen by the external supplier who then restocks Work cell A's empty containers in the input area.

Thus, it can be seen that kanbans are used to control the flow of inventory through the facility. Inventories are not allowed to accumulate beyond the size of each container and the number of containers in the system. When containers are full, production stops until an output area container is emptied, which generates another production kanban.

A simple relationship can be used to determine the number of containers or kanban card sets for a lean production system:

$$\text{No. of containers} = \frac{DT\,(1 + S)}{C},$$

where:

$D$ = the demand rate of the assembly line

$T$ = the time for a container to make an entire circuit through the system, from being filled, moved, being emptied, and returned to be filled again

$C$ = the container size, in number of parts, and

$S$ = the safety stock factor, from 0 to 100 percent

Example 8.1 illustrates the container calculation.

Referring to Example 8.1, reducing inventory in the system (one of the objectives of lean production) occurs when the number of containers used is reduced. When this happens, the circuit time for each container would also have to be reduced to enable the demand to be met. This can be done by reducing setup time, processing time, wait time, move time, or some combination of these.

**Example 8.1 Calculating the Number of Containers in a Kanban System**

Mejza Manufacturing has an assembly line with a demand of twenty Part 1's per hour at Work cell B. The container used for this part holds five Part 1's. If it takes two hours for a container to make a circuit from Work cell B to the next assembly area and back again, and if it is desired to carry 10 percent excess of Part 1 in the system, then the number of containers needed in the system is:

$$\text{No. of containers} = \frac{DT(1+S)}{C} = \frac{20\dfrac{\text{parts}}{\text{hr}}(2\,\text{hr})(1+0.1)}{5\,\text{parts}} = 8.8 \rightarrow 9$$

Note that the number of containers must always be rounded up if there is a fractional number of containers. The maximum Part 1 inventory for this system would be the total number of containers times the container size, or $9 \times 5 = 45$ units.

## Continuous Improvement

As alluded to already, lean systems are never-ending works in progress. Compact layouts are designed to allow work to flow sequentially and quickly through the facility. Inventory is moved from supplier delivery vehicles to the shop floor and placed in containers in designated work cell storage areas.

Purchase orders and production batches are small. In this system, problems often surface, at least initially, as suppliers struggle to deliver the right parts frequently and on time, and as workers strive to maintain output levels while spending more time during the day setting up machines for small production runs. To make the lean system work better, employees continuously seek ways to reduce supplier delivery and quality problems, and in the production area they solve movement problems, visibility problems, machine breakdown problems, machine setup problems, and internal quality problems. In Japanese manufacturing facilities, this is known as **kaizen**. A literal translation of kaizen is "good change." Some firms embrace what is known as a **kaizen blitz**, which is a rapid improvement event or workshop, aimed at finding big improvements quickly. Most kaizen improvements though are small individual events, emphasizing creativity.

Quality improvement is certainly part of the ongoing continuous improvement effort in lean systems. For example, receiving a batch of goods from an external supplier or an internal work cell that does not meet design requirements is like not getting a batch of goods at all. Because of low safety stock levels in lean systems, processing areas needing these supplies will very quickly be out of stock and unable to operate. High-quality levels are then necessary throughout the production system to meet demand. Further discussions of quality and continuous improvement can be found in later segments of this chapter.

## Workforce Commitment

Since lean systems depend so much on waste reduction and continuous improvement for their success, employees must play a significant role in this process. Managers show strong support for lean production efforts by providing subordinates with the skills, tools, time, and other necessary resources to identify process problems and implement solutions. Managers can also create a culture in which workers are encouraged to speak out when problems are found. Georgia-based Universal Technology Company (UTC), a defense contractor, invests heavily in employee education. The company will pay for any worker to obtain an associate's, bachelor's, or master's degree. "The goal for UTC is to have the most highly educated workforce in the world," explains Emily Michelbach, human resources manager at their Athens, Georgia plant. At the corporate level, UTC has spent over $1 billion on the program to date.[35]

In lean manufacturing systems, employees are cross-trained on many of the various production processes to enable capacities to be adjusted as needed when machines break down or when workers are absent. Employees are given time during their day to work on reducing machine setup times, as well as to solve other production problems when they occur. They are also expected to perform a number of quality checks on processed items coming into their work cells. When quality problems are found, workers are empowered to shut down the production process until the source of the problem can be found and corrected. Most employees who work for lean companies enjoy their jobs; they are given a number of responsibilities and are considered one of the most important parts of a successful lean organization.

## Lean Systems and the Environment

In Chapter 4, the topics of ethical and sustainable procurement were introduced and their importance to supply chain management was discussed. Since lean systems are ultimately concerned with waste reduction throughout the firm and its supply chains, the linkage between lean and environmental sustainability should seem clear.

Many organizations have realized the positive impact lean systems can have on the environment—adopting lean practices reduces waste and the costs of environmental management, which in turn leads to improved environmental performance. Further, lean systems increase the possibility that firms will adopt more advanced environmental management systems, leading to yet further performance improvements. Professors King and Lennox analyzed thousands of companies in the early 1990s and found ample evidence of this linkage between the concept of lean and environmental sustainability. They found that firms minimizing inventories and adopting quality standards were more likely to practice pollution prevention.[36]

Other examples abound. A number of LEED certified buildings (Leadership in Energy and Environmental Design, which is a rating system to evaluate the environmental performance of a building) are using lean methods during the building's design phase. These include the first LEED-Healthcare certified project, Group Health Cooperative's Puyallup, Washington Medical Center and a Veterans Administration Healthcare Center in Kernersville, N.C. which incorporates daylighting, high-efficiency HVAC, and a green roof. Iowa-based Rockwell Collins decided to use their successful lean program to reduce its carbon footprint, starting in 2009. Their goal was to achieve a 15 percent reduction by 2014. They eventually exceeded this goal by three percent.[37] More recently, Pakistan-based Interloop's denim plant in Lahore is already one of the largest apparel manufacturing facilities to receive LEED v4 Platinum Certification, the highest standard for any structure assigned by the U.S. Green Building Council. The facility is designed with built-in systems that save up to 50 percent water and more than 50 percent energy. Further minimizing Interloop's carbon footprint is its highly advanced denim laundry, operating on water reuse technology with a reduced dye-to-fiber ratio and shorter wash cycles. This allows the company to produce garments with an extremely low environmental impact, saving 70 percent of the typical water usage during each process.[38]

As discussed in this first portion of the chapter, creating lean processes is a necessary element in successful supply chain management. A second, equally necessary element is the practice of continuous quality improvement—one of the best examples of this is Six Sigma quality. A discussion of Six Sigma quality and its relationship to lean thinking and supply chain management follows.

## The Origins of Six Sigma Quality

Six Sigma quality, many times simply referred to as Six Sigma, was pioneered by global communications leader Motorola in 1987, and is a statistics-based decision-making framework designed to make significant quality improvements in value-adding processes. Six Sigma (with capital S's) is a registered trademark of Motorola. In the 1980s, a senior staff engineer at Motorola named Mikel Harry formed a team of engineers to experiment with problem solving using statistical analyses, and this became the foundation for Six Sigma. Richard Schroeder, vice president of customer service at Motorola, heard about Harry's work, and applied the methodology to his job at Motorola. Soon, both groups were announcing large reductions in errors and related costs. Ultimately, both men left Motorola and formed the Six Sigma Academy, concentrating on training. Today, the firm has been renamed SSA & Company and is a management consultancy based in New York City.[39]

Since Six Sigma is ultimately about pleasing the customer, a very straightforward customer-oriented definition of quality can be employed—*the ability to satisfy customer expectations*. This definition is echoed by the American Society for Quality when it states: "Quality is defined by the customer through his/her satisfaction." In this sense, both a fast-food hamburger and a steakhouse chopped sirloin sandwich can be considered to possess equally high quality, if they meet or exceed the expectations of their customers.

Quality perfection is represented by the term Six Sigma, which refers to the statistical likelihood that 99.99966 percent of the time, a process sample average will fall below a control limit placed 4.5 standard deviations (or sigmas) above the true process mean, assuming the process is in control. This represents the goal of having a defect occur in a process only 0.00034 percent of the time, or 3.4 times out of every million measurement opportunities—very close to perfection. Interestingly, this description makes it sound like the methodology should be called 4½ sigma. The 1½ sigma difference is the subject of much debate, explained by a somewhat confusing term called **sigma drift**.[40] Sigma drift refers to the idea that process variations will grow over time, as process measurements drift off target. In truth, any process exhibiting a change in process variation of 1.5 standard deviations would be detected using quality control charts, instigating an improvement effort to get the process back on target. Table 8.4 shows the **defects per million opportunities** (DPMO) to be expected for various sigmas, using the Six Sigma methodology.

**Table 8.4** Six Sigma DPMO Metrics

| NO. STANDARD DEVIATIONS ABOVE THE MEAN | PERCENT OF DEFECT-FREE OUTPUT | DEFECTS PER MILLION OPPORTUNITIES (DPMO) |
|---|---|---|
| 2 | 69.15 | 308,537 |
| 2.5 | 84.13 | 158,686 |
| 3 | 93.32 | 66,807 |
| 3.5 | 97.73 | 22,750 |
| 4 | 99.38 | 6210 |
| 4.5 | 99.865 | 1350 |
| 5 | 99.977 | 233 |
| 5.5 | 99.9968 | 32 |
| 6 | 99.99966 | 3.4 |

Note: Standard deviations include a 1.5 sigma "drift."

The Six Sigma concept though, is not just concerned with statistics. It is a broad improvement strategy that includes the concepts and tools of **total quality management** (TQM), a focus on the customer, performance measurement, and formal training in quality control methods. Six Sigma embodies an organizational culture wherein everyone from CEO, to production worker, to frontline service employee is involved in quality assessment and improvement. Six Sigma is proactive in nature and seeks to permanently fix the root causes of problems, instead of repeatedly spending time and money tinkering with and patching-up processes as problems occur in the business. In Six Sigma, sources of process variation are sought out and remedied prior to the time these variations can cause production and customer satisfaction problems.

Today, many organizations practice Six Sigma, including early adopters Honeywell, General Electric, and Dow Chemical. In 1999, Ford Motor Company became the first U.S. automaker to adopt a Six Sigma strategy. Automobile manufacturing provides a great example of the need for Six Sigma. Since one automobile has roughly 20,000 **opportunities for a defect to occur** (OFD), and assuming an automobile company operates at an impressive 5½ sigma level (32 DPMO from Table 8.4), this would equate to about one defect for every two cars produced. Improving up to the Six Sigma level would mean about one defect for every 15 automobiles produced. Calculating the DPMO can be accomplished using the following formula:

$$\text{DPMO} = \frac{\text{number of defects}}{(\text{OFD per unit})(\text{number of units})} \times 1{,}000{,}000$$

Example 8.2 illustrates the calculation of DPMO and the use of Table 8.4.

**Example 8.2 Calculating the DPMO for Blakester's Speedy Pizza**

Blake Roberts, owner of Blakester's Speedy Pizza, keeps track of customer complaints. For each pizza delivery, there are three possible causes of complaints: a late delivery, a cold pizza, or an incorrect pizza. Each week, Blake tracks the delivery "defects" for pizza deliveries, and then uses this information to determine his company's Six Sigma quality level. During the past week, his company delivered 620 pizzas. His drivers received 16 late delivery complaints, 19 cold pizza complaints, and 5 incorrect pizza complaints. Blake's defects per million opportunities is:

$$\text{DPMO} = \frac{\text{number of defects}}{(\text{OFD per unit})\ (\text{number of units})} \times 1{,}000{,}000$$

$$= \frac{40}{(3)(620)} \times 1{,}000{,}000 = 21{,}505 \text{ defective pizza deliveries per million.}$$

From Table 8.4, it can be concluded that Blakester's is operating at slightly better than 3.5 Sigma.

Increasingly, companies are using Six Sigma programs to generate cost savings or increased sales through process improvements. In fact, Motorola reported savings of $16 billion from 1986 to 2001, GE saved $4.4 billion from 1996 to 1999, and Honeywell saved $1.8 billion from 1998 to 2000. More recently, Indiana-based truck trailer manufacturer Wabash National used Six Sigma to help it achieve an operating income of $202.5 million in 2016, an increase of 12 percent over the prior year, and a record performance for the fifth consecutive year.[41] These types of outcomes are possible as firms identify customer requirements, uncover all of the opportunities for errors or defects to occur, review performance against Six Sigma performance standards, and then take the actions necessary to achieve those standards. The most successful projects meet strategic business objectives, reduce product and service variations to optimal levels, and most importantly, produce a product or service that satisfies the customer.

In countries such as China and India, where competitive advantage has largely been due to the low cost of labor, many Chinese and Indian companies are today looking to quality management as a way to help them better compete in global markets. The China National Institute for Standards, for example, the national standardization body for China, developed standards for Six Sigma practices in 2012.[42] Additionally, a survey conducted in 2012 of manufacturing companies in Germany, France, Scandinavia, the United States, Canada, India, and China found that 47 percent had launched Six Sigma programs, 43 percent had started zero defect programs, and 83 percent had implemented continuous improvement programs. A majority in each case were either satisfied or very satisfied with the results.[43] One remarkable story in India deserves a note here—the work of the dabbawalas in Mumbai (dabbawala means "one who carries a box"). Dabbawalas collect freshly cooked meals in boxes from the homes of Mumbai residents and deliver them to their customers' offices for a small monthly fee. Five thousand dabbawalas deliver 200,000 boxes per day using bicycles, buses, and trains. Forbes Magazine awarded a Six Sigma certification in 2001 to the dabbawalas based on a 99.999999 percent delivery accuracy rate (an amazingly low rate of 1 error for every 16 million transactions). Further, the dabbawalas have no knowledge of Six Sigma.[44]

Like any other improvement strategy or program, however, Six Sigma cannot guarantee continued or even initial business success. Poor management decisions and investments, or a company culture not conducive to change can undermine even the best Six Sigma program. Ironically, Six Sigma originator Motorola struggled financially for a number of years; in 2009, after losing billions over a three-year period, Motorola was split into two independent companies—Motorola Mobility and Motorola Solutions. In 2012, Google acquired Motorola Mobility.[45] Camera and film maker Polaroid, another early user of Six Sigma, filed for Chapter 11 bankruptcy protection in 2001, and the following year, the firm sold its name and all of its assets to a subsidiary of Illinois-based Bank One Corp.[46]

## Comparing Six Sigma and Lean

Six Sigma and lean actually have many similarities. For lean practices to be successful, purchased parts and assemblies, work-in-process, and finished goods must all meet or exceed quality requirements. Also, recall that one of the elements of lean is continuous improvement, and these are the areas where the practice of Six Sigma can be put to good use in a lean system. Evidence points to the growing use of both of these initiatives simultaneously.

Successful manufacturing companies over the long term must ultimately offer high-quality goods at reasonable prices, while providing a high level of customer service. Rearranging factory floor layouts and reducing batch sizes and setup times will reduce manufacturing lead times and inventory levels, providing better delivery performance and lower cost. These are lean production activities. Reducing waste (such as excess inventories) uncovers process problems. Addressing these process problems requires performance monitoring, use of statistical quality control techniques, and creating long-term relationships with high-quality, high-performance suppliers; these activities are all part of Six Sigma. This short explanation describes how the two concepts can work together to achieve better overall firm performance. Lean production is about reducing waste, while Six Sigma is about solving problems and improving quality. The melding of these methods is called *lean Six Sigma*, discussed next.

## Lean Six Sigma

A term is now being used to describe the combining of lean thinking and Six Sigma quality practices—**lean Six Sigma**, or simply **lean Six**. Since 2007, the U.S. Defense Department's Lean Six Sigma office has completed more than 330 projects and trained more than 1,000 officials on the techniques of lean Six, allowing them to take on new projects themselves. Further, more than 30,000 department employees have been trained in lean Six. Ireland-based Abbott Diagnostics Longford, a healthcare manufacturing facility, applied numerous lean Six Sigma techniques to enhance its processes, and linked its core competencies to principles of operational excellence. As a result, the facility dramatically cut costs, lead times, nonconformance rates, inventory, energy costs, and other wastes, while improving output and employee development and morale. In 2015, Longford earned the Shingo Prize for its accomplishments.[47] The nearby SCM Profile describes PepsiCo's use of Minecraft to teach lean Six Sigma during the pandemic.

### SCM Profile: PepsiCo Uses Minecraft to Teach Lean Six Sigma

Surie/Shutterstock.com

Food and beverage manufacturer PepsiCo was seeking ways to adapt in-person employee training to the realities of the pandemic, but the company had problems with its Lean Six Sigma (LSS) training program. As part of this program, PepsiCo participants used Lego bricks to help simulate problems. The pandemic required PepsiCo to transition to a virtual format, but "There are few to no Lean Six Sigma simulations in the market designed for an online experience or the interactivity needed for this type of training," Molly Nagler, PepsiCo's chief learning officer said.

PepsiCo received an idea from Marco Tapia, a Master Black Belt of PepsiCo's LSS program in Europe. Tapia, who said in a blog post that the idea actually came from his 11-year-old son, suggested a solution using the video game Minecraft. Minecraft allows users to create entire virtual worlds. Tapia recruited his son to build a prototype training solution. The prototype was then given to BlockWorks and the finished product was finally used by more than 300 PepsiCo employees in 2021. The program simulates a 3D PepsiCo distribution center and warehouse.

In the simulation, employees interact with an imaginary distribution center which produces pallets with different products and ships them to a warehouse, which then transports them to customers who placed orders. Trainees seek to reduce waste. Those completing the training are recognized as "Kaizen Leader Trained" within their LSS program and receive a PepsiCo certification. "Minecraft enables you to build with blocks, so the translation is completely intuitive for the learner and the instructor," said Nagler.[48]

## Six Sigma and Supply Chain Management

By now, the supply chain management objectives of better customer service, less waste, and higher quality should be starting to sound familiar. To sustain and improve competitiveness, firms must perform better in these areas than their competitors. Through better process integration and communication, trading partners along the supply chain realize how poor-quality goods and services can cause negative reactions to occur, such as greater levels of safety stock throughout the supply chain, lost time and productivity due to product and component repairs, the increased costs of customer returns and warranty repairs, and, finally, loss of customers and damage to reputations.

The impact of poor quality on the supply chain and the potential damage to a firm's reputation can be illustrated by toy-maker Mattel and its problems regarding the Chinese-made toys it was selling in many of its global markets in 2007. Mattel announced it was pulling 9 million Chinese-made Barbies, Polly Pockets, and other toys off store shelves, due to quality and safety problems. Some of the toys had high levels of lead paint, while others had tiny magnets that could come off and be swallowed. Some of the magnets were in fact swallowed, causing physical harm to the children involved. Obviously, the cost to Mattel and its suppliers, the toy retailers, and the children who played with these toys was very high.[49] Thus, the impacts of poor quality can be felt throughout the supply chain and ultimately by end customers.

Six Sigma is an enterprise-wide philosophy, encompassing an organization's suppliers, employees, and customers. It emphasizes a commitment by the organization to strive toward excellence in the production of goods and services that customers want. Firms implementing a Six Sigma program have made a decision to understand, meet, and then strive to exceed customer expectations; and this spills over to their trading partners as well. Connecticut-based Pratt & Whitney, a manufacturer of aircraft engines, has been ramping-up production of jet engines since 2014. The company relies on suppliers to produce roughly 80 percent of the engines' components and parts. As part of this initiative, the company has invested more than $10 billion in long-term agreements with 90 key suppliers. To aid this endeavor, Pratt & Whitney recently opened an Operations Command Center, which focuses on lean and continuous improvement between the company and its 400 worldwide suppliers. "Our goal is to identify supply chain issues early and collaborate with the suppliers early before a potential constraint or impediment occurs," explains Rita Peralta, general manager of the Command Center.[50]

Many successful companies use Six Sigma methods to assure that their suppliers are performing well and that their customers' needs are being met. Ultimately, this translates into end consumers getting what they want, when they want it, for a price they are willing to pay. While Six Sigma programs tend to vary somewhat in the details from one organization to another, all tend to employ a mix of qualitative and quantitative elements aimed at achieving customer satisfaction. The most common elements addressed in most Six Sigma programs are discussed in the following section.

## The Elements of Six Sigma

The philosophy and tools of Six Sigma are borrowed from a number of resources including quality professionals such as W. Edwards Deming, Philip Crosby, and Joseph Juran; the Malcolm Baldrige National Quality Award and the International Organization for Standardization's ISO 9000 and 14000 families of standards; the Motorola and General Electric practices relating to Six Sigma; and statistical process control techniques originally

developed by Walter Shewhart. From these resources, a number of commonly used elements emerge that are collectively known today as Six Sigma. A few of the quality resources are discussed next, followed by a brief look at the qualitative and quantitative elements of Six Sigma.

## Deming's Contributions

W. Edwards Deming's Theory of Management is explained in his book *Out of the Crisis* and essentially states that since managers are responsible for creating the systems that make organizations work, they must also be held responsible for the organization's problems (not the workers). Thus, only management can fix problems, through application of the right tools, resources, encouragement, commitment, and cultural change. Deming's Theory of Management was the centerpiece of his teachings around the world (Deming died in 1993) and includes his Fourteen Points for Management, shown in Table 8.5.[51]

**Table 8.5 Deming's Fourteen Points for Management**

| | |
|---|---|
| **1. Create a constancy of purpose for improvement of product and service.** | Define values, mission, and vision to provide direction for management and employees. Invest in innovation, training, and research. |
| **2. Adopt the new philosophy.** | Adversarial management–worker relationships and quota work systems no longer work. Management must work toward cooperative relationships aimed at increasing quality and customer satisfaction. |
| **3. Cease dependence on mass inspection.** | Inspecting goods does not create value or prevent poor quality. Workers must use statistical process control to improve quality. |
| **4. End the practice of awarding business on the basis of price tag alone.** | Purchases should not be based on low cost; buyers should develop long-term relationships with a few good suppliers. |
| **5. Constantly improve the production and service system.** | Significant quality improvement comes from continual incremental improvements that reduce variation and eliminate common causes. |
| **6. Institute training.** | Managers need to learn how the company works. Employees should receive adequate job training and statistical process control training. |
| **7. Adopt and institute leadership.** | Managers are leaders, not supervisors. They help, coach, encourage, and provide guidance to employees. |
| **8. Drive out fear.** | A supportive organization will drive out fear of reprisal, failure, change, and loss of control. Fear causes short-term thinking. |
| **9. Break down barriers between departments.** | Cross-functional teams focus workers, break down departmental barriers, and allow workers to see the big picture. |
| **10. Eliminate slogans, exhortations, and targets for the workforce.** | Slogans and motivational programs are aimed at the wrong people. They don't help workers do a better job. These cause worker frustration and resentment. |
| **11. Eliminate numerical quotas for workers and managers.** | Quotas are short-term thinking and cause fear. Numerical goals have no value unless methods are in place to allow them to be achieved. |
| **12. Remove barriers that rob people of pride of workmanship.** | Barriers are performance and merit ratings. Workers have become a commodity. Workers are given boring tasks with no proper tools, and performance is appraised by supervisors who know nothing about the job. Managers won't act on worker suggestions. This must change. |
| **13. Encourage education and self-improvement for everyone.** | All employees should be encouraged to further broaden their skills and improve through continuing education. |
| **14. Take action to accomplish the transformation.** | Management must have the courage to break with tradition and explain to a critical mass of people that the changes will involve everyone. Management must speak with one voice. |

Deming's Fourteen Points are all related to Six Sigma principles, covering the qualitative as well as quantitative aspects of quality management. He was convinced that high quality was the outcome of a philosophy geared toward personal and organizational growth. He argued that growth occurred through top management vision, support, and value placed on all employees and suppliers. Value is demonstrated through investments in training, equipment, continuing education, support for finding and fixing problems, and teamwork both within the firm and with suppliers. Use of statistical methods, elimination of inspected-in quality, and elimination of quotas are also required to improve quality. Today, Deming's work lives on through the Deming Institute, a nonprofit organization he founded to foster a greater understanding of Deming's principles and vision. The institute provides conferences, seminars, and training materials to managers seeking to make use of the Deming operating philosophy.[52]

## Crosby's Contributions

Philip Crosby, a former vice president of quality at the New York-based manufacturer ITT Corporation, was a highly sought-after quality consultant during the latter part of his life and wrote several books concerning quality and striving for zero defects, most notably *Quality Is Free* and *Quality without Tears* (he died in 2001).[53] His findings about quality improvement programs as discussed in *Quality Is Free* were that these programs invariably more than paid for themselves. In *Quality without Tears*, Crosby discussed his four Absolutes of Quality, shown in Table 8.6. Industrial giants such as IBM and General Motors have benefited greatly from implementing Crosby's ideas. Crosby emphasized a commitment to quality improvement by top management, development of a prevention system, employee education and training, and continuous assessment—all very similar to the teachings of Deming.

## Juran's Contributions

Joseph Juran, founder of the Juran Institute (today it is simply known as Juran), helped to write and develop the *Quality Handbook* (now in its seventh edition) and wrote a number of other books on quality as well. Born in 1904, Juran remained an active lecturer right up until his death in 2008 at the age of 103. He also remained active by overseeing his Juran Foundation in New York. "My job of contributing to the welfare of my fellow man," Juran wrote, "is the great unfinished business."[54]

Like Deming, Juran helped to engineer the Japanese quality revolution starting in the 1950s. Juran, similar to both Crosby and Deming, strived to introduce new types of thinking about quality to business managers and employees, but Juran's recommendations did vary somewhat from those of Crosby and Deming. He is recognized as the person who

**Table 8.6 Crosby's Four Absolutes of Quality**

| | |
|---|---|
| **1. The definition of quality is conformance to requirements.** | Adopt a do-it-right-the-first-time attitude. Never sell a faulty product to a customer. |
| **2. The system of quality is prevention.** | Use SPC as part of the prevention system. Make corrective changes when problems occur. Take preventative action. |
| **3. The performance standard is zero defects.** | Insist on zero defects from suppliers and workers. Education, training, and commitment will eliminate defects. |
| **4. The measure of quality is the price of nonconformance.** | The price of nonconformance is the cost of poor quality. Implementing a prevention program will eliminate this. |

brought the human element to the practice of quality improvement. Juran did not seek cultural change but sought to work within the system to instigate change. He felt that to get managers to listen, your message had to be spoken in dollars. To get workers to listen, you had to speak about specific things. So, he used the costs of poor quality to get the attention of managers, and used statistical quality control methods with workers.

Juran's recommendations were focused on his Quality Trilogy, shown in Table 8.7.[55] He found in his dealings with companies that most had given priority to quality control but paid little attention to quality planning and improvement. Thus, while both Japan and the United States had been using quality control techniques since the 1950s, Japan's overall quality levels grew faster than those of the United States because Japan's quality planning and improvement efforts were much greater.

Many characteristics, though, of the Deming, Crosby, and Juran philosophies are quite similar. All three focus on top management commitment, the need for continuous improvement efforts, training, and the use of statistical methods for quality control purposes.

## The Malcolm Baldrige National Quality Award

The **U.S. Baldrige Quality Award** was signed into law on August 20, 1987, and is named in honor of then U.S. President Reagan's Secretary of Commerce, who helped draft an early version of the award, and who was tragically killed in a rodeo accident shortly before the award was enacted. The objectives of the award, which by the way is given only to U.S. firms, are:

- to stimulate U.S. firms to improve quality and productivity,
- to recognize U.S. firms for their quality achievements,
- to establish criteria and guidelines so that organizations can independently evaluate their own quality improvement efforts, and
- to provide examples and guidance to those companies wanting to learn how to manage and improve quality and productivity.

The Baldrige Award is managed by the Baldrige Performance Excellence Program, and administered by the National Institute of Standards and Technology (NIST). Up to 18 awards are given annually and are typically presented by the President of the United States to organizations across six sectors: small business, service, manufacturing, education, health care, and nonprofit/government. The applicants are evaluated in five key areas:

**Table 8.7 Juran's Quality Trilogy**

| | |
|---|---|
| **1. Quality planning.** | The process of preparing to meet quality goals. Identify internal and external customers, determine their needs, and develop products that satisfy those needs. Managers set short- and long-term goals, establish priorities, and compare results to previous plans. |
| **2. Quality control.** | The process of meeting quality goals during operations. Determine what to control, establish measurements and standards of performance, measure performance, interpret the difference between the actual measure and the standard, and take action if necessary. |
| **3. Quality improvement.** | The process of breaking through to unprecedented levels of performance. Identify projects for improvement, organize support for the projects, diagnose causes, implement remedies, and provide control to maintain improvements. |

product and process outcomes, customer outcomes, workforce outcomes, leadership and governance outcomes, and financial and market outcomes.[56] A number of companies have even sprung up to help companies apply for, and hopefully win an award. Table 8.8 shows the 130 Baldrige Award winners from 1988 through 2020.

**Table 8.8** Malcolm Baldrige National Quality Award Recipients (1988 – 2020)[57]

| YEAR | SMALL BUSINESS | MANUFACTURING | SERVICE | EDUCATION | HEALTH CARE | NONPROFIT/GOV'T. |
|---|---|---|---|---|---|---|
| 1988 | Globe Metallurgical | Motorola; Westinghouse Comm. Nuclear Fuel Div. | | | | |
| 1989 | | Xerox Bus. Products and Sys; Milliken & Co. | | | | |
| 1990 | Wallace Co. | Cadillac Motor Car Co.; IBM Rochester | FedEx Corp. | | | |
| 1991 | Marlow Industries | Solectron Corp.; Zytec Corp. | | | | |
| 1992 | Granite Rock Co. | AT&T Network Sys. Group; Texas Instr. Def. Sys. & Electronics Grp. | AT&T Universal Card Svcs.; The Ritz-Carlton Hotel Co. | | | |
| 1993 | Ames Rubber Corp. | Eastman Chemical Co. | | | | |
| 1994 | Wainwright Indus. | | AT&T Consumer Comm Svcs.; GTE Directories | | | |
| 1995 | | Armstrong World Ind. Bldg. Prod. Ops.; Corning Telecomm. Prod. Div. | | | | |
| 1996 | Custom Research; Trident Precision Mfg. | ADAC Laboratories | Dana Comm. Credit | | | |
| 1997 | | 3M Dental Prod. Div.; Solectron | Merrill Lynch Credit; Xerox Business Svcs. | | | |
| 1998 | Texas Nameplate | Boeing Airlift and Tanker Programs; Solar Turbines | | | | |
| 1999 | Sunny Fresh Foods | STMicroelectronics—Region Americas | BI; The Ritz-Carlton Hotel Co. | | | |
| 2000 | Los Alamos Nat'l. Bank | Dana Corp.—Spicer Drvshft Div.; KARLEE | Operations Mgt. Int'l. | | | |
| 2001 | Pal's Sudden Svc. | Clarke American Checks | | Chugach Sch. Dist.; Pearl River Sch. Dist.; Univ. of Wisc.-Stout | | |
| 2002 | Branch-Smith Printing Div. | Motorola Comm., Gov't., and Indus. Sol. Sector | | | SSM Health Care | |
| 2003 | Stoner | MEDRAD | Boeing Aerospace Support; Caterpillar Financial Svcs. Corp. | Community Consol. Sch. Dist. 15 | Baptist Hosp.; St. Luke's Hosp. of Kan. City | |
| 2004 | Texas Nameplate | The Bama Companies | | K. W. Monfort Coll. of Bus. | R. W. Johnson Univ. Hosp. | |
| 2005 | Park Place Lexus | Sunny Fresh Foods | DynMcDermott Petroleum Opns. | Jenks Public Schools; Richland College | Bronson Meth. Hosp. | |

**Table 8.8** Malcolm Baldrige National Quality Award Recipients (1988 – 2020)[57] (continued)

| | | | | | | |
|---|---|---|---|---|---|---|
| 2006 | MESA Products | | Premier | | N. Mississippi Medical Center | |
| 2007 | PRO-TEC Coating | | | | Mercy Health Sys.; Sharp HealthCare | City of Coral Springs; US Army ARDEC |
| 2008 | | Cargill Corn Milling | | Iredell-Statesville Schools | Poudre Valley Health System | |
| 2009 | MidwayUSA | Honeywell Federal Mfg. & Technologies | | | Heartland Health | VA Cooperative Studies Program |
| 2010 | Studer Grp.; Freese and Nichols; K&N Mgt. | MEDRAD; Nestle Purina PetCare | | Montgomery Cty. Pub. Sch. | Advocate Good Sam. Hosp. | |
| 2011 | | | | | Henry Ford Health Sys.; Schneck Med. Ctr.; Southcentral Fndn. | Concordia Publishing House |
| 2012 | MESA | Lockheed Missiles and Fire Cont. | | | N. Miss. Health Svcs. | City of Irving, TX |
| 2013 | | | | Pewaukee School District | Sutter Davis Hospital | |
| 2014 | | | PwC-Public Sector | | Hill Country Memorial; St. David's HealthCare | Elevations Credit Union |
| 2015 | MidwayUSA | | | Charter School of San Diego | Charleston Area Medical Center Health System | Mid-America Transplant |
| 2016 | Momentum Group; Don Chalmers Ford | | | | Memorial Hermann Sugar Land Hospital; Kindred Nursing and Rehab. Center – Mountain Valley | |
| 2017 | Bristol Tennessee Essential Services; Stellar Solutions | | | | Adventist Health Castle; Southcentral Foundation | City of Fort Collins |
| 2018 | Integrated Project Management Company, Inc. | | | Alamo Colleges District; Tri County Tech | Memorial Hospital and Health Care Center | Donor Alliance, Inc. |
| 2019 | | | | Howard Community College | Adventist Health White Memorial; Mary Greeley Medical Center | Center for Organ Recovery & Education; City of Germantown, TN; Illinois Municipal Retirement Fund |
| 2020 | MESA | | | | GBMC HealthCare, Inc.; Wellstar Paulding Hosp. | AARP; Elevations Credit Union |

All Malcolm Baldrige Award applications receive from 300 to 1000 hours of review by quality professional volunteers and are scored in the five key areas mentioned above. Finalists are visited wherein performance is reassessed and final scores tabulated, with the winners selected from this group. Nearly 1700 organizations have applied for the Baldrige Award, nine have won it twice, and one company has won it three times (Oklahoma-based MESA won for the third time in 2020). Thousands of companies around the world have obtained a copy of the Baldrige Award criteria, and perform self-assessments using the form and its point scoring guidelines. Completing a self-assessment using the Baldrige Award criteria identifies the firm's strengths and weaknesses and can aid in implementing various quality and productivity improvement initiatives.

## The ISO 9000 and 14000 Families of Management Standards

In 1946, delegates from 25 countries met in London and decided to create a new international organization, with the objective "to facilitate the international coordination and unification of industrial standards." The new organization, called the International Organization for Standardization or ISO, officially began operations on February 23, 1947. ISO is the world's largest developer of voluntary international standards (there are currently over 23,000 ISO standards). Located in Geneva, Switzerland, ISO today has 165 member countries (note that individuals and companies cannot become members).[58] This topic was first discussed in Chapter 3.

ISO standards are voluntary, are developed in response to market demand, and are based on consensus among the member countries. This ensures widespread applicability of the standards. ISO considers evolving technology and member interests by requiring a review of its standards at least every five years to decide whether they should be maintained, updated, or withdrawn. In this way, ISO standards retain their position as state of the art.

ISO standards are technical agreements which provide the framework for compatible technology worldwide. Developing consensus on this international scale is a major operation. In all, there are some 3700 ISO technical groups with over 50,000 experts participating annually to develop ISO standards. Examples include standards for agriculture and construction, mechanical engineering, medical devices, and information technology developments such as the digital coding of audio–visual signals for multimedia applications.

In 1987, ISO adopted the ISO 9000 family of international quality standards, and revises them every five years. ISO 9001:2015 sets out the criteria for a quality management system and is the only standard in the family with a certification for organizations. It can be used by any organization, large or small, regardless of its field of activity. As of 2021, over 1 million organizations in over 170 countries currently hold a valid certification.[59] The standards have been adopted in the United States by the American National Standards Institute (ANSI) and the American Society for Quality (ASQ). In many cases worldwide, companies will not buy from suppliers who do not possess an ISO 9000 certification.

After the rapid acceptance of ISO 9000 and the increase of environmental standards around the world, ISO assessed the need for international environmental management standards. They formed an advisory group for the environment in 1991, which eventually led to the introduction of the ISO 14000 family of international environmental management standards in 1996. ISO 14001:2015 sets out the criteria for an environmental management system and offers organizations this certification. Some of the more recently adopted 14000 standards are the ISO 14006 standard for the management of ecodesign, ISO 14031,

which provides guidance on the design and use of environmental performance evaluation, and the ISO 14064 standard for greenhouse gas accounting and verification.

Together, the ISO 9000 and 14000 families of certifications are the most widely used standards of ISO, with more than 1.3 million organizations in 175 countries holding one or both types of certifications as of 2021. For both types of standards, European and Asian companies vastly exceed other companies in getting certified. The standards that have earned the ISO 9000 and ISO 14000 families a worldwide reputation are known as "generic management system standards," meaning that the same standards can be applied to any type of organization.

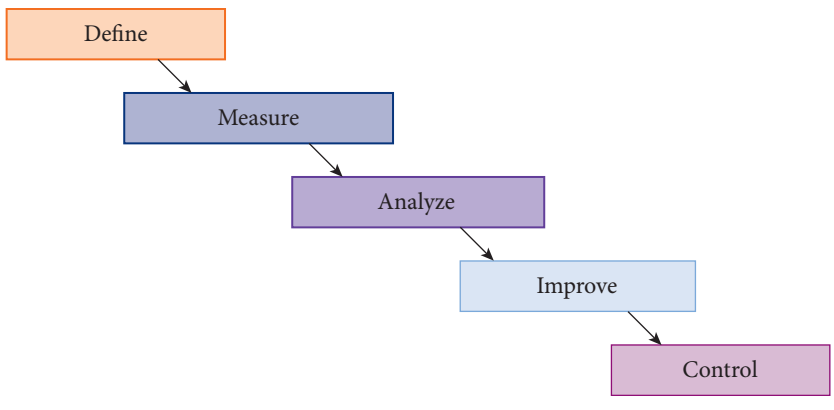
## The DMAIC Improvement Cycle

Figure 8.5 shows the five-step DMAIC improvement cycle, an important element of Six Sigma, listing the sequence of steps necessary to drive process improvement. The cycle can be applied to any process or project, both in services and manufacturing firms. The improvement cycle begins with customer requirements and then seeks to analyze and modify processes or projects so they meet those requirements.

Each of the steps is described below:

1. *Define*: Identify customers and their service or product requirements critical to achieving customer satisfaction (also known as **critical-to-quality (CTQ) characteristics**). Identify any gaps between the CTQ characteristics and process outputs. Where gaps exist, create Six Sigma projects to alleviate the gaps.
2. *Measure*: Prepare a data-collection plan to quantify process performance. Determine what to measure for each process gap and how to measure it. Use check sheets to organize measurements.
3. *Analyze*: Perform a process analysis using the performance data collected. Use Pareto charts and fishbone diagrams to identify the root causes of the process variations or defects.
4. *Improve*: Design an improvement plan, then remove the causes of process variation by implementing the improvement plan. This will require modifying, redesigning, or reengineering the process. Document the improvement and confirm that process gaps have been significantly reduced or eliminated.

**Figure 8.5** The DMAIC Improvement Cycle



5. *Control*: Monitor the process to assure that performance levels are maintained. Design and use statistical process control charts to continuously monitor and control the process. When performance gaps are once again identified, repeat steps 1–5.

Using the DMAIC improvement cycle allows the firm to continuously monitor and improve processes that are keys to customer satisfaction. By concentrating on these key processes and the CTQ characteristics, firms can make large and dramatic improvements in processes, products, and customer satisfaction. Deaconess Health System, for example, a six hospital system in Indiana, has used the DMAIC cycle since 2011 to improve contractual reimbursements from their managed care plans. After just five months of using DMAIC, their dollars collected per day had increased by over $3,800.[60]

## Six Sigma Training Levels

In order to develop and successfully complete Six Sigma improvement projects, specific training in quality improvement methods is available. A number of organizations offer courses and certifications in Six Sigma methods, and the somewhat standardized training levels are summarized in Table 8.9. Global manufacturing giant GE began using Six Sigma in the 1980s, and today, all GE employees are receiving training in the strategy, statistical tools, and techniques of Six Sigma. Eventually, all employees earn their Six Sigma Green Belt designations. Training courses are offered at various levels including basic Six Sigma awareness seminars, team training, Master Black Belt, Black Belt, and Green Belt training.[61] Several of the statistical tools of Six Sigma are discussed next.

**Table 8.9** The Six Sigma Training Levels[62]

| TRAINING LEVELS | DESCRIPTION |
|---|---|
| Yellow Belt | Basic understanding of the Six Sigma methodology and the tools within the DMAIC problem-solving process, including process mapping, cause-and-effect tools, simple data analysis, and process improvement and control methods. Role is to be an effective team member on process improvement project teams. |
| Green Belt | A specially trained team member allowed to work on small, carefully defined Six Sigma projects, requiring less than a Black Belt's full-time commitment. Has enhanced problem-solving skills, and can gather data and execute experiments in support of a Black Belt project. They spend approximately 25 percent of their time on Six Sigma projects of their own or in support of Black Belt projects. |
| Black Belt | Has a thorough knowledge of Six Sigma principles. Exhibits leadership, understands team dynamics, and assigns team members with roles and responsibilities. Has a complete understanding of the DMAIC model, a basic knowledge of lean concepts, and can quickly identify "nonvalue-added" activities. Coaches project teams and provides group assessments. Identifies projects, selects project team members, acts as an internal consultant, mentors Green Belts and provides feedback to management. |
| Master Black Belt | A proven mastery of process variability reduction and waste reduction. Can effectively provide training at all levels. Challenges conventional wisdom through the demonstration of the application of Six Sigma principles and provides guidance and knowledge to lead and change organizations. Directs Black and Green Belts on the performance of their Six Sigma projects and also provides guidance and direction to management teams regarding the selection of projects and the overall health of a Six Sigma program. |

# The Statistical Tools of Six Sigma

## Flow Diagrams

Also called **process diagrams** or **process maps**, this tool is the necessary first step to evaluating any manufacturing or service process. **Flow diagrams** use annotated boxes representing process action elements and ovals representing wait periods, connected by arrows to show the flow of goods or customers through a process. Once a process or series of processes is mapped out, potential problem areas can be identified and further analyzed for excess inventories, wait times, or capacity problems. A simple example of a customer flow diagram for a restaurant is shown in Figure 8.6. Using the diagram, restaurant managers could then observe each process activity and wait period element, looking for potential problems requiring further analysis.

## Check Sheets

**Check sheets** allow users to determine the frequencies of specific problems. For the restaurant example shown in Figure 8.6, managers could make a list of potential problems based on experience and observation, and then direct employees to keep counts of each problem on check sheets for a given period of time (long enough to allow for true problem level determinations). At the end of the data-collection period, problem areas can be reviewed and compared. Figure 8.7 shows a typical check sheet that might be used in a restaurant.

**Figure 8.6** Flow Diagram for a Restaurant

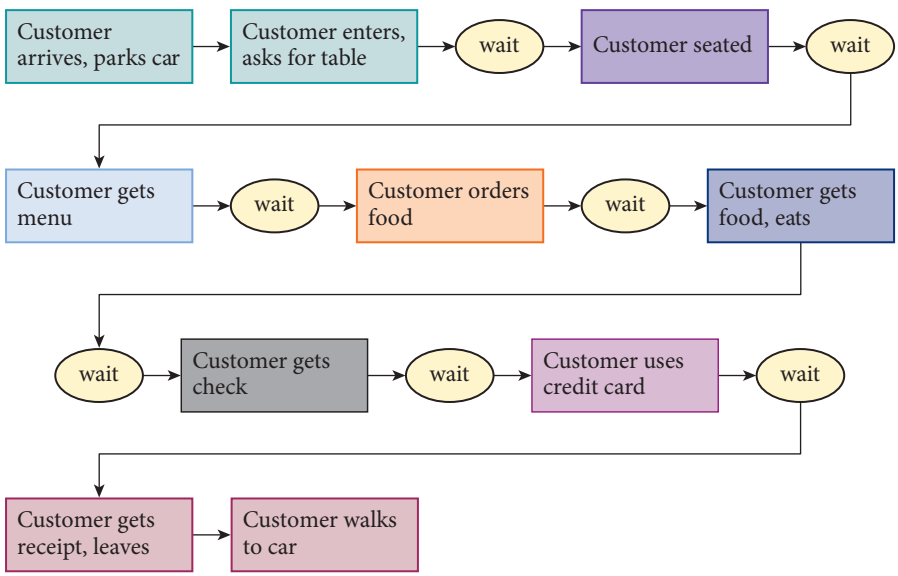


**Figure 8.7** Check Sheet for Problems at a Restaurant

| Problem | Mon. | Tues. | Wed. | Thurs. | Fri. | Sat. | Sun. | Totals | % of Total |
|---|---|---|---|---|---|---|---|---|---|
| Long wait | ////// | ///// | //////// | ////// | ///////// | ////////// | //// | 48 | 26.5 |
| Cold food | | // | / | / | /// | // | | 9 | 5.0 |
| Bad food | // | / | /// | | / | //// | | 11 | 6.1 |
| Wrong food | ///// | // | / | // | ///// | /// | / | 19 | 10.5 |
| Bad server | ////// | /// | ///// | / | ////// | // | / | 24 | 13.3 |
| Bad table | | / | // | | / | /// | / | 8 | 4.4 |
| Room temp. | | | // | /// | ///// | ///// | | 15 | 8.3 |
| Too expensive | / | // | / | / | /// | /// | | 11 | 6.1 |
| No parking | | | // | | ///// | /////// | | 14 | 7.7 |
| Wrong change | ////// | / | //// | | //// | /// | | 18 | 9.9 |
| Other | | / | // | | | / | | 4 | 2.2 |
| **Totals** | 26 | 18 | 31 | 14 | 42 | 43 | 7 | 181 | 100 |

## Pareto Charts

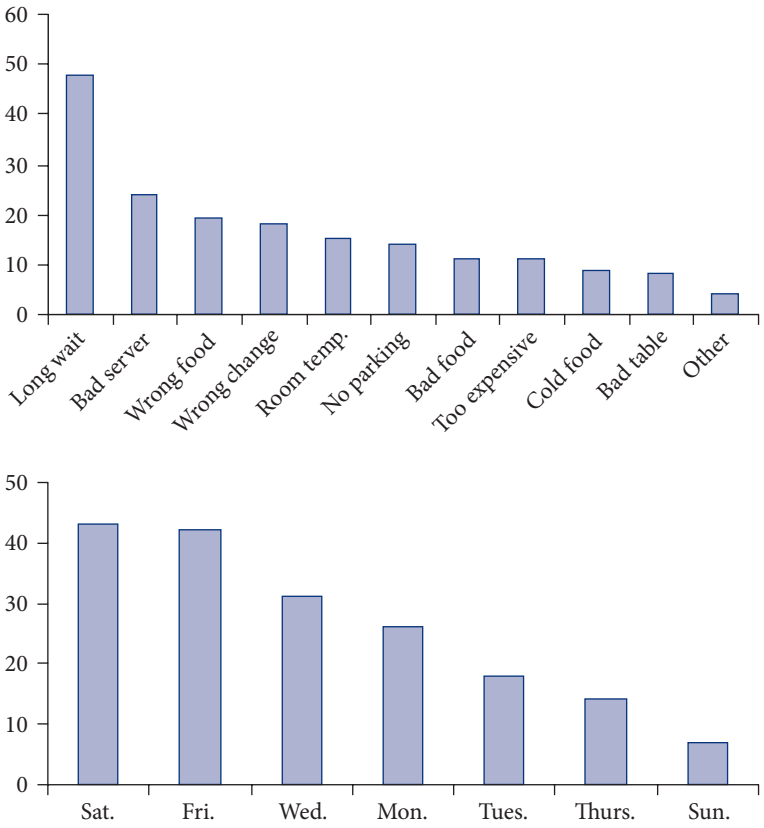
**Pareto charts**, useful for many applications, are based at least initially, on the work of Vilfredo Pareto, a nineteenth-century Italian economist. In 1906, Pareto described the unequal distribution of wealth in his country, observing that 20 percent of the people owned about 80 percent of the wealth. Decades later, Joseph Juran described what he called the **Pareto Principle** referring to the observation that 20 percent of something is typically responsible for 80 percent of the results. Eventually this became widely known as the Pareto Principle or 80/20 Rule.[63] Applied to quality improvement, this refers to the common observation that a few of a firm's problems account for most of the problem occurrences. In other words, firms should fix the few biggest problems first.

The Pareto chart shown in Figure 8.8 is useful for presenting data in an organized fashion, indicating process problems from most to least severe. The top two restaurant problems in Figure 8.7 account for about 40 percent of the instances where problems were observed. Two Pareto charts are shown in Figure 8.8. Note that we could look at the total problem events either from a problem-type or day-of-the-week perspective and see that *long wait* and *bad server* are the two largest problems, while Saturdays and Fridays are the days when most of the problem events occur. Finding the root causes and implementing solutions for these two large problems would significantly decrease the number of problem events at the restaurant.

## Cause-and-Effect Diagrams

Once a problem has been identified, **cause-and-effect diagrams** (also called **fishbone diagrams** or **Ishikawa diagrams**) can be used to aid in brainstorming and isolating the causes of a problem. Figure 8.9 illustrates a cause-and-effect diagram for the most troublesome *long wait* problem of Figure 8.8. The problem is shown at the front end of the diagram. Each of the four diagonals or fishbones of the diagram represents potential groups of causes. The four groups of causes shown, Material, Machine, Methods, and Manpower, commonly referred to as **the 4 Ms**, are the standard classifications of problem

**Figure 8.8** Pareto Charts for Problems in Figure 8.7

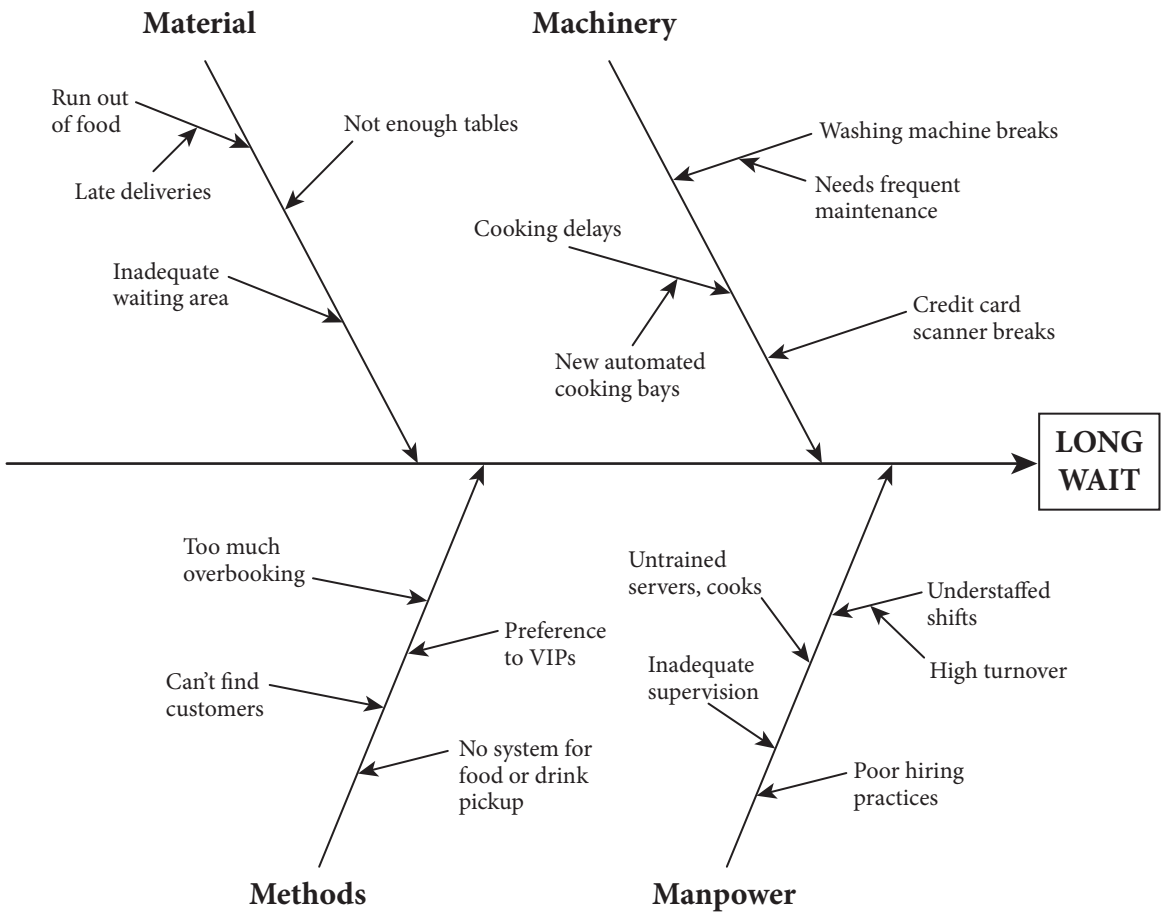



causes and represent a very thorough list for problem–cause analyses. In almost all cases, problem causes will be in one or more of these four areas.

Typically, Six Sigma team members will gather and brainstorm the potential causes for a problem in these four areas. Each branch on the four diagonals represents one potential cause. Subcauses are also part of the brainstorming process and are shown as smaller branches attached to each of the primary causes. Breaking a problem down like this into its causes and subcauses allows workers to then go back to the process and determine the relative significance of each cause and subcause using more specific checklists and Pareto charts once again. Eventually, the firm begins working to eliminate the causes of the problem, starting with the most significant **root causes** and subcauses, until most of the problem's impact disappears.

A properly thought-out cause-and-effect diagram can be a very powerful tool for use in Six Sigma efforts. Without its use, workers and management risk trying to eliminate causes that have little to do with the problem at hand, or working on problems that are quite minor compared to other, more significant problems. Once most of a problem's causes are identified and eliminated, the associated process should be back under control and meeting customer requirements. At this point, firms can design and begin using statistical process control charts, discussed next.

**Figure 8.9** Cause-and-Effect Diagram for the Long Wait Problem




## Statistical Process Control

An important part of Six Sigma and any quality improvement effort, **statistical process control** (SPC) allows firms to visually monitor process performance, compare the performance to desired levels or standards, and take corrective steps quickly before process variabilities get out of control and damage goods, services, and customer relationships. Once a process is working correctly, firms gather process performance data, create **control charts** to monitor process variabilities, and then collect and plot sample measurements of the process over time. The means of these sample measures are plotted on the control charts. If the sample means fall within the acceptable control limits, *and* appear close to and *normally distributed* around the desired measurement, the process is in *statistical control* and the process is permitted to continue; sample measurements and control chart plots also continue. When a sample plot falls out of the acceptable limits or when the plots no longer appear normally distributed around the desired measurement, the process is deemed to be *out of control.* The process is then stopped, problems and their causes are identified, and the causes are eliminated as described earlier. Control chart plots can then resume once the process is back in control.

Control charts are graphic representations of process performance over time, showing the desired measurement (the center line of the control chart) and the process's upper and lower control limits. This visual aid makes it very easy for operators or other workers to plot data and compare performance over time.

## Variations

Variations in process measurements can be either **natural variations** or **assignable variations**. All processes are affected by these variations, and environmental noise or natural variations are to be expected. When only natural variations are present, the process is in statistical control. Assignable variations are those that can be traced to a specific cause (such as the causes shown in Figure 8.9). These assignable variations are created by causes that can be identified and eliminated and thus become the objective of statistical process control efforts.

## Samples

Because of the likelihood of small variations in process measures, samples of data are collected and the sample means are then plotted onto control charts. Sample measures can be either **variable data** or **attribute data**, and each requires a different type of control chart. Variable data are continuous, such as weight, time, and length (as in the weight of a box of cereal, the time to serve a customer, or the diameter of a steel rod). Attribute data indicate the presence of some attribute such as color, satisfaction, workability, or beauty (for instance, determining whether or not a car was painted the right color, if a customer liked the meal, if the light bulb worked, or if the dress was pretty).

Variable data samples are shown as the mean of the sample's measures (for instance, an average of 12.04 ounces in a sample of five boxes of cereal), whereas attribute data are shown as the percent defectives within a sample (for instance, 10 percent or 0.10 of the light bulbs in a sample that did not work). The two types of control charts follow.

## Variable Data Control Charts

When measuring and plotting variable process data, two types of control charts are needed: the $\bar{x}$ **chart** (or *x*-bar chart) and the **R chart**. The $\bar{x}$ chart is used to track the central tendency of the sample means, while the R chart is used to track sample ranges, or the variation of the measurements (the difference between the largest and smallest) within each sample. A perfect process would have sample means equal to the desired measure and sample ranges equal to zero. It is necessary to view *both of these charts* in unison, since a sample's mean might look fine, even though several of the measures might be far from the desirable measure, making the sample range very high. It could also be the case that the sample's range looks fine (all measures are quite close to one another), even though all of the measures are far from the desired measure, making the sample's mean look bad. For variable data then, *both* the $\bar{x}$ chart and the R chart must show that the samples are in control before the process itself is considered in control.

### Constructing the $\bar{x}$ Chart and the R Chart

The first step in constructing any control chart is to gather data (provided the process is already in control and working well). Typically about twenty-five or thirty samples of size five to ten are collected, spaced out over a period of time. Then for each sample, the mean ($\bar{x}$) and the range ($R$) are calculated. Next, the *overall mean* ($\bar{\bar{x}}$) and the *average range* ($\bar{R}$) of all the samples are calculated. The $\bar{\bar{x}}$ and $\bar{R}$ measures become the center lines (the desired measures) of their respective control charts. Example 8.3 provides the data used to

calculate the center lines of the $\bar{x}$ chart and the $R$ chart. The formulas used to calculate the center lines, $\bar{\bar{x}}$ and $\bar{R}$, are:

$$\bar{\bar{x}} = \frac{\sum_{i=1}^{k} \bar{x}_i}{k} \text{ and } \bar{R} = \frac{\sum_{i=1}^{k} R_i}{k},$$

where $k$ indicates the number of samples and $i$ indicates the specific sample.

For the data shown in Example 8.3 we see that $\bar{\bar{x}} = 11.96$ and $\bar{R} = 0.39$. If these measures are seen as acceptable by the Hayley Girl Soup Co., then they can use these to construct their control charts. These means are also used to calculate the upper and lower control limits for the two control charts. The formulas are:

$$\text{UCL}_{\bar{x}} = \bar{\bar{x}} + A_2\bar{R} \quad \text{and} \quad \text{LCL}_{\bar{x}} = \bar{\bar{x}} - A_2\bar{R}$$
$$\text{UCL}_{\text{R}} = D_4\bar{R} \quad \text{and} \quad \text{LCL}_{\text{R}} = D_3\bar{R}$$

where $A_2$, $D_3$, and $D_4$ are constants based on the size of each sample (n) and are shown in Table 8.10 (the constants used are based on an assumption that the sampling distribution is normal and that the control limits are ±3.0 standard deviations from the population mean, which contains 99.73 percent of the sampling distribution). The constants for various sample sizes are shown in Table 8.10.

**Example 8.3 Variable Data Samples of Soup Cans at Hayley Girl Soup Co.**

The Hayley Girl Soup Co., a soup manufacturer, has collected process data in order to construct control charts to use in their canning facility. They collected one sample of 4 cans each hour over a 24-hour period for a total of 24 samples, and the data is shown below.

| HOUR | 1 | 2 | 3 | 4 | $\bar{x}$ | $R$ |
|---|---|---|---|---|---|---|
| 1 | 12 | 12.2 | 11.7 | 11.6 | 11.88 | 0.6 |
| 2 | 11.5 | 11.7 | 11.6 | 12.3 | 11.78 | 0.8 |
| 3 | 11.9 | 12.2 | 12.1 | 12 | 12.05 | 0.3 |
| 4 | 12.1 | 11.8 | 12.1 | 11.7 | 11.93 | 0.4 |
| 5 | 12.2 | 12.3 | 11.7 | 11.9 | 12.03 | 0.6 |
| 6 | 12.1 | 11.9 | 12.3 | 12.2 | 12.13 | 0.4 |
| 7 | 12 | 11.7 | 11.6 | 12.1 | 11.85 | 0.5 |
| 8 | 12 | 12.1 | 12.2 | 12.3 | 12.15 | 0.3 |
| 9 | 11.8 | 11.9 | 12 | 12 | 11.93 | 0.2 |
| 10 | 12.1 | 11.9 | 11.8 | 11.7 | 11.88 | 0.3 |
| 11 | 12.1 | 12 | 12.1 | 11.9 | 12.03 | 0.2 |
| 12 | 11.9 | 11.9 | 11.7 | 11.8 | 11.83 | 0.2 |
| 13 | 12 | 12 | 11.8 | 12.1 | 11.98 | 0.3 |
| 14 | 12.1 | 11.9 | 12 | 11.7 | 11.93 | 0.4 |
| 15 | 12 | 12 | 11.7 | 11.2 | 11.73 | 0.8 |
| 16 | 12.1 | 12 | 12 | 11.9 | 12.00 | 0.2 |
| 17 | 12.1 | 12.2 | 12 | 11.9 | 12.05 | 0.3 |
| 18 | 12.2 | 12 | 11.7 | 11.8 | 11.93 | 0.5 |
| 19 | 12 | 12.1 | 12.3 | 12 | 12.10 | 0.3 |
| 20 | 12 | 12.2 | 11.9 | 12 | 12.03 | 0.3 |
| 21 | 11.9 | 11.8 | 12.1 | 12 | 11.95 | 0.3 |
| 22 | 12.1 | 11.8 | 11.9 | 12 | 11.95 | 0.3 |
| 23 | 12.1 | 12 | 11.9 | 11.9 | 11.98 | 0.2 |
| 24 | 12 | 12.3 | 11.7 | 12 | 12.00 | 0.6 |
| | | | | **MEANS** | **11.96** | **0.39** |

**Table 8.10** Constants for Computing Control Chart Limits (±3σ)[64]

| SAMPLE SIZE, $n$ | MEAN FACTOR, $A_2$ | UCL, $D_4$ | LCL, $D_3$ |
|---|---|---|---|
| 2 | 1.880 | 3.268 | 0 |
| 3 | 1.023 | 2.574 | 0 |
| 4 | 0.729 | 2.282 | 0 |
| 5 | 0.577 | 2.115 | 0 |
| 6 | 0.483 | 2.004 | 0 |
| 7 | 0.419 | 1.924 | 0.076 |
| 8 | 0.373 | 1.864 | 0.136 |
| 9 | 0.337 | 1.816 | 0.184 |
| 10 | 0.308 | 1.777 | 0.223 |

Using the variable data in Example 8.3 along with Table 8.10 for a sample size of four, (not 24), the upper and lower control limits for both the $\bar{x}$ chart and the R chart for the Hayley Girl Soup Co. can be determined:

$$\text{UCL}_{\bar{x}} = \bar{\bar{x}} + A_2\bar{R} = 11.96 + 0.729(0.39) = 12.24$$
$$\text{LCL}_{\bar{x}} = \bar{\bar{x}} - A_2\bar{R} = 11.96 - 0.729(0.39) = 11.68$$

and

$$\text{UCL}_{\text{R}} = D_4\bar{R} = 2.282(0.39) = 0.89$$
$$\text{LCL}_{\text{R}} = D_3\bar{R} = 0(0.39) = 0$$

Next, the means and control limits can be used to construct the two control charts. In Figure 8.10, the data sample means and ranges are plotted on the two control charts, showing the center lines and control limits. From these plots, it appears that the process is indeed in statistical control, and the Hayley Girl Soup Co. can begin using these charts to monitor the canning process. If the process appears out of control on either chart, the control charts would not be useful and should be discarded until problem causes are identified and eliminated and the process is in statistical control.

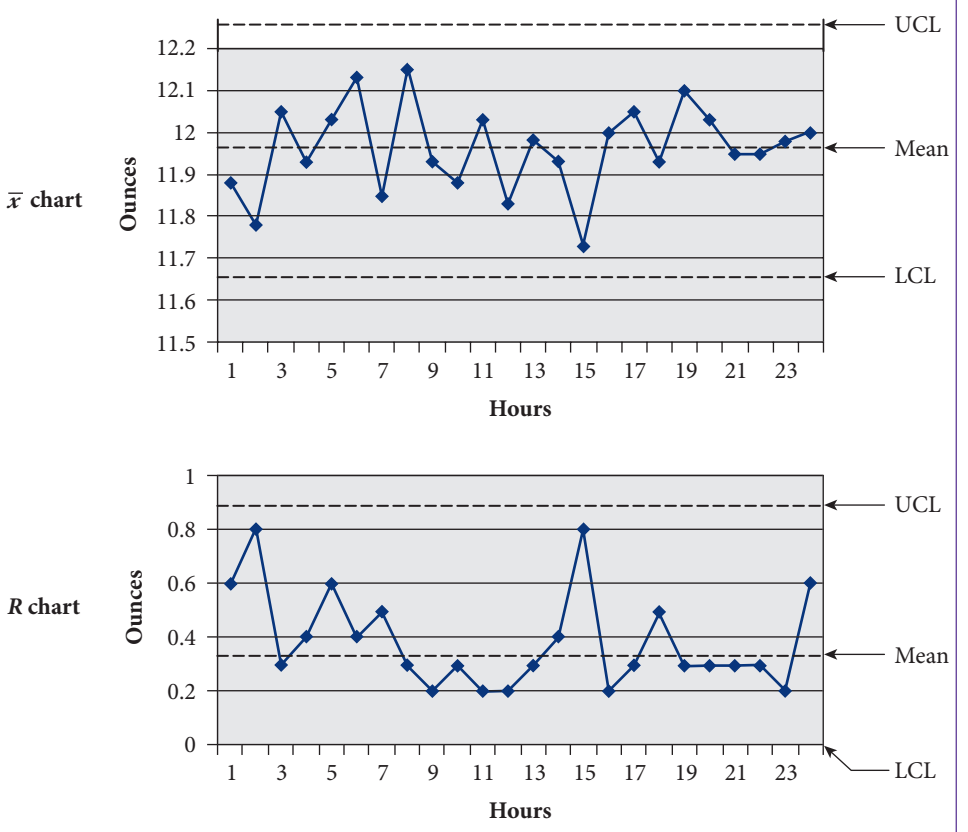
Once a good set of control charts have been created and samples from the process are being statistically monitored, the following steps should be followed:

1. Collect samples of size 4–5 periodically (depending on the type of process and ease of data collection).
2. Plot the sample means and ranges on the two control charts, monitoring whether or not the process is getting out of control.
3. When the process begins to appear out of control, use check sheets, Pareto charts, and fishbone diagrams to investigate causes and eliminate process variations.
4. Repeat steps 1–3.

## Attribute Data Control Charts

When collecting attribute data regarding whether or not a process is producing good or bad (nondefective or defective) output, use of $\bar{x}$ and R charts no longer apply. In these cases, either **P charts**, which monitor the *percent defective* in each sample, or

**Figure 8.10** $\bar{x}$ and *R* charts for the Hayley Girl Soup Co.




**C charts**, which count the *number of defects* per unit of output, are used. Each of these is discussed next.

## Using and Constructing P Charts

This is the most commonly used attribute control chart. If large sample sizes are used when collecting data, they are assumed to be normally distributed and the following formulas can be used to calculate the center line ($\overline{P}$) and the upper and lower control limits for the P chart:

$$\overline{P} = \frac{\sum_{i=1}^{k} P_i}{k},$$

where $\overline{P}$ is the mean fraction defective for all samples collected, $k$ represents the number of samples, $P$ is the fraction defective in one sample, and $i$ represents the specific sample, and:

$$\text{UCL}_p = \overline{P} + z\sigma_p$$
$$\text{LCL}_p = \overline{P} - z\sigma_p,$$

where $z$ is the number of standard deviations from the mean (recall when $z = 3$, the control limits will contain 99.73 percent of all the sample data plots) and $\sigma_{P,}$ is the standard deviation of the sampling distribution. The sample standard deviation is calculated as:

$$\sigma_P = \sqrt{\frac{(\bar{P})(1 - \bar{P})}{n}},$$

where $n$ is the size of each sample. Example 8.4 provides the data used to determine $\bar{P}$, $\sigma_P$, and the control limits for the P chart.

**Example 8.4 Attribute Data for the CeeJay Lightbulb Co.**

The CeeJay Lightbulb Co. makes 40-watt light bulbs, and they have decided to begin monitoring their quality using a P chart. So, over the past 30 days, they have collected and tested 100 bulbs each day. The chart below shows the fraction defectives for each sample and the overall average fraction defective, or $\bar{P}$.

| DAY | FRACTION DEFECTIVE | DAY | FRACTION DEFECTIVE |
|---|---|---|---|
| 1 | 0.01 | 16 | 0.04 |
| 2 | 0.02 | 17 | 0 |
| 3 | 0 | 18 | 0 |
| 4 | 0.03 | 19 | 0.01 |
| 5 | 0 | 20 | 0.03 |
| 6 | 0.01 | 21 | 0.02 |
| 7 | 0.04 | 22 | 0 |
| 8 | 0 | 23 | 0.01 |
| 9 | 0 | 24 | 0.02 |
| 10 | 0.02 | 25 | 0.01 |
| 11 | 0.02 | 26 | 0.03 |
| 12 | 0.03 | 27 | 0 |
| 13 | 0 | 28 | 0.02 |
| 14 | 0.04 | 29 | 0.01 |
| 15 | 0.01 | 30 | 0 |
| | | | $\bar{P} = 0.014$ |

As shown in Example 8.4, $\bar{P} = 0.014$. Calculating $\sigma_p$:

$$\sigma_P = \sqrt{\frac{(0.014)(0.986)}{100}} = 0.012.$$

Now the control limits can be calculated (assuming the limits contain 99.73 percent of the data points, or $z = 3$):

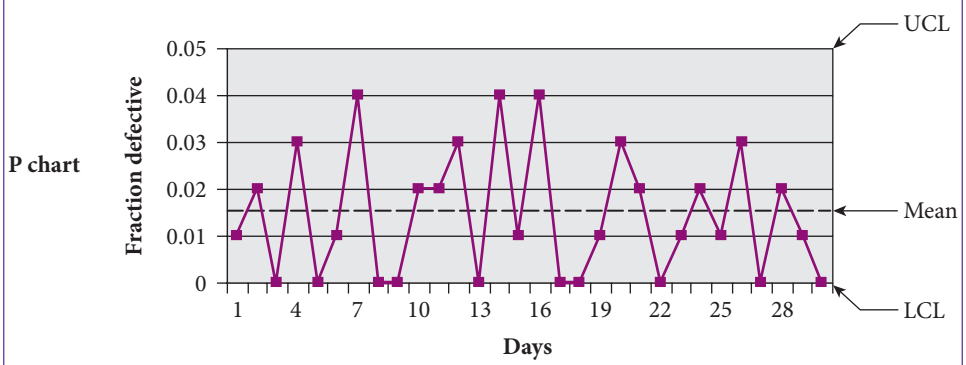
$$UCL_p = 0.014 + 3(0.012) = 0.05.$$

and

$$LCL_p = 0.014 - 3(0.012) = 0.$$

Note that the lower control limit is truncated at zero, as is the case in most P charts. Figure 8.11 shows the P chart for the CeeJay Lightbulb Co. with the fraction defectives

**Figure 8.11** P Chart for the CeeJay Lightbulb Co.




from Example 8.4. Viewing the chart, the process appears to be in control, since the data points are inside the control limits, close to and randomly dispersed around the centerline, and about half the data points are on each side of the centerline. Thus, the CeeJay Lightbulb Co. can begin using this control chart to monitor their lightbulb quality.

## Using C Charts

When multiple errors can occur in a process resulting in a defective unit, then we can use C charts to control the *number* of defects per unit of output. C charts are useful when a number of mistakes or errors can occur per unit of output, but they occur infrequently. Examples can include a hotel stay, a newspaper, or a construction project. The control limits for C charts are based on the assumption of a Poisson probability distribution of the item of interest (commonly used when defects are infrequent). In this case, the distribution variance is equal to its mean. For C charts then,

$\bar{c}$ = mean errors per unit of measure (and also the sample variance),

$\sqrt{\bar{c}}$ = sample standard deviation, and

$\bar{c} \pm 3\sqrt{\bar{c}}$ = upper and lower control limits.

Example 8.5 can be used to illustrate the calculation of the C chart's control limits. In the example, the units of measure are days, thus the average daily defects are 29.1 (the centerline and also the variance). The upper and lower control limits are 45.3 and 12.9, respectively. The Casey Publishing Co. can use the C chart centerline and control limits based on the 30-day error data to monitor their daily editorial error rate.

**Example 8.5 Monitoring Editorial Defects at Casey Publishing, Inc.**

Eight editorial assistants are monitored for defects in the firm's printed work on a monthly basis. Over the past thirty days, a total number of 872 editorial mistakes were found. Computing the centerline and control limits, we find:

$$\bar{c} = \frac{872}{30} = 29.1 \text{ mistakes per day, and the}$$

$$UCL_c = 29.1 + 3\sqrt{29.1} = 45.3 \text{ and } LCL_c = 29.1 - 3\sqrt{29.1} = 12.9.$$

## Acceptance Sampling

When shipments of a product are received from suppliers, or before the shipments are delivered to customers, samples can be taken from each shipment and measured against some quality acceptance standard. The quality of the sample is then assumed to represent the quality of the entire shipment (particularly when shipments contain many units of product, sampling is far less time consuming than testing every unit to determine the overall quality of an incoming or outgoing shipment). Ideally, if strategic alliance members within a supply chain are using Six Sigma quality improvement tools to build quality into the goods they sell, then acceptance sampling can be eliminated and used only when new or untested suppliers furnish goods or materials to the firm. In these situations, **acceptance sampling** can be used to determine whether or not a shipment will be accepted, returned to the supplier, or used for billback purposes when defective units are repaired or eliminated by the buyer.

One topic that arises is how big to make the test sample. One way to assure that the quality of the sample represents the quality of the entire shipment is to make the sample size equal to the size of the shipment (in other words, examine every unit). Since this is usually impractical, firms must assume the risk of incorrectly judging the quality of the shipment based on a sample—note that the smaller the sample size, the greater the risk of incorrectly judging a shipment's quality.

There is a cost to both the supplier and buyer when incorrect quality assessments are made regarding a shipment. When a buyer rejects a shipment of *high-quality* units because the sample quality level *did not* meet the acceptance standard, this is termed **producer's risk**. When this happens, it is called a **type-I error**. Conversely, when a buyer accepts a shipment of *low-quality* units because the sample *did* meet the acceptance standard, this is termed **consumer's risk** and is the result of a **type-II error**. Obviously, trading partners wish to avoid or minimize the occurrence of both of these types of errors. To minimize type-I and type-II errors, buyers and sellers must derive an acceptable sampling plan by agreeing on what constitutes unacceptable defect levels and also a sample size large enough to result in minimal numbers of type-I and type-II errors.

## Statistical Process Control and Supply Chain Management

Ideally, long-standing strategic supply chain trading partners would not need to monitor their inbound and outbound product quality—quality would already be extremely high, and employees could spend their time on more productive pursuits. However, most processes and suppliers are not yet perfect, and the level of competition is so fierce in most industries that firms find they must continually be assessing and reassessing process and product quality levels. Managers should identify processes that are critical to achieving the firm's objectives, decide how to monitor process performance, gather data and create the appropriate control charts, and create policies for collecting process samples and monitoring process and product quality over time. Managers must also work to create a culture where quality improvements are encouraged and employees are empowered to make the changes that will result in improved product and service quality.

## Summary

Supply chain management, lean thinking, and Six Sigma quality make up a hierarchy for breakthrough competitive advantage. In order for supply chain management to reach its full potential and provide benefits to all trading partners, a lean operating philosophy should be adopted. The primary ingredient in the success of a lean program is the use of Six Sigma quality improvement tools. There are a number of practices mentioned within each of these topics that overlap or are very similar such as top management support, workforce involvement, and continuous improvement. This is not surprising given the close ties between supply chain management, lean, and Six Sigma. Considerable time has been spent here, covering lean and Six Sigma because of their critical importance in achieving successful supply chain management and it is hoped that you have gained an appreciation for the topics presented here.

## Key Terms

**acceptance sampling,** 363
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**yokoten,** 327

## Discussion Questions

1. Explain why lean thinking and Six Sigma are so important to successful supply chain management.
2. Briefly explain the primary concerns and objectives of lean production.
3. How is lean production associated with JIT?

4. What does the Toyota Production System have to do with JIT and lean production?
5. What person or people at Toyota is (are) most responsible for the development of the JIT concept?
6. Why was Toyota's first U.S. car such a failure? What did they learn from this experience?
7. Who was responsible for first using the term lean as it related to the auto industry?
8. How is lean thinking associated with supply chain management?
9. Use an example to show how you could use lean thinking with a supplier and a customer.
10. What is yokoten, and what does it have to do with lean thinking?
11. Which do you think is the most important element of lean thinking?
12. What are the seven wastes? Discuss these in terms of a business you are familiar with.
13. What are the Five Ss? Apply these to improve how you could complete your daily homework or study assignments.
14. What are the advantages of close supplier and customer relationships, when practicing lean?
15. What are the advantages and disadvantages of making small, frequent purchases from just a few suppliers? How do we overcome the disadvantages?
16. Why should lean layouts be "visual"?
17. What are manufacturing cells, and why are they important in lean production?
18. Reducing lot sizes and increasing setups are common practices in most lean production settings. Why?
19. What is the origin of the term *kanbans* and why are they used in lean systems?
20. Why are lean systems also known as pull systems?
21. What is kaizen, and why is it so important for successful lean production? What is a kaizen blitz?
22. Discuss the linkage between lean systems and environmental sustainability.
23. Describe Six Sigma's origins and the main parties involved. Why is the concept called "Six Sigma"?
24. How is Six Sigma different from TQM?
25. Describe the lean Six Sigma approach.
26. Describe three ways by which your university could improve quality using elements of Six Sigma.
27. Describe Deming's Theory of Management and how it can be used to improve quality.
28. Which of Deming's 14 points might be the most important. Why?
29. Which do you like better—Deming's, Crosby's, or Juran's approach to quality? Why?
30. Why is the Baldrige Award available only to U.S. companies?

31. In viewing the Baldrige Award's performance categories, how would your firm stack up in these areas (use the university or your most recent employer if you are not currently employed).
32. What are the two most widely used ISO standards, and why are they so popular? If you are currently working, is your firm ISO certified? Is McDonald's?
33. What are critical-to-quality characteristics, and how are they used in Six Sigma?
34. What is the DMAIC improvement cycle, and how could you use it to improve your college study habits?
35. Construct a flow diagram of the ticket purchase/football game attendance process at your university. What areas would you investigate further to identify problems?
36. Construct a cause-and-effect diagram for the following problem: The university course registration and payment process takes too long. Brainstorm some potential causes.
37. What are the two types of process variation, and which one does statistical process control seek to eliminate? What can be done with the other one?
38. Define "variable data" and explain why two control charts are needed to assure that these types of processes are under control.
39. Can a process exhibit sample measurements that are all inside the control limits and still be considered out of control? Explain.
40. What are some variable data and attribute data that could be collected to track the quality of education at your university?
41. How could P charts be used in a manufacturing facility?
42. Explain the difference between a C chart and a P chart.
43. Can a process be considered in control but *incapable* of meeting design requirements? Explain.
44. If one goal of a supplier partnership is to eliminate acceptance sampling, then when would it get done?

## Essay/Project Questions

1. Go to the Baldrige Award website (https://www.nist.gov/baldrige) and find out what organizations have won the award since 2020. Report on any new developments with respect to the Baldrige Award and its recipients—have any recently declared bankruptcy, or are any currently in financial trouble?
2. Write a report on the impact of the 2020 pandemic on product quality.
3. Search the Internet and article databases at your university for the terms *sustainability* and *supply chain management* and write a report on the importance of sustainability in the practice of supply chain management, using company examples.
4. Discuss the implementation of lean and Six Sigma among Chinese and Vietnamese companies.
5. Search the Internet and article databases at your university for the term *Lean Six* and write a report on the latest uses of this method using company examples.

## Problems

1. Heavey Compressors uses a lean production assembly line to make its compressors. In one assembly area, the demand is 100 parts per eight-hour day. It uses a container that holds eight parts. It typically takes about six hours to round-trip a container from one work center to the next and back again. Heavey also desires to hold 15 percent safety stock of this part in the system.
   a. How many containers should Heavey Compressors be using?
   b. Calculate the maximum system inventory for this part.
   c. If the safety stock percentage is reduced to zero, how would this impact the number of containers, all else being equal?

2. Using the information from problem 1, if Heavey desires to reduce their number of containers to eight, how does this impact the system? What has to change, if it is assumed that demand, container size, and safety stock percentage don't change, and what is that change?

3. Eakins Enterprises makes model boats, and it is switching to a lean manufacturing process. At one assembly area, Eakins is using one part container that holds 250 parts, and it wants the output to be approximately 100 finished parts per hour; they also desire a 10 percent safety stock for this part. How fast will the container have to travel through the system to accomplish this?

4. A lean system has 22 containers, each of which can hold 15 parts. The lead time required to round-trip one container through the system is four hours. The required safety stock is 10 percent.
   a. What is the maximum demand rate this system can accommodate?
   b. The company wants to accommodate double the maximum demand rate found in (a). What are all the ways the system could be changed to accomplish this?

5. Jim Corner, owner of Corner Bike Rentals, wants to start analyzing his company's quality. For each bike rental, there are four types of customer complaints: (1) bike not working properly, (2) bike wrong size, (3) bike uncomfortable, and (4) bike broken during operation. During the past week, his company rented 280 bikes. He received 26 total complaints.
   a. What is his company's DPMO for the past week?
   b. What is their Six Sigma operating level?
   c. If Jim wanted to operate at the 5 sigma level, what would his errors have needed to be over the past week?

6. Julie works at Gentry Flower Shoppe, which operates at the 4 sigma level, with about 6,000 DPMO, which was determined recently. At that time, Gentry was found to have 1,500 total defects. They want to improve to the 5 sigma level, or about 500 DPMO. Assuming nothing else changes, what would their new total defect level have to be?

**7.** The following sample information was obtained by taking four doughnuts per hour for 12 hours from Fawcett Bakery's doughnut process and weighing them:

| HOUR | WEIGHTS (GRAMS) | HOUR | WEIGHT (GRAMS) |
|---|---|---|---|
| 1 | 110, 105, 98, 100 | 7 | 89, 102, 101, 99 |
| 2 | 79, 102, 100, 104 | 8 | 100, 101, 98, 96 |
| 3 | 100, 102, 100, 96 | 9 | 98, 95, 101, 100 |
| 4 | 94, 98, 99, 101 | 10 | 99, 100, 97, 102 |
| 5 | 98, 104, 97, 100 | 11 | 102, 97, 100, 101 |
| 6 | 104, 97, 99, 100 | 12 | 98, 100, 100, 97 |

For the data shown above,

**a.** Find the $\bar{x}$ and $R$ for each sample.

**b.** Find the $\bar{\bar{x}}$ and $\bar{R}$ for the 12 samples.

**c.** Find the 3-sigma UCL and LCL for the mean and range charts.

**d.** Plot the data. Does the process look to be in statistical control? Why/why not?

**8.** Through process measuring a number of pizza delivery times, Mary Jane's Pizzeria finds the mean of all samples to be 27.4 minutes, with an average sample range of 5.2 minutes. They tracked four deliveries per hour for 18 hours to obtain their samples.

**a.** Is this an example of variable or attribute sampling data?

**b.** Find the UCL and LCL for both the $\bar{x}$ and $R$ charts.

**9.** A company produces 8-pound bags of rice. As shown below, it gathered 5 samples with 6 bags in each sample for quality control purposes. The weights of each of the bags are listed below.

| | BAGS IN EACH SAMPLE | | | | | |
|---|---|---|---|---|---|---|
| SAMPLE | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | 7.98 | 8.34 | 8.02 | 7.94 | 8.44 | 7.68 |
| 2 | 8.33 | 8.22 | 8.08 | 8.51 | 8.41 | 8.28 |
| 3 | 7.89 | 7.77 | 7.91 | 8.04 | 8 | 7.89 |
| 4 | 8.24 | 8.18 | 7.83 | 8.05 | 7.9 | 8.16 |
| 5 | 7.87 | 8.13 | 7.92 | 7.99 | 8.1 | 7.81 |

**a.** Find the $\bar{x}$ and $R$ for each of the five samples.

**b.** Find the $\bar{\bar{x}}$ and $\bar{R}$.

**c.** Find the 3-sigma UCL and LCL for the mean and range charts.

**d.** Plot the data. Does the process look to be in statistical control? Why/why not?

**10.** Ten customers per hour were asked by the cashier at Sally's Deli if they liked their meal, and the fraction that said "no" are shown below, for a 12-hour period.

| HOUR | FRACTION DEFECTIVE | HOUR | FRACTION DEFECTIVE |
|---|---|---|---|
| 1 | 0 | 7 | 0.1 |
| 2 | 0.2 | 8 | 0 |
| 3 | 0.4 | 9 | 0 |
| 4 | 0.1 | 10 | 0.2 |
| 5 | 0.1 | 11 | 0 |
| 6 | 0.2 | 12 | 0.1 |

For the data shown above, find

**a.** $\bar{P}$.

**b.** $\sigma_P$.

**c.** The 3-sigma UCL and LCL.

**d.** Plot the data. Does customer satisfaction at Sally's appear to be in statistical control? How could we improve the analysis?

**11.** A company collects 20 samples with 100 eggs in each sample. They want to construct a P chart to track the proportion of broken eggs in each sample. The table below shows the number of defective eggs per sample.

| SAMPLE | EGGS | SAMPLE | EGGS | SAMPLE | EGGS |
|---|---|---|---|---|---|
| 1 | 3 | 8 | 6 | 15 | 5 |
| 2 | 5 | 9 | 4 | 16 | 0 |
| 3 | 3 | 10 | 9 | 17 | 2 |
| 4 | 4 | 11 | 2 | 18 | 6 |
| 5 | 2 | 12 | 6 | 19 | 2 |
| 6 | 4 | 13 | 5 | 20 | 1 |
| 7 | 2 | 14 | 1 | TOTAL | 72 |

**a.** Determine $\bar{P}$.

**b.** Determine $\sigma_P$.

**c.** Determine the 3-sigma UCL and LCL.

**d.** Plot the data. Does the egg process appear to be in statistical control?

**12.** Roberto's Steakhouse tracks customer complaints every day and then follows up with their customers to resolve problems. For the past 30 days, they received a total of 22 complaints from unhappy customers. Using this information, calculate

**a.** $\bar{c}$.

**b.** The 3-sigma control limits.

# Cases

## 1. Sharp's Sandwich Shop—Quality Control*

Dawn Sharp is the owner of Sharp's Sandwich Shop. Her shop is open 24/7 and serves many different types of sandwiches, from classic breakfast sandwiches to more exotic burgers and other sandwiches usually consumed at lunch and dinner.

Recently, Dawn addressed inventory management as one of her major production issues. Dawn's goal is to give her customers quick service and a quality product. To accomplish this goal, Dawn divided her menu into four timeframes: breakfast, lunch, dinner, and after hours. Breakfast runs from 5 a.m. to 11 a.m.; lunch begins at 11 a.m. and ends at 3 p.m.; dinner begins early, at 3 p.m., and continues until 9 p.m. Between 9 p.m. and 5 a.m. you can select your sandwich from the after hour's section of the menu.

Sharp's Sandwich Shop is in the heart of downtown New York and New Yorkers are fast moving and always in a rush. Consequently, customers do not want to wait very long

*Written by Rick Bonsall, D. Mgt., McKendree University, Lebanon, IL. The people and institution are fictional and any resemblance to any person or any institution is coincidental. This case was prepared solely to provide material for class discussion. The author does not intend to illustrate either effective or ineffective handling of a managerial situation.

for the sandwich, no matter how unique or complicated it may be. To remedy this, Dawn set up a system where the kitchen produces specific sandwiches in bulk. For example, a basic ham and cheese on rye bread can be made in advance, wrapped, and placed in the ready bin. This way, when a customer orders a ham and cheese on rye, they get it quickly. One of the challenges to this system is that Sharp's sandwiches are very popular because of the quality of the sandwiches. Part of the quality is their freshness. Therefore, whether it is a cold sandwich or a warm sandwich, neither can stay in the premade bins too long. After a set period of time, if a sandwich is still in the bin it is removed and placed in the charity bin. The charity bin contains food that is still edible; however, food that won't be sold to Sharp's customers. The food in the charity bin is donated to a local homeless shelter twice per day.

As Dawn evaluated her inventory problem that was related to the premade sandwich system, she discovered a parallel issue—quality. As part of her revised inventory system, all sandwiches placed in the charity bin are recorded in a waste log. This process enables Dawn to differentiate the "waste" sent to the charity bin from actual waste, that is, items that are thrown in the trash. Previously, Ms. Sharp had assumed that a significant quantity of her overall waste (95 percent) were items placed in the charity bin. However, as she compared her numbers, Dawn discovered that more was going into the trash than she thought.

This revelation was very disturbing to Dawn. Quality was the primary driver in her business. The waste created by her focus on freshness was something Dawn could control, and her new inventory system concerning premade sandwiches has improved that situation. However, the total waste numbers indicated that sandwiches of unacceptable quality were reaching the customer and they were returning the food. This was alarming because New Yorkers were quick to complain and spread the word about poor quality to their friends. Unlike the inventory issue, which was an issue of expense control, this quality issue was one of customer satisfaction and ultimate survival of her business in a city with an abundance of competition.

Once again, Dawn reflects back on her class in Supply Chain Management, specifically the process management chapter on lean and Six Sigma. Dawn recognized that, in a way, she had taken her eye off of quality. Sharp's Sandwich Shop didn't have a clear process to collect data on quality, nor did it utilize any of the quality tools to analyze defects or root causes. Ms. Sharp knew that it was crucial to her business to begin data collection and analysis immediately. Bad customer experiences would spread throughout her customer base in a New York minute. However, her kitchen and eating area were a very fast paced environment. Dawn needed data-collection processes that didn't demand a lot of the food preparers' or the servers' time. Plus, with all the responsibilities of running the business, Dawn's available time for analysis was limited as well. Finally, Dawn instinctively knew that Sharp's Sandwich Shop had to go beyond data collection and analysis. She needed processes that enabled her to address multiple issues such as inventory management and quality.

## Discussion Questions

1. Sharp's Sandwich Shop has two conflicting quality issues—speed and freshness. The premade sandwich system enhances speed; however, it has the potential of affecting freshness. What type of system can Dawn implement that will enable her to keep the process of premade sandwiches, yet guarantee that freshness will be unaffected? Explain how the system would work and why it can effectively enable her to accomplish both goals without any concern that one or the other must suffer.

2. Currently, Dawn is evaluating the quality of the food by the waste, meaning as the cost of waste increases she senses that the quality of the product is decreasing. Recommend to her a better method to evaluate quality than just cost.

3. Dawn decides that she alone cannot implement a good quality program. Clearly, her staff must be involved. Although she has excellent employees, Dawn knows they do not understand the tools of quality. Furthermore, she understands that if things appear too complicated then she won't get their buy-in. Dawn contacts you and requests that you explain to her staff some basic quality tools that will enable them to improve quality, yet are not complex, and will not demand a lot of their time.

## 2. Downey College*

Tuition is the life blood of any four-year college and Downey College is no exception. Each year the Student Affairs Office initiates a campaign to get students to fill out their Free Application for Federal Student Aid (FAFSA) application. As with any tuition aid program, there is a timeframe when you must apply. If you miss the application deadline then you must wait until the following period.

Downey College has lost several students during the enrollment process because the students did not complete their FAFSA application on time. Without the help of federal aid, the students were unable to take the courses they registered for. Hannah Hunt, vice president of student affairs, was eager to improve this process. Competing for student enrollment was a significant challenge and losing students because of FAFSA application errors was frustrating. Hannah decided to review the data from last year to determine how she could tackle the issue this year.

Last year Hannah had her staff develop a check sheet on common errors concerning FAFSA applications. There were five major areas and an "other" area. She had them collect data by student status, that is, freshman, sophomore, junior, and senior. The information is listed below.

| ERROR | FRESHMAN 520 Applications | SOPHOMORE 500 Applications | JUNIOR 580 Applications | SENIOR 530 Applications | Total Errors | % of Total |
|---|---|---|---|---|---|---|
| Not filing by deadline | ///// | //// | ////// | /// | | |
| Wrong FSA ID | // | / | // | //// | | |
| Wrong SSN | //// | /// | / | | | |
| Did not sign FAFSA | ///// | ///// | // | /// | | |
| Understating income | ////// | //// | // | ///// | | |
| Filing wrong year's FAFSA | // | // | ///// | /// | | |
| Other | ///// | //// | // | //// | | |

* Written by Rick Bonsall, D. Mgt., McKendree University, Lebanon, IL. The people and institution are fictional and any resemblance to any person or any institution is coincidental. This case was prepared solely to provide material for class discussion. The author does not intend to illustrate either effective or ineffective handling of a managerial situation.

## Discussion Questions

1. Hannah Hunt's staff is very small; thus, she has limited resources available to tackle these issues. She can focus on either a specific error or on a specific class, for example, freshman. What do you recommend she do and why? Explain the benefit of your recommendation.
2. What is the sigma level of their FAFSA application program? Does the sigma level per class, for example, senior, change your recommendation on whether to focus on a specific error or a specific class? Is there any advantage in this perspective of the data? Explain your opinion to Hannah Hunt.
3. Hannah Hunt believes that filling out and submitting the FAFSA application is a no brainer. She believes that a Six Sigma level should be easy to obtain. Do you agree? Is this a realistic expectation? Explain your viewpoint.

## 3. Automotive Repair Shop War*

Johnny Cruz is the best mechanic in a 50-mile radius. He lives in the small town of Oxbow, Texas. In fact, all the towns within 50 miles of Oxbow are small, with approximately 1,500 residents each. Most businesses survive in this region because competition is scarce. Not all the towns have every convenience. There may be a theater within a cluster of three towns within 30 miles of each other, or a major grocery store in one town while the others have small convenience stores. No one is sure how this process developed; however, it has ensured a respectable living for those in the county.

Johnny Cruz's automotive repair shop benefitted from this type of arrangement. His business has been steady for several years with a strong customer base from four towns in the area. However, Rosie Lamb opened an automotive repair shop six months ago in Knuckle Falls, Texas, and is competing for the same customer base. At first Johnny wasn't worried. He had a solid reputation as a good mechanic and he never gouged anyone. However, as the months slowly passed, Johnny noticed that some of his regular customers stopped coming in for routine maintenance such as oil changes and brake jobs. Some others with major repair needs were going to Rosie as well.

Johnny was a good businessman and knew he needed to stem this flow of customer defections quickly. He went to the local community college and talked with a business professor about the situation. One thing Johnny understood was that he needed data so he could analyze the problem, develop solutions, and make effective decisions. Johnny had read about programs such as Six Sigma. Although he wasn't familiar with it, he did realize that it meant to identify a problem, collect data, analyze the data, and develop alternative solutions. Then, he could select what appeared to be the best solution, implement it, and then circle back around and see how effective it was.

## Discussion Questions

1. Is Johnny Cruz approaching this situation sensibly? Do you think Six Sigma is the best approach or is it overkill? Do you agree with Johnny? If so, explain how Six Sigma can help Johnny. If you don't agree with Johnny, what alternatives does he have?

* Written by Rick Bonsall, D. Mgt., McKendree University, Lebanon, IL. The people and company are fictional and any resemblance to any person or company is coincidental. This case was prepared solely to provide material for class discussion. The author does not intend to illustrate either effective or ineffective handling of a managerial situation.

2. Six Sigma has a lot of tools Johnny can use. Be the community college professor in Oxbow, Texas and explain which tool or tools you would use and in what order. What would each tool enable Johnny to do?

3. Using the problem of defecting customers, develop a fictional cause-and-effect diagram. Develop the four main categories and add the bones of possible causes or issues. Explain, based on your hypothetical scenario, what you see as Johnny's possible major causes.

# Part 3 Continuing Case

## Mullenax Automobile Parts Inc., Process Management*

Odis Mullenax is the owner and president of Mullenax Automobile Parts Inc. His company makes various parts for major automobile manufacturers worldwide. They manufacture intake manifold systems, air induction systems, coolant pump modules, oil filtration systems, coil springs, stabilizer bars, precision springs, and other key components within their three business units. Mullenax Automobile Parts Inc. is one link in a very long supply chain. Odis understands that the supply chain is not a single line of suppliers and buyers. Odis knows that the supply chain is more like a complex web where inputs come from multiple directions, often appearing unrelated to one another.

As Odis and Estella Epperson, vice president of operations, continue to work through their strategic plan, they choose process management as the next challenge to face. Specifically, they believe lean and Six Sigma are the processes required to enable Mullenax Automobile Parts Inc. to achieve the firm's goals of high quality, fast response, and low cost.

Edgar Kalish, director of quality and performance, begins to examine what Mullenax is currently doing to ensure they achieve the desired goals and then determine what process improvements they should make. As Edgar meets with his team, they decide after an extensive brainstorming session to focus on reducing waste. They analyze current data for the following areas: overproducing, waiting, transportation, overprocessing, excess inventory, excess movement, and scrap and rework.

Edgar meets with Madie McConke, director of inventory management, to discuss the processes she had implemented. Since Madie is using methods such as Economic Order Quantity (EOQ) and Inventory Turnover Ratio, Edgar feels that at the moment inventory management is in good hands and excess inventory isn't a major issue at this time. However, after inspecting the warehouse, Edgar suggests Madie implement the Five Ss. Each S is a Japanese term and translates to organization, tidiness, purity, cleanliness, and discipline. These terms also have their English version of the Five Ss.

Edgar and his team take a step backwards and decide the first action is to determine what the Six Sigma level is and what their target should be. They can work with each department and establish what the current state is, then work on processes to move each department toward the desired state. The first department they analyze is manufacturing. For one particular day, the data shows that the number of defects is 750 and the number of units produced is 500. Also, the number of opportunities for a defect (OFD) per unit is 15,000. This information will enable them to calculate the defects per million opportunities (DPMO).

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As Edgar's team continues to review the data, they determine control charts are necessary to identify if the specifications of critical parts are in compliance. They develop both an $\bar{x}$ chart and an R chart. The $\bar{x}$ chart will enable them to track the central tendency of the sample means. The R chart will enable them to track sample ranges or the variation of measurements within each sample. They select a part to do a "test" run that they can share with the manufacturing department. This particular part, AV1, must be between 10 and 11 inches; otherwise, it cannot be used as a universal part for different makes of cars. Below is the data chart. They collected samples each hour for a single shift (8 hours). Each hour they randomly measured 4 parts.

| VARIABLE DATA SAMPLES OF AV1 | | | | | | |
|---|---|---|---|---|---|---|
| **Hour** | 1 | 2 | 3 | 4 | $\bar{x}$ | R |
| 1 | 10 | 10.5 | 11 | 10.9 | | |
| 2 | 9.9 | 10.2 | 11 | 10.8 | | |
| 3 | 11.1 | 10.4 | 10.6 | 10.9 | | |
| 4 | 10.1 | 11 | 10.8 | 11.1 | | |
| 5 | 10 | 10 | 11 | 10.5 | | |
| 6 | 11 | 10.2 | 10.2 | 10.9 | | |
| 7 | 10.1 | 10.6 | 10.4 | 10.9 | | |
| 8 | 11 | 10.7 | 10.5 | 10.4 | | |

## Discussion Questions

**1.** Based on the data provided in the case, calculate the DPMO.

- **a.** Using Table 8.4, what is the approximate Sigma level based on the DPMO?

**2.** Using the data in the **Variable Data Samples of AV1** chart above, calculate the following:

- **a.** $\bar{x}$
- **b.** R
- **c.** $\bar{\bar{x}}$
- **d.** $\bar{R}$
- **e.** UCL of $\bar{x}$
- **f.** LCL of $\bar{x}$
- **g.** UCL of R
- **h.** LCL of R

Note: Use Table 8.10 when calculating UCL and LCL for $\bar{x}$ and R.

**3.** Graph the $\bar{x}$ and R charts. Does the process look to be in control? Why?

**4.** The Japanese Five Ss translate to organization, tidiness, purity, cleanliness, and discipline. These terms also have their English version of the Five Ss. What are they? Which do you think are the most important? Why?

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# PART 4

# Distribution Issues in Supply Chain Management

Chapter 9

# Domestic U.S. and Global Logistics


*There is a conversion from truckload to LTL that people aren't paying attention to. Ask any LTL carrier what percentage of their business is retail today compared to five years ago, and it's more. They're finding retail can't be ignored because of e-commerce and Amazon.*

**—Satish Jindel, president, SJ Consulting Group**[1]

*We had to get all the CEOs of different delivery companies in a room to work out how to do this. Because the biggest barrier to globalization is logistics.*

**—Wan Lin, CEO, Cainiao**[2]

*Those of us in the industry can now explain to our families what we do. When the news cycle starts talking about cold chain, that's pretty sophisticated stuff.*

**—Elouise Epstein, partner, Kearney**[3]

## Learning Objectives

**After completing this chapter, you should be able to**

**LO 1** Understand the strategic importance of logistics.

**LO 2** Identify the various modes of transportation.

**LO 3** Understand how U.S. regulation and deregulation have impacted transportation.

**LO 4** Discuss the global aspects of logistics.

**LO 5** Describe how logistics affects supply chain management.

**LO 6** Examine and understand the interrelatedness of transportation, warehousing, and material handling.

**LO 7** Identify a number of third-party logistics service providers.

**LO 8** Describe the various reverse logistics activities.

## Chapter Outline



## SCM Profile — Bigger, Longer, Faster

In transportation, bigger, longer, and faster usually means better. Since economies of scale in transportation can mean fewer trips, less fuel consumed, better equipment utilization, and lower labor costs, logistics providers have occasionally utilized enormous capacities to gain the benefits of transportation scale economies. And, with the continuing demand for greater shipping speed, some companies are designing ever-faster systems to satisfy demand. Several examples are provided here.

### Motor Carriers

In Australia, large tractor units pull three, four, and even more trailers along long stretches of open road between cities in unpopulated areas with no rail service. These long tractor/trailer combinations are known as road trains. In Australia, road trains can legally be up to 180 feet in length, barreling along at speeds of

Alex Couto/Shutterstock.com

up to 65 miles per hour. In 2006, the record was set for road train length in Clifton, Queensland, Australia, when a Mack Titan tractor pulled 112 trailers for 328 feet. The road train was 4836 feet long and weighed 2,900,000 pounds.[4]

### Rail Carriers


Hung Chung Chih/Shutterstock.com

As of 2016, the fastest regularly scheduled train service is the Shanghai Maglev in China. Charging only about $8 per person, the Maglev runs 19 miles from Shanghai's Pudong International Airport to the Longyang metro station on the outskirts of Shanghai. The train takes just over seven minutes to complete the trip using magnetic levitation technology and reaches a top speed of 267 miles per hour.[5] Currently, the fastest train though, is Japan Railways' maglev bullet train. The bullet train travelled at 603 kph (374 mph), in a test run in 2016 (that's a mile in ten seconds!).[6]

### Air Carriers


Davide Calabresi/Shutterstock.com

The Airbus A380 jetliner and the old Spruce Goose may be big, but they are nowhere near the biggest—that title belongs to the Antonov An-225 commercial jet freighter. It was built in 1988 for the Soviet space program to airlift rocket boosters and their space shuttle. At 275 feet in length with a 290-foot wingspan and a maximum takeoff weight of 640 tons, it dwarfs 787s. When the Soviet Union collapsed in 1990, the aircraft was temporarily mothballed, and then eventually refurbished and put back into service in 2001 for Antonov Airlines. It has transported things once thought impossible by air, such as locomotives and 150-ton generators. It also has allowed vast quantities of relief supplies to be quickly transported to disaster areas, such as quake-stricken Haiti in February 2010.[7]

### Water Carriers

hans engbers/Shutterstock.com

The largest supertanker ever built was the *Seawise Giant*, built by Sumitomo Heavy Industries in 1979. The ship was 1504 feet long with 340,000 square feet of deck, and was too big to pass through the English Channel, the Suez Canal, or the Panama Canal. Fully loaded, the ship weighed 646,000 tons and standing on end, it would be taller than the Empire State Building. The ship was by far the largest ship ever built and had a number of owners and names over the years, but was simply too big; it was dismantled in 2010. The largest containership is currently the CSCL Globe, which was built in 2014. It has an overall length of 1312 feet, and can carry up to 19,100 20-foot containers.[8]

**Pipeline Carriers**


Opsorman/Shutterstock.com

In the North Sea, the world's longest underwater pipeline, finished in 2007 by Norsk Hydro ASA, delivers natural gas from Norway's offshore gas fields to processing plants 746 miles away in the United Kingdom. The sections of pipe were assembled and welded together using the world's largest pipeline-laying ships and then laid continuously on the seafloor, in depths up to 3000 feet. The world's longest on-land pipeline was completed in December 2012, built by the China National Petroleum Corporation and stretching 5400 miles from the central part of China to Shanghai in the east and Guangzhou and Hong Kong in the south. The pipeline cost $22.5 billion to build and helps bring natural gas to 500 million people.[9]

## Introduction

Logistics is necessary for moving purchased materials from suppliers to buyers, moving work-in-process materials within a firm, moving finished goods to customers, returning or recycling goods, and also storing these items along the way in supply chains. Effective logistics systems are needed for commerce to exist in any industrialized society. Goods have little value to customers until they are moved to customers' usage areas at a point in time when they are needed. Logistics thus provides what are termed **time utility** and **place utility**. Time utility is created when customers get goods delivered at precisely the right time, not earlier and not later. The logistics function creates time utility by determining how deliveries can be made in a timely manner and where items should be held prior to delivery. Place utility is created when customers get things delivered to their desired locations.

The official definition of **logistics** from the globally recognized Council of Supply Chain Management Professionals is:

> *The process of planning, implementing, and controlling procedures for the efficient and effective transportation and storage of goods including services, and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements.*[10]

So it can be seen that transportation, warehousing, information systems, and customer service play very significant roles in the logistics function. For supply chains in particular, logistics is what creates the flow of goods between supply chain trading partners, so that costs, service requirements, competitive advantage, and profits can be optimized.

When moving around within a city, between cities, or between countries, it is impossible to ignore the business of logistics, whether it be large trucks ambling along the roadways; trains pulling boxcars, cattle cars, and tanker cars next to highways; warehouses storing goods in cities' industrial sections; airplanes taking off at airports; container ships unloading cargo; or barges floating slowly down rivers. In the United States and other highly industrialized nations, the movement of goods is ever-pervasive. Without it, we as consumers would never have opportunities to find what we want, when we want it, at the many retail outlets we routinely visit each day.

**Table 9.1** Growth of For-Hire Logistics Services (billion $)

| | 2010 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|
| TOTAL U.S. GDP | 14992 | 18238 | 18745 | 19543 | 20612 | 21433 |
| FOR-HIRE LOGISTICS SERVICES TOTAL (% U.S. GDP) | 421 (2.8) | 566 (3.1) | 582 (3.1) | 607 (3.1) | 651 (3.2) | 697 (3.3) |

The U.S. freight transportation system moved 12.5 billion tons of goods valued at more than $14.5 trillion in 2017—about 4 tons of freight per year for every man, woman, and child in the United States. As of 2015 in the United States, there were 4.1 million miles of public roads, 140,000 miles of rail track, 615,000 bridges, 2.3 million miles of natural gas pipelines, 25,000 miles of navigable waterways, 19,000 public and private airports, and 360 commercial shipping ports.[11] Using the latest available statistics from the U.S. Department of Transportation, at the end of 2019 the total annual U.S. for-hire logistics services contribution to the U.S. gross domestic product (GDP) was approximately 3.3 percent, or $697 billion. Table 9.1 shows the growth of for-hire logistics expenditures in the United States, which has more than doubled since 2000.[12]

In this chapter, a number of logistics activities are discussed, along with logistics nomenclature and related events affecting businesses each day. Included are discussions of the modes of transportation, transportation regulation and deregulation in the United States, warehousing and distribution, a number of logistics decisions firms must make, the impact of logistics on supply chain management, the global issues affecting logistics, the impact of e-commerce on logistics activities, and the management of product returns, also called reverse logistics. Some of the transportation basics are reviewed next.

## Transportation Fundamentals

This section reviews a number of important transportation elements within the logistics function, including the objective of transportation, legal forms of transportation, the modes of transportation, intermodal transportation, transportation pricing, transportation security, and transportation regulation and deregulation in the United States. This provides a good foundation for discussing the remaining topics in the chapter, as well as an appreciation for the complex nature of transportation issues in logistics.

### The Objective of Transportation

Although one might think the overriding objective of transportation is obvious—that is, moving people and things from one place to another—for-hire transportation services can go broke doing this inefficiently. For example, over the past 25 years, a number of U.S. passenger airlines have sought bankruptcy protection and asked for concessions from labor unions to keep operating. Some of these airlines include American, Ryan International, United, Continental, America West, US Airways, Delta, Northwest, Hawaiian, Frontier, Aloha, Mesa, and Southern Air. The steep economic downturn from 2009 to 2011, combined with steadily rising fuel prices, only made things more troublesome for transportation companies. In 2014, fuel costs accounted for 35 percent of U.S. airline operating costs, which was triple the percent of cost compared to 2000. Today, jet fuel costs have come down considerably, and are once again about 12 percent of airline operating costs.

The pandemic, though, has also severely impacted transportation companies. In March 2020, people began delaying buying tickets for any type of travel, due to the uncertainty surrounding the outbreak. The scale of disruption for airlines became apparent when British regional airline Flybe ran out of cash and went bankrupt in the first week of March. As countries around the world closed their borders, and many states and nations locked down, air travel declined significantly. Other airlines going bankrupt in 2020 include Missouri-based Trans States Airlines and Compass Airlines, Virgin Australia, and Columbia-based Avianca.[13] Trucking volumes increased initially in 2020 by about 30 percent due to panic buying, then dropped off considerably. Rail volumes decreased by about 20 percent in 2020.[14] Eventually, over 3100 U.S. trucking companies went bankrupt, taking about 115,000 trucks off the road.[15]

Logistics managers seek to maximize value for their employers by correctly communicating the firm's service needs to for-hire transportation providers. Additionally, services and prices are negotiated such that the transportation provider's delivery costs are covered while allowing them an acceptable profit contribution. Finally, logistics managers must ensure the desired services are performed effectively. In the transportation industry, competitive prices may not be high enough to cover transportation providers' fixed and variable costs, and this has created a tremendous problem for a number of airlines and trucking companies as mentioned above, when fuel prices rise over a period of time or when demand falls precipitously. In the most general terms, transportation company objectives should then be to *satisfy customer requirements while minimizing costs and making a reasonable profit*. For logistics or perhaps supply chain managers, this also means deciding which forms of transportation, material handling, and storage, along with the most appropriate vehicle scheduling and routing, to use.

## Legal Forms of Transportation

For-hire transportation service companies are classified legally as common, contract, exempt, or private carriers. The distinguishing characteristics of each of these classifications are discussed below.

### Common Carriers

Common carriers offer transportation services to all shippers at published rates between designated locations. Common carriers must offer their transportation services to the general public without discrimination, meaning they must charge the same rates for the same service to all customers. In the United States, a common carrier is legally bound to carry all passengers or freight as long as there is enough space, the fee is paid, and no reasonable grounds to refuse exist. Because common carriers serve the general public, they are the most heavily regulated of all carrier classifications. Some U.S. examples of common carriers are Southwest Air, Amtrak, UPS, Greyhound, and Carnival Cruise Lines.

### Contract Carriers

Contract carriers might also be common carriers; however, as contract carriers, they are not bound to serve the general public. Instead, they serve specific customers under contractual agreements. Typical contracts are for movement of a specified cargo for a negotiated and agreed-upon price. Some contract carriers have specific capabilities that allow them to offer lower prices than common carriers might charge for the same service. For instance, Southwest Air might enter into a contractual agreement with the Dallas Cowboys

football team to provide transportation for the team's out-of-town games. Shippers and carriers are free to negotiate contractual agreements for price, the commodity carried, liability, delivery timing, and types of service.

### Exempt Carriers

**Exempt carriers** are also for-hire carriers, but they are exempt from regulation of services and rates. Carriers are classified as exempt if they transport certain exempt goods such as produce, livestock, coal, garbage, or newspapers. School buses, taxis, and ambulances are also examples of exempt carriers. The exempt status was originally established to allow farmers to transport agricultural goods on public roads, but today the status has been broadened to include a number of commodities. Rail carriers hauling coal between specific locations are exempt from economic regulation, for instance. All carriers can also act as exempt carriers for these specific commodities and routes.

### Private Carriers

A **private carrier** is not subject to economic regulation and typically transports goods for the company owning the carrier. Firms transporting their own goods typically own and operate fleets of trucks, ships, and/or airplanes, large enough to make the cost of transportation less than what it would be if the firm hired a transportation provider. Flexibility and control of product movements also play major roles in the ownership of a private carrier. Walmart, for instance, with its private fleet of trucks, was able to respond even quicker than U.S. government relief workers after Hurricane Katrina struck the Louisiana Gulf Coast in August 2005 (the strongest hurricane ever recorded in the New Orleans area, it caused over 1800 deaths and $125 billion in damage). Immediately after the disaster, Walmart began hauling food, water, and other relief supplies with its private fleet of trucks to community members and other organizations in the affected areas. In three weeks, it hauled 2500 truckloads of supplies to these areas; additionally, it was able to reopen its stores quickly in the hardest hit areas. Shortly after the hurricane, New Orleans Sheriff Harry Lee was quoted as saying, "If [the] American government would have responded like Walmart has responded, we wouldn't be in this crisis."[16]

## The Five Modes of Transportation

There are five modes of transportation: motor (truck), rail, air, water, and pipeline carriers. Each of these modes offers distinct advantages to customers, and their selection depends on a number of factors including the goods to be transported, how quickly the goods are needed, the price shippers are willing to pay, and the locations of shippers and customers. Discussion of each of the modes follows.

### Motor Carriers

**Motor carriers** (or trucks) are the most flexible mode of transportation and account for almost 71 percent of all the freight tonnage moved in the United States (about 11.8 billion tons in 2019) which is by far the largest of the five modes.[17] Motor carriers offer door-to-door service, local pickup and delivery, and small as well as large shipment hauling. It has very low fixed and variable costs, can compete favorably with rail and air carriers for short to medium hauls (distances shorter than 1000 miles), and is still competitive with other forms of transportation for long cross-country shipments, particularly if there are multiple delivery locations. Motor carriers can also offer a variety of specialized services from refrigerated, to livestock, to automobile hauling.

The primary disadvantages for motor carriers are weather and traffic problems. The tragic collapse of the eight-lane Minneapolis, Minnesota, I-35 West bridge over the Mississippi River in August 2007 killed thirteen people and provided a painful reminder of the importance of a nation's transportation infrastructure. Per day, more than 140,000 vehicles, including approximately 5700 commercial vehicles, used Minnesota's busiest bridge. (In 2005, the bridge was inspected and received a low rating, indicating that it should have been either repaired or replaced.[18] The replacement bridge opened to traffic on September 18, 2008.[19]) Incidentally, every four years, the American Society of Civil Engineers' Report Card for America's Infrastructure depicts the condition and performance of American transportation infrastructure in the familiar form of a school report card—assigning letter grades based on the physical condition and needed investments for improvement. In the 2021 report, America's overall infrastructure grade was a C-. The highest grades were in Rail (B), Ports (B-), and Bridges (C). The worst grades were in Aviation (D+), Dams (D), Levees (D), Roads (D), and Transit (D-).[20]

Motor carriers are most often classified as **less-than-truckload** (LTL) **carriers** or **truckload** (TL) **carriers**. LTL carriers move small packages or shipments that take up less than one truckload, and the shipping fees are higher per hundred weight (cwt) than TL fees, since the carrier must consolidate many small shipments into one truckload and then break the truckload back down into individual shipments at the destinations for individual deliveries. For many small shippers though, using LTL carriers is a much less expensive alternative than using a TL carrier. The LTL industry amounts to only about 10 percent of total trucking revenues and, in the United States, comprises a few very large, national LTL carriers along with a sizeable number of small regional carriers. As of the end of 2019, the five largest LTL carriers in the United States in terms of annual revenues were FedEx Freight ($7.5 billion), Old Dominion Freight ($4.1 billion), XPO Logistics ($3.8 billion), YRC Freight ($3.0 billion), and UPS Freight ($2.7 billion). Most of the regional LTL carriers are small, privately owned companies that specialize in overnight and second-day deliveries. Today, the top five carriers represent over 50 percent of the total U.S. LTL market.[21]

TL carriers, on the other hand, have entire trailers dedicated to a single shipper's cargo. A customer loads a trailer full, then the TL company transports the shipment to a final destination where it is received and unloaded. At the end of 2019, the top five TL carriers in terms of annual revenues were Knight-Swift ($3.5 billion), Landstar ($2.8 billion), J.B. Hunt ($2.6 billion), Schneider ($2.3 billion), and Werner ($1.9 billion). The industry is quite fragmented—about 70 percent of the companies operate fewer than five trucks. In contrast to the LTL market, the top five TL carriers represent only about 8 percent of the market.[22]

Motor carriers can also be classified based on the types of goods they haul. **General freight carriers** carry the majority of goods shipped in the United States and include common carriers, whereas **specialized carriers** transport liquid petroleum, household goods, agricultural commodities, building materials, and other specialized items. In Australia, extra-long truck and trailer combinations (referred to as **road trains**) transport goods between geographically dispersed communities not served by rail (see the chapter opening SCM Profile for discussions of this and other unique transportation services).

## Rail Carriers

**Rail carriers** compete most favorably when the distance is long and the shipments are heavy or bulky. At one time in the United States, rail carriers transported the majority of goods shipped; however, since World War II, their share of the transportation market has steadily fallen (from 2016 to 2021 for example, the rail market shrank by about 1.5 percent per year).[23] The $68 billion per year industry consists of 137,000 rail miles operated by

seven Class I or large railroads (defined as greater than $490 million in annual revenues), 22 regional railroads, and 584 local/short line railroads. Not only does the 137,000 mile system move more freight than any other freight rail system worldwide, but it also provides 167,000 jobs. Today in the United States, rail carriers account for about 1.8 billion tons of freight hauled each year. Rail carriers also offer an advantage that other modes of transportation cannot, including reductions in road congestion, highway fatalities, fuel consumption, and greenhouse gases. Railroads, on average, can transport one ton of freight more than 480 miles on one gallon of fuel, which makes railroads three to four times more fuel efficient than trucks.[24]

Rail service is relatively slow and inflexible; however, rail carriers are less expensive for shippers than air and motor carriers and can compete fairly well on long hauls. To better compete, railroads have purchased trucking companies and can thus offer point-to-point pickup and delivery service using motor carrier trailers and rail flatcars that carry the trailers (known as **trailer-on-flatcar service** or TOFC service). Railroads are also at somewhat of a disadvantage compared with motor carriers with respect to shipment damages, equipment availability, and service frequency.

Because of their abundance, rail companies use each other's rail cars; however, keeping track of the rail cars and getting them where they are needed can be problematic. With advances in railroad routing and scheduling software and rail car identification systems, this has become less of a problem for rail carriers. **Real-time location systems** (RTLSs) on rail cars use active, Wi-Fi-enabled radio frequency identification (RFID) tags to allow tracking of rail cars (and their assets) in real time. The tag is programmed to broadcast a signal identifying its location at regular time intervals. Sensors can also be added to the RTLS tags to monitor the temperature inside refrigerated rail cars, for example, and transmit a signal if the temperature goes out of a preset range.[25]

In the United States, railroad infrastructure and aging equipment have also been problems for the railroads (rail companies own and maintain all track in the United States); however, there has been a spending resurgence since the mid-1980s to replace worn track segments and rail cars, to upgrade terminals, and to consolidate through mergers and acquisitions. Unfortunately, train derailments have begun occurring more frequently, which is forcing the issue of replacing old rail track. Today, railroads spend about 20 percent of their operating revenue on infrastructure repairs and upgrades.[26]

One of the trends in U.S. rail transportation is the use of **high-speed trains**. Today, they are passenger trains operated by Amtrak along the northeast corridor (Boston–New York–Washington D.C.). Originally, Bombardier Inc., a Montreal-based transportation and aerospace company, designed and manufactured Amtrak's Acela Express, an electric high-speed train. These trains could make the Washington D.C. to Boston trip in about 5.5 hours, averaging approximately 85 miles per hour, although top speeds reached 120 miles per hour (congestion from slower trains and the lack of straight-line track tended to reduce the average speeds).[27] Recently though, French train manufacturer Alstom has contracted to provide Amtrak with the next generation of high- speed rail that will replace the current fleet by 2023. These trains will carry one-third more passengers and travel at speeds of up to 160 miles per hour.[28]

While the Acela Express is the only high-speed railroad operating in the United States, other states such as California and Florida are moving ahead with planning for high-speed trains. In 2009, President Obama launched an ambitious high-speed rail program in the United States, for which Congress appropriated $10.5 billion. With these funds, California committed to building a $68 billion high-speed line that will run from San

Francisco to Los Angeles at speeds reaching 200 mph with stops at 24 stations. As of 2020, the California High-Speed Rail Authority is working on the California High-Speed Rail project and construction is under way on sections traversing California's Central Valley. Phase I is planned for completion in 2033.[29] In Florida, since the state declined government assistance, a privately funded "higher-speed" rail project will soon link Miami and Orlando. Originally called All Aboard Florida, the $3 billion train was later renamed Brightline, and began service between Fort Lauderdale and West Palm Beach on January 13, 2018, at speeds of only 79 mph. By 2022, it plans to begin service to Orlando at 125 mph, classifying it as a high-speed rail service.[30]

China today operates the longest high-speed rail network (over 23,000 miles by the end of 2021), with about 2 billion rides per year. By 2035, China plans to further double the size of their already sizeable network.[31] Other countries such as France and Japan also have extensive high-speed rail lines operating. The inaugural high-speed French rail service between Paris and Lyon was in 1981 and has since expanded to connect cities across France and in neighboring countries. The Japanese Shinkansen high-speed rail began operations in 1964 between Tokyo and Osaka. A number of other European countries also use high-speed rail. Malaysia and Singapore recently announced their plans to build a high-speed line connecting Kuala Lumpur and Singapore.[32]

## Air Carriers

Transporting goods (and people) by air is very expensive relative to other modes but also very fast, particularly for long distances. The world's airlines carry over four billion passengers each year. Additionally, airlines create over $2.7 trillion in economic activity globally each year.[33] Providing these services generates over 11 million direct jobs. Comparing contributions to GDP, the global air transport industry is larger than the automotive industry. In fact, if air transport were a country, its GDP would rank it 21st in the world, similar to that of Switzerland or Sweden.[34]

**Air carriers** account for only a small portion of total freight hauled, since aircraft cannot carry extremely heavy or bulky cargo (an exception is the world's largest commercial cargo airliner, the Ukrainian-built Antonov An-225, described in the chapter-opening SCM Profile). For light, high-value goods that need to travel long distances quickly, air transportation is the best of the modal alternatives. For movements over water, the only other modal alternative is water carriage, where the transportation decision is based on timing, cost, and shipment weight. Though the incidence of shipment damage is quite low and schedule frequency is good, air transportation is limited in terms of geographic coverage. Most small cities in the United States, for example, do not have airports or regularly scheduled air service; therefore, air transportation service must be combined with motor carrier service for these locations.

Today, about half of the goods transported by air are carried by freight-only airlines like FedEx, the world's largest air cargo airline (number two is Qatar Airways, followed by UPS)[35]. This represents a significant change since the late 1960s when most air cargo was hauled by passenger airlines. Today, most passenger air carriers are opting to use smaller, more fuel-efficient aircraft, which has reduced their ability to haul cargo. Economic growth in markets such as China has continued to fuel increases in international air cargo. Today, most of the air cargo demand is in the Asia-Pacific region, followed by North America then Europe.[36]

## Water Carriers

Shipping goods by **water carrier** is very inexpensive but also very slow and inflexible. There are several types of water transportation: inland waterway, lake, coastal and

intercoastal ocean, and global deep-sea carriers. Inland waterway carriers (mainly barges) are used to haul heavy, bulky, low-value materials such as coal, grain, and sand, and compete primarily with rail and pipeline carriers. Inland water transport is obviously limited to areas accessible by water (the Mississippi and Columbia Rivers are examples in the United States), and hence growth in this area of transportation is also limited. Like rail and air transportation, water carriers are typically paired with motor carriers to enable door-to-door pick-up and delivery service.

Inland waterway barge transportation in the United States benefits from the demand for oil and petrochemical shipments. The use of water transportation by the petroleum and petrochemical industry is one of the major reasons for establishing refineries and petrochemical facilities along navigable inland waterways. Texas and Louisiana account for approximately 80 percent of the U.S. production of petrochemicals. To carry these shipments, new high-capacity tank barges are being built, and a number of new vendors have started to provide shipping services for the transportation of liquid-bulk cargo.[37]

There have also been developments in **deep-sea transportation** that have made water transportation cheaper and more desirable, even with the slow transportation times. The development and use of supertankers and containerships has added a new dimension to water transportation. Many of today's oil supertankers are more than 1200 feet long (that's four U.S. football fields) and carry over 2 million barrels of oil. The largest oil supertanker was the *Seawise Giant* (as described in the chapter opening SCM Profile). Oil-producing nations can now cheaply ship large quantities of oil anywhere around the globe where demand exists. Additionally, small shippers can ship items overseas cheaply, because of the ability to consolidate small shipments in containers that are placed on board containerships.

Shipping containers allow almost any packaged product to be shipped overseas, and they add an element of protection to the cargo. Containerships carry the majority of the world's water-transported manufactured goods, and they can carry more than 10,000 standard 20-foot containers (these are normally 20 feet in length, 8.5 feet in height, and 8 feet wide but can vary), holding up to 52,000 pounds each, with a total container value sometimes as high as $300 million for a fully loaded ship. In 2019, about 226 million containers were shipped worldwide, and at any given time, there are approximately 5 to 6 million containers being shipped around the globe.[38]

## Pipeline Carriers

**Pipeline carriers** are very specialized with respect to the goods they can carry; however, once the initial investment of the pipeline is recovered, there is very little additional maintenance cost, so over the long-term, pipeline transportation tends to be very inexpensive. Pipelines can haul materials that are only in a liquid or gaseous state and so the growth potential for pipelines is quite limited. One of the interesting items pipelines haul is coal, and they do this by first pulverizing coal into small particles and then suspending it in water to form **coal slurry**. When the coal slurry reaches its destination, the coal and water are separated. Other items transported in pipelines include water, oil, gasoline, and natural gas. The continuous nature of pipeline flow is what makes it unique. Once the product reaches its destination, it is continuously available. Pipelines are today being constructed to haul large quantities of natural gas and oil from desolate areas to existing processing facilities hundreds and even thousands of miles away (see the chapter-opening SCM Profile for more discussion of pipelines). So long as the world remains dependent on energy products such as coal, oil, and natural gas, there will be a need for pipeline transportation.

One of the more controversial pipelines is the proposed Keystone XL pipeline, which originally would transport 830,000 barrels per day of crude oil from the oil sands region of Alberta, Canada, to Steele City, Nebraska, where it would join an existing pipeline going to the U.S. gulf coast. Former President Obama held off on approving it, due to protests from Native Americans regarding the pipeline's proposed route across their land. Former President Donald Trump issued the permits for the pipeline within days of taking office in 2017. President Biden then revoked the permit for the Keystone XL pipeline via executive order hours after his inauguration, the clearest sign yet that constructing a major new pipeline in the United States has become very difficult.[39]

## Intermodal Transportation

**Intermodal transportation**, or the use of combinations of the various transportation modes for one shipment, is a very popular transportation arrangement and can make the movement of goods cheaper, quicker, and more secure. Intermodal transportation dates at least to the early 1800s, when wooden containers were used to transport coal on the Bridgewater Canal in England. Horse-drawn vehicles were used to transfer the coal to and from the canal barges. During World War II, pallets were used to transfer U.S. military equipment quickly between warehouses, trucks, trains, ships, and airplanes. The reduced freight handling meant fewer personnel and faster shipping times. The use of standardized containers grew quickly in the United States when the Interstate Commerce Commission ruled in 1954 that railroads could carry truck trailers and containers on rail flatcars. In the 1970s, third-party shipping agents began moving shippers' goods in trailers and then using railroads for part of the transportation. The early success of these agents spawned hundreds of similar companies, driving the growth of intermodal traffic. Finally, deregulation of the transportation industry spurred intermodal growth to the levels of today.[40]

Most large intermodal transportation companies today such as U.S. companies J.B. Hunt, Hub Group, Schneider, and XPO Logistics offer one-stop, door-to-door shipping capabilities—they transport shippers' goods for a price and then determine the best intermodal transportation and warehousing arrangements to *meet customer requirements as cheaply as possible*.[41] Here is a fictitious shipping example using a number of intermodal combinations:

> *A manufacturing company packs a standard eight-foot container for shipment to an overseas customer. Once packed, the container is then sealed and connected to a motor carrier trailer for transport to a nearby rail terminal. The container is then loaded onto a rail flatcar and double-stacked with another container, where it is then transported to a seaport on the U.S. West Coast. Upon arrival, the container is placed aboard a container ship and transported to Japan. In Japan, the container is off-loaded and moves through customs, where it is then loaded onto another motor carrier trailer for transport to its final destination, where it finally is unsealed, inspected and unpacked. In this example, goods were packed, securely sealed, unsealed and unpacked one time. The container was used in three modes of transportation and was unsealed when customs authorities examined and accepted the goods.*

The above example highlights a number of intermodal transportation combinations. The most common combinations are truck **trailer-on-flatcar** (TOFC) and **container-on-flatcar** (COFC), also called **piggyback service**. The same containers can be placed on board containerships and freight airliners. These combinations attempt to combine the flexibility of motor carriers with the economy of rail and/or water carriers. The BNSF

Railway, headquartered in Texas, operates one of the largest railroad networks in North America, and is one of seven North American Class I railroads. It has over 32,500 track miles covering twenty-eight states and three Canadian provinces and has 25 intermodal facilities. In 2020, BNSF moved 3 million carloads of industrial goods, 1.4 million coal shipments, and 5.2 million intermodal shipments. BNSF serves 40 U.S. ports, with approximately 1200 trains and 34,000 employees.[42]

Another example of intermodal transportation are **ROROs**, or roll-on-roll-off, vessels. These allow truck trailers, automobiles, heavy equipment, and specialty cargo to be directly driven on and off the ship, into secured below-deck garages without use of cranes. The construction of Finnlines' newest environmentally friendly RORO vessel commenced on 8 June 2020 with a completion date sometime in 2021. The vessel incorporates the latest technology available to ensure the lowest $CO_2$ emissions. In addition to lithium-ion battery systems that enable zero-emission operations in port, the ships will be equipped with efficient engines, emission abatement systems and an innovative air lubrication system to reduce hull resistance. The hybrid RORO will be 238 meters long and 34 meters wide. It will have 5600 square meters of car decks and can accommodate 300 TEU containers on the weather deck.[43]

## Transportation Pricing

The two basic pricing strategies used by logistics service providers are **cost-of-service pricing** and **value-of-service pricing**. Further, when the shipments are large enough, carriers and shippers enter into **negotiated pricing**. Obviously, shippers want low prices and carriers want high profits, and these desires are often at odds with one another. Not too many years ago, logistics companies like UPS simply distributed their costs evenly and charged a uniform rate to all customers. As computer pricing models improved, companies were able to more closely identify their costs for various types of customers and differential pricing became more the norm, with small shippers and infrequent users seeing significant price increases. With the recent pandemic, poor economic conditions and excess shipping capacity in some areas allowed shippers to negotiate better terms.[44] These and other pricing topics are discussed below.

### Cost-of-Service Pricing

Cost-of-service pricing is used when carriers establish prices based on their fixed and variable costs of transportation. To do this, carriers must be able to identify the relevant costs and then accurately allocate these to each shipment. Cost-of-service pricing varies based on volume and distance. As shipping volume increases, the portion of fixed costs that are allocated to each individual shipment goes down, allowing the carrier to reduce its prices. Large-volume shipments also allow carriers to charge carload or truckload rates instead of less-than-carload or less-than-truckload rates. Cost-of-service pricing represents the base, or lowest, shipping price for carriers, and in a highly competitive market, carriers will price just above these levels to maintain some minimal level of profitability. As occurred during the recent pandemic, many carriers were unable to maintain prices at even these lowest levels, resulting in a number of bankruptcies.

### Value-of-Service Pricing

In this case, transportation providers price their services at the highest levels the market will bear. Prices are thus based on the level of competition and the current demand for each service. This is a profit-maximizing pricing approach. If a carrier has a service

that is in high demand with little competition, prices will consequently be quite high. As other logistics companies notice the high profit potential of this service, competition will eventually increase, causing prices to fall. As the level of competition increases, carriers will seek ways to reduce their costs to maintain profitability. Today, as some countries return to post-pandemic normalcy, demand for some transportation services exceeds supply, and this has caused value-of-service pricing to predominate. In the airline industry, online booking capabilities combined with revenue management software to control prices as demand fluctuates, have allowed airlines to use value-of-service pricing to maximize revenues.

## Negotiated Pricing

Since the deregulation of transportation in the United States, negotiating transportation prices has become much more common among business shippers and logistics providers. In addition, shippers today are inclined to develop alliances with logistics companies because of the key role they play in allowing firms and their supply chains to be more responsive to changing demand. This has also tended to increase the use of negotiated prices. Shippers want carriers to use cost-of-service pricing, while carriers want to use value-of-service pricing. To maintain an equitable partnership, prices are negotiated such that they fall somewhere between these two levels, allowing carriers to cover their fixed and variable costs and make a reasonable profit, and allowing shippers to get the logistics services they want at reasonable prices.

## Terms of Sale

In many cases, suppliers' terms of sale affect transportation costs. When goods are purchased from a supplier, it may quote a price that includes transportation to the buyer's location. This is known as **FOB destination pricing**, or "free-on-board" to the shipment's destination. This also means that the *supplier will be the legal owner of the product until it safely reaches its destination*. For high-value shipments, small shipments, or when the buyer has little transportation expertise, FOB destination pricing is typically preferred. Otherwise, the buyer may decide to purchase goods and supply its own transportation to the shipping destination; in this case, the supplier quotes the lower **FOB origin pricing**. The goods then become the *legal responsibility of the buyer at the supplier's finished goods pickup location*.

## Rate Categories

Carrier prices or rates can be classified in a number of different ways. **Line haul rates** are the charges for moving goods to a nonlocal destination (e.g., between cities), and these can be further classified as *class rates*, *exception rates*, *commodity rates*, and *miscellaneous rates*. In the United States, **class rates** are published annually by the National Motor Freight Traffic Association (NMFTA), a nonprofit group of motor carrier companies. The class rate standards, called the National Motor Freight Classification (NMFC), are based on an evaluation of four transportation characteristics: density, stowability, handling, and liability. Together, these characteristics establish a shipment's "transportability." There are eighteen classes numbered from 50 to 500—the higher the class rating, the higher the price.[45] **Exception rates** are rates that are lower than the NMFC class rates for specific origin-destination locations or volumes and generally are established on an account-by-account basis. **Commodity rates** apply to minimum quantities of goods that are shipped between two specified locations. **Miscellaneous rates** apply to contract rates that are negotiated between two parties and to shipments containing a variety of goods (in this case, the rate is based on

the overall weight of the shipment). Today, many of the rates carriers charge are classified as miscellaneous, since negotiated rates tend to be used primarily for large shipments.

## Transportation Security

**Transportation security** in the United States, particularly **airline security**, has become a very important issue since September 11, 2001. Congress passed the Aviation and Transportation Security Act in November 2001, creating a large organization (the Transportation Security Administration, or TSA) to oversee transportation security. In 2019, the TSA's over 60,000 (full-time equivalent) transportation security officers screened more than 2.25 million passengers every day at more than 440 airports nationwide and conducted all of the cargo screening on domestic and international-outbound passenger aircraft (the number of passengers screened in 2020 fell by over 60 percent).[46] In addition to the TSA, Congress passed the Homeland Security Act in November 2002, creating the Department of Homeland Security (DHS) to further coordinate and unify national homeland security efforts. It includes the TSA along with twenty-one other federal departments and agencies and has 240,000 employees with an annual budget of about $50 billion to provide overall U.S. security leadership.[47]

A number of problems and actions have resulted from this heightened emphasis on transportation security in the United States. The TSA has had numerous agency chiefs since 9/11 and has spent more than $12 billion to improve security on airplanes and in airports. One of the TSA initiatives includes automated security screening lanes and computed tomography (CT) scanners, at various transportation hubs nationwide. The automated screening lanes incorporate technology and screening station modifications that enhance security effectiveness while decreasing the time travelers spend in security screening by approximately 30 percent. In December 2013, TSA launched its Pre✓® application program, which is a shift toward a risk-based and intelligence-driven approach to security. Through this program, U.S. citizens and lawful permanent residents can apply directly to participate in Pre✓and undergo a background check in order to become eligible for a period of 5 years. Today, about 10 million people are using it.[48] Air cargo transported on passenger aircraft is also subjected to high levels of security checks in the United States. Today, 100 percent of air cargo must be prescreened, as mandated by the Improving America's Security Act of 2007.

With respect to the other modes of transportation, the TSA has been working with railroads to reduce the number of hours that toxic chemicals can spend in transit, resulting in a 54 percent reduction since 2006 in the overall risk of rail tanker explosions or spills. The TSA also has a Pipeline Security Division, which essentially mandates all pipeline operators to implement a pipeline security program. For many truckers and other transportation workers such as U.S. deepwater port workers, one of the latest transportation security initiatives is the use of the **Transportation Worker Identification Credential (TWIC)**, which was mandated by the Maritime Transportation Security Act of 2002 and the Safe Port Act of 2006. The TWIC became mandatory for all port workers in 2009.[49]

Another type of security initiative is the use of PrePass, offered by the nonprofit organization PrePass Safety Alliance, which allows prequalified U.S. motor carriers to bypass state inspection and weigh stations at highway speeds, using automated vehicle identification technology. Today, over 600,000 prequalified commercial vehicles can bypass hundreds of inspection facilities using PrePass, allowing inspection personnel to spend more of their time inspecting other vehicles. Additionally, PrePass saves drivers five to eight minutes and a half gallon of fuel per bypass.[50]

## Transportation Regulation and Deregulation in the United States

The transportation industry in the United States has gone through periods of both government regulation and deregulation. On the one hand, **transportation regulation** is argued by many to be good in that it tends to ensure adequate transportation service throughout the country while protecting consumers in terms of monopoly pricing, safety, and liability. On the other hand, **transportation deregulation** is argued to be good because it encourages competition and allows prices to adjust as supply, demand, and negotiations dictate. In addition, antitrust, safety, and security laws already in place tend to protect transportation consumers. This debate was the subject of a study in 1994 to determine the impact deregulation had on the U.S. motor carrier industry. The study concluded that transportation deregulation has resulted in greater use of cost-of-service pricing, rising freight rates for LTL shipments, and more safety problems, as operators tended to let fleets age and reduce maintenance levels.[51] Today, the U.S. transportation industry remains essentially deregulated; however, a number of regulations (primarily safety and security regulations) still exist and continue to be revised. Over the past few years, when bankruptcies and consolidations occurred, particularly in the airline industry, new calls for entire industry re-regulation have also emerged. Some of the history of transportation regulation and deregulation in the United States is reviewed next.

### Transportation Regulation

Table 9.2 summarizes the major transportation regulations in the United States, starting with the Granger Laws of the 1870s, which led to the Interstate Commerce Act of 1887. Before this time, the railroads in the United States were charging high rates and discriminating against small shippers. So a number of Midwestern states passed laws to broadly regulate the railroads to establish maximum rates, prohibit local discrimination, forbid rail mergers (to encourage competition), and prohibit free passes to public officials. Though the U.S. Supreme Court later struck down these laws, the Granger movement made Congress realize the impacts of railroad monopolies. This led to the passage of the Interstate Commerce Act of 1887.

**Table 9.2** U.S. Transportation Regulation

| DATE | REGULATION | SUMMARY |
|---|---|---|
| 1870s | Granger Laws | Midwestern states passed laws to establish maximum rates, prohibit discrimination, and forbid mergers for railroads (RRs). |
| 1887 | Interstate Commerce Act | States cannot regulate transportation; established Interstate Commerce Commission (ICC); regulated and published rates, outlawed discriminatory pricing, prohibited pooling agreements. |
| 1920 | Transportation Act | Instructed the ICC to establish rates that allowed RRs to earn a fair return; established minimum rates; allowed ICC to set intrastate rates; allowed pooling agreements if they were in the public's best interest. |
| 1935 | Motor Carrier Act | Extended the ICA of 1887 to include motor carriers and brought them under ICC control; established five classes of operators: common, contract, private, exempt, and broker; mergers must be OK'd by ICC. |
| 1938 | Civil Aeronautics Act | Established the Civil Aeronautics Board (CAB) to regulate air carriers; new entrants had to get CAB approval; CAB controlled rates; Civil Aeronautics Administration controlled air safety. |
| 1940 | Transportation Act | Extended the ICA of 1887 to include ICC control over domestic water transportation; ICC controlled entry, rates, and services. |

| DATE | REGULATION | SUMMARY |
|---|---|---|
| 1942 | Freight Forwarders Act | Extended the ICA of 1887 to include ICC control over freight forwarders; ICC controlled entry, rates, and services. |
| 1948 | Reed-Bulwinkle Act | Amendment to the ICA of 1887 legalizing rate bureaus or conferences. |
| 1958 | Transportation Act | Amended the rule of rate making by stating that rates couldn't be held up to protect the traffic of any other mode. |
| 1958 | Federal Aviation Act | Created the Federal Aviation Agency to assume the mission of the CAA; FAA empowered to manage and develop U.S. airspace and plan the U.S. airport system. |
| 1966 | Dept. of Transportation Act | Assumed mission of FAA and a number of other agencies for research, promotion, safety, and administration of transportation; organized into nine operating and six administrative divisions; also established the National Transportation Safety Board. |
| 1970 | Railway Passenger Service Act | Created the National Railroad Passenger Corp. to preserve and upgrade intercity rail passenger service; resulted in the creation of Amtrak. |
| 1975 | Hazardous Materials Transportation Act | Strengthened laws to fight illegal dumping. Created a cradle-to-grave responsibility for hazardous materials. Established minimum standards for transport by all modes. Regulated by DOT. |

The 1887 act created the Interstate Commerce Commission (ICC), which required rail carriers to charge and publish reasonable rates, file them with the ICC, and make them available to the public; and which prohibited discriminatory practices (charging some shippers less than others for the same service). The act also prohibited agreements between railroads to pool traffic or revenues. Between 1887 and 1910, a number of amendments made to the 1887 act increased the ICC's control and enforcement power. These amendments restricted railroads from providing rates and services that were not in the public's best interest, created penalties for failure to follow published rates or for offering and accepting rebates, set maximum rates, and prevented railroads from owning pipelines or water carriers, unless approved by the ICC.

By 1917, increased competition combined with the rate restrictions had created a rail system unable to offer the efficient service the U.S. government needed in its war efforts, and thus the federal government seized the railroads. Railroad companies were guaranteed a profit while the government poured large sums of money into upgrading the rail system. By the end of World War I, Congress had come to realize that all of the negative controls placed on railroads were unhealthy for the industry. They wanted to return the railroads to private ownership. This brought about the first of a number of regulations aimed at positive control, namely the **Transportation Act of 1920**.

The 1920 act instructed the ICC to ensure that rates were high enough to provide a fair return for the railroads each year (Congress initially set this at 6 percent return per year). When companies made more than the prescribed 6 percent, half of the excess was taken and used to fund low-interest loans to the weaker operators for updating their systems and increasing efficiency. The act also allowed the ICC to set minimum rates, allowed joint use of terminal facilities and allowed rail company acquisitions and consolidations. Finally, to keep the railroads from becoming overcapitalized, the act prohibited railroads from issuing securities without ICC approval. The rail system thus became a regulated monopoly.

From 1935 to 1942, regulations were passed that applied to other modes of transportation and these were similar in nature to the 1920 act. A great deal of money was spent during the 1920s and during the Depression, building the U.S. highway system. The time became ripe, then, for the emergence of for-hire motor carriers. The number of small trucking companies grew tremendously during this period, creating competition for the railroads, as shippers opted to use the cheaper for-hire motor carriers. The **Motor Carrier**

**Act of 1935** brought motor carriers under ICC control, thus controlling entry into the market, establishing motor carrier classes of operation, setting reasonable rates, mandating ICC approval for any mergers or acquisitions, and controlling the issuance of securities.

In 1938, the federal government enacted another extension of the Interstate Commerce Act by including regulation of air carriers in the **Civil Aeronautics Act of 1938**. This act promoted the development of the air transportation system and the air safety and airline efficiency by establishing the Civil Aeronautics Board to oversee market entry, establish routes with appropriate levels of competition, develop regional feeder airlines, and set reasonable rates. The Civil Aeronautics Administration was also established to regulate air safety.

The **Transportation Act of 1940** further extended the Interstate Commerce Act of 1887 by establishing ICC control over domestic water transportation. The provisions for domestic water carriers were similar to those imposed on rail and motor carriers. In 1942, the 1887 act was once again extended to cover freight forwarders, with the usual entry, rate, and service controls of the ICC. Freight forwarders were also prohibited from owning any carriers.

A number of other congressional enactments occurred up through 1970, further strengthening and refining the control of the transportation market. In 1948, the **Reed-Bulwinkle Act** gave groups of carriers the ability to form rate bureaus or conferences wherein they could propose rate changes to the ICC. The **Transportation Act of 1958** established temporary loan guarantees to railroads, liberalized control over intrastate rail rates, amended the rule of rate-making to ensure more intermodal competition, and clarified the differences between private and for-hire motor carriers. The **Federal Aviation Act of 1958** replaced the Civil Aeronautics Administration with the Federal Aviation Administration (FAA) and gave the FAA authority to prescribe air traffic rules, make safety regulations, and plan the national airport system. In 1966, the **Department of Transportation Act** created the Department of Transportation (DOT) to coordinate the executive functions of all government entities dealing with transportation-related matters. It was hoped that centralized coordination of all the transportation agencies would lead to more effective transportation promotion and planning. Finally, to preserve and improve the rail system's ability to service passengers, the **Railway Passenger Service Act** was passed in 1970, creating Amtrak.

As discussed earlier, there have been a number of transportation regulations dealing with safety and security, and only the 1975 Hazardous Materials Transportation Act is shown in Table 9.2. Prior to this time, many landfills began refusing to accept hazardous waste, which created a rash of midnight dumping activities along roadways and in vacant lots. Poor coordination and lack of personnel created poor enforcement of existing laws. This law established minimum standards of regulation for transportation of hazardous materials, administered by the DOT. All hazardous waste transporters were forced to register with the proper state and federal agencies, track all pick-ups and deliveries, and cleanup any spills during transports.

## Transportation Deregulation

Beginning in 1976, Congress enacted a number of laws to reduce and eliminate many transportation regulations. These are summarized in Table 9.3. This began the movement toward less economic regulation by allowing market forces to determine prices, entry, and services. At this point in U.S. transportation history, consumers and politicians had the opinion that transportation economic regulations were administered more for the benefit

**Table 9.3 U.S. Transportation Deregulation**

| DATE | DEREGULATION | SUMMARY |
|---|---|---|
| 1976 | Railroad Revitalization and Regulatory Reform Act | The "4-R Act." Railroads were allowed to change rates without ICC approval, within limits; ICC procedures were sped up. |
| 1977 | Air Cargo Deregulation Act | Freed all air cargo carriers from CAB regulations. |
| 1978 | Air Passenger Deregulation Act | Airlines freed to expand routes, change fares within limits; small community routes were subsidized; CAB ceases to exist in 1985. |
| 1980 | Motor Carrier Act | Fewer restrictions on entry, routes, rates, and private carriers. |
| 1980 | Staggers Rail Act | Freed railroads to further establish rates within limits; legalized contract rates; shortened ICC procedure turnaround. |
| 1982 | Bus Regulatory Reform Act | Amended the 1980 MCA to include buses. |
| 1984 | Shipping Act | Partial deregulation of ocean transportation. |
| 1994 | Trucking Industry Regulatory Reform Act | Motor carriers freed from filing rates with the ICC. |
| 1994 | FAA Authorization Act | Freed intermodal air carriers from economic regulation by the states. |
| 1995 | ICC Termination Act | Eliminated the ICC and moved regulatory duties to Dept. of Transportation. |
| 1998 | Ocean Shipping Reform Act | Deregulated ocean liner shipping; allowed contract shipping; rate filing not required. |

of the carriers than the public. In addition, with the bankruptcy filings of a number of railroads in the mid-1970s combined with the Arab oil embargo of the same time period, regulation was receiving much of the blame for an inefficient transportation system.

The **Railroad Revitalization and Regulatory Reform Act**, commonly known as the 4-R Act, was passed in 1976 and made several regulatory changes to help the railroads. First, railroads were allowed to change rates without ICC approval, limited by *threshold costs* on one end and *market dominance* on the other. Threshold costs were defined as the firm's variable costs and the ICC determined whether the firm was in a market dominant position (absence of market competition). A number of ICC procedures were also sped up to aid transportation manager decision making. These same ideas appeared again in later deregulation efforts.

Air freight was deregulated in 1977. No longer were there any barriers to entry provided the firms were deemed fit by the Civil Aeronautics Board. Size restrictions were also lifted and carriers were free to charge any rate, provided there was no discrimination. Finally, carriers did not have to file freight rates with the CAB. This was followed soon after by deregulation of air passenger service in 1978. The targeted beneficiary of passenger airline deregulation was the traveler. In introducing the bill to the Senate floor, Senator Ted Kennedy, one of the bill's principal sponsors, proclaimed, "This bill, while preserving the government's authority to regulate health and safety, frees airlines to do what business is supposed to do—serve consumers better for less." This was a phased-in approach, wherein carriers could slowly add routes to their systems while protecting other routes from competition. Fares could be adjusted within limits without CAB approval. To protect small communities from losing service, all cities with service in 1977 were guaranteed service for ten additional years. In 1981, all route restrictions were to be released, allowing any carrier to operate any route. Airline rates and mergers were to be released from regulation in 1983. Finally, the CAB was to shut down in 1985.

The impacts of deregulation on the U.S. airline industry were enormous—there were thirty-four air passenger carriers in 1977, and only five years later the number had increased

to ninety. Some fares dropped substantially, while other fares went up, and routes to low-demand areas decreased substantially. By 1981, among the major U.S. airlines, only American, Delta, and TWA were making a profit. A number of notable airline failures also occurred in the years following deregulation. Braniff, for instance, after deregulation expanded rapidly in the United States and abroad, purchased a large number of planes, loaded up on debt, and then declared bankruptcy in 1982. They emerged from bankruptcy as a smaller airline; then seven years later declared bankruptcy again, after failing to obtain financing. A short time later, Braniff ceased operations completely. People Express, a new low-fare, no-frills airline that began right after deregulation, followed the Braniff large-expansion-high-debt model, and similarly had trouble operating by 1986, eventually selling out to rival Texas Air, which itself filed for bankruptcy in 1990. In all, some 150 airlines came and went during this period.[52] Fast-forward 30 years—by 2020, due to industry consolidation and further bankruptcies, the four largest airlines in the United States—American, Delta, Southwest, and United, controlled approximately 65 percent of the domestic U.S. market.[53]

Because of the pandemic, 2020 was a terrible year for all airlines, domestic and global. Domestic U.S. air service declined by about 70 percent compared to 2019. In March 2020, the CARES Act became law, which provided passenger airlines $50 billion in financial assistance, with another $8 billion going to cargo airlines. The carriers taking the financial assistance (virtually all) had to maintain certain requirements—they were prohibited from reducing the wages of employees, or involuntarily furloughing workers, and some of these air carriers were also required to maintain a minimum level of service to many domestic cities. Most experts think a recovery in the domestic air transportation market will take three to six years.[54]

Motor carriers were deregulated in 1980. The objectives of this act were to promote competitive as well as safe and efficient motor transportation. Entry regulations were relaxed to make it easier to enter the market—firms had only to show a "useful public purpose" would be served. Route restrictions were removed and restrictions deemed to be wasteful of fuel, inefficient, or contrary to public interest were also removed. And, as with passenger airline deregulation, a large number of new motor carriers began service. By 1981, more than 2400 new motor carrier companies had started up in the United States, and this number would continue in the following years. Unfortunately, by 1990, 11,490 of these companies had declared bankruptcy. This was more than the number of motor carrier bankruptcies in the forty-five years leading up to deregulation in 1980.[55]

Railroads were further deregulated with the **Staggers Rail Act of 1980**. The financial condition of railroads was worsening and this act was aimed at improving finances for the rail industry. With this act, rail carriers were free to change rates within a zone of rate freedom, but the ceiling or market dominance rate was established more definitively as 160 percent of variable costs and varied up to 180 percent, depending on ICC cost formulas. After 1984, rate increases were to be tied to the rate of inflation. Contract rates were also allowed between railroads and shippers.

The **Shipping Act of 1984** marked the end of the initial push by Congress to deregulate the entire U.S. transportation industry. This act allowed ocean carriers to pool or share shipments, assign ports, publish rates, and enter into contracts with shippers. More recently, with the passage of the **ICC Termination Act of 1995** and the **Ocean Shipping Reform Act of 1998**, the Interstate Commerce Commission was eliminated and the requirement for ocean carriers to file rates with the Federal Maritime Commission also came to an end.

Thus, a number of changes in the U.S. transportation industry over the past century have occurred. Economic regulation of transportation occurred for several reasons. Initial

transportation regulations were instituted to *establish the ground rules* as new forms of transportation developed and to *control prices, services, and routes* when monopoly power existed in the industry. Later, deregulation was used to *encourage competition* and *increase efficiency and safety*. Arguments remain as to the success and need for both transportation regulation and deregulation. In the future, as economic conditions change and as technology, political, and social changes occur, transportation regulations will also continue to change.

## Warehousing and Distribution

Warehouses provide very strategic supply chain services—they enable firms to store their purchases, work-in-progress, and finished goods, as well as perform breakbulk and assembly activities. Further, warehouses allow faster and more frequent deliveries of finished goods to customers, which in turn can result in better customer service. Today, companies view warehouses as a competitive resource. Amazon.com, for example, has dramatically expanded its warehouse network over the years to compete better and to offer same-day service in some areas.

As disposable income increases, consumers buy more goods that must move through various distribution systems. In fast growing economies like India and China, this means the demand for warehouses is growing rapidly. In the United States as well, the number of warehouses is growing, and they are becoming larger too. From 2000 to 2012, over 3 billion square feet of warehousing space was added in the United States. In 2015, the average U.S. commercial warehouse size was approximately 215,000 square feet.[56] Today, 400,000-square-foot warehouses are becoming more prevalent (that is almost five soccer fields), and many are much larger. Amazon fulfillment centers average about 800,000 square-feet, and their largest is the new 2021 fulfillment center in Mt. Juliet, Tennessee. The enormous 3.6 million square-foot, five-story center includes highly automated warehouse space.[57] Target is another good example—their largest is an import warehouse in Savannah, Georgia with just over 2 million square feet of space. It was opened in 2006 to serve the Southeast United States with a wide range of goods. The company also operates another 2 million square-foot import warehouse in Washington state as well as a 1.8 million square-foot facility in Virginia.[58]

In many cases today, warehouses are not used to store things, but rather to receive bulk shipments, break them down, repackage various items into outgoing orders, and then distribute these orders to a manufacturing location or retail center. These activities are collectively referred to as **crossdocking**. In this case, the warehouse is more accurately described as a **distribution center** (as noted above, Amazon refers to theirs as fulfillment centers). In other cases, firms are moving warehouses closer to suppliers, closer to customers, or to more centralized locations, depending on the storage objectives and customer service requirements. So, warehouses are still very much in use—some just to store things and others to provide efficient throughput of goods. This section discusses a number of warehousing issues including their importance and the types of warehouses, risk pooling and warehouse location, and lean warehousing.

### The Importance and Types of Warehouses

Firms hold inventories for a number of reasons as explained in Chapter 6—warehouses are used to support purchasing, production, and distribution activities. Firms order raw materials, parts, and assemblies, which are typically shipped to a warehouse location close

to or inside the buyer's location, and then eventually transferred to the buyer's various operations as needed. In a retail setting, a warehouse might be regionally located, with the retailer receiving bulk shipments at the warehouse from many suppliers, then breaking these down and reassembling outgoing orders for delivery to each retail location, while using its private fleet of trucks, or for-hire transportation providers to move the orders to the retail locations. Similar distribution centers are used when manufacturers deliver bulk shipments to regional market areas and then break these down and ship LTL order quantities to customers.

Firms might operate **consolidation warehouses** to collect large numbers of LTL shipments from nearby regional sources of supply, and then consolidate and transport in TL or CL quantities to a manufacturing or user facility located at some distance from the consolidation warehouse. The use of consolidation warehouses and distribution centers allows firms to realize both purchase economies and transportation economies. Firms can buy goods in bulk at lower unit costs and then ship these goods at TL or CL rates either to a distribution center or directly to a manufacturing center or retailer. They can also purchase and move small quantity purchases at LTL rates to nearby consolidation warehouses.

## Private Warehouses

Just as with the private forms of transportation, **private warehouses** refer to warehouses that are privately owned and used by an organization. For firms with large volumes of goods to store or transfer, private warehouses represent an opportunity to reduce the costs of warehousing as well as control the levels of service provided to customers. Currently, one of the largest e-commerce companies, the Alibaba Group, is expanding its number of private warehouses in China to streamline deliveries across the nation. Its logistics arm, Cainiao, has increased its warehouse space significantly over the years. Founded in 2013, Cainiao seeks to give Alibaba a driving role in China's fragmented package delivery industry. In partnership with delivery businesses, it crunches reams of data on everything from order trends to delivery routes and weather patterns to increase efficiency. Cainiao is revolutionizing how logistics is done—every hour, for example, a 3×5-foot automated vehicle picks up packages from Cainiao's depot in Hangzhou and tours a nearby neighborhood. Locals in pajamas pop down to meet the driverless cart at their nearest delivery point and type in a reference number. A door in the vehicle's side flips open and the customer's parcel can be retrieved. The vehicle heads to the next stop, weaving through traffic via 360-degree sensors.[59]

With private warehousing, firms are free to decide what to store, what to process, what types of security to provide, and the types of equipment to use, among other operational aspects. Private warehousing can also enable the firm to better utilize its workforce and expertise in terms of transportation, warehousing, and distribution center activities. As supply chains become more global to take advantage of cheaper sources of supply or labor, the use of private warehouses tends to increase. Finally, private warehouses can generate income and tax advantages through leasing of excess capacity and/or asset depreciation. For these reasons, private warehousing accounts for the vast majority of overall warehouse space in the United States.[60]

Private warehouses can be truly massive, as described earlier with Amazon's and Target's distribution centers. Constellation Europe, a liquor wholesaler, has a private warehouse in Bristol, England for example, totaling just under 1 million square feet. It can house up to 57 million bottles of wine at one time.[61]

Owning warehouses, though, can also represent a significant financial risk and loss of flexibility to the firm. The costs to build, equip, and then operate a warehouse can be very

high and most small- to moderate-sized firms simply cannot afford private warehouses. Private warehouses also restrict firms to locations that may not prove optimal as time passes. Warehouse size or capacity is also somewhat inflexible, at least in the short term. Another problem can be insurance. Insurance companies, in many cases, do not like insuring goods in private warehouses, simply because security levels can be meager or nonexistent, creating a significant concern regarding fires or thefts of goods.

## Public Warehouses

As the name implies, **public warehouses** are for-profit organizations that contract out or lease a wide range of light manufacturing, warehousing, and distribution services to other companies. Public warehouses provide a number of specialized services that firms can use to create customized shipments and goods. These services include the following:

- *Breakbulk*—large-quantity shipments are broken down so that items can be combined into specific customer orders and then shipped out.
- *Repackaging*—after breakbulk, items are repackaged for specific customer orders. Warehouses can also do individual product packaging and labeling.
- *Assembly*—some public warehouses provide final assembly operations to satisfy customer requests and to create customized final goods.
- *Quality inspections*—warehouse personnel can perform incoming and outgoing quality inspections.
- *Material handling, equipment maintenance, and documentation services.*
- *Short- and long-term storage.*

Besides the services shown here, public warehouses provide the short-term flexibility and investment cost savings that private warehouses cannot offer. If a firm's demand changes or its goods change, the short-term commitments required at public warehouses allow the firm to quickly change warehouse locations. Public warehouses allow firms to test various market areas and withdraw quickly if demand does not materialize as expected. The cost for firms to use a public warehouse can also be very small if their capacity requirements are minimal.

More recently, pharmaceutical companies are using public warehouses in conjunction with third-party **cold chains** to ensure their product reaches buyers in good shape. Pharmaceutical cold chains refer to temperature-controlled (2°- 8°C) transportation, transfers, and warehousing. Currently, about half of the best-selling drugs require cold chains.[62] In 2020, however, the demand for ultra-cold (below minus 60°C) chains became a common requirement to transport some of the vaccines, like the Pfizer-BioNTech product. The more traditional cold chain vaccines are those that need to be kept between 2°- 8°C such as the Johnson & Johnson and AstraZeneca vaccines. Significant problems still exist in countries with weaker cold chains, such as in most developing countries.[63] In fact, several global studies according to the National Institutes of Health in January 2020, on the effectiveness of the cold chain for vaccines, concluded that the logistics systems were not up to standard to ensure the quality and stability of the vaccine. "By deploying RFID, bar codes, mobile computers, GPS and cloud-based block-chain technology solutions, the distribution of the COVID-19 vaccine can have complete transparency," says Carl Gustafson, Senior Consulting Director at Texas-based Vizient, a health care services company. "Deploying GPS-enabled RFID tags to verify delivery and receipt and obtain reporting will support identifying weak links in the supply chain," he added.[64]

One of the main disadvantages associated with public warehouses is the lack of control provided to the goods owners. Other problems include lack of communication with warehouse personnel, lack of specialized services or capacity at the desired locations, and the lack of care and security that might be given to goods.

Firms might find it advantageous to use public warehouses in some locations and private warehouses in others. For large, established markets and relatively mature goods, large firms may decide that owning and operating a warehouse makes the most sense, whereas the same firm may lease space and pay for services at public warehouses in developing markets and low-demand areas.

## Risk Pooling and Warehouse Location

One of the more important decisions regarding private warehouses is where to locate them. The location decision affects the number of warehouses needed, the required capacities, the system inventory levels and customer service levels, and finally, the costs of the warehousing system. For a given market area, as the number of warehouses used increases, the warehousing system becomes more *decentralized*. In a **decentralized warehousing system**, responsiveness and delivery service levels will increase since goods will be closer to customers and can be delivered more quickly; however, warehousing system operating and inventory costs will also increase. Other costs that come into play here are outgoing transportation costs to customers and the transportation costs associated with the incoming deliveries of goods to each warehouse. Thus, the trade-off between costs and customer service must be carefully considered as the firm makes its warehouse location decisions. In a **centralized warehousing system**, fewer warehouses means that outbound transportation costs will be higher and service levels will be lower, but system costs will also be lower. This brings up the very important topic of **risk pooling,** which is discussed below.

### Risk Pooling

Risk pooling describes the relationship between the number of warehouses, system inventories, and customer service, and it can be explained as follows:

> *When market demand is random, it is very likely that higher-than-average demand from some customers will be offset by lower-than-average demand from other customers. As the number of customers served by a single warehouse increases, these demand variabilities will tend to offset each other more often, thus reducing overall demand variance and the likelihood of stockouts. Consequently, the amount of safety stock in a warehouse system required to guard against stockouts decreases. Thus, the more* centralized *a warehousing system is, the* lower the safety stock *required to achieve a given system-wide customer service level (recall that in inventory parlance, the customer service level is inversely proportional to the number of stockouts per period).*

As mentioned above, risk pooling assumes that demand at the markets served by a warehouse system is negatively correlated (higher-than-average demand in one market area tends to be offset by lower-than-average demand in another market area). In smaller market areas served by warehouses, this may not hold true, and warehouses would then require higher levels of safety stock. This is why a smaller number of centralized warehouses serving large market areas require lower overall system inventories, compared to a larger number of decentralized warehouses serving the same markets.

A good illustration of this principle occurred in Europe after the formation of the European Union in 1993. Prior to that time, European logistics systems were formed along national lines. In other words, each country's distribution systems operated independently of the others, with warehouses located in each country. With the arrival of a single European market in 1993, these distribution systems no longer made economic sense. For example, Becton Dickinson, an American manufacturer of diagnostics equipment, was burdened in Europe in the early 1990s with just this type of country-specific and costly distribution system. After the formation of the European Union, the company closed its distribution centers in Sweden, France, Germany, and Belgium and shifted all of its distribution operations to a single automated center in Belgium. In less than a year, average stock levels were down 45 percent, write-offs fell by 65 percent, and stockouts were reduced by 75 percent. Other companies in Europe had similar results.[65]

The effect of risk pooling can be estimated numerically by the **square root rule**, which suggests that the system average inventory (as impacted by changing the number of warehouses in the system) is equal to the original system inventory times the ratio of the square root of the new number of warehouses to the square root of the original number of warehouses.[66] A simple illustration of risk pooling is shown in Example 9.1. In the example, reducing the number of warehouses from two to one causes a reduction in average inventory of approximately 29 percent.

The differences between centralized and decentralized warehousing systems can be summarized as follows:

- *Safety stock and average system inventory*—as the firm moves toward fewer warehouses and a more centralized warehousing system, safety stocks and thus average inventory levels across the system are decreased. The magnitude of the reduction depends on the demand correlations in the various market areas.
- *Responsiveness*—as warehouse centralization increases, delivery lead times increase, increasing the risk of late deliveries to customers and reducing the

**Example 9.1 Risk Pooling at Thompson's Boot Barn**

Thompson's Boot Barn currently owns two warehouses in Phoenix and Los Angeles to store its boots prior to shipping them out to retailers and other customers throughout the south-western United States. Bill Thompson, the owner, is considering a change to a more centralized system with just one warehouse in Las Vegas. He is curious to know the impact this will have on his system inventories. The Boot Barn's current inventories are approximately 6000 boots in each warehouse, and its current stockout performance is about 1 percent. Using the square root rule, Bill calculates the new average inventory level needed to maintain the same stockout performance:

$$S_2 = \frac{\sqrt{N_2}}{\sqrt{N_1}}(S_1) = \frac{\sqrt{1}}{\sqrt{2}}(12{,}000) = \frac{1}{1.414}(12{,}000) = 8{,}486 \text{ boots}$$

where:

$S_1$ = total system stock of boots for the $N_1$ warehouses;
$S_2$ = total system stock of boots for the $N_2$ warehouses;
$N_1$ = number of warehouses in the original system; and
$N_2$ = number of warehouses in the new system.

Thompson's new system inventory would be reduced from 12,000 to 8486 boots, or:

$$\%\text{ reduction} = \frac{(12{,}000 - 8{,}486)}{12{,}000} = 0.293 = 29.3\%$$

ability of the organization to respond quickly to changes in demand. Customer service levels may thus be impacted because of issues such as traffic problems and weather delays.

- *Customer service to the warehouse*—as centralization increases, customer service levels provided by the warehouses' suppliers are likely to increase, reducing the likelihood of stockouts for a given level of average system warehouse inventory.
- *Transportation costs*—as centralization increases, outbound transportation costs increase, as LTL shipments must travel farther to reach customers. Inbound transportation costs decrease, since manufacturers and other suppliers are able to ship larger quantities at TL rates to fewer warehouse locations. The overall impact on transportation costs thus depends on the specific warehouse locations, the goods stored, the locations of suppliers, and the modes of transportation used.
- *Warehouse system capital and operating costs*—as centralization increases, warehouse capital and operating costs decrease because there are fewer warehouses, fewer employees, less equipment, and less maintenance costs.

## Warehouse Location

A number of location models and theories have been proposed over the years to optimally locate factories, services, and warehouses. In Chapter 11, a number of location analysis tools are discussed, and these can certainly be useful for locating warehouses. Early in the development of modern transportation and warehousing networks, several well-known economists posited theories regarding warehouse locations that are discussed in this section.

German economist Johann Heinrich von Thünen, who is often regarded as the "father of location theory," argued in the 1820s that transportation costs alone should be minimized when considering facility locations.[67] His model assumed that market prices and manufacturing costs would be identical regardless of the location of the warehouse, so the optimum location would be the one that resulted in the minimum transportation costs. Another German economist a century later, Alfred Weber, proposed an industrial location theory very similar to von Thünen's; he argued that the optimum location would be found when the sum of the inbound and outbound transportation costs was minimized.[68]

In the 1940s, Edgar Hoover recommended three types of location strategies: the market positioned, product positioned, and intermediately positioned strategies.[69] The **market positioned strategy** locates warehouses close to customers, to maximize customer service levels. This strategy might be recommended when there are high levels of competition and distribution flexibility. The **product positioned strategy** locates warehouses close to the sources of supply to enable the firm to collect various goods while minimizing inbound transportation costs. This strategy works well when there are large quantities of goods purchased from many sources of supply and assortments of goods ordered by customers. The **intermediately positioned strategy** places warehouses midway between the sources of supply and the customers. This strategy is recommended when distribution service requirements are relatively high and customers order product assortments purchased from many suppliers. In the 1950s, Melvin Greenhut's location theory was based on profit instead of transportation costs.[70] He argued that the optimum location would be the one that maximized profits, which may not coincide with the minimum cost location, because demand and prices can potentially vary based on location. None of the methods described

here specifically deal with international site selection and today, this remains a complex problem.

Several location heuristics have been developed based on transportation costs, one of which is the location break-even approach, discussed in Chapter 11. The weakness of this approach, as well as some discussed here, is that they fail to consider a number of other factors such as labor availability, labor rates, land cost, building codes, tax structure, construction costs, utility costs, and the local environment. Additionally, if a firm is using a public warehouse, the location selection criteria would need to include warehouse services, lease costs, communication capabilities, reporting frequency, and the operator's reputation. These factors may best be addressed using a weighted factor location analysis, also discussed in Chapter 11.

## Lean Warehousing

As firms develop their supply chain management capabilities, items will be moving more quickly through inbound and outbound warehouses and distribution centers. These warehouses and distribution centers will thus have to develop leaner capabilities. Some examples of these capabilities include the following:

- *Greater emphasis on crossdocking*—warehouse employees receive shipments, break them down, and mix units of product into outgoing shipments. Far fewer goods will be stored for any appreciable time and average warehouse inventory levels will decrease, while the number of stock keeping units will increase.
- *Reduced lot sizes and shipping quantities*—inbound and/or outbound shipping quantities are likely to be smaller and more frequent, containing mixed quantities of goods and thus requiring more handling.
- *A commitment to customers and service quality*—warehouse employees perform warehouse activities so as to meet the requirements of their inbound and outbound suppliers and customers.
- *Increased automation*—to improve handling speed and reliability, more warehouse activities will become automated, from scanner/barcode computer tracking systems, to warehouse management software applications, to automated storage and retrieval systems.
- *Increased assembly operations*—as more firms implement lean systems and mass customization, warehouses will be called upon to perform final assembly operations to meet specific customer requirements. This will change the skill requirements of warehouse employees, along with equipment requirements.
- *A tendency to be green*—since lean operations by their nature, tend to produce less waste, a natural byproduct of lean warehousing is green warehousing.

Most distribution centers are adopting **lean warehousing** concepts. DHL Supply Chain, part of the Deutsche Post DHL Group, is combining wearable "smartglass" devices with warehouse management software at two U.S. warehouses. The company stated the technology replaced handheld scanners and paper job orders in tests at a Dutch warehouse, reducing the time needed to pick an item and pack it for shipping by 25 percent.[71] Pennsylvania-based manufacturer Crown Holdings changed its layout to eliminate the need to transport items between facilities, saving over 20,000 transportation miles, 27 tons of greenhouse gases, and many hours of labor time annually.[72] Alpha Comm Enterprises uses Netsuite's cloud warehousing application to obtain real-time warehouse

and inventory management data as well as sales order information, to allow the company to better respond to customers and to improve internal planning. It's vital for Alpha Comm to be able to run lean warehouses given the fast-paced market it serves where goods reach obsolescence rapidly. All of Alpha Comm's lean warehousing efforts have paid off handsomely with company revenue dramatically increasing from $5 million to $55 million over a six-year period.[73] In fact, if a warehouse operation today is not implementing lean practices, it is falling behind its competition.

## The Impacts of Logistics on Supply Chain Management

As mentioned in this chapter's introduction, logistics refers to the movement and storage of goods from point of origin to point of consumption within the firm and throughout the supply chain and is thus responsible for creating time and place utility. In a managed supply chain setting, these logistics elements are extremely important in that goods must be routinely delivered to each supply chain customer on time, to the correct location, at the desired level of quality, and at a reasonable cost. As mistakes occur in deliveries along the supply chain, more safety stocks must be held, adversely impacting both customer service levels and costs. To make up for lost time, overnight deliveries might also have to be used, adding yet more costs to the logistics bill.

For global supply chains, the logistics function is even more critical. Providing adequate transportation and storage, getting items through customs, delivering to foreign locations in a timely fashion, and logistics pricing can all impact the ability of a supply chain to serve a foreign market competitively. In many cases, firms are forced to use outside agents or **third-party logistics services** (3PLs) to move items into foreign locations effectively.

Purchases from foreign suppliers are also similarly affected by logistics considerations. When firms begin evaluating and using foreign suppliers, logistics costs and timing become critical factors in the sourcing decision. For instance, Chinese suppliers delivering goods to buyers along the U.S. East Coast are in many cases favoring an all-water route through the Panama Canal, rather than dealing with port and traffic congestion on the U.S. West Coast, followed by trucking and rail transportation within the U.S. Buyers get cheaper freight rates and can plan on shipments arriving at a specific time when using an all-water route, whereas the chances of domestic U.S. shipments being held up because of port and traffic congestion and missed rail connections can be significant. All-water shipments have risen significantly since the early 1990s.[74] Because of this, Panama completed a $5 billion widening of the Panama Canal in 2016 to accommodate larger ships, and Nicaragua has for years, been seeking investment to build a canal to compete with the Panama Canal.[75] Containerized cargo numbers are up in every eastern U.S. port. Primarily, the growth has been the result of increased growth in global trade in general and an increase specifically in Asia–Pacific trade.

Thus, the value created for supply chains by logistics can readily be seen. It is what effectively links each supply chain partner. Poor logistics management can literally bring a supply chain to its knees, regardless of the production cost or quality of the goods. Alternatively, good logistics management can be one of the elements creating a competitive advantage for supply chains. A number of these topics are explored further in this section.

### Third-Party Logistics (3PL) Services

Most logistics companies that work for other companies offer both transportation and warehousing services, allowing firms to make better use of distribution alternatives such as

transportation mode, storage location, and customs clearance. Third-party logistics companies, or 3PLs, refers to the outsourcing of logistics processes to a third-party logistics business. Companies began trending toward outsourcing inbound and outbound logistics services to third parties in the 1970s. It makes sense for small companies that do not have fully developed logistics capabilities, and even for large firms entering a new foreign market for example. Some 3PLs provide complete end-to-end supply chain management services, including network optimization, light manufacturing, and other value-added services. Companies with the flexibility to offer logistics services in these areas are taking advantage of the increased service demand, particularly during 2020 and 2021. Large 3PLs such BNSF Logistics have developed significant Mexico–United States cross-border capabilities in recent years to deal with the near-shoring trend and are working with producers in North Dakota to offer the logistics services needed there, to oil companies.[76]

For small firms with no internal logistics expertise and large firms with many sizeable and varied logistics needs, outsourcing logistics requirements to 3PLs can help firms get the services they require at reasonable prices. Many firms outsource some or all of their logistics needs to allow more attention to be placed on their core competencies. In tough economic times, firms tend to use 3PLs to help reduce costs while maintaining customer service levels. During the economic recession of 2009, 80 percent of U.S. companies used a 3PL for at least one area of their supply chains. In Europe, about 66 percent of every logistics euro spent was on outsourcing.[77] In 2020, during the global pandemic, use of 3PLs also grew. "Third-party logistics benefitted from the replenishment of personal protective equipment supplies and other medical products. It was all driven by COVID-19, whether it was from consumers or from hospitals," said transportation and logistics consultancy SJ Consulting president Satish Jindel.[78] Shippers and 3PLs still agree on the benefits of 3PL usage: in a 2016 survey of 3PL usage undertaken by Korn Ferry International, 70 percent of shippers and 85 percent of 3PL services said the use of 3PLs contributed to lower logistics costs. Further, 83 percent of shippers and 94 percent of 3PL services said the use of 3PLs contributed to improved customer service.[79] As of the end of 2020, the three largest global 3PLs were Fulfillment by Amazon, DHL, and Kuehne and Nagel. Interestingly, Amazon's 3PL revenues grew by almost 50 percent compared to 2019 (they provide inbound logistics, warehousing, pick-and-pack services, and distribution for third-party merchants that sell through the Amazon platform)[80].

## Outsourcing End-to-End Supply Chain Management Activities

In some cases, firms may opt to partner with a 3PL for the provision of most or all supply chain management activities. For small firms, it may be due to a lack of expertise and resources. The sheer scale of supply chain activities and cost may also attract large firms that prefer to free up valuable resources for other activities. For example, Kawasaki Motors Corp. U.S.A. had global motorcycle sales of about $1.8 billion in 2015. The U.S. operation also markets and distributes all-terrain vehicles, jet skis and side-by-side utility vehicles, all manufactured at its plant in Lincoln, Nebraska. One recent change includes outsourcing all of its inbound logistics to United Parcel Service. "Instead of focusing so much of our efforts on maintaining logistics and distribution, we now depend on UPS for that, and we can focus on unit delivery from the factory to the dealers and marketing our products in the right way," says Kevin Allen, manager of public relations and brand experience.[81]

## 3PL Supply Base Reduction

As discussed in Chapter 4 of this text, reducing the supply base can provide a number of advantages for the organization. With 3PL service suppliers, the discussion is very

similar—using fewer 3PLs enables the firm to select and use only the best-performing 3PLs as well as to give these 3PLs a bigger share of the firm's logistics needs. This, in turn, results in better levels of service and potentially lower prices. The larger share of business given to each 3PL can be used as leverage when negotiating prices, shipping schedules, and associated services. By the end of 2005, for instance, Hewlett-Packard had halved the number of 3PLs it was using and continued to reduce this number even further. Other companies are similarly seeking to achieve an "irreducible minimum" number of 3PL suppliers. As a matter of fact, a third-party logistics study by Penn State University in 2013 indicated that an average of 58 percent of the users of 3PL services were reducing the number of 3PLs they used or consolidating logistics outsourcing with fewer 3PLs.[82] Thus, 3PL supply base reduction should become an integral part of an effective logistics management strategy particularly in markets characterized by numerous 3PL choices.

## Mode and 3PL Selection

To minimize logistics costs while meeting customer service requirements, firms identify the most desirable transportation modes and 3PL services available for the various markets they serve as well as for their inbound purchased materials. Other costs will also be affected by this decision, including inventory-in-transit carrying costs, packaging costs, warehousing costs, and shipment damage costs. Part 2 of this text discussed the topic of evaluating and selecting suppliers, and again, the topic here is very similar. Firms use a mix of quantitative and qualitative factors to evaluate and select 3PLs, and there are a number of comparative methods available to aid in the decision process, the most common of which is the weighted factor analysis. In a number of surveys conducted, important selection factors were found to be transit-time reliability, transportation rates, total transit time, willingness to negotiate rates and services, damage-free delivery frequency, financial stability, use of electronic data interchange, and willingness to expedite deliveries.[83]

## Creating Strategic Logistics Alliances

Building an effective supply chain very often includes the creation of strategic alliances with providers of logistics services. In fact, in several surveys of various businesses and industries, transportation and warehousing companies were included as supply chain partners in more than 50 percent of the respondents that were actively managing supply chains.[84] In today's intensely competitive business climate, partnering with a 3PL makes even more sense. These partnerships underscore the importance and role played by logistics in supply chain management. A few examples are given here.

Florida-based S-One Holdings, a wholesale distributor, has streamlined its supply chain thanks to a seamless information exchange with its 3PL partner, UPS Global. BMG, an S-One subsidiary, fulfills as many as 5500 orders a month and handles drop-shipping from manufacturers to 16 UPS warehouses in North America, Europe and Asia Pacific. BMG and UPS worked together to integrate feeds from UPS' systems directly into NetSuite's cloud, allowing them to power bi-directional data exchange on sales orders, purchase orders, advance ship notices, return authorizations and more, via web services and an FTP server. The seamless integration allows S-One to be directly integrated with UPS global and supports a $150 million business. Arizona-based Redcat Racing, a distributor of high-end radio controlled cars, also has close relationship with its 3PL partner. Its biggest expense is shipping and holding inventory. Because it's running a cloud-based ERP and inventory management system, Redcat is able to extend the information to its 3PL partner to better balance inventory. Redcat can see at a glance how many orders they ship same-day vs.

next-day or two-days; the days of the month that orders start increasing; which types of orders they are; and how to adjust. Ember Technologies also partnered with one 3PL to create a more effective global logistics system, and this discussion appears in the nearby SCM Profile.

## SCM Profile — Ember Partners with SEKO Logistics for All Its Logistics Needs

Brian Lary/Shutterstock.com

Clay Alexander, inventor of the world's first temperature-controlled mugs, and his company, California-based Ember Technologies, have turned to 3PL company SEKO Logistics, to support their worldwide supply chain needs.

What if your favorite hot drink could stay hot, right to the end? That's exactly what Clay Alexander, an inventor, thought about creating back in 2010. Using radio-controlled batteries, heating elements and sensors to keep the drinks hot, Clay invented the world's first temperature-controlled coffee cup, and started Ember Technologies.

The company's original product was a tall travel mug. Ember first pitched the product to Starbucks—"We put some Starbucks coffee in one of our mugs and asked them to set it at the desired temperature," says Ember COO Phil Poel. "It went over really well."

Starbucks started selling Ember's travel mug in 2016. "They sold out in a couple of weeks," says Poel. Then Starbucks asked Ember for coffee mugs. Their new coffee mug model became a huge success. Best Buy jumped onboard not long after, boosting Ember's sales from $1 million to $14 million "basically overnight," says Poel.

When Ember signed Apple as a customer in 2018, the need for a streamlined, reliable logistics and transportation solution became crucial. "We knew we needed a great third-party logistics partner to handle projects like launching in Apple stores in 26 different countries," says Poel.

Up to that point, Zachary Horton, Ember's shipping coordinator, says the company was using several different 3PLs to get its products delivered to its retail customers. "None of the systems were integrated," he says, "so after exploring our options, we made a conscious decision to make SEKO Logistics our primary 3PL." The two companies began working together in April of 2018.

Before moving to a single 3PL, Ember was using one warehouse for e-commerce and another to supply its retail customers. That setup required two completely different sets of inventories, communication modes, and fulfillment approaches. Today, SEKO handles all of Ember's global product shipments from three locations—the United States, Hong Kong, and the United Kingdom, and all are all fully integrated.

"We're growing quickly and we need a logistics partner that can go with the flow, so to speak," says Poel. "SEKO has been extremely flexible, and is always standing by ready to provide new solutions, come up with new approaches, and work with us to solve our logistics issues. That makes them a great partner for us."[85]

## Other Transportation Intermediaries

In some cases, companies utilize **transportation intermediaries**, which may not own any significant logistics capital assets, to find the most appropriate transportation mode or 3PL service. For many small companies with limited logistics expertise, and in some cases for large companies, where the scale of logistics needs are great, use of these transportation services can make good economic sense. A few of these intermediaries are discussed next.

### Freight Forwarders

Freight forwarders consolidate large numbers of small shipments to fill entire truck trailers or rail cars to achieve discounted truckload or carload transportation rates. They can also provide air transportation consolidation services. These companies pass some of the savings on to the small shippers and then keep the rest as fees. Thus, freight forwarders provide valuable services to both the shipper (lower shipping costs) and the carrier (extra business and higher equipment utilization). Freight forwarders typically specialize in either domestic or global shipments, as well as air or ground shipments. These companies also provide documentation services, special freight handling, and customs clearance.

Lately, the freight forwarding business has been booming as shippers look for ways to further reduce costs. DHL Global Forwarding for example, one of the highest rated firms in both ocean and air freight forwarding, is also one of the world's largest 3PLs. DHL Global Forwarding also provides warehousing, distribution and supply chain solutions. It offers shipping, tracking, export/international delivery, import/inbound delivery, domestic/local delivery, road and rail transportation, contract logistics, international mail, and other services. The parent organization, the DHL Group, is one of the largest private employers worldwide, with a presence in more than 220 countries.[86]

### Logistics Brokers

Also referred to as **freight brokers** and **transportation brokers**, **logistics brokers** bring shippers and carriers together. The logistics broker is legally authorized to act on either the shipper's or carrier's behalf, and typically these companies are hired because of their knowledge of the many transportation alternatives available or the many shippers needing transportation. Besides helping goods move efficiently, brokers also handle cargo claims, obtain specialized equipment, use dependable carriers, and track deliveries in real time. Unfortunately, bad logistics brokers can expose shippers and carriers to significant liability, risk the double payment of freight charges, reduce on-time delivery rates, and harm reputations. Accordingly, shippers and carriers must carefully screen and select their logistics brokers.

Typical arrangements might find small businesses using a broker to handle many of their shipping needs, or trucking companies using brokers to find a back-haul job after a delivery is completed. A number of logistics broker directories exist, enabling shippers and carriers to find one meeting their needs. The world's largest free load board for shippers and truckers can be found at freefreightsearch.com. A **load board** is a site where shippers can post loads for motor carriers to see, and motor carriers can post truck availabilities and locations for shippers to see.

### Shippers' Associations

The American Institute for Shippers' Associations (AISA) defines **shippers' associations** as "non-profit transportation membership cooperatives which arrange for

the domestic or international shipment of members' cargo. Associations will contract for the physical movement of the cargo with motor carriers, railroads, ocean carriers, air carriers, and others. The ability to aggregate cargo and ship the collective membership cargo at favorable volume rates is the key to the existence of the modern day Shippers' Association."[87]

Shippers' associations allow multiple shippers to pool their volumes in order to increase shipment volumes. With a larger shipment volume, the shippers' association may be able to negotiate volume discounts or service contracts with ocean carriers on behalf of its members. These associations also benefit the carriers, in that they help to better utilize their equipment. Because shippers' associations do not identify themselves as 3PLs, brokers, or transportation providers, they are not required to publish or adhere to a number of U.S. transportation regulations and can keep service contracts confidential. Some of the disadvantages of membership include required minimum shipment volumes to receive the benefits of reduced rates. Additionally, some carriers refuse to do business with shippers' associations.

A number of these cooperatives exist for different industries. For example, the North American Shippers Association negotiates service contracts with steamship lines for reduced rates on ocean freight for full container loads of beer, wines and spirits and mineral water in various trading lanes. Membership is open to importers, exporters, distributors, brokers, wholesalers, liquor control boards, and overseas suppliers. The International Shippers Association members are international shippers and forwarders of commercial, military, and government household goods; unaccompanied baggage; and general commodities. Its mission is to provide its members with the lowest rates and best service for the transport of household goods, accomplished by establishing volume-induced discounts. These discounts are realized through contracts with preferred vendors.[88]

### Intermodal Marketing Companies

**Intermodal marketing companies** (IMCs) are companies that act as intermediaries between intermodal railroad companies and shippers. They typically purchase large blocks of flatcars for piggyback service and then find shippers to fill containers, or motor carriers with truckloads, to load the flatcars. Essentially these are transportation brokers for the rail industry. They get volume discounts from the railroads and pass some of this on to the shippers. These companies facilitate intermodal shipping and have become an important service to railroads.

## Environmental Sustainability in Logistics

Today, firms are facing growing pressure to improve environmental performance from customers as well as local, state, and federal governing bodies. Further, an enormous portion of the world's oil reserves are consumed to move goods around the globe (in 2018, the total global cost of logistics exceeded $9.6 trillion, with about $1.9 trillion in the United States). In the United States, a good rule-of-thumb is that up to 10 percent of GDP is attributed to the logistics industry.[89] Today, company managers understand the negative impacts of transportation on carbon footprints, total costs, and overall oil consumption, and are doing something about it. Shifting motor carrier freight to railroads for example, is one strategy that reduces carbon emissions. Governments are also taking note of voter sentiment and beginning to enact more stringent environmental protection laws regarding transportation. Some examples are provided here.

In logistics, one of the big energy wastes comes from trucks returning from their deliveries empty (referred to as **empty miles**). To deal with this problem, some companies are turning to **horizontal collaboration**—the process of two or more companies cooperating at the same level on a certain market activity to realize benefits they could not achieve independently. While horizontal collaboration (HC) can encompass a number of supply chain processes, freight transportation is one activity that offers vast potential for a profitable partnership. Minnesota-based food company Land O' Lakes used to move a number of empty trucks along the eastern seaboard. Working with Nistevo.com, an online logistics matchmaker, it was able to partner with General Mills on one specific route. General Mills was sending its goods from point A to point B on a similar schedule as Land O' Lakes was sending its goods from point B to point A. Both were moving empty trucks back to their origination points. The two companies were able to synchronize loads and reduce empty miles. Through partnerships like this one, Land O' Lakes' was able to save over $2 million a year.[90]

A number of nonprofit organizations have been formed to help logistics companies with their sustainability efforts. Freight activity since1990 has grown by over 50 percent and is projected to nearly double again by 2040, producing more greenhouse gases and air pollution. Experts project that by 2050, global freight transport $CO_2$ emissions will surpass emissions from passenger vehicles. The amount of $CO_2$ gas emitted from driving a truck one mile is enough to fill a 150 gallon fuel tank. On average, a truck emits 123 metric tons of $CO_2$ gas every year.[91]

In the United States, the Environmental Protection Agency launched SmartWay in 2004, a certification program that reduces transportation emissions and improves supply chain efficiency. SmartWay helps companies improve supply chain sustainability by measuring, benchmarking, and improving freight transportation efficiency. The SmartWay website allows users to locate alternative fuel station locations, identify greener vehicles to purchase, and select certified SmartWay transportation companies. They also guide other countries seeking to develop freight sustainability programs. Currently, more than 3700 U.S. organizations participate in SmartWay.[92] The Coalition for Responsible Transportation (CRT), which began in 2007, includes importers, exporters, trucking companies, clean truck manufacturers, and ocean carriers. Through their Clean Truck Initiative, members of CRT work in partnership with U.S. ports to implement clean truck programs that are both environmentally and economically sustainable. CRT members invest millions of dollars in new clean equipment in partnership with federal and state governments, and local ports around the country. By partnering together, ports and their customers can improve the environmental quality of port communities.[93]

Europe's 3PLs and ports have been leading the way toward sustainability by introducing a number of green management initiatives. Damco, the logistics arm of Denmark's AP Moller-Maersk Group, launched a carbon footprint tracker in 2009 called the Supply Chain Carbon Dashboard that allows users to track their supply chain carbon footprint. "It immediately allows you to identify carbon hotspots in your supply chain," says Erling Nielsen, head of Maersk's supply chain development team. Another example is German logistics company DB Schenker's EcoTransIT World application. It allows customers to compare the energy consumption, $CO_2$ and pollutant emissions of all modes of transportation available, given the origination, destination, shipment volume, and freight being transported. Shippers can then select the best route and obtain all the emissions and energy data. Finally, EcoPorts, managed by the European Sea Ports Organization, is a nonprofit association with a current membership of 105 European and African ports and acts as a network platform to create effective collaborations addressing sustainability issues in

European ports and supply chains. The "EcoPort" status is obtained by any European port upon completion of a Self Diagnosis Method (SDM) checklist. Additional credit is provided to ports that are certified with PERS, the only port-sector specific environmental management standard, and ISO 14001.[94]

## Logistics Management Software Applications

As mentioned briefly in Chapter 6, logistics software applications can be added to ERP software suites of applications, as the firm's needs and the users' level of experience dictates. Some of the more popular logistics management applications (aside from the more specific environmental applications discussed above) include **transportation management systems**, **warehouse management systems**, and **global trade management systems**. Companies typically find significant benefits with these logistics execution systems. Many shippers have been opting to use fee-based Internet logistics management portals instead of outright purchases of logistics software to further manage cost outlays. Still, the use of some form of logistics software remains significant. According to an industry survey conducted in 2015, about 60 percent of respondents were using a warehouse management system, and approximately half planned to buy new WMS software.[95] Afterall, consumers are requiring faster shipping, and particularly since 2020, prefer shopping from home. Onfleet, a cloud-based logistics management software provider, recently conducted a survey among 1000 U.S. consumers and found that 76 percent say they would be more inclined to buy from local stores rather than Amazon if those stores offered same-day deliveries. "Delivery has become an expectation, no longer simply a nice-to-have, and must be thought of as a core element of those convenience stores looking to stay relevant, as Amazon continues to drive expectations even higher," stated Khaled Naim, Onfleet's co-founder and CEO.[96] Some of these systems are briefly discussed next.

### Transportation Management Systems

Transportation costs are a significant portion of total logistics costs for many organizations. To help reduce these costs while optimizing service levels, transportation management system (TMS) applications allow firms to find carriers, select the best mix of transportation services and pricing to determine the best use of containers or truck trailers, better manage transportation contracts, rank transportation options, clear customs, track fuel usage and product movements, and track carrier performance. Additionally, regulatory bodies, shippers, and customers want to know the locations of goods in-transit; thus, real-time information about a shipment's location while it is being transported to a final destination is required. Consequently, information may need to be provided by the manufacturer, 3PLs, agents, freight forwarders, and others as goods move through global supply chains. Technologies employed to provide this visibility include barcode scanners, RFID tags, the Internet, and GPS devices. Assisting in the management of all this transportation-related information is the job of a TMS.

A great example of how a TMS is used is the Missouri-based manufacturer American Railcar Industries. It was having difficulty tracking its inbound shipments from suppliers. "We had visibility when the product was ready at suppliers, but then it went into a black hole once it left our vendors' docks until it arrived at our location," says American Railcar purchasing agent Brent Roever. So in 2009, it incorporated a Web-based TMS solution into its purchasing and logistics processes. Afterwards, all of its purchase orders flowed from its ERP system into the TMS, where a preselected list of suppliers could view the

orders. Suppliers responded to the orders and indicated how and when the order would be shipped. The system then notified the purchasing team at American Railcar when the shipment was picked up and when it was expected at the specified location based on established delivery times.[97] The nearby SCM Profile describes Queen Transportation & Logistics' use of a TMS.

A new focus today is the transformation of TMSs to digital capabilities. Using a TMS to run transportation operations is viewed a key first step in developing a truly digital freight brokerage operation. This is now happening on a daily basis, with upstart digital freight

## SCM Profile: Queen Transportation & Logistics Uses TMS from Orbcomm

Frank11/Shutterstock.com

North Carolina-based Queen Transportation & Logistics provides local and national logistics services. "Shippers call on us for a single, dependable source of freight transportation," according to VP Daniel Queen. "We continuously invest in the newest safety systems."

Driver satisfaction was a large part of Queen Transportation's decision in 2019 to equip its entire fleet with Orbcomm in-cab systems and to begin using the company's transportation management software. "With a previous tablet-based solution, our drivers had ongoing connectivity issues that often forced them to resort to using paper logs," Queen relates. "The time-consuming process was impacting their productivity and led to retention concerns. We're also using Orbcomm's integration with the Drivewyze PreClear Weigh Station Bypass solution so our drivers do not always need to stop at scales," Queen continues. "We didn't fully understand until we implemented it how much easier it was going to make our drivers' lives. Orbcomm's solution is also helping us improve safety by providing live, onboard driver performance scoring that helps correct unsafe driving behaviors and reduce accidents and violations."

With Queen Transportation's previous system, reliability and delays in data updates also led to customer service issues. The lack of accurate, timely data and integrated information also limited the effective use of the fleet's previous system. "Now, we can use the Orbcomm solution to enhance efficiency through increased visibility and auditing," Queen says. "It also improves communication, which enhances customer service," Queen continues. "With vastly improved GPS tracking data on exact vehicle locations, we can work with customers to streamline operations at facilities, including determining where there is excessive detention time."

The capability to collect data from vehicle engine, brake and other systems is also giving Queen Transportation access to valuable analytics and timely reporting. The information speeds up the service capabilities of the fleet's technicians, which Queen notes lowers the carrier's maintenance costs. Queen Transportation is realizing significant savings with Orbcomm solutions. "Within two years we expect to realize a full return on investment in their technology in improved efficiency and performance," Queen reports.[98]

brokers like Convoy, Uber Freight and Transfix taking steps to leverage their respective technologies as a competitive advantage in a competitive market.[99]

## Warehouse Management Systems

Many firms are purchasing ERP systems that include a TMS coupled with a warehouse management system (WMS) to further enhance their supply chain management effectiveness. For example, a company might use its TMS to forecast shipping volumes based on data provided by its WMS and then recommend the most efficient modes of shipping. The WMS could then pick items and schedule warehouse usage based on TMS shipping information. Warehouse management systems track and control the flow of goods from the receiving dock of a warehouse or distribution center until the items are loaded for outbound shipment to the customer. RFID tags placed on goods and pallets within the distribution center are used to identify goods to the WMS. The goals of a WMS include reducing distribution center labor costs, streamlining the flow of goods, reducing the time goods spend in the distribution center, managing distribution center capacity, reducing paperwork, and managing the crossdocking process. A WMS can improve warehouse productivity by repositioning goods to reduce the distance that goods and/or pickers must travel. Reducing these travel times can improve warehouse productivity by 10 to 20 percent.

Wisconsin-based 3PL provider, WSI, decided to expand its e-commerce services. To do this right, WSI said it needed a warehouse management system (WMS) purpose-built for connected commerce, with the ability to adapt to future market changes. In 2021 WSI will be replacing its prior system with the Manhattan Active Warehouse Management system. The WMS is designed to unify every aspect of the distribution process. The system coordinates the work between any combination of automation, robotics and labor.[100]

## Global Trade Management Systems

As the desire to better manage complex global supply chains becomes more common, the need to comply with foreign and domestic security regulations also increases. This, combined with the continued search for cheaper supplies and reduced logistics expenditures, has brought about the need for global trade management (GTM) systems. Additionally, when former U.S. President Trump pulled the United States out of the Trans-Pacific Partnership (TPP) and renegotiated the North American Free Trade Agreement (NAFTA) to form the United States-Mexico-Canada Agreement (USMCA), it created confusion among global trading partners. This pushed companies to explore and then adopt GTM software. For GTM software vendors, this presented new opportunities to grow, expand, add capabilities and help shippers manage their regional and global trade agreements. "GTM can be a good risk mediator," says Will McNeill, research analyst at Gartner. "You can use the intelligence built into the systems to really figure out what the global opportunities are."[101]

For many firms, the U.S. Customs and Border Protection (CBP) security filing requirement (shippers and carriers must submit cargo information to the CBP 24 hours prior to ocean freight being loaded onto a vessel bound for the United States) has added to the import documentation headaches. Illinois-based fastener importer, XL Screw Corp., with 100 to 300 import filings per month, decided it needed an in-house GTM system. The system proved to be a simple answer to CBP requirements. The biggest benefit for XL Screw is the ability to enter data for a specific shipment, store it in the system, and then use it to complete forms for other shipments.[102]

## Global Logistics

For global goods movements, logistics managers must be aware of a number of issues not impacting domestic movements such as regulatory requirements, import/export limitations, port and warehousing issues, and the modes of transportation available. In the United States, freight movement to Europe or Asia involves either air or water transportation and then most likely motor and/or rail transportation to the final destination. Between most contiguous countries, rail and motor carrier shipments tend to be the most common modes of transportation. There can be a number of logistics problems and infrastructure differences found as goods are moved from one country to another. In Europe, rail transportation tends to be much more prevalent and reliable than rail transportation in the United States, because European track, facilities, and equipment are newer and better maintained. Water carriers may be the dominant mode of transportation in countries with a great deal of coastline and developed inland waterways. In under- and undeveloped countries, ports may be very poorly maintained and equipped and a paved highway system may be nonexistent. A number of these and other global logistics topics are discussed next.

### Global Freight Security

While a number of logistics security topics have already been discussed, one issue needing further discussion is motor freight security at U.S. border crossings. In the past few years, the trucking industry has worked with U.S. Customs and Border Protection to develop the **Customs-Trade Partnership Against Terrorism program (C-TPAT)** and its security program called the **Free and Secure Trade program (FAST)**. C-TPAT is a voluntary supply chain security program focused on improving the security of private companies' supply chains (international trucking in particular) with respect to terrorism. To participate in FAST, motor carriers must become C-TPAT certified, and their commercial drivers must complete an application and undergo a background check. FAST enrollment is open to truck drivers from the United States, Canada, and Mexico. The majority of dedicated FAST lanes are located in northern border ports in Michigan, New York and Washington and at southern border ports from California to Texas. Participation in FAST requires that every link in the supply chain, from manufacturer to carrier to driver to importer, is C-TPAT certified. All FAST participants receive expedited cargo clearance and access to dedicated FAST lanes at border crossings. Today, over 11,400 companies worldwide have become C-TPAT certified, including U.S. importers/exporters, U.S./Canada highway carriers; U.S./Mexico highway carriers; rail and sea carriers; licensed U.S. Customs brokers; U.S. marine port authority/terminal operators; U.S. freight consolidators; ocean transportation intermediaries and non-operating common carriers; Mexican and Canadian manufacturers; and Mexican long-haul carriers.[103]

### Global Logistics Intermediaries

Global logistics intermediaries provide global shipping, consolidation, and import/export services for firms and offer expertise that can prove very useful for most organizations involved in global commerce. A number of these intermediaries that have not already been discussed are briefly discussed here.

#### Customs Brokers

**Customs brokers** move global shipments through customs for companies as well as handle the necessary documentation required to accompany the shipments. These specialists

are often used by companies requiring expertise in exporting goods to foreign countries. Their knowledge of the many import requirements of various countries can significantly reduce the time required to move goods internationally and clear them through customs.

### International or Foreign Freight Forwarders

These services move goods for companies from domestic production facilities to foreign destinations (or vice versa) using surface and air transportation and warehousing. They consolidate small shipments into larger TL or CL shipments, decide what transportation modes and methods to use, handle all of the documentation requirements, and then disperse the shipments at their destinations. They also determine the best routing to use; oversee storage, breakbulk and repackaging requirements; and provide for any other logistics requirements of the seller. Use of **foreign freight forwarders** can reduce logistics costs, improve customer service, and allow shippers to focus resources on other activities. Many companies exporting or importing goods use the services of foreign freight forwarders because of their expertise and presence in foreign markets.

Until recently, many shippers were importing and shipping high-quality, low-cost goods from "far-shore" operations (e.g., U.S. buyers purchasing goods from Chinese manufacturers). Today, some buyers are utilizing a strategy called **right-shoring**. Right-shoring combines near-shore, far-shore, and domestic opportunities into a single, flexible, and cost-driven approach to purchasing and logistics. As crude oil prices fluctuate, for example, buyers find they must be much more flexible regarding where crude oil is purchased. This has created an even greater need for globally connected freight forwarders.[104]

### Trading Companies

**Trading companies** put buyers and sellers from different countries together and handle all of the export/import arrangements, documentation, and transportation for both goods and services. Most trading companies are involved in exporting and they usually take title to the goods until sold to foreign buyers. They enjoy economies of scale when exporting goods as they ship large quantities of consolidated shipments, using established transportation and warehousing services. In the United States, the Export Trading Company Act was signed into law in 1982 to promote U.S. exports and to help U.S. exporters improve their competitiveness. Within the U.S. Department of Commerce, the Export Trading Company Affairs (ETCA) office helps promote the development of joint ventures between U.S. and foreign companies and the use of export trade intermediaries. The ETCA office was created by the Export Trading Company Act of 1982.[105]

### Non-Vessel Operating Common Carriers

Also referred to as NVOCCs or simply NVOs, **non-vessel operating common carriers** operate very similarly to foreign freight forwarders but normally use only scheduled ocean liners. They consolidate small international shipments from a number of shippers into full container loads and then handle all of the documentation and transportation arrangements from the shippers' dock area. NVOCCs assume responsibility for cargo from point of origin to final destination; however, they do not own any vessels. They enter into contracts with ocean liners, which may then subcontract with rail or motor carriers for land travel.

## Foreign-Trade Zones

**Foreign-trade zones** (FTZs) are secure sites within the United States under the supervision of the U.S. Customs and Border Protection. These sites are authorized by the

Foreign-Trade Zones Board, chaired by the U.S. Secretary of Commerce, and are comparable to the *free trade zones* that exist in many other countries today. FTZs, while located near ports or international airports in the United States, are considered to be outside U.S. Customs territory, where foreign or domestic merchandise can enter without formal customs entry or payment of duties or excise taxes. Companies operating in FTZs bring goods and materials into the designated U.S. site and might use storage, assembly, testing, packaging, repairing, and export services. No retail activities are allowed, however. If the final product is exported out of the United States, no domestic duties or excise taxes are levied. If the final product is imported into the United States from the FTZ, duties and taxes are paid at the time the goods leave the FTZ.

Congress established the Foreign-Trade Zones Board in 1934 to encourage U.S. firms to participate in global trade. As of the end of 2019, there were 193 active general purpose FTZs in the United States located in all fifty states, bringing in about 11 percent of all imported goods and exporting about 7 percent of all U.S. exported goods. The FTZs are used by about 3200 companies and directly support over 460,000 U.S. workers with more than $750 billion in merchandise moving through these areas each year. In addition to petroleum, pharmaceutical, automotive, and electronics companies are the largest users of U.S. FTZs.[106]

## The United States–Mexico–Canada Agreement

The **United States–Mexico–Canada Agreement** (USMCA), formerly called the North American Free Trade Agreement (NAFTA), took effect on July 1, 2020, replacing NAFTA. NAFTA was a trading accord between the United States, Canada, and Mexico, and was put into effect on January 1, 1994. By 2008, all duties and quantitative restrictions within the three countries were removed. The objectives of NAFTA were to facilitate cross-border trade among the three countries, increase investment opportunities, and promote fair trade. Regional trade increased sharply over NAFTA's first two decades, from roughly $290 billion in 1993 to more than $1.1 trillion in 2016. Due to the success of NAFTA, the United States today has free trade agreements with 20 countries.

NAFTA, though, was not without its detractors. Critics of the deal argued that it was to blame for job losses and wage stagnation in the United States, driven by low-wage competition, companies moving production to Mexico to lower costs, and a widening trade deficit. The USMCA, is in many ways, a continuation of the original NAFTA. It seeks to promote and protect free trade between the three countries. Many of its provisions are simply updates to original rules that were over 25 years old. There are some major differences though, from NAFTA which include:

- Building labor protections in Mexico—labor is cheaper in Mexico than it is in the United States. The USMCA adds additional protections for workers in Mexico such as any violations of labor laws are punishable by the cancellation of shipments, products of forced labor are barred from importation, and workers can organize and bargain collectively.
- Under NAFTA, drug companies enjoyed protections for lucrative sub-divisions of the pharmaceutical industry. These protections have now been removed.
- Technology and data companies now enjoy increased protections related to intellectual property and privacy concerns.
- USMCA increases efforts to keep production in North America rather than in competing nations in Europe and Asia. Because of this, the United States backs

the push for U.S. business owners to invest in industrial buildings in Mexico for their companies. For example, to qualify for zero tariffs, automakers must produce 75 percent of a vehicle's content in North America, up from the 62.5 percent that had been required under NAFTA; they must utilize high-wage factories (min. $16 dollar per hour average salary) for at least 40-45 percent of the parts for a vehicle; and ensure that 70 percent of the steel and aluminum used in a new vehicle is melted and poured within North America.[107]

## Reverse Logistics

**Reverse logistics** (sometimes also known as **returns management**) refers to the backward flow of goods *from* customers in the supply chain, occurring when goods are returned, either by the end-product consumer or by a business customer within the supply chain. In other words, reverse logistics refers to the movement, storage, and processing of returned goods. Returns are increasing in part, today because of the growth of online shopping, direct-to-store shipments, and direct-to-home shipments. Occasionally, the use of cheap and untested foreign suppliers causes a number of product recalls. On August 1, 2007, for example, California-based Mattel, the world's biggest toymaker, recalled almost 1 million Chinese-made Mattel toys because they were covered with paint containing high levels of lead. Unbeknownst to Mattel, its primary Chinese supplier had subcontracted the work to a small Chinese toy manufacturer. The very next week, Mattel again was forced to announce a large recall for Chinese-manufactured toys containing small magnets that posed a choking hazard. In fact, eight of Mattel's nine toy recalls from 2004 to 2007 were for Chinese-made goods.[108]

Traditional retail customer returns can account for 6 to 10 percent of sales, while returns to retail websites are 20 to 30 percent of sales. According to the Reverse Logistics Association, the sheer volume of returns in the United States alone is $150 to $200 billion per year *at cost*. Additionally, the logistical costs to process these returns can also be very high—now running approximately $100 billion each year in the United States for transportation, handling, refurbishment, repackaging, remarketing, disposal, and lost sales. Besides the significant impact on costs, returns also can have a direct negative impact on the environment, customer service, the firm's reputation, and profitability if not managed properly. "Reverse logistics is all about damage control and making the process as customer-friendly as possible," says Lou Cerny, vice president of Sedlak Management Consultants. "You've already disappointed the customer once, now you have to close the loop as soon as possible."[109]

Some companies view returns as *zombie inventory* (inventory that just won't die). It sits unsold in storerooms, takes up space on store shelves, or creates bottlenecks in distribution centers, as workers try to determine what should be recycled, repaired, or discarded. However, other companies take a hidden-profit view of returns. "Reverse logistics enables the extension of the life of a product, so that its return is not a 100 percent loss," says Jim Gerard, a segment manager at UPS. "It's a process of receiving goods back for the purpose of preparing them for resale or to recapture the valuable part of the unit for reuse or resale in an entirely different area of the after-market," he adds.[110]

Many firms hire a 3PL company specializing in reverse logistics to ensure these items are managed correctly. Processing more than 600 million returned items annually, Pennsylvania-based Genco for example, a division of FedEx, provides triage, test and repair, remarketing and product liquidation solutions for companies. With over $1.6 billion in annual revenue and more than 11,000 employees in over 130 operations, Genco

offers various product lifecycle or reverse logistics services to companies in the technology, consumer, industrial, retail and health care markets.[111]

## The Impact of Reverse Logistics on the Supply Chain

Returns can represent significant challenges to a supply chain. In many cases, reverse logistics is viewed as an unwanted activity of supply chain management. In these cases, reverse logistics is seen simply as a cost of doing business or a regulatory compliance issue. Problems include the inability of information systems to handle returns or monitor reverse product flow, lack of worker training in reverse logistics procedures, little or no identification on returned packages, the need for adequate inspection and testing of returns, and the placing of potentially damaged returned goods into sales stocks. A poor reverse logistics system can affect the entire supply chain financially and can have a large impact on how a consumer views a product brand, potentially impacting future sales. Some studies indicate that the real costs of returns take up roughly 3 to 5 percent of total revenue. "Surprisingly, for the traditional bricks-and-mortar retail operations, returns are three to four times more expensive than forward-outbound-shipments. In some industries such as book publishing, catalog retailing, and greeting cards, over 20 percent of all goods sold are eventually returned to the vendor," says Adam Robinson, who oversees the marketing strategy for Cerasis, a third-party logistics provider.[112]

From a marketing perspective, an effective returns process can create goodwill and enhance customers' perceptions of product quality and purchase risk. From a quality perspective, product failure and returns information can be used by quality personnel in root cause analyses and by design personnel to reduce future design errors (the number one reason for a product return is a defective or damaged item). From a logistics perspective, returned goods can still create value as original goods, refurbished goods, or repair parts. This also tends to reduce disposal costs. Thus, while 46 percent of companies report losing money on product returns, about 8 percent actually report making money. Online shoe merchant Zappos has a very high return rate (about 35 percent) but views this as a competitive advantage—they provide free returns with no questions asked, but also boast very high repurchase rates.[113]

## Reverse Logistics and the Environment

Reverse logistics can have a positive impact on the environment through activities such as recycling, reusing materials and goods, or refurbishing used goods. **Green reverse logistics programs** include reducing the environmental impact of certain modes of transportation used for returns, reducing the amount of disposed packaging and product materials by redesigning goods and processes, and making use of reusable totes and pallets. "Sustainability is playing an important role in reverse logistics," says Paul Vassallo, marketing director for UPS. "More and more companies are looking to reduce their impact on the environment and search for carbon-neutral ways to dispose of product."[114]

# Summary

This chapter has discussed the important role logistics plays in the global economy and to supply chains in particular. Though this is a very broad topic, we have attempted to review the elements within U.S. domestic and global logistics to give the reader an adequate understanding of the entire field of logistics and its relationship to supply chain management. These elements include the basics of transportation, third-party transportation

providers, warehousing, sustainability in logistics, global logistics, and reverse logistics. It is hoped that readers have gained an understanding of the many elements within the broad topic of logistics and why these are so important to the successful management of supply chains.

## Key Terms

**air carriers,** 390

**airline security,** 395

**centralized warehousing system,** 404

**Civil Aeronautics Act of 1938,** 398

**class rates,** 394

**coal slurry,** 391

**cold chains,** 403

**commodity rates,** 394

**consolidation warehouses,** 402

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**United States–Mexico–Canada Agreement,** 420

**value-of-service pricing,** 393

**warehouse management systems,** 415

**water carrier,** 390

## Discussion Questions and Exercises

1. What is logistics and how does it provide time and place utility?
2. Why are logistics issues important to business success?
3. What are the important activities or elements in logistics?
4. What is the objective of transportation, for a business?
5. Why do you think that for-hire logistics expenditures have quadrupled over the past 30 years in the United States?
6. List the legal forms and modes of transportation. Which mode is the least expensive? Which mode carries the most freight? Which mode is growing the fastest? Shrinking the fastest?
7. What are some intermodal transportation alternatives?
8. What is the difference between TL and LTL shipments? Why are LTL shipping fees higher per cwt than TL shipping fees?
9. What is a road train? If you had to classify them, would you say they are general freight carriers or specialized carriers?
10. Why do you think the fastest trains are found outside the United States? Where is the fastest train operating today?
11. When would you want to use value-of-service pricing instead of cost-of-service pricing? When would you want to use negotiated pricing?
12. What is FOB destination pricing, and when would you want to use it?
13. What does transportation security refer to, and which mode of transportation is most affected by security concerns?
14. What is PrePass and what are its advantages?
15. Is government regulation of transportation good or bad? Why?
16. Is transportation in the United States regulated today or deregulated? Why?
17. Describe three different types of warehouses and the advantages of each.
18. If storing goods in a warehouse is bad, since it increases inventory carrying costs, why are the number and size of warehouses increasing in the United States?
19. What is the difference between a distribution center and a warehouse?
20. What are cold chains and what type of warehouse is used for these? What do cold chains have to do with the recent pandemic?
21. Define risk pooling and the advantages and disadvantages of centralized warehousing. What assumption does risk pooling make?
22. For which situation (centralization or decentralization) does risk pooling result in less safety stock? Why?
23. What type of warehouse location strategy do you think Amazon uses? Why?
24. What is a lean warehouse? When are they used?
25. Why is logistics so important for successful supply chain management?

**26.** What are 3PLs and why are they used? What types of companies use them? Why is their use growing so rapidly?

**27.** Can 3PLs be effective supply chain partners? Why?

**28.** Are transportation intermediaries also a form of 3PL? Explain.

**29.** Describe several kinds of transportation intermediary.

**30.** What are the impacts of logistics on environmental sustainability? How can these impacts be minimized?

**31.** What are empty miles and how can carriers reduce them?

**32.** What are the most common logistics management software applications and why are they beneficial to users?

**33.** Could you have a TMS without an ERP system? Or without a WMS?

**34.** Describe C-TPAT and FAST. Which transportation modes use these?

**35.** What do you think the most pressing global logistics problem is today? Why?

**36.** Describe several global logistics intermediaries. Could they also be considered 3PLs?

**37.** What are foreign-trade zones? How are they different from free-trade zones? What benefits do they provide?

**38.** Why was NAFTA replaced by the USMCA? How is the USMCA currently affecting trade among the United States, Canada, and Mexico? Do you think the USMCA is good for domestic U.S., Mexican, and Canadian producers? Why?

**39.** What is reverse logistics? How does it impact supply chain management?

**40.** How can reverse logistics have a positive impact on the environment? On profits? On customer service? On repeat purchases?

## Essay/Project Questions

**1.** Go to the BNSF website (www.bnsf.com) and describe the types of intermodal services offered.

**2.** Search on the term "green logistics" or "sustainable logistics" and write a report on logistics strategies used to reduce carbon emissions.

**3.** Write a report on Amazon's warehousing system in the United States.

**4.** Write a report on the global deregulation of the airline industry.

**5.** Search on the term "port security software" and describe how these software applications help to assure port security and global cargo security.

## Problems

**1.** A current warehouse system has six warehouses with 3000 units at each warehouse. If the company desires to change the number of warehouses to become more centralized and keep the same customer service level, determine the average warehouse inventory levels, using the number of warehouses below and the square root rule.

**a)** three warehouses

**b)** one warehouse

**c)** What is the percentage reduction in system inventory for the two systems above, compared to the original system?

**2.** A current warehouse system has six warehouses with 3000 units at each warehouse. If the company desires to change the number of warehouses to become more decentralized and keep the same customer service level, determine the average warehouse inventory levels, using the number of warehouses below and the square root rule.

**a)** nine warehouses

**b)** twelve warehouses

**c)** What is the percentage increase in system inventory for the two systems above, compared to the original system?

## Cases

### 1. Whipple Logistics Company's Transportation Challenge*

Ruby Shelton is part of the Executive Development Training Program. As part of her Executive Development Plan, Ruby has temporarily been assigned to the Transportation Division of Whipple Logistics Company. The objective is to expose her to different parts of the company as a method of grooming her for a senior position someday.

Ruby is excited about the opportunity. Her background is in Operations Management therefore, she is familiar with transportation requirements, although not an expert. Doreen Delgado is Ruby's mentor in the program. Doreen is a senior vice president and participated in the program when she was a junior executive. She understands the value of such a learning experience.

Whipple Logistics Company has several new clients who want a briefing on the best mode of transportation for their businesses. Doreen assigned Ruby to this project. Doreen believes this is the perfect instrument to help Ruby develop a deep appreciation of the importance of selecting the best mode of transportation for specific goods. Ruby is to prepare the briefing for the new clients.

Ruby understands that this is a great opportunity to learn more about Whipple's clients' needs. Her research illustrates that the best mode of transportation often depends on the industry using it. Industries that deal in bulk goods such as corn, soybeans, wheat, cement, crude oil, and coal must decide which mode of transportation is best. That decision is often based on the distance over which the shipment must be moved. Trucks have a cost advantage for short distances up to 500 miles; consequently, they function primarily as the short haul option. As the distance increases, rail has a cost advantage over trucks; however, barges have the greatest cost advantage if a waterway connects the point of origin and the destination.

Although Whipple Logistics Company provides shipping services to all industries, the new clients were primarily shipping large bulk items. For bulk shipments barges are the least expensive mode of transportation. However, waterways do not go everywhere; consequently, the critical factors are the shipment origin and its proximity to navigable waterways.

Ruby began to investigate what besides cost could be a driving factor. She discovered that seldom were single barges alone used to haul cargo. Generally, barges are cabled together

* Written by Rick Bonsall, D. Mgt., McKendree University, Lebanon, IL. The people and institution are fictional and any resemblance to any person or any institution is coincidental. This case was prepared solely to provide material for class discussion. The author does not intend to illustrate either effective or ineffective handling of a manage-rial situation.

in what is called a 15-barge tow, giving it a capacity of 22,500 tons[1]. Ruby wondered how this compared to the capacity of rail and trucks. She knew that rail cars are also connected together to increase capacity. The standard is a 100-car train whose hauling capacity is 11,200 tons[1]; thus, it takes two 100-car trains to match a 15-barge tow. A third option is semi-trucks or "18-wheelers". A single semi-truck can haul 26 tons.[1] Unfortunately, the drawback of semi-trucks is they are a single shipping system, unlike barges or rail cars that are combined to create a larger shipping system. Approximately 870 semi-trucks[1] would be required to equal the cargo capacity of either a 15-barge tow or two 100-car trains.

Ruby decided that barges are the best bulk transportation option, if the origin and destination can be accessed by water. She appreciated that it was more complex that just cost though. One needs to factor in possible delays due to weather and the hauling capacity of a specific mode of transportation.

## Discussion Questions

1. How should Ruby approach this briefing? Should she explain each type or should she discuss only the concept of intermodal transportation? Explain your recommendation; why do you think one approach is better than another, that is, what is the benefit to those being briefed?
2. In your opinion, which mode of transportation has the most potential for problems? Explain why you say that.
3. Identify the mode of transportation that is the most flexible and the one that is the least flexible. Explain why you consider them as the most and least flexible.

## Source:

1. Iowa Department of Transportation (2014). http://www.envisionfreight.com/value/?id=illustration

## 2. Treadwell Distribution Centers*

Treadwell Distribution Centers is a full service fulfillment company. Its clients contract with Treadwell to warehouse and distribute their goods. Treadwell also processes any returned items for its clients. Recently, the challenges associated with reverse logistics are growing.

The volume of returns has grown significantly. In order to enhance their competitive advantage, Treadwell's clients are offering a free return policy. There is no charge for shipping items back to the warehouse. The companies provide their customers with a pre-paid shipping label. In addition, there is no restocking fee. This policy, used by most of Treadwell's clients, has driven this increase in returned items.

Up to this point, Treadwell had a computerized based management system, but not one that was specifically designed for warehouse management. Their system was sort of home grown and its capability was expanded as the business expanded. However, with the reverse logistics issues, the system is no longer viable.

In addition, government regulations and pressure from local environmental groups are creating another issue for Treadwell Distribution Centers, environmental sustainability.

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The environmental sustainability issue has two components that are contributing to the sustainability concerns, transportation and reverse logistics. From a transportation perspective Treadwell's trucks are racking up an increasing number of empty miles. More often than not, the trucks are returning empty.

Reverse logistics is another matter. Treadwell is getting pressure from its clients to collect data on the returns. In the past all Treadwell did was accept the return, follow a predetermined process to see if the return was salvageable and either dispose of it or send it back to the original manufacturer. However, the data the clients want is much more detailed, e.g. can it be repaired, or refurbished? Since Treadwell's competitors are offering enhanced data collection, so must Treadwell.

## Discussion Questions

1. What is your recommendation to Treadwell concerning their issues of sustainability and reverse logistics? What actions can they take to remedy their management of these concerns? Explain the benefits of taking such actions.
2. Treadwell Distribution Centers is in a very competitive industry. Are there any options concerning reverse logistics that can enable Treadwell to turn it from a liability to an asset? Explain why you believe yes, or believe no.
3. Is there anyone Treadwell can turn to who can help them with the empty miles issue? If so, explain how. If not, explain why not.

## 3. Honeycutt Warehouse and Shipping Corporation*

Honeycutt Warehouse and Shipping Corporation is a global company that specializes in shipping and warehousing of goods. Honeycutt Warehouse and Shipping Corporation owns and operates its own transportation fleet consisting of barges, rail cars, and semi-trucks. Ms. Minnie Harmon, chief operating officer, is looking to expand operations into several emerging markets. Minnie is looking at either acquiring other companies or building from scratch. Minnie is concerned about Honeycutt's carbon footprint. She is a strong believer in protecting the environment; thus, wants to improve their sustainability results.

Since their warehouse and shipping facilities will be at the selected locations for many years, Minnie believes that warehouse location selection is one of the most critical decisions to be made. Therefore, she called her senior staff together to develop a proposal on how to address location selection and sustainability.

Minnie's staff discussed the usual factors that must be studied, and whether the location was domestic or worldwide. Key factors to consider were labor, land availability and cost, proximity to markets, proximity to suppliers, taxes, and incentives. Since Honeycutt Warehouse and Shipping Corporation is looking to expand into emerging markets, currency exchange and stability, as well as national competitiveness, must also be examined.

As mentioned earlier, Minnie was concerned about the environment and wanted to ensure sustainability was addressed too. Therefore, one key to sustainability was reducing energy consumption. Honeycutt Warehouse and Shipping Corporation moves hundreds of

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thousands of tons of cargo each year. Honeycutt's fleet energy consumption is enormous, consequently, pollution is also a worry. Ms. Harmon's staff discussed how to address these sustainability issues. One method was to employ state-of-the art technology such as more fuel efficient engines, however, that could not be accomplished for the entire fleet at once because the cost would be prohibitive.

Ms. Harmon's staff realized that expanded warehouse location selection factors would enable them to minimize these sustainability concerns. Instead of focusing on either proximity to markets or suppliers, a more balance assessment could significantly reduce energy consumption and pollution. Thinking long term and analyzing the transportation needs from that viewpoint, they could ascertain a more efficient use of the transportation options. The Council of Logistics defines logistics as "the process of planning…the efficient, effective flow of goods…from point of origin to point of consumption". Consequently, Minnie and her staff knew they must utilize all the tools of logistics management to address not only the best cost per shipment, but all the concerns associated with freight transportation, such as energy consumption and pollution. Therefore, although it had not be an element of their warehouse location selection process in the past, it must now include sustainability as a major factor.

### Discussion Questions

1. Instead of focusing only on one modal alternative for their shipping, companies can use a combination of modes. Explain that approach and would this be an option for Honeycutt Warehouse and Shipping Corporation? Why?
2. What are some examples of tools, programs, or partnerships that Honeycutt Warehouse and Shipping Corporation can use to improve logistics sustainability? Explain how they can help.
3. What are some issues with barge, rail, and truck transportation systems that affect sustainability?

## PART 4 Continuing Case

Note: This case is available online only.

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Chapter **10**

# Customer Relationship Management


*One recent study tells us that consumers' digital penetration has vaulted ahead by 10 years in the past three months. Things. Have. Changed. Therefore, incremental change is not enough—you need to do more. This time around, you can't just think "outside the box." You need to blow up the damn box.*

**—Gary Magenta, chief change architect at Root Inc**[1]

*The CRM market is accelerating rapidly worldwide and the outlook has never been stronger.*

**—Larry Augustin, CEO of SugarCRM**[2]

*CRM solutions manage customer data, but have never once managed a customer relationship.*

**—Loren Padelford, executive vice president at Skura**[3]

## Learning Objectives

**After completing this chapter, you should be able to**

**LO 1** Discuss the strategic importance of CRM.

**LO 2** Describe the components of a CRM initiative.

**LO 3** Calculate customer lifetime value.

**LO 4** Discuss the implementation procedures for CRM programs.

**LO 5** Describe how information is used to create customer satisfaction and greater profits for the firm.

**LO 6** Discuss the importance of data security in CRM.

**LO 7** Describe how social media and cloud computing have impacted CRM.

## Chapter Outline



## SCM Profile A CRM Application for Small Businesses

NDAB Creativity/Shutterstock.com

Hyther Nizam, President of Texas-based Zoho Corp., has released Bigin, a new CRM software application designed specifically for small and micro businesses. Companies can be up and running in 30 minutes on Bigin, start keeping track of their customers, and improving customer relationships without worrying about high costs or steep learning curves. "Small businesses are the heart and soul of our communities and with business owners struggling more than ever right now, our goal is to bring them world-class customer relationship management technology at an extremely affordable price," says Nizam. "Small businesses can stop relying on dozens of spreadsheets to manage customer activities and instead move to a CRM that is easy to use and allows them to focus on growing and building strong customer relationships," Nizam adds.

If businesses outgrow Bigin, they can upgrade to Zoho CRM with ease. Bigin supports 26 languages, including Arabic. The Bigin CRM application highlights include:

- Bigin allows users to get up and running within 30 minutes.
- The option to create fully customizable stages allows small businesses to run their distinct customer operations inside their CRM.

- Making and receiving calls anytime, anywhere allows users to choose from a range of popular telephony providers. Bigin pulls information on each customer and prospect that is being called, helping users to have informed conversations.
- Bigin helps sales personnel reduce the time spent on repetitive manual tasks with automated workflows.
- Bigin's analytics dashboards empower businesses to make smarter decisions based on data and up-to-date key performance metrics.
- Users can manage emails and access key business information in real time with Bigin's mobile applications.

The Zoho Corporation has its international headquarters in Chennai, India. Zoho has more than 8000 employees. Over 50 million users around the world, across thousands of companies, rely on Zoho every day to run their businesses, including Zoho itself.[4]

## Introduction

Customer relationship management becomes necessary as soon as a company enters a market and finds some customers for its goods and services. To keep customers satisfied, coming back and telling others, firms must continually develop new goods and services while discovering ways to add more value to existing goods and services. This is particularly true in today's tough, crowded economic climate, which has made customers smarter and more willing to switch company allegiances. The often-told story that "finding a new customer costs five times as much as keeping an old customer" is one of the motivations behind customer relationship management. Over time, value can be demonstrated to customers through reliable on-time deliveries, high quality goods and services, competitive pricing, innovative new goods and services, attention to varying customer needs, and the flexibility to respond to those needs adequately. Managing and improving customer relationships start with building core competencies that focus on customer requirements, and then continuing with delivering goods and services in a manner resulting in high levels of customer satisfaction.

Customer relationship management, or simply CRM, has come to be associated with automated transaction and communication applications—a suite of software modules or a portion of the larger enterprise resource planning system as described in Chapter 7. The global market for CRM applications is growing rapidly—it was approximately $40.2 billion in 2019 up from $26 billion in 2015, and is expected to grow at a 14 percent per-year rate from 2020 to 2027.[5] CRM includes applications for sales force automation, marketing automation, and customer service and support management. Social Media Management, Customer Experience Management, and Activity and Participant Management are among some of the newly available CRM applications. Most large firms have made sizeable investments in CRM applications along with company websites that capture data in an effort to automate the customer relationship process, and in some respects, these have provided significant benefits to the companies and their customers. Additionally, software-as-a-service (SaaS) or cloud-based applications dominate the CRM market and sales of these applications are growing twice as fast as other applications.[6]

As described above, the growth of CRM is continuing. Companies want access to customer data in real-time, with mobile and cloud CRM solutions leading the way. In fact, according to one business research organization, 91 percent of companies with more than 11 employees now use CRM software. Further, of the firms investing in CRM software, 47 percent plan to increase spending on help desk and customer service software. This investment in customer service software shows that businesses are trying hard to retain existing clients.[7]

Customers today like the convenience of communicating or transacting over the Internet; however, individualized contact between a company and its customers is also needed to ultimately keep customers satisfied and coming back. Two of the most recent trends in CRM are use of social networks and cloud computing and both of these will be discussed in this chapter. Companies are using both as a means to build better customer relationships. Some applications allow a company for instance to extract information automatically about people from a social network like LinkedIn and load it directly into one of its CRM systems. Other applications include the use of a service provider's eMarketing cloud to send email "blasts" to thousands of customers. It is estimated that the United States will spend over $350 million on email advertising in 2021, which makes a lot of sense given email's consistently highly-rated ROI of a $51 return on every $1 spent.[8]

Businesses are rediscovering the need to provide personalized services to their customers. Today we see that a firm's Internet presence and software applications, though desirable for many types of information or product transactions, are not sufficient to satisfy most customers in a wide range of industries. Touching goods and talking face-to-face with company representatives remain integral parts of the customer experience. Thus, CRM must still include talking to customers, understanding their behavior and their requirements, and then building a system to satisfy those requirements. Most importantly, CRM must be more than just software.

With the rapid pace of technological change, comes many new and exciting ways to obtain and utilize customer information, and many of these will be highlighted throughout this chapter. While company-customer interactions are becoming more automated and as more e-services are created, organizations will still find they must continue to identify and develop new ways to add value to customer relationships in order to maintain a competitive advantage. Cultivating the human element in customer relationships will always remain a necessary factor in creating that value. Ultimately CRM, if used effectively, allows both sides to win—customers get what they want from businesses, while businesses continue to find new customers and satisfy old ones.

## Customer Relationship Management Defined

Simply put, **customer relationship management** refers to *building and maintaining profitable long-term customer relationships*. The elements comprising CRM vary based on the industry, the size of the company, and familiarity with CRM software applications. In the final analysis though, all forms of CRM seek to keep the firm's customers satisfied, which creates profits and other benefits for the firm. A few specific definitions of CRM are provided here:

- "The infrastructure that enables the delineation of, and increase in customer value, and the correct means by which to motivate valuable customers to remain loyal—indeed to buy again."[9]
- "… helps the firm focus on its relationships with individual people—including customers, service users, colleagues, or suppliers—throughout the firm's lifecycle with them, including finding new customers, winning their business, and providing support and additional services throughout the relationship."[10]
- "… a core business strategy for managing and optimizing all customer interactions across an organization's traditional and electronic interfaces."[11]

Because of the intense competition in most markets today, CRM has become one of the leading business strategies—and potentially one of the most costly. Most executives who haven't already implemented CRM applications, are planning on investing in them soon. And while investments in CRM are in the tens of billions of dollars each year as previously stated, it appears that some of this investment is not fundamentally improving customer relationships, making customers more loyal, or resulting in positive returns for the companies implementing CRM. In 2017, CIO magazine reported that around one-third of all CRM projects fail. That was actually an average of a dozen analyst reports. In fact, depending on the survey, the implementation failure rate of CRM systems is as high as 90 percent, according to *Harvard Business Review*. One survey evaluation from MIT found that 55 to 75 percent of companies fell short of their expected ROI from their CRM systems.[12]

So why are many CRM programs failing? Several researchers who have studied this problem refer to the "seven deadly sins of CRM failure." These are: viewing CRM primarily from a technology perspective, a lack of customer-centric vision, not understanding the concept of a customer's lifetime value, insufficient top management support, not re-engineering business processes, underestimating the challenges in integrating various sources of data, and underestimating the challenge in effecting change.[13] Thus it is the people aspect of CRM that is often lacking. "If people are not using the system consistently, referrals and follow-ups will fall through the cracks," explains Floyd Salamino, VP/consulting for Texas-based Marquis Software. "Staff involvement is crucial, so seek their participation early in the process to create ownership and buy-in." Because employee resistance can contribute to CRM failure, Salamino advises recognizing the individuals who tend to resist change and working with them to strengthen buy-in. "Think broadly. Who are you going to impact when implementing CRM?" asks Brett Wooden, chief retail officer for Oregon-based Providence Federal Credit Union. "If you implement CRM without collaboration, you begin to work in silos, and you can lose the transfer of knowledge, especially if departments are not used to having conversations or they're workflow dependent on one another." Finally, Wooden adds, "Poor planning, a lack of communication, and overwhelming your staff can create negative thinking. Instead, ask employees a lot of questions right at the start. Find out their needs and look for potential roadblocks. Every organization is different, but your goals can be common."[14]

While corporations may collect customers' purchase, credit, and personal information, place it on a database, and use it to initiate some type of direct marketing activity, in too many cases no substantive efforts are put forth to engender a customer's trust and loyalty—*to build customer relationships*. If building and maintaining relationships were truly what companies were seeking, they would for instance, return phone messages, make it easy to return or service goods, and make it easy for customers to get accurate information and contact the right people inside the organization. Consider this—as a customer, how often, in your dealings with organizations, have you been made to feel valued?

Too often, companies today have delegated customer relationship management, certainly one of the most important activities of the firm, to third-party CRM services, software developers, and internal IT departments whose goal is to collect data, design databases, and use models to predict consumer buying patterns, for instance. Though it is a potentially valuable support element in CRM programs, data mining alone does not build the customer relationship. A number of years ago, Jessica Keyes, a well-known information system author and consultant, stated in an interview in the magazine *Infotrends*, "Technology does not beget a competitive advantage, any more than paint and canvas beget a van Gogh."[15] These kinds of activities should be used in tandem with individual attention to build genuine long-term value for customers. Successful CRM programs require cultural

change, effective CRM project management and employee engagement, leading to strategies that cultivate long-term relationships with customers, aided by the information gathered from CRM applications.

Simply put, companies need to *treat their customers right*. Not only does this mean providing the goods and services they want at competitive prices, but it also means providing support services, product knowledge, and other offerings that add value and create customer satisfaction. Because customers are not all the same, firms must identify and segment their customers, then provide different sets of desired goods and services to each segment. As noted CRM consultant Barton Goldenberg has been telling clients for years—a successful CRM initiative is 50 percent people, 30 percent process, and 20 percent technology.[16]

Thus, a successful CRM program is both simple and complex—it is simple in that it involves training users and treating customers right, to make them feel valued. It is complex in that it also means finding affordable ways to identify (potentially millions of)

## SCM Profile: Del Taco Brings Tech to Serve Its Customers


TonelsonProductions/Shutterstock.com

California-based Del Taco began developing a digital strategy several years ago, launching an app as part of a companywide digital transformation. Contracts with delivery businesses were also initiated, so when March 2020 rolled around, the chain was well positioned to weather COVID-19 and grow. In fact, delivery grew 300–400 percent during the pandemic. Drive-thru grew to more than 80 percent.

"Obviously, with the pandemic, guests just started using the technology out of necessity to access restaurant brands," said CEO and President John D. Cappasola Jr. "It was a rapid adoption that occurred out of necessity so, with that, we recognized the curve was going to move quickly and that's when we decided there were two things we wanted to invest in that would be smart ways of how we were going to pivot out of this pandemic." Those two things were technology and growth.

A customer retention platform launched in the fall of 2021, and is expected to be a boon for Del Taco's loyalty program. "It's a whole new mobile app, a whole new mobile app experience. It'll be loyalty and we'll be baking in some neat things into loyalty," said Chief Marketing Officer Tim Hackbardt.

Tech will help at the restaurant level, since Del Taco places an emphasis on the drive-thru, a factor accelerated in 2020. The company unveiled its Fresh Flex prototype in 2020, a new restaurant design that could allow for anywhere from a traditional location complete with dining room, to a drive-thru-focused location about half that size. "Things changed quite a bit during COVID-19 and so we wanted to make sure we were appropriately putting in that optionality so we could do different things with the prototype," said Cappasola.[12]

customers and their needs, and then designing customer contact strategies geared toward creating customer satisfaction and loyalty. Doing these things right will produce bottom line results.

The delivery services of online retailer Amazon for example, are very simple for the consumer, although actually some very complicated CRM tasks take place behind the scenes. "I think what ensured that Amazon was a dotcom winner was being dedicated to the initial principle of focusing on the customer," says Rakhi Parekh, group product manager at Amazon.co.uk. "We started off by passing-on the cost advantage of the model to consumers, with low prices, then extended that to clever use of their data so that we could work out what else they might enjoy." Today, Amazon continues to search for better ways to serve not only their consumer-customers, but their merchant-customers as well. The nearby SCM Profile describes Del Taco's efforts to build customer loyalty.

## Key Tools and Components of CRM

A number of elements are required for the development of effective CRM initiatives and these include segmenting customers, predicting customer behaviors, determining customer value, personalizing customer communications, automating the sales force, and managing customer service capabilities. Each of these elements is discussed in detail below.

### Segmenting Customers

One of the most basic activities in CRM is to **segment customers**. Companies group customers in varieties of ways so that customized communications and marketing efforts can be directed to specific customer groups. Efforts to up-sell and cross-sell can be directed to some groups, while efforts to discourage further purchases might be made to others. The global recession in 2009 for instance, may have changed some customer preferences, which in turn changed how firms segmented and marketed to these segments. Anything with the potential to change buying habits will eventually result in a different form of segmentation.

Customer segmentation can occur based on sales territory or region, preferred sales channel, profitability, goods purchased, sales history, demographic information, desired product features, and service preferences, just to name a few. Analyzing customer information can tell companies something about customer preferences and the likelihood of customers responding to various types of **target marketing** efforts. By targeting specific customer segments, firms can save money by avoiding marketing efforts aimed at the wrong customers. Using target marketing, firms can also avoid becoming a nuisance to customers, which could drive them to competitors. The Ice Cream Shop for example, Unilever's virtual store that uses freezers in places like gas stations and convenience stores and is available in over 1500 locations across the United States has found at-home ice cream sales to be a bright spot during the pandemic. Orders through The Ice Cream Shop also generate consumer data. Online shops can build one-to-one relationships with consumers while gathering information that can be used for target marketing efforts.[18]

#### Permission Marketing

An extension of target marketing is **relationship marketing** or **permission marketing**. The idea is to let customers select the type and time of their communications with organizations. These days, consumers are bombarded with thousands of commercial messages each day in every form of communication imaginable. The general consensus is that there

are simply far too many ads, consumers ignore most of them, and no one is really trying to do anything to reduce them. Additionally, the advertising industry seems forever on the lookout for new ways to introduce commercial messages.

One example of new advertising is **mobile marketing**, or placing advertising messages on mobile phones. Users opt-in to get all of their services on cell phones, including advertising. "Text messaging is an essential component of any integrated mobile marketing plan," said James Citron, CMO and co-founder of Mogreet. "Text marketing is accessible by 98 percent of U.S. cell phone users and yields the highest open rate within mobile marketing."[19] One form of mobile marketing is the use of quick response codes, or **QR codes**. It involves using the camera function on a smart phone and installing a QR code reader on the phone. Consumers worldwide are using their mobile phones while in-store to compare prices, scan quick response codes and make purchases. This fusion of mobile and physical is in line with the general omnichannel trend that has formed on the global retail market. The Asia-Pacific region is one of the global leaders in terms of using mobile phones for online shopping. China is the world leader in mobile commerce, and this method of shopping dominates e-commerce in the country. Almost three out of every four of China's e-commerce transactions are carried out on a mobile device, generating $873.3 billion in sales in 2019.[20]

Thus in permission marketing, customers choose to be placed on (opt-in) and then taken off (opt-out) of text, e-mail, or traditional mailing lists for information about goods and services. It is becoming possible on websites, for consumers to specify exactly what they are interested in, when they want information, what type of information they want, and how they want it communicated. This kind of customer self-segmenting requires sophisticated software capabilities to track individual customers and their interaction preferences as well as the capability to update these preferences over time. With this capability, firms can better design multiple, parallel marketing campaigns around small, specific segments of their customer base, automate portions of the marketing process, and simultaneously free up time previously spent manually managing the marketing process. Facebook, LinkedIn, and Instagram for example, allow companies to create their own customized webpages that potential consumers choose to visit. Because visitors to these pages are self-selecting, this essentially amounts to permission marketing. This enables companies to identify interested consumers, engage them in dialogues, and market goods and services to them. As of 2021, Coca-Cola had more than 105,000,000 Facebook fans, about 6,100,000 followers on LinkedIn worldwide, and over 2,700,000 followers on Instagram.

## Cross-Selling

**Cross-selling** occurs when customers are sold additional goods as the result of an initial purchase. The initial purchase allows the seller to segment the customer. E-mails to customers from Amazon.com describing other goods purchased by people who purchased the same product a customer just bought, is an attempt at cross-selling. If the additional goods or services purchased are even more profitable than the original purchase, this can provide significant add-on profits for the firm. In addition, if firms are successful at cross-selling the right goods at the right time to the right customers, then customers perceive this as individualized attention, and it results in more satisfied and loyal customers.

When Bank of America acquired Merrill Lynch in 2009 for $50 billion, a number of cross-selling opportunities arose, since its wealth management employees could view each customer's savings and checking accounts along with their investment portfolios. One year later, these cross-selling opportunities were bearing fruit—the global wealth management business had increased for Bank of America and profit margins were in excess of

20 percent—significantly higher than industry averages.[21] Sometimes though, aggressive cross-selling can lead to mis-selling, as Wells Fargo exhibited in 2016. As many as two million phantom accounts and credit cards were created for clients without their knowledge. And the purpose was clear: to inflate sales numbers, hit targets and boost bonuses. More than 5000 staff lost their jobs over the affair. Wells Fargo was fined $185 million and billions of dollars was wiped off its market value, demoting it from its rank as the world's most valuable lender.[22]

## Predicting Customer Behaviors

By understanding customers' current purchasing behaviors, future behaviors can be predicted. Using data mining software and customer behavior analytics allows firms to predict which goods customers are likely to purchase next and how much they would be willing to pay. In this way, companies can revise pricing policies, offer discounts, and design promotions to specific customer segments. Sheldon Gilbert, the creator of Proclivity, a behavior predicting software used by New York-based Proclivity Systems, knows all about you—your favorite color, how many times you added that flat screen TV to your online shopping cart without buying it, and what you like to do in your spare time. Sheldon explains, "Every time you click a link, it's a request for information you're making to a server. We can then mine the data stored on the servers to create a profile of a person's likes and dislikes or proclivities," says Gilbert. LayerRx, a Proclivity company, allows pharmaceutical companies to sell digital ads for instance, to cardiologists researching myocarditis or virologists researching zika.[23] Along with determining what customers might purchase next, another desirable CRM activity is **customer defection analysis**.

### Customer Defection Analysis

Reducing customer defections (also referred to as **customer churn**) is another component of managing long-term customer relationships. And it can pay handsomely as well. According to Harvard Business School research, a 5 percent improvement in customer retention can result in a 75 percent increase in profits.[24] Knowing which customers have quit purchasing and why, can be very valuable information for organizations. Recent research has found that the top three reasons for customer churn are—changes in customer needs; significant drop in product quality/customer service; and the competition offering better prices or deals.[25] Not only can these customers be approached to encourage a return to the business, but the customer churn knowledge gained can be used to reduce future defections. "If I've got an 80 percent satisfaction rate, the focus needs to be on the 20 percent of dissatisfied customers," says Bob Furniss, president of CRM consultancy Touchpoint Associates of Tennessee. "If I can understand what's occurring in the 20 percent, then my impact is much more profound than being satisfied with the satisfaction rate."[26]

Offers of money, phones, or free minutes from cellphone service companies are examples of efforts to regain customers who have defected to another phone service. In some cases though, organizations may actually *want* some customers (the unprofitable ones) to defect. By determining the value or profitability of each of the defecting customers, firms can design appropriate policies for retaining or regaining some customers as well as policies to discourage additional purchases from the other, unprofitable customers (also termed *firing customers*). In some department stores, for instance, customers who repeatedly return merchandise are at some point given only store credit instead of cash. Businesses sometimes refer to these customers as *vampire customers* (as in they "bleed the company dry"). By monitoring purchase histories, firms can see if this type of discouragement makes customers quit returning merchandise.

## Customer Value Determination

Until recently, determining **customer value** or **customer profitability** was difficult for most CRM systems. Today though, by integrating with ERP systems, capturing customer profitability information is possible. However, improper use of this information can cause poor decisions to be made. For instance, some customers that are unprofitable now, may become profitable later. A health club for instance, may have some unmarried members who rarely make other purchases at the club but frequently visit and use the facility. While this type of member might be seen as unprofitable, it is likely that if these members are satisfied with the club, they will tell others; and at some point they may marry and upgrade to a family membership. Thus, it is necessary to determine **customer lifetime value** (CLV) such that appropriate benefits, communications, services, or policies can be directed toward (or withheld from) customers or customer segments.

Unless a firm has knowledge of customer profitability, they may be directing sizeable resources catering to customers who are actually unprofitable. For instance in a study published a few years ago by consultant and database marketing author Arthur Middleton Hughes, he described how Boston-based Fleet Bank's marketing staff was working hard trying to retain customers who were actually losing money for the bank. In fact, half of Fleet's customers were deemed unprofitable, with the bottom 28 percent gobbling up 22 percent of the bank's total annual profits. (Fleet has since merged with Bank of America).[27] Calculating CLV is based on a projection of a customer's lifetime purchases, the average profit margin on the items purchased, and the net present value of the customer's projected profits. Thus, the CLV can be calculated using the net present value of an annuity as shown here:

$$\text{NPV}_\text{A} = \text{P}\left[\frac{1-(1+i)^{-n}}{i}\right]$$

where:

A = customer A
P = average annual profit, or (annual sales × profit margin)
$i$ = annual discount rate, and
$n$ = expected lifetime in years.

Example 10.1 illustrates this calculation.

### Example 10.1 Calculating Customer Lifetime Value

The Nevada Seed Company sells grass seed and drought-tolerant plant seeds to area plant nurseries. They have decided to project the lifetime value of each of their nursery customers in order to design individualized grass and plant seed promotions. Their top two customers have the following characteristics:

| | AVG. ANNUAL SALES | AVG. PROFIT MARGIN | EXPECTED LIFETIME |
|---|---|---|---|
| Nursery A: | $22,000 | 20% | 5 years |
| Nursery B: | $16,000 | 15% | 15 years |

Using a discount rate of 8 percent, and treating the average sales figures as annuities, the present value of the two nursery lifetime values is:

$$\text{NPV}_\text{A} = \text{P}\left[\frac{1-(1+i)^{-n}}{i}\right] = \$22{,}000(.2)\left[\frac{1-(1+.08)^{-5}}{.08}\right] = \$4{,}400\left(\frac{0.319}{.08}\right) = \$17{,}568$$

$$\text{NPV}_\text{B} = \text{P}\left[\frac{1-(1+i)^{-n}}{i}\right] = \$16{,}000(.15)\left[\frac{1+(1+.08)^{-15}}{.08}\right] = \$2{,}400\left(\frac{0.684}{.08}\right) = \$20{,}542$$

Based on these calculations, Nursery B is deemed more important because of the higher expected lifetime value.

Estimating customers' total lifetime purchases can also help to focus resources on managing the right customers. Consider two business customers for example, one with purchases of $2 million per year and the other with annual purchases of $1 million. At first glance, the first customer might seem more valuable; however, if that customer's total purchases from all suppliers for similar goods is $3 million whereas the second firm's total purchases of similar goods is $20 million, then the second firm suddenly has much more potential for additional sales and should be managed with that potential in mind.

## Personalizing Customer Communications

Knowledge of customers, their behaviors, and their preferences allows firms to customize communications aimed at specific groups of customers. Referring to customers by their first name, or suggesting services used in the past communicates value to the customer and is likely to result in greater levels of sales. The Ritz-Carlton Hotel for instance, profiles its customers in order to provide the accommodations each person prefers on subsequent visits.

CRM software that can analyze a customer's **clickstream**, or how they navigate a website, can tailor a website's images, ads, or discounts based on past usage of the site. Website businesses may also send personalized e-mails for instance with incentives to lure customers back, if it has been a while since their last purchase. A quick-change oil and lube shop might send a postcard to a customer's address every 90 days, reminding them it's time for an oil change while offering a discount on the next visit. On the same card, they may also offer discounts on other services that the customer has used in the past, such as a radiator flush, a tune-up, or a tire-rotation. With time, this customization capability improves, as the firm learns of additional services, goods, and purchasing behaviors exhibited by various customers.

### Event-Based Marketing

Another form of personalized communication comes with the ability to offer individual promotions tied to specific events. Banks for example, may try to market automated mortgage payment services to all of their customers who have recently applied for and received a home mortgage loan. The same bank might offer home improvement loans to customers once their mortgages reach an age of five years. The idea with **event-based marketing** (also referred to as trigger-based or event-driven marketing) is to offer the right goods and services to customers at just the right time. When entertainment venues or restaurants ask for the birth dates of their customers as they purchase tickets or meals for instance, they can direct future discounts to occur on days they are likely to be celebrating. Or, when bank customers call to determine the payout on an existing home mortgage, this indicates the customer is considering a different bank—an event-based tactic might be to transfer the caller to a special customer-save group at the call center. With large volumes of customers, event-based promotion strategies are impossible without computer automation, so event-based marketing capabilities tend to be popular requirements among firms purchasing CRM systems.

## Automated Sales Force Tools

**Sales force automation** (SFA) products are used for documenting field activities, communicating with the home office, and retrieval of sales history and other company-specific documents in the field. Today, sales personnel need better ways to manage their accounts,

their business opportunities and their communications while away from the office. To supply these capabilities, firms have been using CRM tools since the early 1990s to help management and sales personnel keep up with the ever-more complicated layers of information that are required as the number of customers and prospects increase. When field sales personnel have ready-access to the latest forecasts, sales, inventory, marketing plans, and account information it allows more accurate and timely decisions to be made in the field, ultimately increasing sales force productivity and improving customer service capabilities.

Jonel Engineering's cloud-based sales force analytics tool, Sales Insight, harnesses mobile computing power to enable sales teams to score more wins and attract new business opportunities. Bidding and forecasting functions are tightly coupled with powerful analytics tools that quickly identify key market trends impacting service levels and overall customer performance. A four-dimensional analytical model ranks customers based on profit, payment, productivity, and ease of doing business, providing sales managers a holistic view of how servicing a specific customer impacts the bottom line. "Our goal is to take sales force automation to the next level," says Jonel President Mike Lawson.[28]

## Sales Activity Management

These tools are customized to each firm's sales policies and procedures and offer sales personnel a sequence of pages/activities guiding them through their sales processes with each customer. These standardized steps assure the proper sales activities are performed and also put forth as a uniform sales process across the entire organization. The use of a **sales activity management system** reduces errors, improves sales force productivity and boosts customer satisfaction. Along with the prescribed sales steps, field sales reps can be reminded of key customer activities as they are needed, generate mailings for inactive customers, be assigned tasks by management and generate to-do lists. "Nearly every sales leader I meet would like to increase the productivity of their sales teams—but they struggle to identify which activities and behaviors will make a difference," said Jim Benton, co-founder of California-based ClearSlide, a sales engagement platform provider. A recent report states that on average, sales managers have less than 20 percent of their time available to help sales reps sell, and fewer than 60 percent of sales reps achieve their sales quota plans.[29]

## Sales Territory Management

**Sales territory management systems** allow sales managers to obtain current information and reporting capabilities regarding each sales person's activities on each customer's account, total sales in general for each sales rep, their sales territories, and any ongoing sales initiatives. Using these tools, sales managers can create sales teams specifically suited to a customer's needs, generate profiles of sales personnel, track performance, and keep up with new leads generated in the field. Territories can be based on geography or customer types, and are used to promote effective usage of the sales team to maximize sales opportunities, provide superior customer service, and expand existing customer relationships. Poorly planned sales territories for example, can reduce face-time for sales personnel, resulting in lower sales.

## Lead Management

Using a **lead management system** allows sales reps to follow prescribed sales tactics when dealing with sales prospects or opportunities, to aid in closing the deal. These applications can generate additional steps as needed to help refine the deal closing and negotiation process. During this process, sales personnel can generate product configurations

and price quotes directly, using laptops or handheld devices remotely linked to the firm's server. In addition, leads can be assigned to field sales personnel as they are generated, based on the requirements of the prospect and the skill sets of the sales reps. Thus, lead management capabilities should result in higher deal closing success rates in less time. Another common characteristic allows managers to track the closing success of sales personnel and the future orders generated by each lead. As a matter of fact, an insurance study in 2016 found that insurance companies with lead management systems sold thirteen percent more policies per household compared to companies without this type of system.[30]

### Knowledge Management

Sales personnel require access to a variety of information before, during, and after a sale including information on contracts, client and competitor profiles, client sales histories, corporate policies, expense reimbursement forms, regulatory issues and laws, sales presentations, promotional materials, and previous client correspondence. Easy access to this information enables quick decision-making, better customer service, and a better-equipped and more productive sales staff. When sales and other skilled personnel leave an organization, years of accumulated knowledge walk out the door with them, unless a system is in place to capture this information for further use. A **knowledge management system** (KMS) gives the organization this capability.

Once knowledge is stored in a KMS, it must be readily accessible through a variety of devices, including smartphones and tablets. Electronic devices are necessary for communication in an increasingly digitized world. Knowledge management systems should also be linked to other applications that support various business processes and workflows. A KMS captures, stores, recalls and improves corporate knowledge. Lessons learned as well as documented work processes should both be linked to the KMS.

## Managing Customer Service Capabilities

A key objective for any CRM initiative is the ability to provide good customer service. In fact, with any process dealing with the customer, a primary objective is always to provide adequate levels of customer service. But what does customer service actually mean? In Chapter 7, customer service was discussed in terms of safety stock and managing inventory. In Chapter 9, customer service was tied to delivering goods on time. And as mentioned earlier in this chapter, customer service can also mean answering customers' questions and having disputes or product and service problems resolved appropriately and quickly. Thus, many definitions of customer service can be found. As a matter of fact, numerous customer service rankings exist and are published each year. Unfortunately, complaints about shoddy customer service abound in many organizations today and this represents one area where organizations can create real competitive advantage, if customer service processes are designed and managed correctly. The next segment defines customer service and discusses several elements of customer service.

### Customer Service Defined

One **customer service** definition covers most of the elements mentioned above, and that is the "**Seven Rs Rule**".[31] The seven Rs stand for having the *right* product, in the *right* quantity, in the *right* condition, at the *right* place, at the *right* time, for the *right* customer, at the *right* cost. In logistics parlance for instance, a **perfect order** occurs when all seven Rs are satisfied. This customer service definition can be applied to any service provider or

manufacturer, and for any customer. A misstep in any of the seven areas results in lower levels of customer service. Consequently, competitive advantage can be achieved by creating an organization which routinely satisfies the seven Rs.

Organizational performance measures are often designed around satisfying some of the seven Rs. For example, reducing stockouts to one percent means that customers get the product or service they want 99 percent of the time; and having an on-time delivery performance of 97 percent means that customers get their orders at the right time 97 percent of the time. Other customer service measures are typically designed to measure *flexibility* (responding to changes in customer orders), *response* (responding to requests for information), *recovery* (the ability to solve customer problems), and *post-sales support* (providing operating information, parts, equipment, and repairs). In the airline industry, customer service is measured using frequencies of lost or damaged baggage, bumped passengers, canceled flights, on-time flights, and customer complaints. In North America, according to readers of the *Travel + Leisure* website, Southwest Airlines, Alaska Airlines, Hawaiian Airlines, JetBlue Airways, and Delta Air Lines were the top-rated air carriers in terms of customer service in 2019 (prior to COVID-19), while United, American, and Frontier were rated the worst, according to the *Wall Street Journal*.[32]

Providing award-winning services to customers keeps them returning, however this also comes at a cost. Firms must consider the costs of providing good customer service (such as faster transport, greater safety stock levels, more service provider training, and better comforts) as well as the benefits (keeping customers' future profit streams). In organized supply chain relationships, firms often work together in determining (and paying for) adequate customer service, because the long term costs of poor customer service can be substantial for all supply chain trading partners.

Customer service elements can be classified as **pretransaction**, **transaction**, and **posttransaction elements** as defined below.

- Pretransaction elements: these customer service elements precede the actual product or service purchase; examples are customer service policies, the organization's service structure, and the service system's flexibility.
- Transaction elements: these elements occur during the sale of the product or service and include the order lead time, the order processing capabilities, and the distribution system accuracy.
- Posttransaction elements: these elements refer to the after-sale services and include warranty repair capabilities, complaint resolution, product returns, and operating information.

To provide high levels of service and value to customers, firms seek to continually satisfy the seven Rs while also developing adequate customer service capabilities before, during, and after the sale. Call centers have been used in many organizations to improve customer service and supply chain performance and this topic is discussed next.

## Call Centers

**Call centers** or **customer contact centers** have existed for many years, and some organizations have used these effectively to satisfy and keep customers loyal, while others have seen them as a necessary cost of doing business and viewed them as a drain on profits. As call centers became automated, customer service representatives were able to quickly see how similar questions were answered in the past, and resolve problems more quickly, resulting in greater call center effectiveness. Call center systems can categorize calls,

determine average resolution time, and forecast future call volumes. These automated systems can reduce call center labor costs and training times, and improve the overall productivity of the staff, while improving customer service levels.

Within the past ten years, most call centers implemented virtual queuing systems, and most callers see this as a convenient call center characteristic. The virtual queue allows callers to request a callback from an agent without losing their place in the phone queue, which frees up callers' time, reduces caller frustration and also reduces call center toll charges for keeping callers on hold. More recently, call centers have created interfaces with mobile applications to further enhance the customer experience. When a mobile customer can't complete his or her transaction, the application automatically forwards the entire history of the customer's mobile session to the contact center. The contact center then places the customer in a virtual queue and sends the customer a notice of when an agent will call. The customer has the option of taking the callback as scheduled, or rescheduling it to a more convenient time. Either way, there are no wasted phone minutes. The agent also knows what steps the customer has already gone through and was attempting to do, when the issue popped up. When the call to the customer is made, the agent knows the entire transaction context, who the customer is, and their purchase history.[33]

Aside from solving customer problems, call centers today are also viewed increasingly as a source of revenue for the firm. In fact, a survey of managers at U.K. and U.S. in-house call centers revealed that 60 percent viewed their call centers as profit centers. Today, call center staff are expected to pursue cross-sell and up-sell opportunities. "How do we get more member interactions? How do we get our call center or contact center to drive more sales? It's not sales versus service. It's in addition to. We have to be sales-focused to drive business because we don't have the interactions that we used to in our branches. We're continuing to see steadily decline, and in five years that's going to be an issue. It's something that we have to start planning for now," says Eric Weikart, managing director and call center expert at Arizona-based Cornerstone Advisors.[34]

While the practice of call center outsourcing has been around several decades, in the latter 1990s and the 2000s outsourcing call centers to offshore companies really exploded. The growth of the Internet, a boom in telecommunications capacity, cheap foreign labor, and education systems in areas like the Philippines, India, and Pakistan which encouraged the development of an English-speaking workforce all acted to create a perfect environment for the offshoring of call centers (along with other types of businesses). Today though, with the move towards onshoring and reshoring, this trend is reversing. Security issues are also hastening this trend. Many companies are outsourcing call center services to domestic companies. Tree Rings for example, a call center outsourcing provider taps into communities of experienced retirees to staff his call center. "When you run a call center, it's all about using high quality, highly educated labor. Here in the Phoenix area, we have a large population of retired adults with long careers behind them, many of whom still want to work part-time. It occurred to me that these are some of the best workers available," says owner, Steve Shefveland.[35]

## Measuring Customer Satisfaction

Measuring customer satisfaction remains somewhat of a tricky proposition. Customers are frequently given opportunities to provide feedback about a product, service, or organization through customer feedback cards placed at cash registers or on tables. Customer surveys are also provided with purchased goods, or shown on firms' websites. In most cases though, the only time these forms are filled out or emails are sent is when customers are experiencing a problem. Given this, companies still can find valuable uses

for the information. Responses can be analyzed and used to find solutions for the most commonly occurring problems. In CRM applications, customer satisfaction surveys can be personalized to fit specific customer segments, and responses can be matched to respondents' profiles to provide the company direction on improving its communication and service capabilities for various groups of customers. The design of the surveys themselves can be a particular problem. In some cases, surveys don't ask the questions customers want to answer. On many website surveys, customers are more often asked about the design of the website instead of how the firm is performing or what the customer may be happy or unhappy about.

On the other hand, actually talking with and listening to customers, and then taking action based on what customers are saying lets customers know the firm is completely engaged. Domino's Pizza for example, completely redesigned its product offerings in 2012 after listening to unflattering customer comments. As a result, Domino's stock price went from $33 per share at the start of 2012 to $431 per share in 2021. According to new product development expert and author Don Adams, many companies are designing a new product, testing it with some potential customers, and then measuring their success by watching sales. Instead, Adams says companies should initiate feedback from customers prior to designing goods. "There's no substitute for respectful dialogue with customers," says Adams.[36]

In this section of the chapter, the common elements necessary for successful CRM programs were reviewed. Many of these involve the use of technology and software. But having numerous software applications does not necessarily guarantee CRM success. A number of other factors come into play before, during, and after programs are implemented that must be adhered to, in order to give the firm and its CRM program a good chance of finding and keeping profitable customers. The next section will discuss this very important aspect of CRM.

## Designing and Implementing a Successful CRM Program

Designing and then implementing a CRM program can be a real challenge, because it requires an understanding of and commitment to the firm's customers, adherence to CRM goals, knowledge of the tools available to aid in CRM, support from the firm's top executives and the various departments that will be using the CRM tools, and a continuous awareness of customers' changing requirements. Poor planning is typically the cause for most unsuccessful CRM initiatives, because of the temptation to start working on a solution or to purchase several CRM applications before understanding the problem. The firm must first answer this question: *What are the problems a CRM program is going to solve?* This must involve employees from all functional groupings across the firm, as well as input from the firm's key customers. Putting together a sound CRM plan will force the organization to think about CRM needs, technology alternatives, and the providers that sell them. Selecting the right tools and providers is an important step, but should not occur until a CRM plan is completed.

Aside from creating a CRM plan and getting the firm's employees to buy-in to the idea and uses of CRM tools, managers must also consider any existing CRM initiatives implemented in piecemeal fashion across the firm. Integrating new and existing applications into one enterprise-wide initiative should be one of the primary objectives of the CRM implementation process. Additionally, the firm must decide on specific performance outcomes and assessments for the program and provide adequate training to the CRM application users.

## Creating the CRM Plan

Putting together a solid plan for a CRM project is crucial both as an aid to purchasing and implementing CRM applications, and to obtain executive management approval and funding for the project. The plan should include the objectives of the CRM program, its fit with corporate strategy, new applications to be purchased, the integration with or replacement of existing methods or legacy CRM systems, the requirements for personnel, training, policies, upgrades and maintenance, and the costs and time frame for implementation. Once this document is completed, the firm will have a roadmap for guiding the purchase and implementation process.

The objectives of any CRM initiative should be customer-focused. Examples might include increasing sales per customer, improving overall customer satisfaction, more closely integrating the firm's key customers with internal processes, or increasing supply chain responsiveness. These will vary somewhat based on the overall strategic focus of the firm. Once these objectives are in place, tactical goals and plans can be instituted at the functional level, consistent with the CRM objectives. Finally, tactical performance

### SCM Profile — Zendesk's Sunshine Cloud CRM Application

California-based Zendesk's Sunshine is an open CRM application offered in the cloud on Amazon Web Services (AWS). Sunshine enables businesses to connect and understand all of their customer data and gives companies the ability to customize the CRM and also add apps as needed.

Photon photo/Shutterstock.com

Companies must deal with customers' changing needs and expectations, but are frequently held back by their legacy systems. Traditional CRM applications limit the view of customers and do not allow customer data spread across numerous systems to be integrated into one view of the customer. Most of these older CRM tools are at odds with developers' need for customizability. "It's time to break free from CRM platforms that think they're the center of the universe and lock you into an outdated view of the world," says Mikkel Svane, Zendesk founder and CEO. "We built Sunshine to shed light on the many different dimensions of customers and their data, while giving developers the freedom to build the way they want in the public cloud."

The AWS cloud offers security, scalability, and reliability, making Sunshine's CRM more flexible than traditional applications. Businesses gain the benefits of the cloud to easily move data between Sunshine and their other applications. Sunshine allows customers to store and connect all their customer data. With Zendesk's Profiles application, businesses can create a single, unified view of the customer across all applications. With Zendesk's Events, companies can capture any customer activity such as customer service interactions, website visits, purchase transactions, and shipping history in a historical timeline. And finally, with Zendesk's Sell, their sales force automation tool, information will be able to flow seamlessly between support and sales within Sunshine, resulting in a single connection with customers and better alignment between sales personnel.[37]

measures can be used to track the ongoing performance of the CRM program. This performance will serve to justify the initial and ongoing costs of the program. Some of today's CRM applications are available in the cloud. Zendesk's Sunshine CRM is one example, as described in the nearby SCM Profile.

## Involving CRM Users from the Outset

In order to get acceptance of a new CRM initiative, employee involvement and support is required. This comes about by enlisting the help of everyone affected by the initiative from the very beginning. Employees need to understand how the CRM program will affect their jobs before they will buy-in to it. Creating a project team with members from sales, customer service, marketing, finance and production for instance, will tremendously aid in the selection, training, use, and acceptance of the CRM program. The team can contact CRM application providers and collect information regarding capabilities and costs, and they can also collect baseline or current customer service, sales, complaint, and other meaningful performance information. The team should also be heavily involved in evaluating and selecting the CRM applications, and then implementing and integrating the applications in each department. As the implementation process continues, closely monitoring system performance will keep users convinced of its value, and keep everyone committed to its success.

Quite a bit of research has been conducted to study CRM implementations and most have found a direct relationship between program success and employee involvement. Several researchers in New Zealand for instance, talked with managers at three banks which had implemented CRM programs several years earlier. Two of the banks had failed to focus on employee buy-in while the third bank introduced a new sales culture to complement its CRM project, to win employee support. Eventually, the third bank's CRM system proved to be much more successful. In another example, Beene Garter, a Michigan area accounting firm, designed an internal contest to "sell" CRM to its employees. "Teams were assigned 'homework' on client records and the software tracked who entered updates," says Den Ouden of Beene Garter. "The contest mirrored components of the Olympics and was called 'Go for the Gold' to tie into the software name, GoldMine," she adds. Their success was remarkable. Users' attitudes about the CRM project changed from anxiety associated with entering all the data, to familiarity which created easy adoption and continuous use.[38]

## Selecting the Right Application and Provider

Once the organization has completed its plan for CRM, it should have a fairly good idea of what they are going to do, and which activities will require automation or technology. The job then becomes one of finding an appropriate application, and determining how much customization will be required to get the job done. Finding the best application and supplier can be accomplished a number of ways including:

- visiting a CRM-oriented tradeshow
- using a CRM consulting firm
- searching CRM or business publications such as *CRM Magazine*, *Call Centre Helper*, and *Inside Supply Management*
- using the knowledge of internal IT personnel, who already know the market, and
- searching the many CRM supplier directories and websites.

Firms should seek help from a number of these alternatives, and internal IT personnel should be viewed as internal consultants for the application and the supplier identification and selection process. Firms must analyze and compare the various goods available. In her CRM handbook, Jill Dyché recommends comparing the following software characteristics:[39]

- integration and connection requirements (the hardware, software, and networking capabilities)
- processing and performance requirements (the volume of data and number of users it can support)
- security requirements
- reporting requirements (preformatted and customized reporting capabilities)
- usability requirements (ability for users to customize the software, display graphics and print information)
- function enabling features (workflow management, e-mail response engine, predictive modeling capabilities), and
- performance capabilities (response times for various queries).

Comparing these CRM capabilities should narrow the list of qualified vendors substantially. When finally selecting a supplier for the application, one of the primary criteria for firms to consider is the support available from the application provider. Vendors offering implementation and after-sale user support that meet the needs of the firm should be valued more highly than other vendors. Suppliers offering free trial usage to verify their applications' capabilities is another element that needs to be considered. Finally, cost and contract negotiations should be carefully considered.

## Integrating Existing CRM Applications

In most firms, CRM systems are not one single product, but rather a suite of various applications that have been implemented over time. One of the biggest mistakes made is that departments across the firm implement various CRM applications without communicating these actions to other departments. Eventually, these systems will interfere with each other, as they communicate with the same customer, sending confusing and irritating signals that can chase customers away quickly.

Customer contact mechanisms need to be coordinated so that every CRM application user within the firm knows about all the contact activity for each customer. Today, this lack of integration is leading to real problems as call centers and sales offices seek to please and retain customers by adopting customer loyalty programs, customer tracking mechanisms and various customer contact mechanisms like Twitter and Facebook, without making this information widely-known and available within the firm. Additionally, multiple standalone CRM applications throughout the company result in duplication of effort, incompatible formats, wasted money and disgruntled customers. Compatible CRM modules are needed which are linked to one centralized database or **data warehouse** containing all customer information. Thus, from one database, users in the organization can retrieve information on a customer's profile, purchase history, promotion responses, payment history, web visitations, merchandise returns, warranty repairs, and call center contacts.

By integrating CRM information obtained throughout the firm, managers can analyze the information and make much more customer-focused decisions. Using predictive models and statistical analyses, firms can identify customers most likely to purchase certain products,

respond to a new promotion, or churn. As the number of customers grows however, their transactions and the desire to analyze all of this information is referred to as **big data analytics**. While analyzing large amounts of data has been around a long time (in the 1950s people analyzed data by hand from spreadsheets), today the process is extremely fast and can analyze much more data for quick decisions. The ability to analyze data today and make quick decisions is amazing—retailer Macy's adjusts pricing in near-real time for 73 million items, based on demand and inventory; Walmart.com uses text analysis, machine learning and even synonym mining to produce relevant search results, which has improved online purchase completions by 10 to 15 percent; and the Los Angeles and Santa Cruz police departments has taken an algorithm used to predict earthquakes, tweaked it and started feeding it crime data, which results in predictions of where crimes are likely to occur down to 500 square feet. Los Angeles has seen a 33 percent reduction in burglaries and a 21 percent reduction in violent crimes in areas where the software is being used. And finally, for those old enough, who can forget the story of hedge fund manager Mike Burry (made famous in the Christian Bale movie "The Big Short") who was able to read the data pertaining to the subprime mortgage loans prior to 2008 and see the devastating effect they were going to have on the world's economy.[40]

## Establishing Performance Measures

Performance measures linked to CRM program objectives (and customers) allow managers to monitor the progression of their systems in meeting objectives. It also serves to keep everyone excited and informed about the benefits of a well-designed program, and will identify any implementation or usage problems as they occur, allowing causes to be found and solutions to be implemented quickly.

At the organizational level, performance measures should concentrate on areas deemed strategically important, such as CRM program productivity, new customers added, or sales generated from the CRM program. Some examples of these measures are listed in Table 10.1. Note

**Table 10.1** CRM Program Performance Measures[41]

| PERFORMANCE MEASUREMENT TYPE | DEPARTMENT OR USER-LEVEL PERFORMANCE MEASURES | | |
|---|---|---|---|
| | **Field Sales** | **Call Center** | **Marketing** |
| **Customer Loyalty** | 1. % customer repurchases<br>2. avg. # repurchases<br>3. # customer referrals | 1. # customer product information requests<br>2. # customer praises | 1. % existing customers responding to promotions<br>2. # customer referrals |
| **Customer Satisfaction** | 1. avg. # customer visits to resolve problem<br>2. # field service visits per customer | 1. # complaints per customer<br>2. % first call resolution | 1. % customers responding more than once to promotions<br>2. # customers engaged using social contacts |
| **Average Sales Revenue per Customer** | 1. # sales quotas met<br>2. % repeat visits resulting in sales | 1. sales per customer call<br>2. cross-sales and up-sales per customer call<br>3. % calls converted | 1. # website/social visits per customer<br>2. website/social purchases per customer |
| **CRM Productivity** | 1. % sales quotas met<br>2. # new leads generated<br>3. % new leads closed | 1. avg. caller time<br>2. # complaints resolved<br>3. sales/call/hr.<br>4. transactions/agent/hr. | 1. # segment catalogs produced<br>2. # promotional e-mails sent<br>3. # marketing campaigns<br>4. avg. campaign response rate |
| **CRM User Satisfaction** | 1. sales rep. satisfaction score | 1. call center agent satisfaction score | 1. user satisfaction score |
| **CRM User Training** | 1. hrs. training per year per rep.<br>2. # CRM applications trained per rep. | 1. hrs. training per year per agent<br>2. # CRM applications trained per agent | 1. hrs. training per year per user<br>2. # CRM applications trained per user |

that the performance measures cover the customers, the CRM program itself and the users. Additionally, all of the metrics should be transparent and easy to measure. At the user level, other more tactical performance measures should be developed and tracked, supporting the firm-wide strategic measures. Linking performance measures in this way will give the firm the best chance of a successful program implementation and continued management of the program into the future.

## Training for CRM Users

Another important step in the implementation process is to provide and require training for all of the initial system users, and then provide ongoing training as applications are added or as other personnel begin to see the benefits of the CRM system. Training can also help convince key users such as sales, call center, and marketing personnel of the benefits and uses of CRM applications. Training is one area crucial to CRM program success. Unfortunately, in a survey conducted by *Customer Relationship Management* magazine, 43 percent of the respondents said their user training "needed improvement."[42] Unless the users are shown the personal gains they'll receive for taking time to learn the applications and their capabilities, the CRM program will most likely go unused or underused. Karen Ainley, product manager at U.K.-based CRM software developer Sage emphasizes that shortcuts in training can ultimately prove costly. "The perception that CRM is so easy to use that you don't need training is a fallacy. By dismissing the need for training in the hope that users will simply 'learn on the job' and adapt their way of working, companies really are limiting the software's potential."[43]

Training managers and users in the key customer contact areas can also help the firm decide what customizations to the CRM applications are required, before the system is put into use. This is particularly important for larger firms where supply chains and the sales and marketing processes are complex. In many cases, CRM system implementation means that other systems already in place will be phased out or merged with the new system. Training can help personnel decide how best to phase out old systems and phase in the new ones. CRM consultant Barton Goldenberg suggests that firms should create a training profile for each of its CRM system users to provide training before, during, and after the implementation in one or more of these areas: computer literacy training, business process training, CRM application training, remedial training, and new user training.[44]

# Trends in CRM

Some of the top trends in CRM for 2021 and beyond are the customer experience, use of artificial intelligence, adopting mobility, and use of social media.[45] These topics will be discussed next.

## The Customer Experience

Engaging with customers is today more than ever, making the customer experience an important brand differentiator. The customer experience is one of the top priorities for 65 percent of executives according to 2020 joint research conducted by *Forbes* and California-based software developer Salesforce. And consumers agree, where 80 percent of respondents to a 2020 Salesforce survey ranked their experiences just as important as goods or services. According to customer service expert and best-selling author Shep Hyken, when it comes to the customer experience, convenience is king. "The company that's easiest to do business with is ultimately going to win," he says.

## Artificial Intelligence

Today, artificial intelligence (AI) is experiencing the major growth within CRM, according to Salesforce research. Its 2020 State of Marketing report indicated that marketers using AI jumped from 29 percent in 2018 to 84 percent in 2020. One of the biggest benefits of AI is its capacity to take over tedious, time-consuming manual tasks. The ultimate goal is to use robotic automation to enhance CRM user productivity. AI enhances service agents' abilities to help customers. It does this by analyzing customer data such as past calls and buying patterns to generate a profile that gives agents a better understanding of the customer. This lets the agents deliver a more personalized customer interaction.

## Mobile CRM

For field sales personnel, mobility has long been a key requirement for CRM. But, as processes have become more complex, the workforce becomes more scattered and buyer demands place more pressure on sales reps to perform. Placing CRM capabilities into the workforce's hands is today a given. The COVID-19 pandemic also emphasized the need to utilize mobility. According to business consultant and IT specialist David Dozer, "As workforces became distributed and remote almost overnight, many companies struggled to get people access to the basic systems they needed to effectively work. This wake-up call is going to be a huge driver of CRM systems as we head into 2021. Businesses will be looking towards CRM to fill the gaps that were uncovered in 2020. This means accessibility from anywhere, anyplace and anytime is going to be very important."

## Use of Social Media

Social media has recently become a focal point for CRM, due to the impact of COVID-19. With in-person communications and experiences suddenly stopping in 2020, digital channels became the go-to for everything. Digital platforms offer safety, speed, and convenience. The business world has changed—consumer interactions with companies are projected to be 60 percent online and 40 percent in-person going forward, according to Salesforce, a near reversal from 2018 when interactions were 42 percent online and 58 percent in-person. Companies are able to connect with their audience using social media in real time and build brand equity where prospects and customers are already spending time. It also enables one-to-one marketing and the personal attention customers crave.

## Summary

In this chapter, we introduced and discussed the elements of CRM, its place within the field of supply chain management, the requirements for successful CRM program implementation and the current trends in CRM. As we learned in this chapter, customer relationship management is really all about listening to customers, learning about customers, and treating customers right. For as long as there have been businesses, some firms have been very successful at keeping customers satisfied and coming back, while others have not. For the past ten or fifteen years though, both the level of competition in the market place as well as available computer technology and software capabilities, has been increasing quite dramatically. Thus, we have seen a shift in CRM toward use of technology, software, and the Internet to better analyze, segment, and serve customers with the objective of maximizing long term customer profitability.

Firms today are learning how to combine many channels of customer contact to better serve customers, resulting in better customer satisfaction and more sales. Though many traditional CRM applications are expensive, firms can use a structured approach to design an appropriate plan, and then analyze and select the right applications and vendors to implement a successful CRM program. Cloud-based CRM applications have also become a major consideration in the development of many firms' CRM efforts.

## Key Terms

**big data analytics,** 456
**call centers,** 450
**clickstream,** 447
**cross-selling,** 444
**customer churn,** 445
**customer contact centers,** 450
**customer defection analysis,** 445
**customer lifetime value,** 446
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**sales activity management system,** 448
**sales force automation,** 447
**sales territory management systems,** 448
**segment customers,** 443
**Seven Rs Rule,** 449
**target marketing,** 443
**transaction,** 450

## Discussion Questions and Exercises

1. Define the term *customer relationship management* and what has impacted the way companies view CRM over the past 15 or 20 years.
2. How does the actual practice of CRM differ from the use of CRM software?
3. Why have so many CRM efforts failed? Can you cite a personal example of a good or bad CRM effort?
4. Describe why CRM is so important in managing supply chains. What do firms with good CRM programs do? Can you cite an example aside from the ones mentioned in this chapter?
5. What is *segmenting customers* and why is it perhaps the most important activity in CRM? What do firms typically do with the segments of customers?

6. Define these terms: permission marketing, cross-selling, and churn reduction.
7. How would an analysis of customer defections help the firm become more competitive?
8. Why is the determination of customer lifetime value important?
9. Pick a specific company near your residence and describe how they could personalize their communications with you, the customer.
10. Describe several ways that CRM applications can increase the effectiveness and productivity of a firm's sales force.
11. How does *your definition* of customer service compare to the *Seven Rs Rule*?
12. Describe some businesses in your area providing good customer service, then list some providing poor customer service.
13. Describe the types of customer service that come before, during, and after the sale. Why are they important to CRM?
14. Are call centers good or bad for the firm? What has been your experience with call centers?
15. Do you think call center outsourcing negatively affects customer service? Explain.
16. Could self-service websites be used in place of call centers? Explain.
17. How should customer satisfaction be measured at a bank? A restaurant? A manufacturing firm? A retailer?
18. Do you think CRM applications unnecessarily invade customers' privacy? Explain.
19. Describe the steps necessary for designing and implementing a successful CRM program.
20. What is the most common mistake made, when designing and implementing a CRM program?
21. How do you think CRM performance should be measured? Suggest several performance measures for a specific company.
22. What sort of problems can occur with a firm's existing or legacy CRM applications?
23. What do *big data* and *big data analytics* refer to?
24. Why is CRM program user training so important? How could the training requirement be minimized?
25. How can firms help to assure the privacy and security of their customers' information and data?
26. How do various social media impact an organization's CRM methods? Should firms use social media for attracting new customers?
27. What do you think the true value of social CRM is?
28. What is *cloud computing* and what are its advantages for CRM?
29. How is AI impacting CRM?
30. What is mobile CRM and why is it important today?

## Essay and Project Questions

1. Go to the International Customer Management Institute's website: www.icmi.com and look at several news stories. Describe a new development in call center usage or technology.
2. Identify an on-demand Internet CRM provider and see if you can determine what is "free" and what is not.
3. Search on the term "call center technology" and describe a few of the latest uses of technology in call centers.
4. What are some of the latest developments in Internet privacy laws?
5. Identify some of this year's best and worst customer service providers. Have you dealt with any of these companies? Please describe your experiences.

## Problems

1. From the information given below, rank the customers in terms of their lifetime value.

| | AVG. ANNUAL SALES | AVG. PROFIT MARGIN | EXPECTED LIFETIME |
|---|---|---|---|
| Customer A: | $ 2500 | 17% | 8 years |
| Customer B: | $ 4000 | 12% | 6 years |
| Customer C: | $ 1200 | 30% | 12 years |

   Use a discount rate of 6 percent and treat the average annual sales figures as annuities. Should any of these customers be fired?

2. A tree provider to plant nurseries is trying to use customer lifetime value to determine the value of its customers. Two customers are shown below. Use customer lifetime value to determine the importance of each customer. Use an 8 percent discount rate. What do you recommend?

| | AVG. ANNUAL SALES | AVG. PROFIT MARGIN | EXPECTED LIFETIME |
|---|---|---|---|
| Customer A: | $21,500 | 20% | 10 years |
| Customer B: | $14,000 | 10% | 6 years |

## Cases

### 1. Polly's Sweet Treats and Drinks*

Iris Rice has managed Polly's Sweet Treats and Drinks for ten years. The owner, Mamie Hammond, essentially gave Iris full control about seven years ago. Mamie had established Polly's almost 30 years ago and has been in semi-retirement for about the last five years. Mamie is considering selling the store and is giving Iris first choice. Iris is extremely excited about the prospect of owning her own business. However, Iris wants to expand the offerings and ultimately increase the number of locations.

*Written by Rick Bonsall, D. Mgt., McKendree University, Lebanon, IL. The people and institution are fictional and any resemblance to any person or any institution is coincidental. This case was prepared solely to provide material for class discussion. The author does not intend to illustrate either effective or ineffective handling of a managerial situation.

Iris asked Mamie if she could have one year to investigate how changes will be received by customers. Although excited, Iris is also very nervous about being an owner. It is one thing to manage a business owned by someone else and another to own it yourself. Mamie reflected on how she felt when she started Polly's. Mamie wanted Polly's to stay successful and would like it to grow as well. Iris was an excellent manager; therefore, Mamie believed Iris would be an excellent owner. Consequently, Mamie thought it was worth the time to let Iris make some changes and build her confidence.

Polly's Sweet Treats and Drinks has a variety of customers. Although Iris has never officially put them in any specific categories, now that she may be the owner, she began thinking along those lines. Polly's opened at 11 a.m. and closed at 8 p.m. Much of the lunch crowd consists of young mothers with children in school, on up to senior citizens. Around 3 p.m., the complexion of the crowd changes. It becomes dominated by teenagers. This made sense since school let out around 3 p.m. As 6 p.m. approached, Iris noticed that families were the predominant group.

Currently, the menu consisted of dessert-like food such as cakes, pies, tarts, muffins, doughnuts, and other pastries. The drinks were a variety of sodas that included diet and caffeine-free drinks. Polly's also served a variety of hot and cold teas, hot and cold coffees, as well as milk, hot chocolate, milk shakes, and frozen drinks.

Although Polly's Sweet Treats and Drinks has been in business for about 30 years and it still has a strong customer base, Iris is concerned about the future. She believes that for her to eventually expand and add new stores she will need a new menu. Iris thinks that she will have to expand the menu to include things beyond sweet treats and drinks. She is thinking about adding sandwiches and possibly a single blue plate special for those who may want a "full-course" type meal.

Iris has a Bachelor's degree in Business. The one point that her favorite professor drilled into her was that you need data to make effective decisions. Once you collected the data you had to analyze them, then use them to drive your decisions. Currently, Iris has no data except for her casual observations of what is happening in the store from 11 a.m. to 8 p.m. In order to make the best decisions for Polly's Sweet Treats and Drinks, Iris understood she needed to collect some data. She could not assume that the changes she felt were necessary were the changes the customers would accept.

She talked it over with Mamie. Mamie's concern was that since such a variety of customers visited Polly's it would be a challenge to fulfill all their likes. Plus, many people liked the store as it was. They had visited it as children and now brought their kids there. Would they lose customers or gain them if changes were made? After much discussion Mamie and Iris agreed that they needed more information about what their customers liked and didn't like.

## Discussion Questions

1. Iris Rice is planning to take a huge step toward changing Polly's Sweet Treats and Drinks' business strategy. What does she need to do to collect the type of data she'll require to make an effective decision? Explain what you would do if you were her. What would be your plan? Be specific.

2. Assume Iris moves forward with her plan to change the menu. This could alter the current customer base. Advise her on actions she should take to address customer defections. Explain how the actions will benefit her and potentially prevent customer defections.

3. The case suggests that many of Polly's Sweet Treats and Drinks' customers are from the same community. Parents came there as children and are now bringing their children there. Would you recommend that Iris use social CRM? Why or why not?

## 2. Perfection Call Center*

Perfection Call Center performs customer service activities for several different companies, large and small. Although the current clients are very satisfied, new business has been hard to obtain. Therefore, the Board of Directors recently hired Tim Roy as the new director of Perfection Call Center. His primary responsibility is to grow the business.

Tim is very familiar with call centers. He has worked in one or been associated with one most of his professional life. He decided that before he did anything else, he needed to observe how things were going in Perfection and understand its strengths and weaknesses. The professionalism of the call center personnel was beyond reproach. Tim listened in on call after call from different operators and found them to be polite, knowledgeable, and solution-oriented.

Tim's next task was to meet with clients and obtain a thorough understanding of how they felt about Perfection. As he talked with senior people from each client company, Tim discovered that everyone was extremely happy. In fact, Tim would even go as far as to declare that the clients were delighted with the services they received from Perfection.

To Tim's tremendous surprise, he discovered that Perfection Call Center did not collect very much performance data. In addition, he found out that most of the current clients had started with Perfection in its early days of operation; consequently, the relationship between them and Perfection had gradually grown very strong over the years. The result was a customer base that trusted Perfection to naturally do an outstanding job for them.

Unfortunately, potential new clients were not as trusting. They wanted to see proof that Perfection Call Center was as good as they claimed. What historical data did they have that illustrated past customer satisfaction? More importantly, what type of reports would they provide new customers to demonstrate they were meeting their expectations? Tim now saw the problem. Perfection Call Center was extremely good at what it did; however, beside testimonials from current clients, they could not prove it.

### Discussion Questions

1. Does Tim's conclusion make sense to you—that is, do you agree with it? What specific information could Perfection Call Center provide moving forward that would demonstrate to new clients that Perfection was meeting expectations?
2. Tim also discovered that Perfection Call Center had an outdated call center system. He decided to request a major update from the Board of Directors. The issue is that Tim was brought in to raise revenues through new clients, not to increase expenses with new systems. Develop an argument for Tim that highlights the benefits of upgrading the call system. Explain how it can drive customer satisfaction, which potentially drives new business.
3. Besides providing the usual customer problem resolution services, Tim believes there are other services that his call center could provide that would enhance his clients' revenue streams, and through its contract enable Perfection to trigger bonuses based on those increased revenues. What type of additional services could Perfection provide that addresses this point? Explain how those services would potentially enhance Perfection's clients' revenue, thus their own.

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### 3. Burley's Biscuits, Beef, and Veggies*

Bob Burley and his brother Buford ran the best restaurant in Dallas, Texas. Many out-of-towners would visit Dallas and go to Burley's Biscuits, Beef, and Veggies for a good wholesome meal. One thing that Bob and Buford had going for them in a town as active as Dallas was that their restaurant was open 24/7. This was especially important for all the big game days. No matter what the professional sport was, thousands flocked to the city to watch their favorite team.

Bob and Buford were living high on the hog, but they weren't the type to take anything for granted. They knew they had the best food in the area and the service was second to none. However, in-between major sports events and other activities such as concerts, the restaurant wasn't always filled to capacity. A full restaurant with people wanting and waiting to get in was what Bob and Buford desired.

The Burley brothers discussed what to do at great length. There had to be some way to entice people out of their homes and into the restaurant every day of the week. Bob and Buford hoped that whenever a family decided to go out to eat the first place that would cross their mind was Burley's Biscuits, Beef, and Veggies.

Jose Sanchez was a close friend of the Burley brothers. Jose owned a marketing firm and one of Jose's specialties was customer relationship management (CRM). One day, Jose heard the brothers talking about ways they could fill the restaurant. Jose interrupted and starting asking them about their CRM program. Bob and Buford told Jose they didn't have one. They weren't clear on what exactly a CRM program was. Jose explained that it simply meant building and maintaining profitable long-term customer relationships. Jose asked how many customers were return customers. Although they had a lot of people they saw over and over again in the restaurant, neither Bob nor Buford knew the specific number. Jose then stated the obvious—the Burley brothers had to develop and implement a CRM program if they wanted to achieve their dream of non-stop business.

### Discussion Questions

1. We know from the case that Bob and Buford have customers from many different segments. They could segment them by sports, business people, regulars, breakfast, lunch, or dinner crowd. How should Jose and explain to the Burleys the advantages of segmenting customers? What types of customer relationship management activities should they implement that would drive business to the restaurant? Explain how those CRM activities would help.
2. Bob is excited about implementing social CRM. Buford is against using social CRM. Who do you agree with and why?
3. As part of their CRM initiative, Buford wants to utilize the "Seven Rs Rule." Can this truly be part of their CRM program or is it just a nice sounding "slogan"? Explain whether or not it can help as part of the CRM program.

## PART 4 Continuing Case

Note: This case is available online only.

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# Chapter 11

# Global Location Decisions

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*A company's full potential can be realized when its assets are optimally located. Location decisions are long-term and involve significant financial commitment and risk, which makes a sound location strategy a critical component of a company's overall business strategy.*

**—Deloitte[1]**

*Looking forward, value chains disrupted by evolving technologies, such as digitalization, automation and 3D printing, will significantly impact how companies invest and how they define a competitively advantaged location.*

**—IBM Institute for Business Value[2]**

*McDonald's has been extraordinary at site selection; it was a pioneer in studying the best places for retail locations. One of the things it did is study very carefully where sprawl was headed.*

**— Eric Schlosser, author, "Fast Food Nation"[3]**

*Globalization continues to reshape the international economy. For many organizations, global expansion can have a tremendous positive impact on both top and bottom line. For others, expanding or relocating a business may be a matter of survival, as they face increasing pressure from foreign competitors.*

**—Greg Wiebe, partner, KPMG LLP[4]**

## Learning Objectives

**After completing this chapter, you should be able to**

**LO 1** Explain the impact of global location strategy on a supply chain.

**LO 2** Identify the factors influencing location decisions.

**LO 3** Understand the impact of the regional trade agreements on location decisions.

**LO 4** Use several location evaluation models.

**LO 5** Understand the advantages of business clusters.

**LO 6** Explain the impact of sustainable development on facility location.

**LO 7** Understand the impact of the COVID-19 pandemic on facility location.

## Chapter Outline



## SCM Profile — Amazon's Global Logistics Facilities Network


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Jeff Bezos founded Amazon.com in 1995. Amazon's corporate mission is to be the "Earth's most customer-centric company." Amazon is guided by four principles: customer obsession rather than competitor focus, passion for invention, commitment to operational excellence, and long-term thinking. The company's global operations are in the United States, Australia, Brazil, Canada, China, France, Germany, India, Italy, Japan, Mexico, Netherlands, Spain, and United Kingdom. The company directly employs 1.3 million people worldwide. There are more than 1.9 million small and medium-sized businesses selling on Amazon's website. They have 200 million global Prime members and in 2020 their total net income was $21.33 billion.[5]

The early belief in electronic commerce was that millions of customers could be served without requiring the infrastructure of a Sears or Walmart. Today, online retailers are finding that without their own warehouses and shipping capabilities, customer service can suffer.

The objective is to improve logistics and reduce shipping times to customers. The company currently has several facility types including Fulfilment Centers/Distribution Centers (DCs), Pantry/Fresh Food Fulfillment Centers, Sortation Centers, Delivery Stations, airport hubs, and Prime Now Hubs, totaling 838 in the United States.[6] Other worldwide logistics facilities located in Europe are in Austria, Czech Republic, France, Germany, Italy, Netherlands, Poland, Republic of Ireland, Slovakia, Spain, Sweden, and the United Kingdom. In Asia, the fulfillment centers are found in Australia, China, India, Japan, and Singapore. Amazon also has logistics facilities in Canada, Mexico, and Brazil. Outside the United States, Amazon has 723 such facilities/centers/hubs. Amazon's massive logistics network far exceeds that of any retailer in terms of scale and coverage. By strategically locating its logistics facilities and improving its operations, Amazon is able to provide faster customer service globally.

Although Amazon uses third party logistics companies such as UPS, FedEx, and DHL for delivery, it has built its own fleet of delivery vehicles especially for its Prime customers. Amazon's "Last Mile" delivery for small packages involves Amazon Sprinter vans, independent Amazon flex drivers, and other local courier companies. To achieve Amazon's goal of one-day delivery for its Prime customers, the location of fulfillment centers is critical. Amazon also launched The Climate Pledge in September 2019. The pledge requires their transportation providers to measure and report greenhouse gas emissions regularly and to implement decarbonization strategies. Transportation is a major part of Amazon's business and it has a goal of achieving net zero carbon by 2040. As such it is investing more than $1 billion in Rivian to deliver 100,000 electric vans.[7]

## Introduction

Locating a facility is an important decision affecting the efficiency and effectiveness of managing supply chains, the level of service provided to customers, and a firm's overall competitive advantage. A supply chain is a network of facilities working together, and the location of production facilities, offices, distribution centers, and retail sites determines the efficient flow of goods to and from these facilities. Once a decision on locating a facility is made, it is costly to move or shut down that facility. Thus, facility location has a long-term impact on a supply chain and must be an integral part of a firm's supply chain strategy. With increased globalization and investments in technology infrastructure, faster transportation, improved communications, and open markets, companies can locate anywhere in the world—previously thought to be impossible. Amazon.com has shown that by strategically locating its logistics facilities and improving its operations, the company is able to provide faster service globally (see the opening SCM Profile).

It would appear that easy access to global markets and corporate networks makes the role of location less important as a source of competitive advantage. However, successful business clusters in areas such as Silicon Valley, Wall Street, the California wine region, and the Italian leather fashion center, show that location still matters. The existence of business clusters in many industries provides clear evidence that innovation and successful competition are concentrated geographically. Dr. Michael Porter suggests that the immediate business environment is just as important as the issues impacting companies internally, in affecting location decisions.[8] Business clusters are discussed in detail later in this chapter.

Global location decisions involve determining the location of the facility, defining its strategic role, and identifying markets to be served by the facility. For example, Honda's global location strategy of building cost-effective manufacturing facilities in areas that best

meet the requirements of local customers has served the company well. Honda's "Small Born" manufacturing strategy is to start small and expand production as local demand increases. This approach allows the company to be efficient and profitable, even when production volumes are low. Honda's first auto plant in the United States was built in Marysville, Ohio. Then the company added a second factory in East Liberty, Ohio. As demand for Honda automobiles continued to increase, Honda opened a facility to assemble the Odyssey minivans in Alabama and an auto plant producing Civic GX Natural Gas Vehicles in Indiana. Honda's Ridgeline trucks, which were built previously in Canada, are today produced in the Alabama plant. Toyota, Nissan, Mercedes, BMW, Volkswagen, Kia Motors, and Hyundai have also built assembly plants in the United States to cater to the U.S. automobile markets.

The COVID-19 pandemic caused a shift in mindset regarding global location decisions. Due to the pandemic, many facilities were forced to shut down or reduce their operations. There were high demands for some product such as toilet paper, eggs, paper towels, hand soap, and hand sanitizer, while demand for automobiles and other non-essential products plummeted. This issue will be discussed later in the chapter.

## Global Location Strategies

Global location decisions are made to optimize the performance of the supply chain and be consistent with the firm's competitive strategy. However, COVID-19 showed what a global pandemic can do to an interconnected global economy. Seemingly overnight, everything changed: ports closed, planes were grounded, businesses shuttered, and workers were sent home. The movement of people across borders came to a standstill, as most countries imposed partial or complete border closures in response to the pandemic. The global economy stalled. According to the 2020 IBM Institute for Business Value Global Location Trends annual report, 60 percent of the survey respondents indicated they were planning to consolidate activities in their home country in 2020, while only 27 percent of the respondents expected to consolidate activities abroad. This is vastly different from previous years.[9] Nevertheless, a firm competing on cost is more likely to select a location that provides a cost advantage. For instance, Amazon.com, as discussed in the chapter opening SCM Profile, locates logistics facilities in areas that will minimize logistics and inventory costs. Many toy manufacturers have also moved their factories to Vietnam, Thailand, or China because of cost advantages provided by these countries.

A firm that competes on speed of delivery, such as the FedEx Corporation, uses the hub-and-spoke approach to location determination. FedEx's first and largest hub in the United States is in Memphis, Tennessee. This site has 48 miles of conveyer belts, the capacity to sort 1.3 million packages, and has 7000 employees. About 150 to160 trunk aircrafts and 130 trucks arrive at the Memphis International Airport every night. The objective is to have each container delivered from vehicle to sorting hub in under 30 minutes. The belts convey 180,000 items an hour through the scanner.[10] Planes land at the rate of one every ninety seconds. In addition to the SuperHub in Memphis, FedEx has six main hubs in the United States in Oakland, California; Newark, New Jersey; Fort Worth, Texas; Indianapolis, Indiana; Anchorage, Alaska; and Miami, Florida (serving Latin America). International main hubs are in Toronto, Canada; Dubai, UAE; Paris, France; Cologne, Germany; Osaka, Japan; Guangzhou, China; and Singapore.[11] Each of the hubs has been picked for its central location and easy access to customers.

To get the most out of foreign-based facilities, managers must treat these plants as a source of competitive advantage. These foreign facilities have a strategic role to perform. Professor Kasra Ferdows of Georgetown University suggests a framework consisting of six strategic roles depending on the strategic reason for the facility's location and the scope of its activities:[12]

- *Offshore factory:* An **offshore factory** manufactures products at low cost with minimum investment in technical and managerial resources. These products tend to be exported. An offshore factory imports or locally acquires parts and then exports all of the finished products. The primary objective is simply to take advantage of low labor costs. For example, in the early 1970s, Intel built a labor-intensive offshore factory to produce simple, low-cost components in Penang, Malaysia.
- *Source factory:* A **source factory** has a broader strategic role than an offshore factory with plant management heavily involved in supplier selection and production planning. The source factory's location is dictated by low production cost, fairly developed infrastructure, and availability of skilled workers. Hewlett-Packard's plant in Singapore started as an offshore plant in 1970 but with significant investments over a ten-year period was able to become a source factory for calculators and keyboards.[13]
- *Server factory:* A **server factory** is set up primarily to take advantage of government incentives, minimize exchange risk, avoid tariff barriers, and reduce taxes and logistics costs to supply the regional market where the factory is located. An example would be Coca-Cola's international bottling plants, each serving a small geographic region.
- *Contributor factory:* The **contributor factory** plays a greater strategic role than a server factory by getting involved in product development and engineering, production planning, making critical procurement decisions, and developing suppliers. In 1973, Sony built a new server factory in Bridgend, Wales. By 1988, the factory was involved in the design and development of many of the products it produced and now serves as a contributor factory in Sony's global manufacturing network.[14]
- *Outpost factory:* The **outpost factory** is set up in a location with an abundance of advanced suppliers, competitors, research facilities, and knowledge centers to get access to the most current information on materials, components, technologies, and products. Since the facility normally produces something, its secondary role can be that of a server or an offshore factory. For example, Lego still produces molds and toys in Denmark, Germany, Switzerland, and the United States in spite of the higher manufacturing cost.[15] Lego's factories serve as outpost facilities with access to research facilities, institutions of higher learning, and sophisticated suppliers of plastic materials.
- *Lead factory:* A **lead factory** is a source of product and process innovation and competitive advantage for the entire organization. It translates its knowledge of the market, competitors, and customers into new products. In the early 1970s, both Intel and Hewlett-Packard established offshore factories in Southeast Asia. Over time, the strategic roles of these factories were upgraded to that of lead factories.

## Critical Location Factors

One of the most challenging tasks as a company grows, relocates, or starts up, is where to position assets strategically to create a long-term competitive advantage. Some of the questions and concerns that need to be addressed for each potential location are:

- What will be the reaction of shareholders, customers, competitors, and employees?
- Where is the target market located?
- Will the location provide a sustainable competitive advantage?

- What will be the impact on product or service quality?
- Can the right people be hired?
- What will be the effect on supply chains?
- What is the projected cost?
- What will be the impact on delivery performance?
- How will the market react?
- Is the transfer of people necessary, and, if so, are employees willing to move?

There are three levels of location decisions: the global market or country selection, the subregion or state selection, and the community and actual site selection. The process starts with an analysis of the region of the world that bears a strategic interest to the organization, and, eventually, a country is targeted. Once the country is selected, the focus shifts to finding a subregion or state within the country that best meets the company's location requirements. Finally, the community and site for the facility are selected. The weighted-factor rating model, which is discussed later in this chapter, can be used to make a location decision at each of the levels we have mentioned. Table 11.1 lists a number of factors affecting each of the three levels of location decisions and discussions of each of these factors follows.

## Regional Trade Agreements and the World Trade Organization

An understanding of regional trade agreements and the **World Trade Organization** (WTO) is critical to the facility location decision process because of its impact on tariffs, costs, and the free flow of goods and services. The WTO is the successor to the General Agreement on Tariffs and Trade (GATT), which was responsible for setting up the multilateral trading system after World War II. Today, the WTO is the "only global international organization dealing with the rules of trade between nations. At its heart are the WTO agreements, negotiated and

**Table 11.1 Important Factors in the Location Decision Process**

| LOCATION FACTOR | COUNTRY | REGION/STATE | COMMUNITY |
|---|---|---|---|
| Regional trade agreements—trade barriers, tariff, and import duties | X | | |
| Competitiveness of nations—economic performance, government efficiency, business efficiency and infrastructure | X | | |
| Government taxes and incentives | X | | |
| Currency stability | X | | |
| Environmental issues | X | X | X |
| Access and proximity to markets | X | X | X |
| Labor issues | X | X | X |
| Access to suppliers | X | X | X |
| Logistics issues | X | X | X |
| Utility availability and cost | X | X | X |
| Quality-of-life issues | X | X | X |
| State taxes and incentives | | X | X |
| Right-to-work laws | | X | X |
| Local taxes and incentives | | | X |
| Land availability and cost | | | X |

signed by the bulk of the world's trading nations and ratified in their parliaments. The goal is to ensure that trade flows as smoothly, predictably and freely as possible."[16] As of 2020, the WTO had 164 members and its goal is to help producers of goods and services, exporters, and importers conduct their business. There are approximately 25 countries seeking to join the WTO, and these are called observer countries. Other functions of the WTO include administering the agreements, providing a forum for trade negotiations, handling trade disputes, monitoring national trade policies, providing technical assistance and training programs for developing countries, and cooperating with other international organizations.

As of June 15, 2021, there were 349 regional trade agreements under the WTO.[17] Examples of the better-known regional trade agreements are the **European Union (EU),** the **United States-Mexico-Canada Agreement (USMCA),** the **Southern Common Market (MERCOSUR),** the **Association of Southeast Asian Nations (ASEAN),** the **Common Market for Eastern and Southern Africa (COMESA),** the **Regional Comprehensive Economic Partnership (RCEP),** and **Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP)**. Several of these are discussed here:

- *The European Union (EU):* Set up after World War II, the European Union was officially launched on May 9, 1950, with France's proposal to create a European federation consisting of six countries: Belgium, Germany, France, Italy, Luxembourg, and the Netherlands. A series of accessions in 1973 (Denmark, Ireland, and the United Kingdom), 1981 (Greece), 1986 (Spain and Portugal), 1995 (Austria, Finland, and Sweden), 2004 (Czech Republic, Estonia, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Slovenia, and Slovakia), 2007 (Bulgaria and Romania), and 2013 (Croatia) has resulted in a total of 27-member states. Currently, the EU has five candidate countries—Albania, Montenegro, North Macedonia, Serbia, and Turkey.[18] Two highlights of the EU are the establishment of the single market in 1993 and the introduction of the euro notes and coins on January 1, 2002. The euro (€) is the official currency of 19 out of 27 EU countries. These countries are collectively known as the Eurozone. In 2015, Greece became the first country to default on an IMF loan payment. EU member countries then provided bailout aid to Greece to enable the country to service its debt obligations. In 2016, British citizens voted to exit the European Union. The United Kingdom has to invoke an agreement called Article 50 of the Lisbon Treaty to leave the EU, giving the two sides two years to agree on the terms of the split. The United Kingdom withdrew from the EU officially on January 31, 2020.
- *The United States-Mexico-Canada Agreement (USMCA):* The original trade agreement among the United States, Canada, and Mexico was called NAFTA and was implemented on January 1, 1994. NAFTA created the world's largest free trade area, currently with over 450 million people and GDP of more than US $20 trillion.[19] Many tariffs were eliminated with an immediate effect, while others were phased out over periods ranging from five to fifteen years. According to the Office of the U.S. Trade Representative, "U.S. exports to Canada and Mexico support more than 3 million American jobs and U.S. trade with NAFTA partners has unlocked opportunity for millions of Americans by supporting Made-in-America jobs and exports."[20] In addition, Canada and Mexico are two of the United States' largest export markets and these countries buy more made-in-America goods and services than any other countries in the world. The United States renegotiated the North American Free Trade Agreement, replacing it with an updated and rebalanced agreement, which is now called the **United States-Mexico-Canada Agreement (USMCA)**, and which came into force on July 1, 2020. For merchandise entered into commerce on or before June 30, 2020, NAFTA rules continue to apply. (see Chapter 9 for further discussion of the USMCA).

- *The Southern Common Market (MERCOSUR):* This economic and political agreement among Argentina, Brazil, Paraguay, Uruguay, and Venezuela was formed in March 1991 with the signing of the Treaty of Asuncion. The agreement was created with the goal of forming a common market/customs union between the participating countries for free movement of goods, services, and people, and was based on economic cooperation between Argentina and Brazil that had been in place since 1986. After Paraguay was suspended in 2012 for violating the Democratic Clause of Mercosur, Venezuela was added as a full member but was then suspended on December 1, 2016. Associate members include Bolivia, Chile, Colombia, Ecuador, Peru, and Suriname. The total population of the member states is more than 307 million.[21]
- *The Association of Southeast Asian Nations (ASEAN):* This association was created in 1967 in Bangkok, Thailand and is comprised of the ten countries in the Southeast Asian region: Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam. The primary objective of ASEAN is "to accelerate the economic growth, social progress and cultural development in the region through joint endeavors in the spirit of equality and partnership in order to strengthen the foundation for a prosperous and peaceful community of Southeast Asian Nations.[22]
- *Common Market for Eastern and Southern Africa (COMESA):* COMESA was established in 1994 to "be a fully integrated, internationally competitive regional economic community with high standards of living for all its people ready to merge into an African Economic Community."[23] The mission of COMESA is to "Endeavour to achieve sustainable economic and social progress in all Member States through increased co-operation and integration in all fields of development particularly in trade, customs and monetary affairs, transport, communication and information, technology, industry and energy, gender, agriculture, environment and natural resources."[24] COMESA has nineteen member states: Burundi, Comoros, D.R. Congo, Djibouti, Egypt, Eritrea, Ethiopia, Kenya, Libya, Madagascar, Malawi, Mauritius, Rwanda, Seychelles, Sudan, Swaziland, Uganda, Zambia, and Zimbabwe.
- *Regional Comprehensive Economic Partnership (RCEP):* 15 Asia-Pacific countries signed the RCEP on November 15, 2020 through a virtual signing ceremony hosted by Vietnam. The countries involved are Australia, Brunei, Cambodia, China, Philippines, Indonesia, Japan, Korea, Laos, Malaysia, Myanmar, New Zealand, Singapore, Thailand, and Vietnam. India, which was in the initial list of countries, withdrew from the agreement. This is the first trade agreement between Asia's three largest economies of China, Japan, and Korea. The members account for 30 percent of global population and 30 percent of global GDP.[25] The RCEP represents the world's largest (somewhat) free trading area. The agreement is expected to eliminate 90 percent of the tariffs for imports between member countries within 20 years.
- *Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP).* The trade agreement includes eleven countries: Australia, Brunei, Canada, Chile, Japan, Malaysia, Mexico, New Zealand, Peru, Singapore, and Vietnam, which came into force on December 30, 2018.[26] This agreement evolved from the original Trans-Pacific Partnership (TPP) after the United States left the group in 2017. The United Kingdom is currently seeking membership. The total member economies represent 13.4 percent of global GDP. The CPTPP together with the USMCA, EU, and RCEP represent the world's top four free trade areas.

## Competitiveness of Nations

A nation's competitiveness (in international trade) is defined by the Organization of Economic Cooperation and Development (OECD) as "a measure of a country's advantage or disadvantage in selling its products in international markets."[27] Competitiveness is considered to be a tool and an objective of economic policy. All things equal, a country with a higher competitiveness ranking would provide a better business climate for locating a facility than another country that is listed as less competitive. There are two competing sources for national competitiveness rankings. One is the *World Competitiveness Yearbook* published annually by the Swiss business school IMD, and the other is *The Global Competitiveness Report,* prepared by the World Economic Forum (WEF). According to Arturo Bris, Director, IMD Competitiveness Center, and Professor of Finance, "There is no single nation in the world that has succeeded in a sustainable way without preserving the prosperity of its people. Competitiveness refers to such an objective: it determines how countries, regions, and companies manage their competencies to achieve long-term growth, generate jobs, and increase welfare. Competitiveness is therefore a way towards progress that does not result in winners and losers: when two countries compete, both are better off."[28]

IMD's World Competitiveness Ranking features 63 economies and provides businesses with the basic information on location decisions. There are 337 criteria, which are broadly grouped into four competitiveness factors:

- *Economic Performance* (5 subfactors): "Macro-economic evaluation of the Domestic Economy, International Trade, International Investment, Employment, and Prices."
- *Government Efficiency* (5 subfactors): "Extent to which government policies are conducive to competitiveness: Public Finance, Fiscal Policy, Institutional Framework, and Business Legislation and Societal Framework."
- *Business Efficiency* (5 subfactors): "Extent to which the national environment encourages enterprises to perform in an innovative, profitable, and responsible manner: Productivity and Efficiency, Labor Market, Finance, Management Practices, and Attitudes and Values."
- *Infrastructure* (5 subfactors): "Extent to which basic, technological, scientific, and human resources meet the needs of business: Basic Infrastructure, Technological Infrastructure, Scientific Infrastructure, Health, and Environment and Education."

The 2020 World Competitiveness Ranking results provide an analysis of the data collected and ranks nations according to their abilities to create and maintain an organization's competitiveness. Data from the report can be used to compare countries globally, to see five-year trends, to understand strengths and weaknesses, and to examine factors and subfactors. In addition, businesses can use the yearbook to determine investment plans and assess locations for new operations. The top ten rankings from IMD are shown in Table 11.2. The United States is ranked tenth in 2020, behind Singapore and Denmark, the top two countries. Singapore's success can be attributed to its strong economic performance which comes from robust international trade and investment, employment, and labor market measures. In addition, Singapore has stable performances in both its education system and technological infrastructure with telecommunications and Internet bandwidth speed playing key roles. Denmark, ranked second, has a strong economy, labor market, and health and education systems. The country did very well in international investment and productivity, and is top in business efficiency in Europe.[29]

| Table 11.2 | IMD 2020 World Competitiveness Report[30] |
|---|---|
| **RANKING** | **COUNTRY** |
| 1. | Singapore |
| 2. | Denmark |
| 3. | Switzerland |
| 4. | Netherlands |
| 5. | Hong Kong SAR, Germany |
| 6. | Sweden |
| 7. | Norway |
| 8. | Canada |
| 9. | UAE |
| 10. | USA |

The World Economic Forum defines competitiveness as "the set of institutions, policies, and factors that determine the level of productivity of a country."[31] For the 2020 special report, the WEF paused comparative country rankings on the Global Competitiveness Index due to the pandemic. Instead, the special edition is "dedicated to elaborating on the priorities for recovery and revival, and considering the building blocks of a transformation towards new economic systems that combine "productivity", "people" and "planet" targets."[32] Please see the nearby SCM Profile for a brief summary report on their findings on how economies should look at the strategies for revival and transformation as they recover from the COVID-19 pandemic.

## SCM Profile — World Economic Forum Global Competitiveness Report[33]

The deep global economic downturn which was triggered by the COVID-19 pandemic has profound economic and social consequences. As such, the World Economic Forum (WEF) has decided to pause competitive country rankings based on the Competitiveness Ranking Index. Instead WEF prepared the 2020 Global Competitiveness Report to focus on how economies should look at the strategies for revival and transformation as they recover from the pandemic. One of the key findings regards reviving and transforming the enabling environment shown below:[34]

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- Before the crisis, a long existing issue was the ongoing and consistent erosion of institutions. The pandemic sped up digitalization in advanced economies and made catching up more difficult for developing countries that were lagging before the crisis. During the transformation phase, governments should ensure that public institutions have strong governance principles and to recapture public trust by serving their citizens better.

- Another concern before the crisis was the high levels of debt and widening inequalities in selected economies. The COVID-19 pandemic had resulted in emergency and stimulus measures that have increased already high public debt to unprecedented levels, while tax income has been decreasing. In the longer-term transformation stage, countries would have to adopt more progressive taxation policies, and rethink how corporations, wealth, and labor are taxed.

During the pandemic, some areas critically stalled or declined, while in others there was a marked improvement compared to previous trends. The top five areas that experienced the most movement downward in advanced economies were: competition in network services, collaboration between companies, competition in professional services, competition in retail services, and ease of finding skilled employees. In emerging economies, these five areas were: business costs of crime and violence, judicial independence, organized crime, extent of market dominance, and public trust of politicians. The top five areas that experienced the most upward movement in advanced economies were: government's responsiveness to change, collaboration within a company, venture capital availability, social safety net protection, and soundness of banks in advanced economies. In emerging economies these were: collaboration within a company, government's responsiveness to change, efficiency of train services, venture capital availability, and country capacity to attract talent in emerging economies.

The Executive Opinion Survey identified several common areas that helped countries better manage the impact of the pandemic on their economy and people. Business leaders generally agreed that the following have contributed to countries' resilience to the health crisis: 1) economic digitization and digital skills; 2) safety nets and financial soundness; 3) governance and planning; and 4) health system and research capacity. It is critical that countries build back better economies and return to growth that improves benefits for the people and the world.

In the more "normal" Global Competitiveness Report of 2019, 141 economies were examined, using what the WEF describes as their "12 Pillars of Competitiveness" to determine the rankings. These are briefly described below.

## The World Economic Forum's 12 Pillars of Competitiveness:[35]

1. Institutions—the legal and administrative framework.
2. Infrastructure—the transportation, telecommunications, and power networks.
3. ICT adoption—how readily the economy adapts to new technologies.
4. Macroeconomic stability—the stability of the macroeconomic environment is important for business and includes such issues as fiscal deficits, inflation rates, unemployment, and GDP growth rates.
5. Health—investment in health services and quantity and quality of basic education.
6. Skills—amount of secondary, tertiary, vocational, and on-the-job training in the workforce.
7. Product market—overall environment for exchange of goods.
8. Labor market—the environment for male and female workers.
9. Financial system—how resources are channeled to businesses.
10. Market size—the availability of domestic and international markets for firms.

11. Business dynamism—the quality of the overall business networks and quality of individual firms' operations and strategies.
12. Innovation capability—overall support for innovative activities.

Each indicator or pillar, is scored using a scale from 0 to 100, and shows how close an economy is to the ideal state or "frontier" of competitiveness. The scores are then combined across the twelve indicators. The top ten countries are shown in Table 11.3. As to be expected, comparing the two competitiveness reports finds a number of commonalities.

## Government Taxes and Incentives

Government incentives, business attitudes, economic stability, and taxes are important location factors. Several levels of government must be considered when evaluating potential locations. At the federal level, a *tariff* is a tax imposed by the government on imported goods to protect local industries, support the country's balance of payments, or raise revenue. Thus, countries with high tariffs discourage companies from importing goods into the country. At the same time, high tariffs encourage multinational corporations to set up factories to produce locally. However, membership in the WTO requires countries to open up their markets and to reduce the tariffs imposed on imported goods. Regional trade agreements such as the USMCA, MERCOSUR, and EU also serve to reduce tariffs among member nations to promote the free movement of goods. Many countries have set up *free trade zones (FTZs)* where materials can be imported duty-free as long as the imports are used as inputs to the production of goods that are eventually exported. If the goods are sold domestically, no duty is paid until they leave the free trade zones.

In the United States, as of 2021, 42 states have a broad-based personal income tax, and 44 states have a corporate income tax. For example, Nevada is a business-friendly state that does not have a corporate income tax, state personal income tax, corporate franchise tax, or inventory tax. Companies such as Amazon.com have taken advantage of this by setting up warehouses in Nevada. There are seven states that do not have an individual income tax.[37] New Hampshire and Tennessee have a limited income tax on individuals. These two states tax dividends and interest. Location incentives at the state and local government levels are also important. For example, China has been the dominant supplier of solar panels. However, First Solar, a U.S. company is trying to change that. They will be investing in a new $680 million state-of-the-art factory in Ohio to double its production capability of solar panels.

**Table 11.3 2020 WEF Global Competitiveness Report[36]**

| RANKING | COUNTRY |
|---|---|
| 1. | Singapore |
| 2. | USA |
| 3. | Hong Kong SAR |
| 4. | Netherlands |
| 5. | Switzerland |
| 6. | Japan |
| 7. | Germany |
| 8. | Sweden |
| 9. | United Kingdom |
| 10. | Denmark |

This factory will be the largest solar manufacturing complex outside of China.[38] The company is confident of receiving support from the U.S. government with trade tariffs and tax advantages.

## Currency Stability

One factor that impacts business costs and consequently location decisions is instability in currency exchange rates. Any organization involved with international business will be subjected to the risk of currency fluctuation. Exchange rate plays an important role in determining the cost of production in another country. For example, let's say a U.S. company has a factory in Vietnam. If the Vietnamese dong is devalued by 20 percent, this translates to a production cost 20 percent lower in U.S. dollars. Likewise, an increase in the exchange rate for the Vietnamese dong will result in a 20 percent higher production cost in U.S. dollars. Amazon.com, which does business globally, is exposed to foreign exchange rate fluctuations and risks associated with its international operations as presented in its 2020 10-K report as shown below on foreign exchange risk:[39]

> *During 2020, net sales from our International segment accounted for 27 percent of our consolidated revenues. Net sales and related expenses generated from our internationally-focused stores, including within Canada and Mexico (which are included in our North America segment), are primarily denominated in the functional currencies of the corresponding stores and primarily include Euros, British Pounds, and Japanese Yen. The results of operations of, and certain of our intercompany balances associated with our internationally-focused stores and AWS are exposed to foreign exchange rate fluctuations. Upon consolidation, as foreign exchange rates vary, net sales and other operating results may differ materially from expectations, and we may record significant gains or losses on the remeasurement of intercompany balances. For example, as a result of fluctuations in foreign exchange rates throughout the year compared to rates in effect the prior year, International segment net sales decreased by $2.4 billion in comparison with the prior year.*

## Environmental Issues

How the environment is managed has a significant impact on human health. The inability to dispose of solid and hazardous waste, plus the presence of illegal waste, contributes to high incidences of diseases such as hepatitis A and amebiasis. Global warming, air pollution, and acid rain are issues that are increasingly being debated as the price to pay for industrialization. Millions of people live in cities with unsafe air, with asthma cases at an all-time high. In response to rising environmental concerns, the Clinton Administration negotiated the North American Agreement on Environmental Cooperation (NAAEC) as a supplementary environmental agreement to NAFTA (now USMCA). The key objectives of the agreement are to "foster the protection and improvement of the environment in the territories of the Parties for the well-being of present and future generations" and "promote sustainable development based on cooperation and mutually supportive environmental and economic policies."[40] The agreement provides a framework for the three USMCA countries to conserve, protect, and enhance the North American environment and to effectively enforce environmental laws.

With trade liberalization, there is a need for environmental cooperation. The World Trade Organization agreement makes direct reference to sustainable development and the desire to protect and preserve the environment. The WTO members recognize that "their

relations in the field of trade and economic endeavor should be conducted with a view to raising standards of living, ensuring full employment and a large and steadily growing volume of real income and effective demand, and expanding the production of and trade in goods and services, while allowing for the optimal use of the world's resources in accordance with the objective of sustainable development, seeking both to protect and preserve the environment and to enhance the means for doing so in a manner consistent with their respective needs and concerns at different levels of economic development."[41] The WTO has an important role to play to achieve the UN's Agenda 2030 for Sustainable Development and collaborates closely with the UN's Department for Economic and Social Affairs to monitor progress towards attaining the Sustainable Development Goals (SDGs). The SDGs are listed below:[42]

- Goal 1. End poverty in all its forms everywhere
- Goal 2. End hunger, achieve food security and improved nutrition, and promote sustainable agriculture
- Goal 3. Ensure healthy lives and promote well-being for all at all ages
- Goal 4. Ensure inclusive and equitable quality education and promote life-long learning opportunities for all
- Goal 5. Achieve gender equality and empower all women and girls
- Goal 6. Ensure availability and sustainable management of water and sanitation for all
- Goal 7. Ensure access to affordable, reliable, sustainable, and modern energy for all
- Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment, and decent work for all
- Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
- Goal 10. Reduce inequality within and among countries
- Goal 11. Make cities and human settlements inclusive, safe, resilient, and sustainable
- Goal 12. Ensure sustainable consumption and production patterns
- Goal 13. Take urgent action to combat climate change and its impacts*
- Goal 14. Conserve and sustainably use the oceans, seas, and marine resources for sustainable development
- Goal 15. Protect, restore, and promote sustainable use of terrestrial ecosystems; sustainably manage forests; combat desertification; and halt and reverse land degradation; and halt biodiversity loss
- Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
- Goal 17. Strengthen the means of implementation and revitalize the global partnership for sustainable development

Consumers and nongovernment agencies are now pressuring multinationals to be more environmentally conscious. Global organizations are assessing their total environmental footprints by focusing on carbon and life-cycle analysis. The life-cycle approach looks beyond just the carbon footprint since it focuses on a cradle-to-grave analysis of how products and services affect the environment. Walmart for example, has a program to assist

suppliers in managing their energy and materials usage and carbon emissions, and now companies such as Procter & Gamble, IBM, and Pacific Gas & Electric have adopted this approach. See also the chapter-opening SCM Profile on Amazon where the company is investing heavily in electric vans to reduce its carbon footprint.

## Access and Proximity to Markets

Initially, many companies outsourced their manufacturing to China because of its cost competitiveness. However, as China's per capita income continues to rise, more and more companies are indicating that their main reason for being in China is to have access to the local markets rather than for export reasons. As such, many companies are now expanding into China not only to take advantage of the lower costs but also to access local markets. Likewise, Honda is a global company that aims to build plants in locations that best satisfy the needs of local customers. Honda has assembly plants in the United States, Japan, Malaysia, China, and Indonesia, to name a few markets where Honda sells its vehicles.

In the service industry, proximity to customers is even more critical. Few customers will frequent a remotely located gas station or a supermarket if another more accessible alternative is available. Similarly, fast-food restaurants are well situated next to busy highway intersections to take advantage of the heavy traffic. Walmart's early supercenters were located in predominantly rural markets to avoid direct competition with major discount stores in large metropolitan areas. Many regional chains, such as Jamesway, Bradlees, Caldor, Venture, and Hills went out of business because they were not competitive with larger and more efficient chains such as Walmart and Target. More recently, Walmart has changed its location strategy to include urban locations in the west and northeast regions of the United States. In China, Walmart's location strategy has focused more on downtown areas, where most of the customers are located. McDonald's, for example, is looking for the next big urban sprawl which indicates where their customers are likely going to be.

Ashley Furniture Industries, the largest home furnishings manufacturer, has a new plant in Advance, North Carolina, reversing the trend to move manufacturing to China. Ashley recognizes that speed in meeting customer demand is becoming more critical. The company is further expanding that facility by 1 million square feet to enhance its ability to serve consumers and retail customers along the East Coast, particularly in the Southeast.[43] While the company still sources items such as glass and mirrors globally, larger and heavier components and upholstery are made in the United States. Amazon.com has performed quite well in meeting customers' needs quickly. In this era of instant gratification and fast turnaround on product delivery, many companies are finding out that it is better to manufacture their products domestically. Ford is another manufacturer that has moved manufacturing of its F-650 and F-750 trucks from Mexico to an assembly plant in Avon Lake, Ohio. As a result, shipping costs are reduced due to proximity to market and manufacturing quality has improved. One of the reasons that Fuyao Glass Industry Group moved its plant from China to Ohio is to be close to its customers. Fuyao is a Chinese auto glass supplier with 20 percent of the global market share. "For our customers, they had the expectations that you will be located close to them for supply chain stability," Fuyao Chairman Cao Dewang (aka Cho Tak Wong) said. "If you ship from China, it is subject to all sorts of disruptions such as weather or shipping company delays."[44]

## Labor Issues

Issues such as labor availability, productivity, and skill; unemployment and underemployment rates; wage rates; turnover rates; labor force competitors; and employment trends are key labor factors when making facility location decisions.

Mexico has long competed on cheap labor but cannot continue to depend on this source of competitive advantage because of the emergence of lower labor cost countries like China. While China's labor cost is low compared to many countries, inflation and high economic growth has contributed to a sharp increase in wages there. Consequently, the apparel industry, which depends heavily on cheap labor, is beginning to see a shift in production from the "textile hub" in southern China to Vietnam or Cambodia because of the comparatively cheaper labor costs there.

Although it is true that low labor cost is an important factor in making location decisions, sustainable competitive advantage depends on productive use of inputs and continual product and process innovations. Singapore is an example of a country that first relied on cheap labor to attract foreign direct investments. Over time, Singaporeans were able to increase the level of worker skills and develop human resource capabilities. The country moved from a producer of low-cost goods to one making high value-added products.

## Access to Suppliers

Many firms prefer locations close to suppliers because of material availability and transportation cost reasons. The proximity of suppliers has an impact on the delivery of materials and, consequently, the effectiveness of supply chains. Japanese electronics makers are finding that China is a better place to set up manufacturing facilities even though it means the cost to transport finished products to the U.S. market is higher. The reason is that a high proportion of components needed to make finished electronic products are made in China. Apple's iPhones, for example, are produced mainly by Foxconn in China.

## Logistics Issues

The cost of logistics is an important factor to be considered in a location selection strategy. Ease and speed of transportation are other considerations. For example, goods destined for the northeastern United States from Asia have two options. Option 1 is to ship goods through the Panama Canal and unload in a New York or New Jersey port before being transported to a final destination. Option 2 is to ship to Los Angeles and transport by rail to a final destination. Option 2 is not only more cost effective but also faster. Please refer to the section on global logistics in Chapter 9 for more detailed discussions on this important issue. In other examples, the Suez Canal, which connects the Mediterranean Sea at the canal's northern end to the Red Sea in the south, has been an important waterway for a long time, because it is the shortest maritime route from Europe to Asia. Before that, ships heading for Asia had to embark on a taxing and time-consuming journey around the Cape of Good Hope at the southern tip of Africa. In 2021, a major logistics disaster happened when the Ever Given, a 400m-long (1,312ft) container ship, became wedged across the canal after running aground amid high winds. The blockage caused hundreds of ships to be stuck in the traffic jam causing a major disruption in global trade and millions of dollars in lost revenues for the Suez Canal Authority. The container ship was eventually refloated following a six-day salvage operation.[45] China's Belt and Road Initiative, launched in 2013, is a massive infrastructure project stretching from East Asia to Europe. The initiative involves an intricate network of railways, energy pipelines, highways, streamlined border crossings, a port in Pakistan, and bridges in Bangladesh, all with the aim of creating what China calls a "modern Silk Road" trading route to kick start a new era of globalization.[46]

## Utility Availability and Cost

The availability and cost of electricity, water, and gas are also important location considerations. In economically emerging countries, it is not unusual that the supply of electricity has not kept pace with the high speed of development, resulting in work stoppages due to electrical outages. Even developed countries, such as the United States, are not immune to energy problems, although for different reasons. The largest blackout in U.S. history occurred in 2003, with more than 50 million people without power in the Northeast, Midwest, and parts of Canada. The primary cause of the blackout was a software problem in the control room of the FirstEnergy Corporation in Ohio. Energy experts are concerned with the weakness of the U.S. power grid and predict that the United States could be one big catastrophic event away from a total power grid meltdown in the country.

In heavy industries, such as steel and aluminum mills, the availability and cost of energy are critical considerations. The concern for companies is to have the power available when needed, at an affordable price. Consequently, areas such as upstate New York, the Tennessee Valley, and parts of Canada, which provide low-cost power, are gaining in location popularity because of their plentiful energy supply. With the explosive growth in energy-intensive industries such as machinery, auto, and steel, demand for electricity has outpaced the generating capacity in China and the country has experienced power shortages in the past. However, the power generated by the Three Gorges Dam Project, completed in 2012, the world's largest hydropower complex, will help meet China's rapidly growing energy needs. With an increasing number of manufacturing facilities being added in China, the country must continue to invest in clean power-generating plants. China today is the world's largest producer and installer of solar power systems in the world. China's 14th Five-Year Plan, covering the period 2021–2025, was implemented beginning in March 2021.[47] China has set a target to be carbon-neutral by 2060.

## Quality-of-Life Issues

Quality of life can be defined as "general well-being of individuals and societies."[48] So what exactly are the issues affecting quality of life? While there is no definitive agreement on a set of **quality-of-life factors**, the Chamber of Commerce in Jacksonville, Florida for example, has annually prepared a report on the overall quality of life in the metropolitan area based on a comprehensive set of factors, which include the following:[49]

- *Achieving Educational Excellence:* Performance in terms of high-school graduation rates, college entrance test scores, teacher salaries, student–teacher ratios, and number of degrees awarded at universities and higher-education institutions provides an indicator of the quality of the education system.
- *Growing a Vibrant Economy:* Performance indicators such as net employment growth, new housing starts, and the unemployment rate show the economic health of the community. The economy must also be sufficiently diverse to allow for long-term careers for both spouses.
- *Preserving the Natural Environment:* Performance indicators include an air-quality index, average daily water use, and the amount of recycled waste diverted from landfills. A viable recycling program and clean air indicate a community's commitment to a green environment and the future health of the community.
- *Promoting Social Well-being and Harmony:* Performance indicators include whether racism is a problem, number of births to single mothers, volunteerism

rate, and homeless survey count. A community where people and organizations contribute time and money to helping others in need shows a happy, affluent, and caring environment.

- *Enjoying Arts, Culture, and Recreation:* Performance measures include the public and private support for the arts, number of public performances and events, and library circulation. A community that offers choice in terms of cultural, entertainment, recreational, and sporting activities is a more attractive location than one offering fewer of these options.
- *Sustaining a Healthy Community:* Performance indicators include the infant mortality rate, number of people without health insurance, cancer death rate, suicide rate, and new HIV cases. The ability to access good, affordable medical care provides residents with peace of mind and determines whether the community is a desirable place to live.
- *Maintaining Responsive Government:* Performance measures in this category include voter turnout, satisfaction rate with city services, number of neighborhood organizations, and a diverse and representative government. In the current economic situation, many state and local governments in the United States have been struggling to balance their budgets due to a slow growth economy and are considering cutting services and increasing taxes. This, in turn, will tend to negatively impact the quality of life.
- *Moving Around Efficiently and Safely:* This factor can be measured by indicators such as the average commute time to work, bus ridership, number of airport passengers, and the motor vehicle accident rate. If the roads are constantly jammed with traffic, this causes huge losses of productive time. The ability to travel easily within the area and to other locations affects the quality of life of the residents.
- *Keeping the Community Safe:* Performance indicators here include violent crime rate, percentage of people who feel safe in their neighborhood, people reporting being victims of crime, and the murder rate. In the United States, there has been a trend toward suburban living because of the perception of safer neighborhoods and, therefore, a better place to live.

## Right-to-Work Laws

In the United States, as of December 2020, there are 27 states with **right-to-work laws**. A right-to-work law "secures the right of employees to decide for themselves whether or not to join or financially support a union."[50] In the last few decades, there has been a shift in the U.S. auto industry to the South, with assembly plants built in Tennessee, South Carolina, and Alabama, all of which are right-to-work states. Dubbed the *Southern Auto Corridor,* this cluster represents a new era in U.S. auto manufacturing. The trend to locate in the sunny, incentive-friendly, nonunionized South will most likely continue to grow.

## Land Availability and Cost

As land and construction costs in most big cities continue to escalate, the trend is to locate in the suburbs and rural areas. Suburban locations can be attractive because of the cost and wide choice of land, available workforce, and developed transportation network. As mentioned earlier, when Honda first decided to set up a factory in the United States, it located in Marysville, a small town about 40 miles from Columbus, Ohio. Affordable

land near the highway was readily available, and Honda could draw its workforce from several communities around Marysville. Similarly, when Honda built its assembly plant in Alabama to meet the increased demand for its Odyssey minivans and sport utility vehicles, the site was located in Lincoln, 40 miles east of Birmingham. When Honeywell decided to move its manufacturing facility from Phoenix, Arizona, to China, the decision was to go to Suzhou, a city about 30 miles from Shanghai. Although the Pudong industrial zone in Shanghai was an attractive site, Suzhou had lower land and labor costs, which were deemed important decision factors.

While we have observed many U.S. manufacturers moving overseas to find cheaper production locations, one Chinese billionaire moved his operations to the United States. According to Cao Dewang, Chairman of Fuyao Glass, "a combination of cheap land, reasonable energy prices, and other incentives means that, despite higher manufacturing costs, he can still make more money by making glass in the United States than by exporting Chinese-made panes to the U.S. market."[51] Fuyao Glass invested more than $1 billion to open two U.S. factories in Moraine, Ohio and Plymouth, Michigan. The glass maker was able to acquire the former General Motors assembly plant in Ohio that had been vacant since late 2008 for $15 million and secured more than $10 million in tax credits and infrastructural enhancements from Ohio.[52]

## Facility Location Techniques

Two techniques that are commonly used by organizations to assist in making global location decisions are described here: the weighted-factor rating model and the break-even model. The two techniques are discussed below.

### The Weighted-Factor Rating Model

The **weighted-factor rating model** is a method commonly used to compare the attractiveness of several locations along a number of quantitative and qualitative dimensions. Selecting a facility location using this approach involves the following steps:

1. Identify the factors that are considered important to the facility location decision.
2. Assign weights to each factor in terms of their relative importance. Typically, the weights sum to 1.
3. Determine a relative performance score for each factor considered. Typically, the scores vary from 1 to 100, although other scoring schemes can be used.
4. Multiply the factor score by the weight associated with each factor, and sum the weighted scores across all factors.
5. The location with the highest total weighted score is the recommended location.

Since the factors, the individual weights, and the scores are subject to interpretation and bias by the analyst, it is highly recommended that a team approach be used when performing this type of analysis. Ideally, the team should include representatives from marketing, purchasing, production, finance, and transportation, and possibly a key supplier and customer impacted by the location.

Determining the scores for each factor can include several intermediate steps. Comparing a labor cost score, for instance, might include determining an acceptable wage scale, along with insurance, taxes, and training costs and any other associated labor costs for

each potential location. Then the total labor costs can be compared and translated into the final labor cost scores for each location by assigning the lowest-cost location the maximum score and then assigning the other locations a score based on their respective labor costs. Example 11.1 illustrates the use of the weighted-factor location model.

**Example 11.1 The Weighted-Factor Location Model**

The following factors have been identified as critical to making a location decision among three countries: China, Singapore, and Indonesia. A group of functional managers has determined the factors, weights, and scores to be used in the analysis.

| IMPORTANT LOCATION FACTORS | FACTOR WEIGHTS (SUM TO 1) | CHINA SCORES (1–100) | SINGAPORE SCORES (1–100) | INDONESIA SCORES (1–100) |
|---|---|---|---|---|
| Labor cost | 0.20 | 100 | 40 | 90 |
| Proximity to market | 0.15 | 100 | 60 | 80 |
| Supply chain compatibility | 0.25 | 80 | 80 | 60 |
| Quality of life | 0.30 | 70 | 90 | 60 |
| Stability of government | 0.10 | 80 | 100 | 50 |

To determine where the new facility should be located, the weighted scores for the three countries are calculated as follows:

China $= 0.20(100) + 0.15(100) + 0.25(80) + 0.30(70) + 0.10(80) = 20 + 15 + 20 + 21 + 8 = 84.$
Singapore $= 0.20(40) + 0.15(60) + 0.25(80) + 0.30(90) + 0.10(100) = 8 + 9 + 20 + 27 + 10 = 74.$
Indonesia $= 0.20(90) + 0.15(80) + 0.25(60) + 0.30(60) + 0.10(50) = 18 + 12 + 15 + 18 + 5 = 68.$

Based on the total weighted score, China would be the recommended country in which to locate the new facility.

## The Break-Even Model

The break-even model is a useful location analysis technique when fixed and variable costs can be determined for each potential location. This method involves the following steps:

1. Identify the locations to be considered.
2. Determine the fixed cost for each facility. The components of fixed cost are the costs of land, property taxes, insurance, equipment, and buildings.
3. Determine the unit variable cost for each facility. The components of variable cost are the costs of labor, materials, utilities, and transportation.
4. Construct the total cost lines for each location on a graph.
5. Determine the break-even points on the graph. Alternatively, the break-even points can be solved algebraically.
6. Identify the range over which each location has the lowest cost.

Example 11.2 illustrates the use of the break-even model.

**Example 11.2 The Break-Even Model**

Three locations have been identified as suitable candidates for building a new factory. The fixed and unit variable costs for each of three potential locations have been estimated and are shown in the following table.

| LOCATION | ANNUAL FIXED COST ($) | UNIT VARIABLE COST ($) |
|---|---|---|
| A | 500,000 | 300 |
| B | 750,000 | 200 |
| C | 900,000 | 100 |

Given a forecasted demand of 3000 units per year, the best location can be found by first plotting the three total cost curves, represented by

$$TC_A = 500{,}000 + 300Q$$
$$TC_B = 750{,}000 + 200Q$$
$$TC_C = 900{,}000 + 100Q$$

The three curves are shown in Figure 11.1.

Next, the break-even point between Location A and Location B is determined:

$$TC_A = TC_B$$
$$500{,}000 + 300Q = 750{,}000 + 200Q$$
$$100Q = 250{,}000 \text{ and then } Q = 2500 \text{ units.}$$

This indicates that producing less than 2500 units per year would be cheaper at Location A (when the lower fixed cost predominates), while producing more than 2500 units per year would be cheaper at Location B (when the lower variable cost predominates).

Next, the break-even point between Location B and Location C is determined:

$$TC_B = TC_C$$
$$750{,}000 + 200Q = 900{,}000 + 100Q$$
$$100Q = 150{,}000 \text{ and then } Q = 1500 \text{ units.}$$

This indicates that producing less than 1500 units per year would be cheaper at Location B, while producing more than 1500 units per year would be cheaper at Location C.

Finally, the break-even point between Location A and Location C is determined:

$$TC_A = TC_C$$
$$500{,}000 + 300Q = 900{,}000 + 100Q$$
$$200Q = 400{,}000 \text{ and then } Q = 2000 \text{ units.}$$

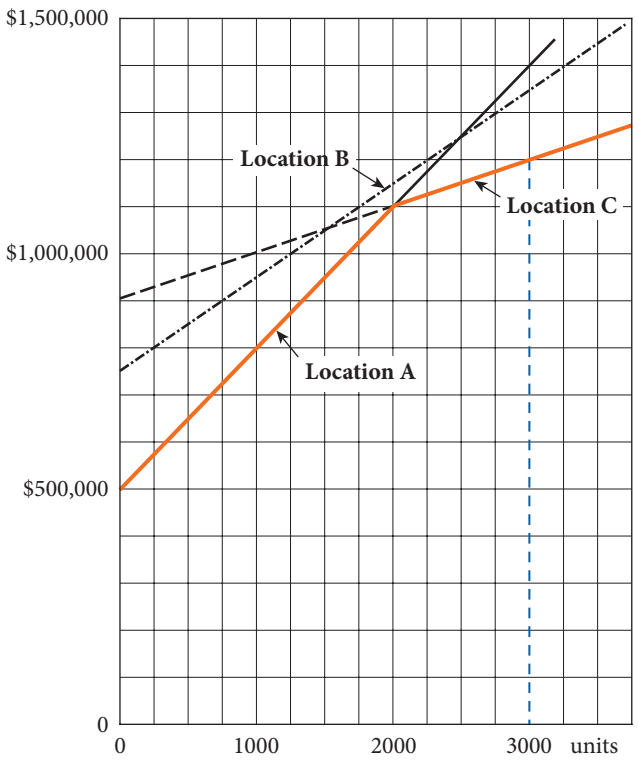
This indicates that producing less than 2000 units per year would be cheaper at Location A, while producing more than 2000 units per year would be cheaper at Location C (shown in red in Figure 11.1). Based on the cost curves shown in Figure 11.1, Location C has the lowest total cost when producing the forecasted quantity of 3000 units per year (shown by the dotted blue line in Figure 11.1). If, however, the annual demand forecast was 1000 units, then Location A would be preferred. From Figure 11.1, it can be seen that Location B would never be the preferred location when comparing the costs of all three sites simultaneously.

## Business Clusters

Over the last decade, a number of trends have dramatically impacted the facility location process. Markets are increasingly globalized due to the liberalization of trade, technological advances, and increased demand from many regions of the world. Countries compete against one another for foreign direct investment. Having the necessary information to compare countries across a multitude of factors will help managers make better location decisions. Today, more **business clusters** are being created globally. Research parks and special economic/industrial zones serve as magnets for business clusters.

The concept of business clusters represents a new way of thinking about location decisions, challenges conventional logic on how companies should be configured, and provides a different approach to organizing a supply chain. What exactly are these *business clusters?* According to Michael Porter, "clusters are geographic concentrations of interconnected companies and institutions in a particular field. Clusters encompass an array of linked industries and other entities important to competition."[53] Locating research and development, component manufacturing, assembly operations, marketing, and other associated businesses in one area can improve the supply chain, technology sharing, and information sharing.

**Figure 11.1** Break-Even Graph




There are different types of business clusters. First type is the high-tech clusters such as Silicon Valley in California, East London Tech City in England, and Paris-Saclay, in France. Another is the factor endowment clusters, which are created due to a competitive advantage arising from a geographic location.[54] Examples are the vineyards of Napa and Sonoma in California, Burgundy and Champagne in France and the Lombardy region in Italy, where good grapes can grow in the sunny countryside. Then we have the knowledge-service clusters that are found in many developing countries defined as "geographic concentrations of lower-cost technical and analytical skills serving rising global demand for commoditized knowledge services"[55] such as software engineering and other IT-based services. In developing countries, we also see the creation of low-cost manufacturing clusters involving auto production, electronics, and textiles. These clusters are typically well supported by foreign companies. A discussion of three of these countries follows:

- *Mexico:* Mexico has long been a hotbed for electronics manufacturers, with many located in cities such as Tijuana, Mexicali, Tecate, Chihuahua, Saltillo, Reynosa, and Guadalajara. Examples of major global companies operating in Mexico are IBM, Motorola, Hewlett-Packard, Siemens, Ericsson, Samsung, LG Electronics, Sony, and Panasonic. With the USMCA, goods can be exported duty-free to North America, allowing Mexico to become an electronics manufacturing center for the Americas. Mexico, for example, produces nearly one-quarter of the world's television receivers.

- *Taiwan:* Taiwan, dubbed the "Silicon Island" by *Forbes,* is a leading manufacturer of computer hardware and has the largest global market share for motherboards, modems, and scanners. Intel and Compaq are two major investors in Taiwan, due partly to the large pool of engineers possessing technical degrees.
- *India:* India is a major player in the software industry and country of choice for customized software development. India has the world's third-largest pool of scientific and technical personnel. India also provides a significant cost advantage due to its low labor cost. Companies such as IBM, Microsoft, Oracle, and Motorola have built facilities in India's silicon valleys: Bangalore, Hyderabad, and Mumbai.

There are many reasons why clusters are successful. One is the close cooperation, coordination, and trust among clustered companies in related industries. Another reason is the fierce competition for customers among rival companies located in the cluster. Companies are more productive in their operations because of access to the local supplier base, information, and technology. Companies are able to recruit from the local pool of skilled and experienced workers, thus reducing hiring costs. Due to the intensity of competition within the business cluster, peer pressure, and constant comparison among rivals, companies tend to respond quicker to customer needs and trends. Clusters thus provide the competitive environment that promotes increasing innovation and profitability.Not all clusters are successful. For example, Michigan suffered through plant closings and employee layoffs in the auto industry due to the industry's overreliance on gas-guzzling auto designs and the oil shock in the 1970s. The groupthink mentality among the cluster participants of General Motors, Ford, and Chrysler in Detroit made it more difficult for individual companies to try new ideas and see the need for radical innovation in fuel economy automobile designs.

## Sustainable Development and Facility Location

The World Commission on Environment and Development (the Brundtland Commission) defines **sustainable development** as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[56] Sustainable development is important because what we do today will affect future generations. The critical issues in sustainable development are energy consumption/production, air pollution, and climate change. These issues are strongly related to one another and need to be considered in an integrated manner and linked to economic, social, and environmental policies. As such, sustainable development will need fundamental changes in values and principles that influence development strategies and innovation. The increased global consumption of fossil fuels has increased global warming. In addition, prices of crude oil have continued to rise as demand has increased. More expensive oil translates to increased cost of production of goods and delivery of services. Ultimately, this is affecting supply chain costs. This calls for the development of cleaner, more fuel-efficient and affordable energy technologies as well as renewable energy technologies.

It is clear that industrial development is the engine for economic growth and eradicating poverty in emerging countries. However, resource efficiency and technology innovation are opportunities for reducing cost and increasing competitiveness and employment, issues that are central to managing an effective supply chain. Air pollution has serious impacts on human health, environment, and the economy. A related issue is climate change and preserving the world's ecosystem. Due to the importance of climate change, most countries joined an international treaty, the United Nations Framework

Convention on Climate Change (UNFCCC) "…to begin to consider what can be done to reduce global warming and to cope with whatever temperature increases are inevitable."[57] Several scientists reported that global warming caused by greenhouse gases has led to destabilization of the ice sheet in the West Antarctic glaciers. On December 12, 2015, parties to the UNFCCC reached a landmark agreement to combat climate change. The Paris Agreement on Climate Change is a binding agreement bringing all nations together on a common cause to implement ambitious plans to fight **climate change** and adapt to its effects. Its goal is to "limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels. To achieve this long-term temperature goal, countries aim to reach global peaking of greenhouse gas emissions as soon as possible to achieve a climate neutral world by mid-century."[58] The United States left the Paris Agreement on Climate Change a few years ago but has rejoined in 2021.

Another project with environmental implications is the Keystone XL pipeline, which is projected to move heavy oil sands oil from Alberta, Canada to the U.S. Gulf Coast. Environmentalists have been fighting to stop this controversial project because of the impact that processing this Canadian heavy oil might have on climate change and public health in the event of oil spills. Supporters of the project argue that jobs will be created and that the Alberta oil will be extracted and transported to markets whether the Keystone XL pipeline is built or not. The project has stirred years of heated debate. Former U.S. President Trump revived the Keystone XL Pipeline and Dakota Access Pipeline projects after they were rejected by former President Obama. Currently, oil companies are processing this oil and moving it using trucks and trains, which are also argued to be creating high levels of greenhouse gases, along with oil spills. When President Biden became President in 2021, he issued an executive order to once again stop the project.

Tesla was the first company to mass-produce electric cars. Today the term EV (electric vehicles) is very much in the news. Tesla leads the way in electric cars but all the major auto manufacturers such as GM, Ford, Stellantis (formerly Chrysler and Fiat Chrysler), Volkswagen, Mercedes, Volvo, and BMW are ramping up their efforts in developing electric cars. One of the biggest challenges is the mileage of the cars before a charge is needed. Developing longer lasting batteries is the key. Access to charging stations is another critical issue. Volvo aims to have fully electric cars making up to 50 percent of their sales by 2025. Volkswagen has also announced that 70 percent of sedan and SUV sales in Europe will be totally electric by 2030.[59] GM is committed to 30 new global electric vehicles by 2025. Mary Barra, Chair and CEO of GM said, "Climate change is real, and we want to be part of the solution by putting everyone in an electric vehicle."[60] Meanwhile, hybrid and plug-in hybrid cars such as the Toyota Prius are becoming more popular.

A similar term, **green development**, has been used to describe environmentally friendly development. The difference between green development and sustainable development is that green development "prioritizes what its proponents consider to be environmental sustainability over economic and cultural considerations."[61] An example would be the installation of a state-of-the-art waste treatment plant with a very high maintenance cost in a poor country. Due to the high maintenance cost, the ideal plant from an environmental standpoint may not be sustainable and likely will be shut down. From a sustainable development perspective, it would be acceptable to have a less effective environmental technology but one that can be maintained by the users of the equipment. When decision makers consider both economic and social issues in addition to environmental concerns, then sustainable development is more logical.

## Additive Manufacturing and Its Impact on Facility Location

New technology developed recently may well change the landscape for manufacturing (see the nearby SCM profile on reshoring of shoe manufacturing in the US). **Additive manufacturing** or **3D printing** is a "process of making a three-dimensional solid object of virtually any shape from a digital model."[62] The technology was first developed by MIT, and funded by grants from the Office of Naval Research and the National Science Foundation. Production using a 3D printer involves laying down a very thin layer of stainless steel or ceramic powder and using liquid binder to fuse the different layers to form the final product. The technology is applicable to wide range of industries such as defense, aerospace, automotive, medical, and metals manufacturing. Initially, 3D printing was used for rapid prototyping, but new developments make it possible for use in actual production. Benefits of additive manufacturing include shorter lead times, mass customization, reduced parts count, more complex shapes, parts on demand, efficient material use, and lower energy consumption. The National Additive Manufacturing Innovation Institute (NAMII) in Youngstown, Ohio, has been rebranded to America Makes, which is "the nation's leading and collaborative partner in AM (Additive Manufacturing) and 3DP (3D Printing) technology research, discovery, creation, and innovation." The organization is working to accelerate AM and 3DP to increase the nation's global competitiveness.[63]

### SCM Profile — Challenges of Reshoring Shoe Manufacturing in the US

Andrea Quintero Olivas/Shutterstock.com

Today, 99 percent of shoes sold in the United States are manufactured overseas in countries such as China, Vietnam, and Indonesia. Adidas built its first robotic shoe manufacturing factory, known as a Speedfactory, in Ansbach, Germany in September 2016. They opened a second Speedfactory near Atlanta in 2017. Using Speedfactories, a pair of shoes can be produced in about five hours. With a typical Asian factory, the supply lead time including the shipping to Europe is more than a month. Surprisingly, Adidas ceased all production at its two Speedfactories in 2020.[64] Robots were used to replace human workers to improve savings and efficiency. While robots are a powerful automation tool to have, they are also difficult to quickly reconfigure and reprogram the robotic arms and computer vision systems for new designs. With the Speedfactories, Adidas was limited by the number of shoe models it could produce, which was a big problem. The company appeared anxious to return production to Asia since the know-how and suppliers are located there.

Reebok (owned by Adidas) is looking to change the way shoes are being made. Reebok used 3D printing to produce the Liquid Speed running shoes in a factory in Rhode Island in 2017. According to Bill McInnis, head of development for Reebok, "Every shoe from every brand is created using molds—an expensive, time-consuming process. With Liquid Factory, we wanted to fundamentally change the way that shoes are made, creating a new method to manufacture shoes without molds."[65] The production process involves using proprietary

liquid resin to create the outer sole by building one layer at a time. McInnis said, "The Liquid Factory process is very flexible in that each machine can be used to create as many different concepts as imagination allows—it's programming, not molds. Scaling up is a matter of installing more Liquid Factory machine setups. The local manufacturing also gets us much closer to the consumer in terms of speed to market."[66] Since molds are unnecessary, the Liquid Factory can be built anywhere to meet the market demand. According to Chau Nguyen, Market Segment Manager for Footwear, PM North America, BASF, "the point of automation is to shorten the production cost and enable that automation. So instead of a person sitting there and putting a sole on, they were able to dispense it in 3D on the part itself—that saved a lot of time."[67] Reebok's Liquid Factory is an example of how technological innovations can bring manufacturing back to the United States.

Digital dentistry is one growth area for the technology where dentists use 3D printers to build teeth, dentures, braces, and implants in-house. Joseph DeSimone, CEO of Carbon 3D, explained that "dentists can now print a tooth in 6.5 minutes."[68] In digital dentistry, there is no need to make physical impressions. Dentists can use intraoral scanners to provide a full view of the anatomy of the mouth, jaws, and teeth, and allow accurate models to be built by 3D printers that fit with high accuracy, minimum discomfort, and beautiful cosmetics. 3D printers enable on-site production at the dental clinics, which is faster, more economical, and predictable than ordering the implant from an outside vendor.

The affordability of 3D printers could keep businesses from going overseas for their manufacturing needs or bring manufacturing back to the United States. Another aspect of 3D printing is speed. For example, Reebok is building the Liquid Factory in Rhode Island that uses 3D printing to make shoes. Reebok is able to create and customize the design of shoes in real time and to achieve a new speed in making shoes.

A small business or an entrepreneur (such as a dentist) can now afford to have its own little factory. However, major companies are experimenting with 3D printers, which will likely move the technology closer to the mainstream market and make the technology even more affordable. Shown below are three prime examples of major companies using 3D printers to create new products, improve old ones, and improve their business processes:

- **General Electric**

  General Electric, the world's largest manufacturer, is an early adopter of 3D printing. They have recently introduced the "brilliant factory" concept, which is "a sophisticated factory that combines lean manufacturing, advanced and additive manufacturing with advanced software analytics to enhance productivity."[69] Manufacturing has evolved from the Industrial Revolution where the assembly line was introduced. Today, with the emergence of 3D printing, we are seeing more and more innovations in the manufacturing industry. According to Philippe Cochet, SVP & Chief Productivity Officer, General Electric, "Additive manufacturing, or 3D printing, is another piece that was in its infancy just 10 years ago, but represents an enormous area of opportunity for manufacturing. Additive technologies allow us to create parts with precision and efficiency to a degree previously unheard of, create new types of parts that were previously impossible to produce, and reduce waste during production by using only the raw materials needed. These advancements will swing the pendulum back to domestic sourcing in the United States"[70]

- **Boeing**

  The airline company was an early adopter of 3D printing technology. It has been reported that Boeing has more than 20,000 3D-printed plastic parts used in their aircraft. Recently, Boeing announced they have hired the Oxford Performance Materials company to make 600 3D-printed parts for its Starliner space taxis. "Oxford's parts will help Boeing lower costs and save weight on each seven-seat capsule, compared with traditional metal and plastic manufacturing," said Larry Varholak, president of Oxford's aerospace business.[71] The Guinness World Records has certified that the world's largest 3D-printed object measuring 17.5 feet long, 5.5 feet wide, and 1.5 feet tall is a wing trim that will be used in the forthcoming Boeing 777X airplane. The 3D object is made by the Oak Ridge National Laboratory, one of Boeing's research partners in the United States.

- **Reebok**

  Reebok's Liquid Factory based in Rhode Island uses 3D Printing to produce its high-end shoes. For more information on the Liquid Factory, please see the nearby SCM Profile. It allowed Reebok to produce shoes in the United States, which in the past were made mostly in Asian factories. According to McInnis, head of development for Reebok, "The next generation of Liquid Factory products will be even more innovative, as we can create the entire shoe using the Liquid Factory process—outsole, cushioning and upper fit systems—the whole shoe. We are looking forward to bringing many more products to market that incorporate the ground-breaking Liquid Factory process."[72]

## COVID-19 and Its Impact on Global Location Strategies

The pandemic has greatly impacted lives and businesses globally. Many employers are wondering what effects the pandemic will have on the workforce and industries in the future. IBM's report on "Global Location. Trends: 2020 Special Edition" notes the following:[73]

> *For decades, technology and global trade agreements have enabled organizations to locate components of their operations where they can find the best mix of quality resources while optimizing total operating cost. Location strategy was like chess, with organizations selecting locations with the greatest value proposition for a specific business function. Freedom of movement of people, goods, and services was relatively unrestricted.*

The pandemic quickly changed everything as ports closed, planes were grounded, businesses were shuttered, workers were sent home, and many countries partially or fully closed their borders. The saying, "business location as usual," is no longer true. As a result of the pandemic, many companies are expected to increase the use of digital technologies and automation in the future. The digital transformation effort is expected to have an impact on the company's global operating footprints. IBM's report indicates a greater focus on availability of skills as a location criterion, implying that digital technologies and automation will likely alter skills requirements instead of replacing the requirement for talent. As a result of digital technologies and automation, workforces will be required to develop new skills.[74]

Two other issues that rise to the top are supply chain diversification and risk mitigation. New questions emerge regarding consolidation (few suppliers) versus diversification (many suppliers). (See Chapter 2 for more discussion on this issue). Now, with the pandemic at the forefront of corporate location risk considerations, companies will have to reevaluate the benefits and risks of a consolidated footprint. The conventional argument for consolidation is that having fewer locations makes it easier to manage employees, build culture, and reduce costs. However, geographic diversification also helps companies reduce the risk of disruptions to business operations.

## Summary

Facility location decisions can provide organizations with a competitive advantage and, therefore, must be an integral part of their overall strategic plans. The effectiveness of a supply chain is influenced greatly by facility locations. Increased globalization and improved technologies have resulted in a variety of options for companies to locate their facilities. Today, companies must consider a number of factors when analyzing potential locations; several comparison methods are available when considering the country, region, and community for a facility location. Business clusters often provide for strong business development, collaboration, growth opportunities, and improved supply chain management. The existence of successful clusters suggests that innovation and competition are concentrated geographically. China today represents an attractive location for many of the world's top companies due to its inexpensive labor and huge market potential. There has been much discussion about sustainable development and the greening of supply chains and their effect on global location decisions. Emerging technologies such as additive manufacturing or 3D printing will have a major impact on how companies view manufacturing and where they locate production facilities. Finally, the pandemic has caused companies to reevaluate their location strategies.

## Key Terms

**3D printing,** 491

**additive manufacturing,** 491

**Association of Southeast Asian Nations (ASEAN),** 473

**business clusters,** 487

**climate change,** 490

**Common Market for Eastern and Southern Africa (COMESA),** 473

**contributor factory,** 471

**Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP),** 473

**European Union (EU),** 473

**green development,** 490

**lead factory,** 471

**United States-Mexico-Canada Agreement (USMCA),** 473

**offshore factory,** 471

**outpost factory,** 471

**quality-of-life factors,** 483

**Regional Comprehensive Economic Partnership (RCEP),** 473

**right-to-work laws,** 484

**server factory,** 471

**source factory,** 471

**Southern Common Market (MERCOSUR),** 473

**sustainable development,** 489

**weighted-factor rating model,** 485

**World Trade Organization,** 472

## Discussion Questions

1. What is the impact of facility decisions on a supply chain?
2. Why is demand management important for effective supply chain management?
3. What are business clusters? Provide several examples of business clusters in a variety of countries. What are the advantages of clustering?
4. What are the factors influencing facility location?
5. Discuss the major regional trade agreements in Asia, Africa, Europe, Latin America, and North America.
6. What is the World Trade Organization, and what is its role in world trade?
7. What are the critical factors in making community and site decisions?
8. Discuss Walmart's location strategy.
9. Discuss Amazon's global facilities network.

10. Define *quality of life*. Why is quality of life an important factor in facility location? Is the set of quality-of-life factors used by the Chamber of Commerce in Jacksonville, Florida, a good one? Please explain.
11. What is a right-to-work state? What are the advantages or disadvantages of doing business in a right-to-work state?
12. Why is China an attractive location for many businesses?
13. What are the challenges of doing business in China?
14. Discuss the six strategic roles of a foreign facility.
15. What is sustainable development, and why is this policy important to a country and the world at large?
16. What is the difference between green development and sustainable development?
17. Explain why 3D printing may lead to a revival of manufacturing in the United States.
18. Provide examples of major U.S. companies that are using 3D printing and explain why they are reshoring their manufacturing back to United States.
19. How has the pandemic affected location decisions?

## Essay/Project Questions

1. Go to the website of IMD—World Competitiveness Yearbook at http://reports.weforum.org/global-competitiveness-index/#topic=data. Select any region of the world such as Africa and Middle East, Americas, Asia and Pacific, and Europe and Eurasia. Prepare a report showing the regional highlights and include a performance overview of selected countries in the region.
2. Go to the World Economic Forum website at http://www.weforum.org/. Select "Initiatives" from the top menu. Then select "Shaping the Future of Production." Based on the articles presented in the website, prepare a report discussing how emerging technologies will transform production systems, business models, and sustainability.
3. Go to the website of the World Trade Organization at www.wto.org. Click on the menu item "Documents, data, and resources" and select the option on "Economic research." Under "Publications" select the latest World Trade Report. Explain the key findings of the report and the changing landscape of international trade and the emergence of global value chains.
4. Go to the website of the U.S. Commercial Service at https://www.export.gov/ccg. First, select a country you wish to study. Based on the country commercial guide, prepare an assessment of the suitability of the country for doing business in the particular industry you wish to study.
5. Go to the website http://www.reshorenow.org/, and prepare a report on why U.S. companies should move manufacturing back to the United States.
6. What is the future of electric vehicles? Research the Internet and discuss the plans of the major auto manufacturers.
7. Research the *Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP)* on the Internet. What are the advantages and disadvantages of the United States withdrawing from this trade agreement?

# Problems

1. The Soft Toys Company has collected information on fixed and variable costs for four potential plant locations.

| LOCATION | ANNUAL FIXED COST ($) | UNIT VARIABLE COST ($) |
|---|---|---|
| A | 200,000 | 50 |
| B | 300,000 | 45 |
| C | 400,000 | 25 |
| D | 600,000 | 20 |

   a. Plot the total cost curves for the four plant locations on a single graph.

   b. Find the break-even points and determine the range of demand for which each location has a cost advantage.

   c. The sales manager predicts that demand will be 30,000 units. Which facility is best for the predicted demand?

2. The Vienna Company has identified four locations to set up a new production facility. They have determined the fixed and variable costs associated with each location as follows:

| LOCATION | ANNUAL FIXED COST ($) | UNIT VARIABLE COST ($) |
|---|---|---|
| Philadelphia | 10,000 | 6 |
| Atlanta | 30,000 | 5 |
| Miami | 60,000 | 4 |
| Houston | 70,000 | 7 |

   a. Plot the total cost curves for the three plant locations on a single graph.

   b. Find the break-even points and determine the range of demand for which each location has a cost advantage. Which city has no cost advantage at all?

   c. Which plant location is best if demand is i) 40,000 units, ii) 15,000 units?

3. Amazing is looking to open up a new fulfillment center as part of their expanding network to meet faster delivery needed for their prime customers in California. To assist the company in deciding where to locate this new fulfillment center, three sites have been identified with the information shown below.

| CRITICAL LOCATION FACTORS | FACTOR WEIGHT (SUM TO 1) | CITY OF INDUSTRY SCORES (1–100) | ONTARIO SCORES (1–100) | SAN BERNARDINO SCORES (1–100 ) |
|---|---|---|---|---|
| **Labor availability** | 0.10 | 85 | 90 | 70 |
| **Proximity to market** | 0.25 | 100 | 80 | 80 |
| **Supplier base** | 0.20 | 90 | 100 | 95 |
| **Taxes** | 0.20 | 80 | 70 | 80 |
| **Utilities** | 0.10 | 85 | 85 | 75 |
| **Transportation** | 0.15 | 90 | 75 | 85 |

   Which site would be best for the fulfillment center?

4. The Gamecock Brewery is planning to build another brewery for the expanding U.S. market. The company has identified five critical location factors and their relative weights. The scores for each of the three potential sites are shown in the following table. Which site should be selected for the new brewery?

| CRITICAL LOCATION FACTORS | FACTOR WEIGHT (SUM TO 1) | COLUMBUS SCORES (1–100) | LAS VEGAS SCORES (1–100) | CARSON SCORES (1–100) |
|---|---|---|---|---|
| **Labor cost** | 0.10 | 70 | 90 | 50 |
| **Proximity to market** | 0.25 | 100 | 90 | 80 |
| **Supplier base** | 0.20 | 80 | 100 | 70 |
| **Quality of life** | 0.30 | 90 | 60 | 60 |
| **Taxes** | 0.15 | 60 | 80 | 90 |

# Cases

## 1. Quigley Global Transportation*

Queenie Quigley is a very successful entrepreneur. She grew up in an ocean port city and loved the sea. Her father was a commercial fisherman and often took her with him during the summer. Her love for the sea triggered an interest in international shipping. Queenie knew that an ocean transportation business would provide services that would always be needed, and she eventually created a large, successful ocean transportation company.

Queenie understands that her transportation company has to be located at major shipping ports to get the best contracts. Often her clients want to board the ship and look around to see how their cargo will be handled and stored. While those types of clients are not frequent shippers, they are willing to pay a premium price to ensure their goods get to the distant locations undamaged. A brief tour aboard one of the Quigley Global Transportation vessels appears to instill confidence and trust.

Quigley Global Transportation currently has ships stationed in the following ports: Hong Kong; Rotterdam, Netherlands; Los Angeles, USA; New York-New Jersey, USA; Santos, Brazil; and Ambarli, Turkey.[1] These ports were rated as number 5, 11, 19, 23, 39, and 48 out of the top 50 worldwide in 2015.[1] Queenie believes her selection of these ports was a crucial factor in her company's success. As the old adage goes, it is all about location, location, location. These ports gave Quigley Global Transportation a set of locations that enabled her company to serve all major areas of the world—North America, South America, Europe Middle East, and Asia. However, Queenie knew there were still many opportunities for business if she could expand into other major ports.

One key criterion was the twenty-foot equivalent unit or TEU. The TEU is a common unit of measure, even though it is an inexact unit of measure. The unit basically describes the common shipping container that is 20 feet by 8 feet by 8 feet. Ports are rated by the volume shipped through them each year, in millions of TEU. Obviously, from the perspective of potential business Queenie's company could obtain, total TEU handled per year is her number one criterion for selecting the next port. In the past, Queenie's expansion strategy was based on opportunities that gained her access to a major continent. She had sought out contracts that she knew would lead to a foothold in a port. However, now that Quigley Global Transportation was on solid footing, Queenie wants to develop selection criteria

*Written by Rick Bonsall, D. Mgt., McKendree University, Lebanon, IL. The people and institution are fictional and any resemblance to any person or any institution is coincidental. This case was prepared solely to provide material for class discussion. The author does not intend to illustrate either effective or ineffective handling of a managerial situation.

that are more robust. She decided to use the weighted factor rating model as her selection tool for the next port. She is still convinced that TEU should be the number one criterion. Although she has four other factors shown in the table below, Queenie has not decided on their importance. She thought if she looked at her current ports through that criteria it would help her decide on how to weight the criteria going forward.

| COUNTRY | PORT RANKING BY TEU[1] (1 = BEST) | EASE OF DOING BUSINESS BY COUNTRY[2] | GDP GROWTH BY COUNTRY—2016[3] | GETTING CREDIT BY COUNTRY[2] | ENFORCING CONTRACT BY COUNTRY[2] |
|---|---|---|---|---|---|
| Brazil | 39 | 123 | −3.3% | 101 | 37 |
| Hong Kong, China | 5 | 4 | 1.4% | 20 | 21 |
| Netherlands | 11 | 28 | 1.7% | 82 | 71 |
| LA, USA | 19 | 8 | 1.6% | 2 | 20 |
| NY, USA | 23 | 8 | 1.6% | 2 | 20 |
| Turkey | 48 | 69 | 3.3% | 82 | 33 |

## Discussion Questions

1. Queenie has a very challenging task ahead of her. As stated, she didn't use any selection system for the first six ports except that she secured a contract with a client and then built that into a foothold in that port. Queenie wants a more effective selection system moving forward. Her first criterion is still TEU and she plans to weight it at 30 percent on a scale of 0–100 percent No two criteria can have the same weighting; Queenie wants some sort of distinction between each one. What is your recommendation for weighting the other four criteria? Why did you weight each one as you did? Explain the logic of your weighting.

2. Queenie wants to expand her business into Africa. Based on her initial analysis there are no ports large enough in many African countries to make them viable by themselves. However, transporting goods from another port to African ports would be a sound business move. Queenie had her staff provide a list of five ports that could be used to serve Africa. Using the recommendation you provided her for the weighting-factor model and the chart below, select the best port for Quigley Global Transportation.

| COUNTRY | PORT RANKING BY TEU[1] (1 = BEST) | EASE OF DOING BUSINESS BY COUNTRY[2] | GDP GROWTH BY COUNTRY—2016[3] | GETTING CREDIT BY COUNTRY | ENFORCING CONTRACT BY COUNTRY |
|---|---|---|---|---|---|
| United Arab Emirates | 44 | 28 | 2.3% | 101 | 25 |
| Sri Lanka | 28 | 110 | 5.0% | 118 | 116 |
| Saudi Arabia | 36 | 147 | 1.2% | 82 | 105 |
| Malta | 49 | 132 | 4.1% | 139 | 58 |
| Spain | 33 | 85 | 3.1% | 62 | 29 |

3. Review the locations of the ports listed in question two (using the World Fact Book[3] can help). Keeping the TEU as criterion number 1, which of the other criteria would you change to enhance the selection process? Think in terms of the African question. What factors would be better criteria from a business and supply chain perspective? Explain your reasoning.

[1]http://www.worldshipping.org/about-the-industry/global-trade/top-50-world-container-ports

[2]World Bank Doing Business – www.doingbusiness.org

[3]World Fact Book – https://www.cia.gov/library/publications/the-world-factbook/index.html

## 2. Pittman's Fireplaces*

Percy Pittman recently took over the family business. Pittman's Fireplaces has been in business since 1922. It was started by Percy's grandfather and then passed on to Percy's father. The business has thrived. They install fireplaces throughout the United States. In addition to the fireplaces, Pittman's Fireplaces sells all the accessories you can imagine to make your fireplace the centerpiece of your room.

Percy wants to take the business to the next level, and go international. The reputation of Pittman's Fireplaces is excellent. They have installed many fireplaces in the homes of diplomats who are representing their countries in the United States. Furthermore, many international businessmen who keep homes in New York, Los Angeles, Chicago, and other large U.S. cities, have purchased Pittman's fireplaces and accessories.

As Percy ruminates about how to proceed with his business expansion, he considers the following points. One, he would need to consider labor. What skills must a worker have and what skills can Pittman train them on? Another consideration is wages. Percy believes in paying a fair wage for a fair day's work; however, labor costs are a huge expense in any business. Materials are another critical factor for Pittman's Fireplaces. Percy sources the finest wood, marble, granite, and other types of stonework for their fireplaces. The final consideration is the local environmental laws. Pittman's Fireplaces sells gas burning fireplaces, wood burning fireplaces, and electric fireplaces. The rules, regulations, and laws are often different in cities, counties, and states. Percy assumes he will encounter the same situation in foreign countries.

Percy decides he will investigate three countries, United Kingdom, Germany, and Finland. His initial criteria for his weighted factor model are labor costs, weather (cold winters), environmental laws, and trade agreements with the United States. However, as Percy continues to ponder the best factors, he isn't yet sure which are the best ones to use as location selection criteria. The wrong set of criteria could result in selecting the wrong country for his foreign expansion.

### Discussion Questions

1. Percy is investigating several tools to help him make his decision as to which country he should expand into first. He thinks that these tools may also guide him in deciding which specific factors he should use to evaluate the three countries, United Kingdom, Germany, and Finland. Percy is reviewing both the 2016 Global Competitiveness Report and the 2016 World Competitiveness Yearbook. Clearly, in both documents the three countries are rated significantly different. Obviously, this is a critical decision for the future of Pittman's Fireplace. As a businessperson what is your opinion regarding of the two references Percy should use? Explain your answer.

2. Percy has decided that he will not have more than five factors as part of his weighted factor model. Currently, he is thinking of four factors—labor costs, weather, environmental laws, and trade agreements with the United States. However, when he was originally pondering the situation he thought along these lines—labor-skill set, labor-wages, material sourcing, and environmental laws. Based on the case, do you believe the final four are the absolute best four for Percy to select, or should he go with his original four, or some different ones? Explain why you agree or disagree with him. Justify your views either way. In addition, what should be the fifth factor?

*Written by Rick Bonsall, D. Mgt., McKendree University, Lebanon, IL. The people and institution are fictional and any resemblance to any person or any institution is coincidental. This case was prepared solely to provide material for class discussion. The author does not intend to illustrate either effective or ineffective handling of a managerial situation.

3. Assume that Percy has selected Finland as the best location to begin his international expansion. Now, Percy begins to put costs together. He forecasted 7000 fireplaces per year. Calculate the breakeven points for the three countries. Should Percy still go with Finland, or should he select another country? If the forecast was 5000 should Percy ignore the weighted factor model? Explain why or why not?

| LOCATION | ANNUAL FIXED COST ($) | UNIT VARIABLE COST ($) |
|---|---|---|
| Finland | $550,000.00 | $180.00 |
| Germany | $450,000.00 | $200.00 |
| United Kingdom | $400,000.00 | $220.00 |

## 3. O'Leary Management Solutions*

Mary O'Leary is an extremely successful management consultant. Mary worked for several large corporations in various roles before starting her consulting business. Mary's forte is using long established management concepts and applying them in innovative ways. Consequently, Mary is a much sought after consultant. As the years have passed, Mary has hired other very talented people and trained them in her approach.

Currently, O'Leary Management Solutions is located is New York. However, her company of consultants travels all over the United States. At last count, they consulted in 32 states on a routine basis. Technology helps limit some of the travel. Conferences calls, email, and transferring files using the cloud all help O'Leary work closely with their clients, while being efficient with their own time management.

As Mary reviews her company's current status and looks toward its future she wonders if it is time to open a second office location. Although technology helps, Mary is a big believer in hands-on consulting. Her experience tells her that meeting people face to face, when trying to find a solution to their issues, is crucial. That is getting more and more difficult to do, particularly in states closer to the west coast.Mary plans to address this idea with her staff, but in the meantime, she did some personal brainstorming about what factors she should consider when choosing a second location. Her employees were all high powered, highly educated, successful people, many who have families. All enjoy their time off, although they don't get much of that. Although government regulations weren't a big concern, taxes for her company and employees were. Mary felt it was best to think long term and anticipate further growth, such as what new states could be future markets. One key marketing factor for O'Leary is being located in the high rent section of the business district. This is as important as her employees being well groomed and well dressed. First impressions often sealed the deal.

Mary eventually decides that opening a second office is a must. She schedules a meeting with her staff for next Thursday and plans to explain why they are opening another office and share her thoughts about the selection criteria. Also, she plans to get their feedback on what would be the best location selection criteria since some of them will have to move there.

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### Discussion Questions

1. The textbook lists 11 major community factors to use as selection criteria for choosing a location. Mary realizes that all factors are important; however, 11 are too many because it waters down the effect of each factor's weight. Therefore, Mary wants no more than five major factors. Based on the information in the case, which factors should Mary and her staff choose? Explain why the specific factors you picked are pertinent to Mary's company.
2. Building on question one, weight the five factors you choose for O'Leary Management Solutions. Mary has expressed that she does not want any two factors with the same weight. Explain why you rated them as you did, that is, why one criterion is more or less important than another.
3. Mary is thinking that quality of life may be one of the factors they should pick. However, it is much too general a term to be a good indicator of the best location. Therefore, she believes it would be best to create a weighed factor rating matrix just for quality of life. Each location can be looked at through that specific criteria as well and the score each receives can then put inputted into the broader selection matrix. There are nine quality of life factors listed in the textbook. This time, Mary wants no more than four for this sub-weighted factor rating analysis. Which four would you recommend and why? How would you weight them and why?

## PART 4 Continuing Case

Note: This case is available online only.

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# Chapter 12

# Service Response Logistics


*Over the last few months, we witnessed an unprecedented surge in open positions across many industries, creating fierce competition for talent among organizations of all sizes. As the U.S. economy begins to reopen, this trend will only accelerate, and employers —particularly those within the services sector or that require workers on-site, must adapt quickly to attract and retain workers.*

**—Heather Salerno, Appcast senior VP of marketing[1]**

*When the news broke of the Ever Given (Suez Canal) blockage, our team immediately sprang into action to create a live dashboard, mapping all Zencargo shipments with vessels that were affected by the blockage. They then worked directly with affected customers to arrange mitigations and alternative plans."*

**—Zencargo CEO Alex Hersham[2]**

## Learning Objectives

**After completing this chapter, you should be able to**

**LO 1** Understand how supply chain management for services differs from supply chain management for manufacturers.

**LO 2** Define service response logistics and describe all of its elements.

**LO 3** Understand the importance of service layouts and perform a layout analysis using several techniques.

**LO 4** Describe the strategies for managing capacity, wait times, distribution and quality in services.

**LO 5** Understand queuing system design issues and calculate queue characteristics.

**LO 6** Use various techniques for managing customers' perceived waiting times.

**LO 7** Understand the different distribution channels available for services.

**LO 8** Define service quality, and describe how to measure and improve it.

## Chapter Outline



### SCM Profile — How Two Restaurants Dealt with COVID-19

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Jeff Ruby's Steakhouse has seven locations in Kentucky, Ohio and Tennessee. Carson's Food & Drink, has experienced high demand since it opened its Lexington, Kentucky location in 2017. Both operations brought more than 40 years of restaurant experience to its COVID-19 decision making. The restaurant closures happened in March, 2020. As owner of Carson's, Mark Fichtner knew he "had a huge job ahead of me, not just as a business owner but as the person responsible for 85 other lives that worked for me. My job was to deliver the news of closing and only doing curbside take-out. My job in the midst of this incredible situation was to be the eternal optimist and to be the foundation my employees could stand on," he said. "They have given me so much over the past few years at Carson's. I had decided from the first day we closed to the public that I was going to take care of the staff that has taken care of me. I decided to pay them and their health insurance until we could reopen," he said.

Britney Ruby Miller, president and CEO of Jeff Ruby's, took COVID-19 very seriously. Long before the restaurants had to close in March, Miller created an internal task force to begin contingency planning, including how they would market carryout and delivery. When the order to close came in March, Miller had decided to continue paying for full health care coverage for its 500+ employees. Like other restaurants, Ruby's closed its restaurant operations, which did require laying off many employees, then transitioning to take-out only. Miller said Ruby's kept its corporate taskforce team on full time, including general managers and chefs. Jeff Ruby's Steakhouse locations kept enough staff to continue the hot meal takeout they had always provided and to meet demand for a new product: $120 "meal kits" designed to feed four at Ruby's level of quality.

"Carson's restaurant," Fichtner said, "is all about great food, drinks and service, but it is also about the environment that we have created with a Prohibition and rustic yet elegant feel, along with a great patio, live jazz, and a wonderful brunch on the weekends. How do you deliver the Carson's experience in a take-out box handed to you in your car for you to dine at home?" Working with managers however, Fichtner developed family-style meal packages, cocktails to go, 50 percent off bottles of wine, and holiday meal kits for Easter, Mother's Day, and Father's Day. They rearranged the dining room to accommodate the new take-out business. "Curbside take-out was very successful," he said, "and yet not even close for us to break even weekly. This has been one of the most difficult things I have ever gone through, personally and professionally," Fichtner added. "But I am deeply grateful for the managers and staff I have to work with; they are the ones that made Carson's what it is and will continue to do so."[3]

## Introduction

While most of the concepts of supply chain management discussed up to this point in the text can be applied to service organizations, this chapter introduces and discusses supply chain management concepts suited particularly to services and the service activities of manufacturers. Services differ from manufacturers in a number of ways including the tangibility of the end product, the involvement of the customer in the production process, the assessment of product quality, the labor content contained in the end products, and facility location considerations. Many services are considered **pure services**, offering few, if any tangible goods to customers. Examples are consultants, lawyers, entertainers and stockbrokers. Other services may offer end products containing a tangible component such as restaurants, repair facilities, transportation providers and public warehouses. Most manufacturers, on the other hand, have tangible goods with a relatively small service component that might include maintenance, warranty repair, and delivery services, along with customer call centers.

In most services, customers are either directly or indirectly involved in the production of the service itself. In this sense, services are said to provide **state utility**, meaning that services do something to things that are owned by the customer (such as transport and store their supplies, repair their machines, cut their hair, and provide their healthcare). Managing the interactions between service firms and their customers while the service is being performed is the topic of this chapter and is of paramount importance to the ultimate success of service organizations.

To generate initial and repeat customer visits, services must be located near their customers, they must know what their customers want, and they must be able to satisfy these needs quickly and in a cost-effective manner. This requires service firms to adequately hire,

train and schedule service representatives; to acquire technologies and equipment to aid in the provision of services; and to provide the right facility, network, and procedures to continually satisfy customers. Problems or mistakes that occur during the delivery of services most likely mean an increase in service delivery time, a reduction in customer satisfaction, lower perceived service quality, and lost current and future sales.

The important role services play in the global economy is becoming more evident today as developed countries become increasingly service oriented and as the Internet creates global "e-preneurs" whose businesses exist solely on the Internet. Service jobs are replacing those in manufacturing as productivity gains in manufacturing mean fewer laborers are needed to make the same volume of goods. In the United States for instance, services have been, by far, the biggest contributor to GDP, accounting for over 68 percent in 2019. In the United Kingdom, services provided about 71 percent of GDP; in France, 70 percent; and in Japan, 69 percent. As a contrast, in underdeveloped countries like Afghanistan, Cambodia, Ethiopia, and Indonesia, services accounted for 56 percent, 39 percent, 37 percent, and 44 percent of GDP respectively.[4]

Successful firms today are busy identifying and improving the customer-desired service elements in their product offerings, in order to provide better value through attention to these elements. These efforts are at the heart of service operations and the topic of service response logistics. Let's first review service operations in general and then move on to discuss service response logistics in particular.

## An Overview of Service Operations

Services include organizations such as retailers, wholesalers, transportation and storage companies, healthcare providers, financial institutions, schools, real estate companies, government agencies, hotels, and consulting companies. Since the 1950s, the ratio of services to manufacturing and agriculture in terms of its share of the U.S. workforce has been increasing quite dramatically, and it is extremely likely that current university graduates entering the job market will be employed in some service role. In the United States and other developed economies, as the population has generated more wealth, they have continued to demand more services. In 1960 for example, Americans were spending about 46 percent of their personal consumption income on services. Today, Americans spend about 70 percent on services.[5]

On the other hand, India, the world's second largest emerging economy (after China), has experienced a continued growth of their service sector. Their economy has shifted away from an agrarian economy toward a more service-oriented economy, which has improved the standard of living in India and boosted domestic consumption. This has helped to bolster overall productivity and competitiveness of companies in India, creating higher-value jobs. Services now account for about 50 percent of India's GDP.[6] Multinational restaurant chains are moving into India rapidly. Yum! Brands Inc., owner of Taco-Bell, KFC, and Pizza Hut, has expanded rapidly in India, from 230 at the end of 2009, to 857 in 2020. Dominos Pizza is also expanding in India with 1325 stores as of the end of 2019, and is growing rapidly.[7]

Some of the differences between goods and services are listed below:

- Services *cannot be inventoried*. Typically, services are produced and consumed simultaneously—once an airliner has landed, or surgical operations are performed, or legal advice is given, customers have "consumed" the service. For this

reason, services often struggle to find ways to utilize their employees during low demand periods and to serve customers effectively during busy periods.

- Services are often *unique*. High-quality service providers with well-trained and motivated employees have the capability of customizing services to satisfy each customer—insurance policies, legal services and even fast-food services can be uniquely designed and then delivered to customers. Thus, hiring and training become important issues for satisfying individual customer needs.
- Services have *high customer-server interactions*. Services often require high levels of server attention, whether it means delivering purchased goods to a specific location at the buyer's facility, analyzing data, answering customer questions, resolving complaints or repairing machinery. Many services today are finding ways to automate or standardize their service products, or to utilize customers to provide some of the service, to reduce costs and improve productivity. For instance, the past few years have seen a rapid growth in automated, self-serve services such as purchasing goods online, performing checkout services at grocery stores, and completing one's taxes.
- Services are *decentralized*. Service facilities must be decentralized because of their inability to inventory services and because of competition. Therefore, finding good, high traffic locations is extremely important (even Internet-based services must locate their advertisements where they will be easily seen by people using search engines).

Thus, services, whether they are stand-alone organizations or departments in goods producing firms, must be managed in ways that will take into account these various service characteristics. A number of service elements are discussed next.

## Service Productivity

The basic measure of productivity is shown by the following formula:

$$\text{Productivity} = \frac{\text{Outputs produced}}{\text{Inputs used}},$$

where service outputs produced might be customers served, the number of services performed or simply sales dollars; and inputs might be shown as labor hours or labor dollars (for a **single-factor productivity** measure). Alternately, inputs can be shown as the sum of labor, material, energy and capital costs (for a **multiple-factor productivity** measure). The productivity measures used in an organization might be based on manager preferences or industry standards. Further, firms measure productivity to gauge their successes in employee training, equipment or technology investments, and cost reduction efforts.

Productivity and its growth over time are commonly used indicators of a firm's (or a country's) economic success. For most services, automation can be a troublesome issue when calculating productivities, and the labor content per unit of output can be quite high relative to manufactured goods. These two things can lead to a declining productivity growth rate as a nation's economy becomes less manufacturing oriented and more services oriented. In the United States, the non-farm labor productivity growth rate has declined from about 2.8 percent per year in the 1950s to about 1.2 percent per year today. Because of this growth in services, service productivity now drives the advanced economies around the world, and this caused a major disruption in standards of living after the economic recession of 2008 and the pandemic in 2020.

This productivity growth problem has been termed **Baumol's disease**, named after noted U.S. economist William Baumol. In the 1960s, he and his colleague, William Bowen, argued that productivity growth tended to be low in service-oriented economies. And, in fact, this effect was realized in the United States from the mid-1970s through the mid-1990s as productivity growth averaged a relatively low 1.5 percent per year. Since the mid-1990s, however, productivity growth in the United States has been up and down, leading to other theories such as the **Walmart effect**, which postulates that the booming growth in information technology has allowed many big-box retailers such as Walmart to realize large productivity growth rates. Today, some economists are even saying that Baumol's disease has been "cured."[9] Something akin to the Walmart effect is occurring in the healthcare industry in North Carolina, as described in the nearby SCM Profile.

In services with high labor costs, there is often a desire to reduce labor costs to improve productivity (since labor cost is considered a productivity input). This can lead companies to relocate to reduce labor costs, outsource jobs to other, lower cost service providers, or lay off workers. These can be risky strategies, since relocating can create added and unforeseen costs, outsourcing reduces managerial control, and reducing the workforce can adversely affect morale, service quality, and service availability. A service productivity example appears in Example 12.1.

## SCM Profile — Hospital Consolidation in North Carolina


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A consolidation of North Carolina's hospital industry is currently underway, putting greater control in the hands of a few large organizations. Healthcare providers are trying to become more efficient, by becoming larger. "I call it the Walmart effect," says state Rep. Donny Lambeth, a former executive at Wake Forest Baptist Medical Center. "The big hospitals in North Carolina have gone after the smaller ones for years. But quite frankly, I think they looked around and said, 'We still need to get bigger to leverage our operations.'"

For example, Charlotte-based Atrium Health and Winston-Salem-based Wake Forest Baptist Health agreed to a combination in October 2020. The combination has the potential for the region to become a "Silicon Valley" of healthcare in North Carolina.

Local opposition to the transaction is muted, with several sources surprised that Wake Forest Baptist didn't negotiate more benefits for Winston-Salem. "It doesn't look like they drove as hard of a bargain as they could have," Lambeth says. "Wake brings a whole lot to the table because of its national reputation, which is something that Atrium has wanted for a long time." Wake Forest Baptist though, has not reported good operating results in recent years. Thus, it may have lacked the financial strength to make specific demands.

Underlying these and other healthcare mergers is the pressure to contain sky-high medical costs. North Carolina has the second-highest medical costs, behind only Alaska, according to market-research news group WalletHub. "Everyone realizes the cost of health care is ridiculously high," Lambeth says. "Rates will have to stabilize and go down. [Hospitals] know that things have to become more efficient."[10]

### Example 12.1 Productivity at the Ultra Ski Shop

The Ultra Ski Shop rents snow skis for 15 weeks each year and employs five people. The owner wants to track productivity performance measures using the data shown below.

| INPUTS AND OUTPUTS | 2020 |
|---|---|
| Skis rental revenue | $66,000 |
| Labor cost | $10,800 |
| Lease payments | $24,000 |
| **INPUTS AND OUTPUTS** | **2021** |
| Skis rental revenue | $69,500 |
| Labor cost | $11,600 |
| Lease payments | $24,500 |

Single-factor productivities

2020: Labor productivity = $66,000 sales/$10,800 = 6.11 sales $ per labor $.
Lease productivity = $66,000/$24,000 = 2.75 sales $ per lease $.

2021: Labor productivity = $69,500 sales/$11,600 = 5.99 sales $ per labor $.
Lease productivity = $69,500/$24,500 = 2.84 sales $ per lease $.

Multiple-factor productivities

2020: $66,000 sales/[$10,800 + $24,000] = 1.90 sales $ per input $.

2021: $69,500 sales/[$11,600 + $24,500] = 1.93 sales $ per input $.

Labor productivity grew from 2020 to 2021 by (5.99 − 6.11)/6.11 = −0.02 = −2%. Lease productivity grew from 2020 to 2021 by (2.84 − 2.75)/2.75 = 0.033 or 3.3%. Multiple-factor productivity grew by (1.93 − 1.90)/1.90 = 0.016 or 1.6%. Ultra management should look into why labor cost grew faster than ski revenue from 2020 to 2021.

Other strategies for increasing service productivity address the numerator of the productivity equation. One example is the use of technology or automation to increase outputs. Manufacturers and services have been looking to automation for years as a way to increase productivity, but the pandemic increased interest for robotics and process automation technologies. In 2020, a survey by Honeywell of employees at companies that directly manage warehouses, distribution centers or fulfillment centers found that 51 percent of them were more willing to invest in automation as a result of the pandemic. Two-thirds of respondents said they were increasing spending on automation or artificial intelligence either "somewhat or significantly."[11]

Improving service productivity can be quite challenging because of the desire in many cases for customized, labor-intensive services and because of the difficulty of assessing service quality (for instance, was the car fixed properly? Was the client properly defended? Was the hired comedian funny?). A complete discussion of service quality appears later in the chapter.

## Global Service Issues

The growth and export of services are occurring everywhere as world economies improve and the demand for services increases. Even during the recent pandemic, services were finding ways to stay competitive and expand. Just a few examples include Goldbelly, which gained a major boost from the pandemic, added over 400 restaurant partners since the start of the pandemic. The company's partner restaurants were able to sell meal kits as well

as smaller, frozen versions of popular menu items across the United States to try to recover lost revenue amid dining room restrictions. Goldbelly's success came as many full-service restaurants turned to meal kits to grow their off-premise offerings and keep customers engaged.[12] Additionally, Swedish livestream shopping technology company Bambuser acquired marketing technology company Relatable for approximately $24 million. The acquisition of Relatable, whose proprietary technology facilitates searching for and booking influencers for creator marketing initiatives, follows a year of major growth for Bambuser, including a recent $60 million funding round in February and the launch of U.S. and U.K. headquarters at the end of 2020. Bambuser's sales rose 844 percent year-over-year in the first quarter, with monthly recurring revenue up 550 percent as it converted many pilots into long-term contracts.[13]

Successfully managing services as they expand into foreign markets involves a number of issues:

- *Labor, facilities and infrastructure support.* Cultural differences, education and expertise levels can prove to be problematic for firms unfamiliar with local human resources. Firms must also become adept at locating the most appropriate support facilities, suppliers, transportation providers, communication systems and housing.
- *Legal and political issues.* Local laws may restrict foreign competitors, limit use of certain resources, attach tariffs to prices or otherwise impose barriers to foreign services. Some countries require foreign companies to form joint ventures with domestic businesses.
- *Domestic competitors and the economic climate.* Company managers must be aware of their local competitors, the services they offer, their pricing structures and the current state of the local economy. Firms can devise competitive strategies by modifying their services to gain a local or regional competitive advantage.
- *Identifying global customers.* Perhaps most importantly, managers must find out where potential global customers are, through use of the Internet, foreign government agencies, trading partners or foreign trade intermediaries. Once potential customers are identified, managers can begin modifying their service products to meet the needs of these customers.

More on global service expansion can be found later in the chapter.

## Service Strategy Development

Manufacturing and service organizations use one or more of the three generic competitive strategies: cost leadership, differentiation, and focus.[14] Each of these is briefly discussed below in relation to services.

### Cost Leadership Strategy

Using a **cost leadership strategy** often requires a large capital investment in automated production equipment and significant efforts in the areas of controlling and reducing costs, doing things right the first time, standardizing services and aiming marketing efforts at cost-conscious consumers. Walmart has been successful using its strategy of everyday low prices to attract and keep customers. It offers goods at a cheaper price than its competitors, rather than using promotions. Walmart is able to achieve this due to its large quantity purchases and its highly efficient supply chains. Other good cost leadership examples include McDonald's, Ikea, and Southwest Airlines.[15]

### Differentiation Strategy

Implementing a **differentiation strategy** is based on creating a service that is considered unique. The uniqueness can take many forms including customer service excellence (Ritz-Carlton hotels), brand image (the Google logo and its variations for holidays), variety (Marshalls merchandise) and use of technology (Amazon's cloud computing, warehouse robots, online grocery shopping). Differentiation strategies are often created as the result of companies listening to their customers. Services are beginning to engage customers more effectively through various touch-points such as the phone, store locations, catalogs, social media, and online sites. New York-based Citigroup is well-known for its social media savvy. "Money is a highly sensitive topic," says Michelle Peluso, Citigroup's global consumer chief marketing and Internet officer. "One of the things social media allows us to do is to listen in to hear what people say about our brand, our competitors, our industry, products and services, and our people."[16] Differentiation does not necessarily mean higher costs and prices; it merely refers to the ability of the service company to offer unique elements in their service products. In many cases, though, it may mean the customer is willing to pay more for the service. Advertisements, logos, awards and company reputations all play a part in creating the perception of uniqueness among a service's potential customers.

### Focus Strategy

A **focus strategy** refers to a service that can effectively serve a narrow target market or niche better than other firms trying to serve an entire market. Companies specializing in these market niches can provide customized services and expertise to suit the specific needs of these customers. For instance, a neighborhood hobby shop is more likely to serve the needs of hobby enthusiasts than a big-box retailer like Carrefour or Walmart, even though they might sell some of the same merchandise. Within each market niche, firms can then exhibit characteristics of differentiation or cost leadership. Florida-based French Fry Heaven, a gourmet French fry restaurant, started in 2011 and sells many types of French fries and potatoes. They have found success serving this narrow fast-food niche. Their mission is: To serve the best fries on earth, be everywhere people are hungry, leave you with a smile on your face and make a significant positive impact on the world! Today they are once again expanding with locations in Florida and New Jersey.[17]

## The Service Delivery System

Customers actually purchase a bundle of attributes when purchasing services, including the *explicit service* itself (storage and use of your money at a bank), the *supporting facility* (the bank building, drive-up tellers and website), *facilitating goods* (the deposit forms, monthly statements and coffee in the lobby), and *implicit services* (the security provided, friendly atmosphere in the bank, privacy, and user-friendliness of the website). Successful services deliver this bundle of attributes in a cost-conscious manner, while still satisfying customer requirements. Service managers define their companies' **service bundles** and then design the most effective delivery system.

**Service delivery systems** fall along a continuum with mass-production, low customer contact systems at one extreme (such as ATMs) and highly customized, high customer contact systems at the other (such as an expensive beauty salon). Many delivery system designs seek to physically separate high-contact (front-of-the-house) operations from low-contact (back-of-the-house) operations to allow use of various management techniques to maximize performance of each area (such as in a restaurant). **Back-of-the-house operations** tend to be managed as manufacturing centers, where the emphasis is on maximizing quality outputs while achieving economies of scale. Technical people are hired

for specific well-defined tasks, and technology is employed to increase productivity. On the other hand, **front-of-the-house operations** are characterized by hiring front-line service providers with good public relations skills, taking good care of customers, and giving employees the power and resources to solve customers' problems quickly and effectively.

Hospitals provide good examples of organizations characterized by a clear separation of high-contact and low-contact services. Administrative offices, labs, drug storage, laundry, and food preparation, for instance, are low-contact, back-of-the-house operations in a hospital. Managing these elements of the hospital service bundle can make a tremendous difference in profitability. No customer contact exists, so the emphasis is on materials management, space utilization, automation, and technical skills. However, patient care, prescription services, emergency room, and other high-contact services directly involve patients in the delivery of these services. In these cases, customer-server interactions must be managed so that customers get what they need in an effective way.

### Auditing the Service Delivery System

The service bundle delivery system should be audited periodically to assess the system's ability to meet customer expectations in a cost-effective way. Monitoring customer complaints, talking to and observing customers, and tracking customer feedback using customer comment cards and website comment forms (as well as looking at the bottom line) are ways to continually monitor the service delivery system. **Walk-through service audits** can be used to observe service system attributes from the time customers initially encounter the service until they leave. Several tools have been developed and used for this purpose including service system surveys to be completed by managers, employees, and/or customers, and service process maps (as discussed in Chapter 8). The objective of the service audit is to identify service system problems or areas in need of improvement.

## Service Location and Layout Strategies

Good locations provide barriers to entry and competitive positioning for services as well as generate high levels of demand. Once a location has been secured, firms can begin to consider layout strategies that help to maximize customer service, server productivity, and service efficiencies. Since location strategies and analysis models were discussed in Chapter 11, only a brief discussion of location considerations is included here, followed by the design of service layouts.

### Location Strategies

Location decisions are extremely important for most services because they have a significant impact on customer visits and, consequently, the long-term profits of the company (how likely is it that customers would visit a clothing store, for instance, in an otherwise abandoned shopping center?). Location selection is viewed as a moderate- to long-term decision because of the typically high costs of construction, remodeling, and relocation. (Note: Here, it is assumed that service locations are permanent structures, although some services actually are not bound by this assumption, as with online services, a small legal office renting space in an office building, or a music teacher who visits customers' homes.)

Global market opportunities, global competitors, and technological and demographic changes contribute to the importance of a good location. In all location evaluations, it is desirable to consider a number of relevant factors to reduce reliance on managers' personal preferences and intuitions. Although intuition can certainly be a valuable location analysis tool, many disastrous location decisions have been made on the basis of intuition and not much more. For example, one-time Las Vegas gambler, entrepreneur, and self-proclaimed "Polish maverick" Bob Stupak built the 1,149-foot Stratosphere Hotel and Casino, which opened in

a rundown neighborhood on the fringes of the famous Las Vegas Boulevard or "the Strip" in 1996. Within just a few months, the hotel was in financial trouble, partly because of the lack of foot traffic in the area. Stupak defaulted on payments to the bondholders who had put up the construction funds, and corporate raider Carl Icahn subsequently bought the bonds for $82 million (much less than half their original value). He assumed control of the hotel in 1998. His company then sold this and three other Nevada casinos to Goldman Sachs Group's Whitehall Street Real Estate Fund in 2008 for a profit of over $1 billion.[18]

A number of location analysis models can be used as aids in the location decision, and these include the weighted factor location model and the center of gravity model (refer to Chapter 11 for use of these models).

## Layout Strategies

**Service layout strategies** work in combination with location decisions to further support the overall business strategies of differentiation, low cost, or market focus. Office layouts tend to be departmentalized to allow specialists to share resources; many retailers like U.K.-based Tesco PLC also tend to be departmentalized to assist customers in finding items to purchase, whereas other retailers may have centers throughout the store to entice customers to try things out and buy on impulse; commercial airliner layouts segment customers, minimize the time to restock and service the galleys and lavatories, and allow for fast passenger boarding and exit (at least in theory!); casino layouts are designed to get customers in quickly and then keep them there by spacing out the attractions; and self-serve buffet restaurant layouts are designed to process customers quickly. Warehouse layouts consider matching the goods handled to the specific layout required. These are just a few examples, and many service layouts use multiple layout strategies. As customer preferences, goods, technologies, and service strategies change, layouts also tend to change. Several specific service layout design tools are illustrated below.

### Departmental layouts that reduce distances traveled

Service layouts can be designed to reduce the travel times of customers or service workers when moving from one area to another. An example of a layout where this might be a primary consideration would be a health clinic. The waiting area is located in front where customers enter, and the examination rooms are located nearby. The doctors' offices might be centrally located, whereas the lab, storage and x-ray rooms might be located farther to the back of the clinic away from most of the patients. A primary consideration is how far nurses, doctors and patients have to walk to reach the various areas within the clinic. The objective would be to place high traffic volume departments close to each other to minimize the total distances traveled by everyone per day. Example 12.2 illustrates a design tool for this type of layout.

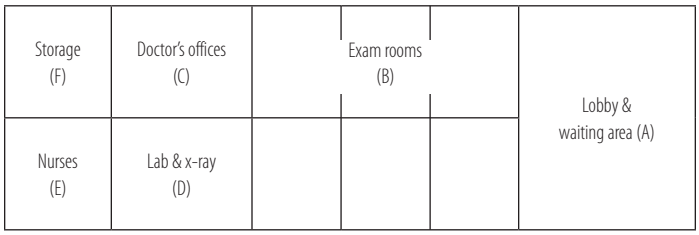
### Departmental layouts that maximize closeness desirability

Designing service layouts to place certain desirable pairs of departments closer to one another is another useful type of layout analysis tool and is often used for retail or office layouts. Here, the importance is placed on the relationships between various departments. In a convenience store, for instance, it would be preferable to have the cashier close to the entrance and the cold food items in the back, close to the cold storage areas and the rear loading doors of the store. In an office setting, it might be desirable to have the receptionist close to the office entrance and the file room, with the managers close to the conference room. For each department pair, a **closeness desirability rating** is determined, with the objective being to design a layout that maximizes an overall desirability rating for the entire facility. Example 12.3 illustrates this concept. It should also be noted that it can be advantageous to use both of the analyses illustrated in Examples 12.2 and 12.3 for a given layout problem; in this way, the evaluation team could consider the best layout from both a distance traveled and closeness desirability perspective.

## Example 12.2 Layout of Thompson Health Clinic

The Thompson Health Clinic wants to see whether there is a better layout that will reduce the time doctors and nurses spend walking throughout the clinic. The existing layout is shown below, along with the number of trips and the distances between each department.

**Existing Layout**




**Interdepartmental Doctors' and Nurses' Trips/Day**

| | B | C | D | E | F |
|---|---|---|---|---|---|
| A | 55 | 0 | 0 | 50 | 0 |
| B | | 40 | 15 | 40 | 0 |
| C | | | 15 | 60 | 10 |
| D | | | | 30 | 0 |
| E | | | | | 18 |

**Distances between Departments (meters)**

| | B | C | D | E | F |
|---|---|---|---|---|---|
| A | 20 | 40 | 40 | 60 | 60 |
| B | | 20 | 20 | 40 | 40 |
| C | | | 10 | 20 | 20 |
| D | | | | 20 | 20 |
| E | | | | | 10 |

To analyze the existing layout, the total distance traveled per day is calculated as follows:

$$\text{Total distance traveled} = \sum_{i=1}^{n}\sum_{j=1}^{n} T_{ij}D_{ij}$$

where $n$ = number of departments
$i, j$ = individual departments
$T_{ij}$ = number of trips between departments $i$ and $j$
$D_{ij}$ = distance from department $i$ to department $j$

The objective is to find the layout resulting in the lowest total distance traveled per day. For the layout shown above, we find:

Total distance traveled per day = 55(20) + 50(60) + 40(20) + 15(20) + 40(40) + 15(10) + 60(20) + 10(20) + 30(20) + 18(10) = 9130 meters

From the layout and the trips and distances shown, it can be seen that the nursing station should be closer to the lobby and waiting area, closer to the exam rooms, and closer to the doctors' offices. This can be accomplished by switching departments E and D (nurses and lab/x-ray). This also creates a trade-off, since now departments C, B, and A will all be farther from department D. To calculate the new total distance traveled per day, the distance table must be modified as shown below. The asterisks denote changes made to the table.

**Distances between Departments**

| | B | C | D | E | F |
|---|---|---|---|---|---|
| A | 20 | 40 | 60* | 40* | 60 |
| B | | 20 | 40* | 20* | 40 |
| C | | | 20* | 10* | 20 |
| D | | | | 20 | 10* |
| E | | | | | 20* |

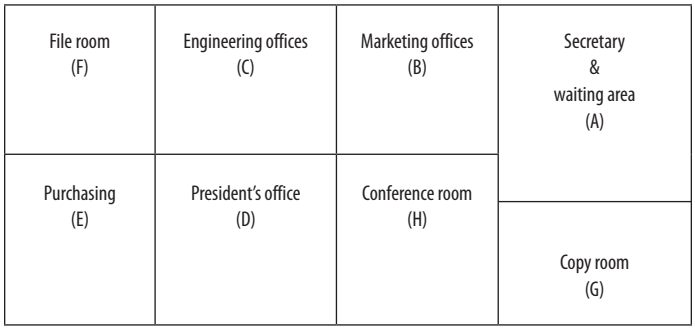
The new total distance can then be calculated as follows:

Total distance traveled per day = 55(20) + 50(40) + 40(20) + 15(40) + 40(20) + 15(20) + 60(10) + 10(20) + 30(20) + 18(20) = 7360 meters

This is a better layout (not necessarily the best) and only one of a large number of potential layouts. The layout distance improvement is $\frac{9130-7360}{9130} = 0.193$ or 19.3%. Typically a number of layouts are evaluated as shown here, until either the lowest-total-distance layout or some other reasonable alternative lower-distance layout is found.

## Example 12.3 Closeness Desirability Rating for an Office Layout

**Existing Office Layout**




**Desirability Ratings**

| | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|
| A | 2 | 0 | −1 | 2 | 2 | 3 | −1 |
| B | | 0 | 2 | 1 | 1 | 0 | 3 |
| C | | | 2 | 2 | 0 | 0 | 1 |
| D | | | | 1 | −1 | −1 | 3 |
| E | | | | | 3 | 1 | 2 |
| F | | | | | | 3 | 1 |
| G | | | | | | | 0 |

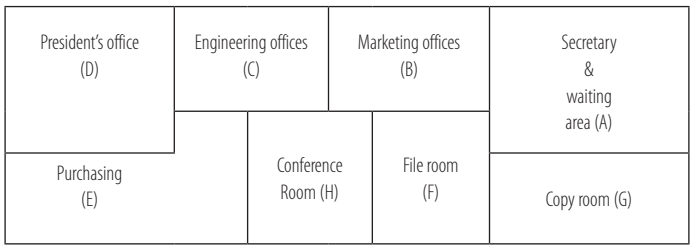
The desirability ratings are based on a (−1 to 3) scale, where −1 = undesirable, 0 = unimportant, 1 = slightly important, 2 = moderately important and 3 = very important. To calculate the score for the above layout, we count the closeness desirability score only when departments are adjacent to each other. For this layout:

Closeness desirability score = (A/B:2) + (A/H:-1) + (A/G:3) + (B/C:0) + (B/H:3) + (C/F:0) + (C/D:2) + (D/E:1) + (D/H:3) + (E/F:3) + (G/H:0) = 16 points

Note that department pairs are not counted twice, and are also not counted if only the corners are touching. To find a better layout, we could place the department pairs with a rating of 3 adjacent to each other, and place adjacent pairs with a rating of −1 such that they are not adjacent. For instance, the file room (F) could be moved adjacent to the copy room (G), and the conference room (H) could be moved farther away from the secretary and waiting area (A).

The new layout might look like this:

**New Office Layout**




The closeness desirability score for the new layout shown above would then be:

Closeness desirability score = (A/B:2) + (A/F:2) + (A/G:3) + (B/C:0) + (B/H:3) + (B/F:1) + (C/D:2) + (C/E:2) + (C/H:1) + (D/E:1) + (E/H:2) + (H/F:1) + (F/G:3) = 23 points

On the basis of this analysis, it can be concluded that the second layout is better; like the previous example, though, there are many potentially good layouts, so a number of those should be evaluated prior to selecting the most appropriate one.

## Supply Chain Management in Services

In many respects, service-producing organizations are like goods-producing organizations: both make purchases and therefore deal with suppliers; incur order costs and inventory carrying costs; and transport, count, store, and assess the quality of their purchased inventories. For some services, purchased items are part of the service provided and are extremely important sources of competitive advantage (as with a retailer or restaurant), whereas for others, this may be a less important concern (for example law offices and barber shops). Service firms also purchase **facilitating products** such as computers, furniture and office supplies that are not part of the services sold but rather consumed inside the firm, and these materials must also be managed. Table 12.1 shows some typical transportation, warehousing and inventory considerations at several different types of services.

In other respects, though, service firms are unlike goods-producing organizations, in that services typically deal with the end customers in their supply chains, whereas most goods-producing firms deal with wholesalers, distributors, other manufacturers or retailers. In other words, service products are typically not passed on to customers further down a distribution channel. Thus, any goods that are delivered as part of the service are typically consumed or used by the immediate customers.

Service firms also interact closely with their customers, and the services performed in many cases contain higher labor content than manufactured goods. Customers probably have no idea what resources or facilitating goods were used to deliver the services they purchase; rather, customers' primary concerns are with the service itself and the way it is delivered. For this reason, the distribution elements of interest to services revolve around customers and how they are being served. A good example of this can be found in the transportation industry. When shippers want things moved, they want the move performed at a specific time, delivered to a specific place, delivered on time and performed as economically as possible. Most large transportation companies today have sophisticated information systems to allow customers to track deliveries as well as determine the best combination of warehousing, transportation mode, port-of-entry, routing, pricing, and consolidation.

One of the latest automated transportation elements are autonomous trucks. Taken together with double 53-foot. trailers or triple 28-foot. trailers, autonomous trucks could lead to a sizable reduction in logistics costs. Automating transportation though, comes with more challenges and if successful, may reduce transportation jobs. "Robust autonomous

**Table 12.1 Transportation, Warehousing, and Inventory Considerations in Services**

| SERVICES | TRANSPORTATION | WAREHOUSING AND INVENTORY |
|---|---|---|
| Banks | • Movements of checks, coins/cash among branches and operations centers<br>• Movement of checks to cities with Federal Reserve processing centers | • Office supplies and coins/cash<br>• Furniture and computers<br>• Files |
| Hospitals | • Movement of medical supplies to stockrooms<br>• Transfers of patients<br>• Movement of medical records, test results and films among units | • Surgical/medical supplies<br>• Pharmaceutical supplies<br>• Office furniture<br>• Medical equipment |
| Phone Companies | • Inbound transportation of switches, parts and equipment to warehouses<br>• Transportation of construction equipment and supplies to job sites<br>• Routing of consumer goods to retail outlets | • Parts, equipment, consumer goods<br>• Repair truck parts and equipment<br>• Construction supplies |

Adapted from Drazen, E. L., R. E. Moll, and M. F. Roetter. *Logistics in Service Industries*. Oak Brook, IL: Council of Logistics Management, 1991: 24–26.

technology [need to be] capable of dealing with variable weather conditions, invisible lane markings, hackers, communication system disruptions," says John Larkin, managing director of investment banking firm Stifel Capital Markets. "Taken alone, autonomous trucks operating on the interstate highway system would likely eliminate the persistently challenging driver shortage and might destroy highway-to-rail intermodal conversion economics."[19] In fact, in 2019, a startup Cupertino, California intelligence company completed what was called "the world's first autonomous cross-country freight delivery trip," making a 41-hour, 2,800 mile delivery of 40,000 pounds of butter through a dozen states to a small town in Pennsylvania—without a driver at the wheel.[20] The nearby SCM Profile describes an autonomous trucking company making deliveries in the Tucson, Arizona area.

## SCM Profile: TuSimple's Autonomous Trucking Efforts

Scharfsinn/Shutterstock.com

San Diego-based TuSimple is recognized as a leader in the move toward autonomous freight trucks. For the past several years, TuSimple has been running paid loads from Tucson to Texas and California (with a driver on board until approval is granted for driverless operations in 2024). "Ten percent of our nation's corridors move almost 80 percent of goods and we're initially focusing on the South and Southwest freight corridors, a massive accessible market we think is ripe for autonomy," says Jim Mullen, TuSimple's Chief Administrative Officer. "We've developed technology that we believe nobody else in the industry has developed and we've been road demonstrating it for the last five years, the first in the autonomous truck space to do what we call surface road, going over surface streets, navigating left turns and traffic signals and merging onto the Interstate from Tucson to Phoenix and back, daily," he adds.

Dealing with several aspects of autonomous trucking was most challenging for TuSimple—the lack of drivers and capacity, and the service restrictions; the safety aspects; and the environmental aspects. "The long-haul driver shortage is real," says Mullen. "The American Trucking Association talks about a shortage of 60,000 drivers currently with a predicted shortfall of 100,000 drivers in the next two years. Plus, the median age of a truck driver is now 47 which is already five years older than the median workforce age in the U.S.," he adds. "We have about 5000 fatalities and 30,000 serious injuries every year in the U.S. involving crashes with large trucks, crashes mainly caused by human error like driver distraction, driver fatigue, or noncompliance with the rules of the road," Mullen says. "Autonomous trucks are going to help solve those problems."

An additional benefit for driverless trucks will be a decrease in insurance premiums. "Trucking companies have been taking bankruptcy or folding entirely as a result of insurance costs and claims causing them to shut their doors. We can help the industry solve those safety problems and save money in the process," says Mullen.

Autonomous trucks have also been shown to be greener than manually-driven trucks. "The University of California, San Diego compared twelve months of our data comparing the two methods and that data showed a ten percent improvement in miles-per-gallon in the autonomous vehicles versus the driver-driven," Mullen says. "We're confident our vehicles are greener and more fuel-efficient to help the industry deal with its carbon footprint."[21]

## Service Quality and Customers

The satisfaction or perceived level of quality a customer experiences with regard to the service is of paramount concern to most services. The concept of service quality includes many elements, and these can change over time—recently, for example, customers of many businesses include sustainability as an element in their definitions of service quality. Food waste in restaurants is one place where sustainability can add to service quality. "Approximately four to ten percent of food purchased by restaurants is wasted before reaching the consumer," claims NY-based Grace Communications Foundation, whose mission is to increase public awareness of the relationships among food, water, and energy. "Drivers of food waste at restaurants include oversized portions, inflexibility of chain store management and extensive menu choices. On average, diners leave 17 percent of their meals uneaten, and 55 percent of edible leftovers are left at the restaurant. This is partly due to the fact that portion sizes have increased significantly over the past 30 years, often being two to eight times larger than USDA or FDA standard servings," the foundation notes.[22]

Service quality assessments vary based on both the tangible and intangible elements of the services supplied and the satisfaction of the customers receiving the services. Many call centers that fail to satisfy customers for example, provide opportunities for improvement in service quality. With respect to call centers, the "gold standard" of service quality is their first call resolution score or the percent of callers whose problem is solved on their first call. Companies like Canada-based Service Quality Measurement Group survey call center customers and then identify what the call centers with the highest first call resolution score are doing right. These best practices are then communicated to the call center clients.[23]

All the elements of supply chain management including supplier selection, transportation, warehousing, process management, quality assessment, distribution, and customer service hold strategic importance for the long-term success of service organizations. While the previous chapter sections above have discussed many of these elements, the remainder of this chapter is devoted to the portion of supply chain management of greatest concern to service organizations and the service arms of goods-producing companies—namely, the activities associated with the production and delivery of the actual service.

## The Primary Concerns of Service Response Logistics

**Service response logistics** is defined as the management and coordination of the organization's activities that occur while the service is being performed.[24] Managing these activities often means the difference between a successful service experience and a failure. The four primary activities of concern in service response logistics are the management of service capacity, waiting times, distribution channels and service quality. Since a service cannot be inventoried, managing service capacity enables the firm to meet variable demand—perhaps the most important concern of all services. When demand variability cannot be adequately met, the firm must resort to managing queues or waiting times to keep customers satisfied. Demand management tactics also play a role in the service firm's ability to satisfy varying levels of demand. Customer waiting times are closely related to the customer's view of service quality and, ultimately, customer satisfaction. Since services usually must be decentralized to attract customers while providing adequate service delivery times, use of various distribution channels also becomes important to the delivery of service products. Each of these service elements is discussed in detail in the following sections.

## Managing Service Capacity

**Service capacity** is most often defined as the number of customers per day the firm's service delivery systems *are designed to serve*, although it could also be some other period of time such as customers per hour or customers per shift. Capacity measures can be stated somewhat differently too, depending on the service industry standard—for instance, airline companies define capacity in terms of available seat miles per day. Most services desire to operate with some excess capacity, to reduce the likelihood of having long queues and waiting times develop. For service employees dealing directly with customers, service capacity is largely dependent on the number of employees providing the services and the equipment they use in these activities.

Since service outputs can't be inventoried, firms are forced to either turn away customers when demand exceeds capacity, make customers wait in line, or hire additional personnel. Since hiring, training, supervising and equipping service personnel are quite costly (in many cases 75 percent of total operating costs), the decision of how many service personnel to hire greatly affects costs, productivity, and ultimately sales and profits. Ideally, firms want enough service capacity (or service personnel) to satisfy variable demand, without having too much excess (and costly) capacity. This can be a tricky proposition if demand varies erratically throughout the day, week, or month, as is typical in a great many services. Thus, an important part of a service manager's job is to forecast demand for various segments of time and service processes, and then provide enough capacity to meet the forecasted demand.

When things work out right, a service operates at an optimal **capacity utilization**. Capacity utilization is defined as:

$$\text{Capacity utilization (percent)} = \frac{\text{Actual customers served per period}}{\text{Capacity}} \times 100.$$

As utilization approaches (and sometimes even exceeds) 100 percent, services become more congested, service times increase, wait times increase and the perceived quality of service deteriorates. With utilization close to 100 percent, even a slightly greater than average service time for several customers can cause queues to become very long (some readers may recall, for instance, waiting one or two hours beyond an appointment time to see a busy doctor). Thus, an optimal utilization would leave some level of capacity unutilized (perhaps 15 to 25 percent depending on the volatility of demand), so that variations in service times and customer demand won't severely affect customer wait times.

In the transportation industry, after an initial surge in consumer demand in the early days of the pandemic in 2020, freight volumes weakened dramatically in many sectors of the industry after states issued stay-at-home orders beginning in late March, shutting down much of the economy. Many retailers, manufacturers, restaurants and other businesses temporarily closed down or slowed production while Americans adhered to social distancing and stay-at-home guidelines. Many trucking fleets in North America described a range of experiences, with some citing steady volumes or even upticks in demand, while many more saw demand drop significantly. One fleet said its revenue plummeted by 40 to 50 percent.[25] The pandemic has further worsened the shortage of drivers as well. Comparing the demand for trucks from April 2020 to April 2021, shippers' requests for trucking services increased by 577 percent, while postings of trucks available to move loads were down 17 percent. The huge increase pertains to the rapid increase in economic activity as the pandemic slowed down.[26]

The two most basic strategies for managing capacity are to use a **level demand strategy** (when the firm utilizes a constant amount of capacity regardless of demand variations) or a **chase demand strategy** (when the amount of capacity is allowed to vary with demand). When a level demand strategy is used, the firm is required to use **demand management** or **queue management** tactics to deal with excess customers. When a chase demand strategy is used, effective plans must be in place to utilize, transfer or reduce service capacity when there is excess available and to develop or borrow capacity quickly when demand exceeds capacity. Capacity management techniques that are useful when demand exceeds available service capacity are discussed next, followed by a discussion of capacity management when service capacity exceeds demand.

## Capacity Management When Demand Exceeds Capacity

An initial observation might be to simply let customers wait, or alternately, hire workers when demand exceeds existing capacity and then lay them off when capacity exceeds demand. Most likely, though, firms would like to avoid these options because of the expenses of finding, hiring, training and supervising new workers; the loss of current and future business when customers wait too long in queues; as well as the expense and damage to the firm's reputation when laying-off workers. Instead, a number of other methods can be employed to minimize the costs of hiring and laying off workers, and the cost of letting customers wait in line. These methods include cross-training and sharing employees, using part-time employees, using customers, using technology, using employee scheduling strategies and, finally, using demand management techniques to smooth or shift demand. Each of these methods is discussed next.

### Cross-training and sharing employees

Have you ever been waiting in line to pay for items at a retail store and thought to yourself, "Why don't they use some of these other workers that are just standing around to ring up customers' purchases?" Many service firms, though, do make wide use of this employee-sharing strategy. Quite often in many service firms, some processes are temporarily overutilized while other processes remain under- or unutilized. Rather than hiring someone to add capacity to the overutilized processes, progressive firms have adequately hired and cross-trained workers to be proficient in a number of different process functions. Thus, when demand temporarily exceeds service capacity in one area, creating a customer queue, idle workers can quickly move to that process to help serve customers and reduce the time customers spend waiting in a queue.

By sharing employees among a number of processes, firms create the capability to quickly expand capacity as demand dictates while simultaneously minimizing the costs of having customers wait or the costs of hiring and laying off workers. This type of resource sharing arrangement can occur in almost any type of organization, from retailers to banks, hospitals, and universities.

### Using part-time employees

Use of part-time employees is also seen as a lower-cost way to vary capacity. The hourly wages and costs of fringe benefits are typically lower than those of full-time employees. Firms use full-time employees to serve that stable portion of daily demand, while scheduling part-timers for those historically busy periods (such as lunch and dinner times, holidays, weekends, or busy seasons). Part-time employees can also be used to fill in during the vacation periods, off days, and sick days of full-time employees. Laying-off part-time employees during slower periods is also viewed as more acceptable to the permanent full-time workforce and is somewhat expected by the part-time employees.

## Using customers

As the need to contain costs and improve productivity and competitiveness continues, firms know that customers themselves can be used to provide certain services, as long as it is seen by customers as value enhancing. The benefits of self-service include faster service, more customized service, and lower prices, since firms need fewer employees. The benefits for the companies include lower labor costs and additional service capacity. In this sense, customers are "hidden employees," allowing the firm to hire fewer workers and to vary capacity to some extent as needed. The trade-off for customers is that they expect to pay less for these services, since they are doing some of the work. This includes services like bagging groceries, filling soda cups, and filing taxes.

In other cases, though, customers might actually pay the same or more for the service, as when using self-checkout at grocery stores or using 24-hour automated teller machines. Customers perceive the work they perform as saving time or providing some other benefit. Thus, if firms can identify service process jobs that customers can perform, if they can provide process directions that are easy to understand and learn, and if they can adequately satisfy the customers who are being asked to perform the work, then using customers as service providers creates yet another method for managing capacity. U.K.-based Photo-Me International, which owns 44,500 self-service photo booths and other self-service businesses (such as launderettes) in 17 countries, and operates solely with the self-service concept.[27]

## Using technology

Providing technological assistance in the form of computers, software applications, or other equipment to service company personnel can improve the ability of servers to process customers, resulting in more service capacity, faster service completion times, better service quality and the need for fewer employees. Voice-activated telephone response systems, online banking, purchasing, selling and comment systems, and field sales software applications are just a few examples of technology helping the provision of services. Some forms of technology may completely replace the need for sales or other types of in-person service personnel as in the case of Amazon.com and other online retailers. Advances in software capabilities and cloud computing have also allowed services to share use of expensive software systems like reservation systems and property management systems, which greatly improve productivity while reducing labor and software development costs. Retailers are also increasingly using contactless payments, in part due to the pandemic, and the numbers are only increasing. Gartner, a research and advisory company, predicts that by 2024, 80 percent of ordering and replenishment will be touchless for most organizations. Additionally, ACI Worldwide, a provider of real-time digital payment software and solutions, found that 35 percent of consumers would be willing to leave their preferred grocers for others that allow them to pay in-store in a touchless manner.[28]

Technology can also enable service standardization—providing the service exactly the same way every time, as with automated teller machines or ticketing machines. In many cases, service standardization is viewed as a high-quality characteristic by customers seeking specific, fast, periodic services. Standardization allows services to be accessed anywhere at any time, without the need for relearning the service process.

## Using employee scheduling policies

As mentioned briefly above, properly scheduling workers allows firms to adjust capacity to accommodate varying demand. Businesses forecast demand in short time increments during the day and then convert the demand to staffing requirements for each period,

given the average service capabilities for workers. The problem of assigning workers to shifts is complicated by the number of hours each day, the number of days each week the business is open, the timing of days off and consecutive days off, and employee shift preferences. The objective of worker scheduling is to adequately serve customers with the minimum number of employees, while also assigning equitable work shifts to employees. Employee scheduling software is available to provide managers with multiple scheduling solutions to this problem.

Use of part-time workers, as stated earlier, makes scheduling easier and is illustrated in Example 12.4. In the example, the manager uses full-time workers for the base level requirement for the five-day week, while using part-timers to fill out the remaining requirements each day.

**Example 12.4 Workforce Scheduling at Rose Plumbing Supply**

The manager of Rose Plumbing Supply has determined his workforce requirement as shown below for the five-day workweek. Given these requirements, Bill sees that he needs two full-time employees working all five days, resulting in the part-time requirements as shown (found by subtracting two from each workday requirement). To satisfy these requirements with the fewest number of part-time employees, he begins by assigning Part-timer No. 1 to the maximum number of workdays (Monday, Thursday and Friday). Part-timer No. 2 is assigned to the maximum number of workdays remaining (Monday and Friday). Then Part-timers 3 and 4 are assigned to the remaining workday (Friday).

| | MONDAY | TUESDAY | WEDNESDAY | THURSDAY | FRIDAY |
|---|---|---|---|---|---|
| **Workers Required** | **4** | **2** | **2** | **3** | **6** |
| **Full-time Workers** | 2 | 2 | 2 | 2 | 2 |
| **Part-time Workers** | 2 | 0 | 0 | 1 | 4 |
| **Part-timer No. 1** | 1 | | | 1 | 1 |
| **Part-timer No. 2** | 1 | | | | 1 |
| **Part-timer No. 3** | | | | | 1 |
| **Part-timer No. 4** | | | | | 1 |

### Using demand management techniques

Even when accurate forecasting and good capacity management techniques are used, there are many occasions when demand exceeds available capacity. As stated earlier, forcing customers to wait in line for a long period of time may result in lost current and future business and damage to the firm's reputation. Organizations can try to reduce demand during busy periods using several short-term demand management techniques. These include raising prices during busy periods to reduce demand and shift it to less busy periods, taking reservations or appointments to schedule demand for less busy periods, discouraging undesirable demand through use of screening procedures and marketing ads, and segmenting demand to facilitate better service (examples include use of first-class and economy-class seating, and use of express and regular checkout stations). These tactics are combined with the capacity management techniques discussed earlier to provide the firm with the ability to better serve customers. The next section describes capacity management techniques for periods when service capacity exceeds demand.

## Capacity Management When Capacity Exceeds Demand

When capacity exceeds demand, the firm is faced with the problem of managing excess capacity. Too much excess capacity means higher fixed costs, resulting in higher prices for the services provided, and may also affect customers' perceptions of quality (readers

may recall their own quality perceptions when walking into a mostly-deserted restaurant at peak dinner hours). Besides the obvious long-term solution of laying workers off and reducing location size, firms may be able to find other uses for service capacity or use demand management techniques to stimulate demand.

### Finding other uses for capacity

One way to utilize excess capacity is to develop additional service products. Periodic lack of demand might be particularly troublesome for services with seasonal demand such as hotels, airlines, and ski resorts. For these services, management may try to develop service products that the firm can provide during their characteristically slow periods. This might include airlines partnering with resorts to provide vacation packages during off-peak seasonal periods, hotels booking business conferences during slow periods, or ski resorts designing mountain bike trails or building cement luge runs for summer use. Firms can also make use of cross-training to shift or transfer employees to other areas temporarily needing more capacity, as described earlier. For instance, swimming pool builders might train and then use their construction workers to build pool enclosures during the winter months.

In an interesting use of excess electricity capacity, Canada is gearing up for handling the electricity demand for all-electric and plug-in hybrid cars, with over 141,000 units at the end of 2019, and growing rapidly. Currently, Canada's hydro, coal, natural gas and nuclear power sources go largely unused during nighttime hours, and this power can't easily be turned off. It thus becomes wasted power. Consequently, Canada is using smart electricity meters to charge users cheaper rates for power usage during off-peak hours, which allows electric cars to be cheaply recharged at night. "We have the resources and the electricity," says Al Cormier, executive director of the not-for-profit organization Electric Mobility Canada. "We should take advantage of this opportunity."[29]

### Using demand management techniques

When capacity exceeds demand, demand management techniques can be used to stimulate demand. These include lowering prices during off-peak periods as described above, early-bird dinner specials or mid-week hotel rates, as well as designing aggressive marketing campaigns for use during slow business periods. Marriott's loyalty program for example, Bonvoy, offers peak and off-peak pricing to drive program redemptions to the low occupancy periods. And, the London-based Bob Bob Ricard restaurant boasts off-peak and mid-peak pricing strategies, in which menu pricing is based on time and day of visit. Off-peak pricing at, say, Monday lunch is 25 percent lower than at primetime Saturday evening, while the mid-peak rate is about 15 percent below the regular rate.[30]

Managing capacity in services thus involves techniques to adjust capacity and either stimulate or shift demand to match existing capacity to demand. When an oversupply or undersupply of capacity exists, service times, waiting times, cost, and service quality all suffer, which ultimately impact the competitiveness of the firm. The second concern in service response logistics is discussed next—managing queue times.

## Managing Queue Times

**Queue times** are frequently encountered every day by consumers including waiting at checkout counters, waiting for a table at a restaurant, and waiting on hold on the cellphone. Ideally, service managers would like to design **queuing systems** such that customers never

## SCM Profile iPads Reduce Service Times at Tucson Subaru


H_Ko/Shutterstock.com

In 2019, Tucson Subaru in Arizona began having its express service advisers use iPads as a way to reduce customer service times. Along with fast customer check-ins, the iPads have helped keep the three express advisers on task. "Express advisers are a little more green, so it prompts them to do the video walk-around and take the pictures and check the different things," service director Scott Gregg says. "They have a little checklist on there—they have to check off wiper blades, tires, things like that. So it assists them in developing good habits."

Gregg says his team has encountered a few issues with the iPads, but nothing major. Charging the five iPads each night is part of an adviser's routine and is strictly enforced. Since purchasing the iPads for express service, Tucson Subaru has reduced by 17 minutes, the time it took to get a customer written up, into the shop and the work completed. Express service customers now have their cars' work completed, on average, in 57 minutes. Gregg monitors advisers' performance on the iPads daily to make sure they are using them correctly. "Otherwise, they want to go back to the old ways writing notes on a piece of paper, which is not really faster but in their mind, it is for some reason," he says.

Express service adviser Brittney Ottaviano says she's not necessarily a "fan of technology" but does like how quick the iPad lets her work. "I'm able to pull up all their information and have them confirm it," she says. "Then I do the walk-around and get a signature. So it's very quick and makes it easier for [the customer] as well. They love it; they think it's really cool."

Every two weeks, Gregg reviews with his advisers their key performance indicators and customer satisfaction scores to discuss areas in which they can improve. High-performing advisers are rewarded with monthly bonuses based on performance, customer satisfaction and net promoter scores.[31]

have to wait in a queue; however, the cost of maintaining enough excess service capacity to handle peak demand and unexpectedly high levels of demand is simply too expensive. Thus, managers use information they have about their customers as well as their service employees to design adequate queuing systems and then couple this with management of customers' perceived waiting times to minimize the negative impact of waiting in line. Many businesses have resorted to using text messaging to reduce queue lengths and wait times. The nearby SCM Profile discusses the use of iPads to reduce wait times for service customers at an auto dealership.

Good queue management consists of the management of *actual waiting times*, as well as *perceived waiting times*. To accomplish this, managers must consider a number of issues:

- What is the average arrival rate of the customers?
- In what order, will customers be serviced?
- What is the average service rate of the service providers?
- What is the average service time requirement of customers?

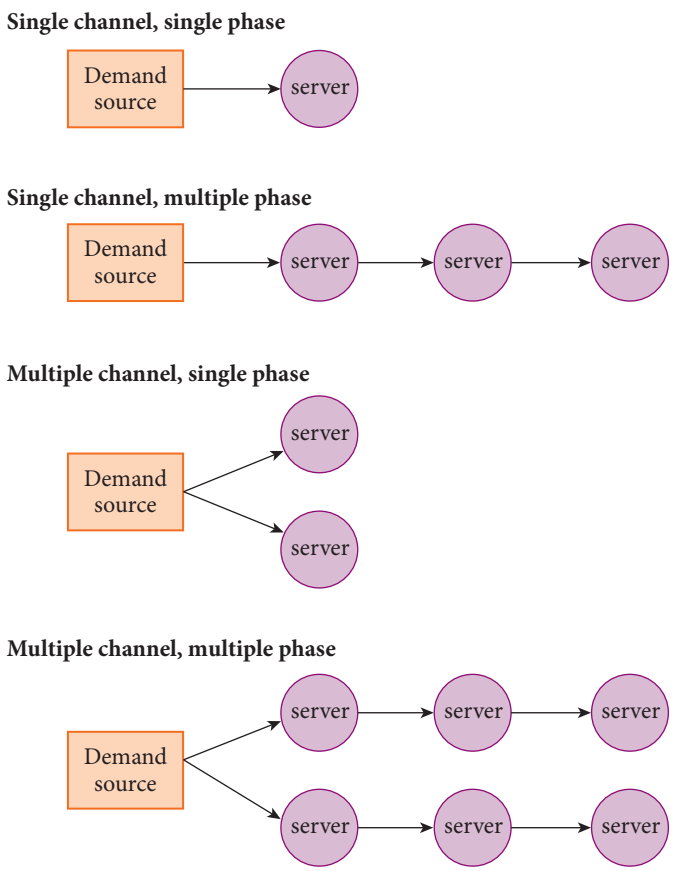
- How are customers' arrival and service times distributed?
- How long will customers actually wait in a queue before they either leave or lower their perceptions of service quality?
- How can customers be kept in line even longer without lowering their perceptions of service quality?

Answers to these questions will allow the firm to adequately design a queuing system that will provide acceptable service to most customers while minimizing the service system cost and the cost of lost and disgruntled customers. Properly thought-out and designed queuing systems decrease waiting times and subsequently the need for further managing waiting times; however, occasionally, waiting time management tactics must be utilized to decrease perceived waiting times. The design of queuing systems is discussed first, followed by a discussion of managing perceived waiting times.

## Queuing System Design

The four types of queuing system configurations are shown in Figure 12.1. The most appropriate queuing system depends on the volume of customers to be served, the willingness of customers to wait in a queue, the physical constraints imposed by the service

**Figure 12.1** Queuing System Configurations



structure and the number and sequence of services to be performed. The outputs from various queuing systems that managers need to compare are the average number of customers in the queue and in the system, the average waiting time in the queue and in the system, and the average server utilization (the "system time" includes the waiting time and the actual service time). As alluded to earlier, the primary elements of all queuing systems are the *input process*, the *queue characteristics* and the *service characteristics*. These elements are discussed next, along with several applications.

## The Input Process

Customer arrivals are referred to here as the demand source. The size of the demand source can be considered either infinite or finite. Many situations (along with the examples covered later) assume an unlimited or infinite demand source such as customers arriving at a retail outlet, whereas other situations have a finite-sized demand source, such as ticketed customers showing up for a concert at an arena.

Customers also arrive at a service according to an **arrival pattern**. When students show up for a scheduled class, this is an example of a known or *deterministic interarrival time*. In many cases as in a retail establishment, customers show up in a random pattern, and the *Poisson distribution* (named after the 19th century French mathematician Siméon Denis Poisson) is commonly used to describe these customer arrivals. Using the Poisson distribution, the probability of $x$-customers arriving within some time period, $T$, is expressed as:

$$P_{x(T)} = \frac{e^{-\lambda T}(\lambda T)^x}{x!}$$

where $\lambda$ = average customer arrivals in time period $T$
$e$ = 2.71828 (natural log base),
$T$ = time period in hours (usually assumed to be 1), and
$x!$ = $x$ factorial = $x(x-1)(x-2)\ldots(1)$.

Example 12.5 illustrates the use of this formula.

**Example 12.5 Arrivals per Hour at Jay's Quick Lube Shop**

Jay's Quick Lube Shop can service an average of four cars per hour with a partial crew of three employees, and the owner Jay is interested in calculating the probability they can handle all the customers on Saturdays with the partial crew, instead of his usual full crew of five. Given an average arrival rate of three customers per hour on Saturdays, he uses the Poisson distribution to calculate the probabilities of various customer arrivals per hour, shown below.

| NUMBER OF ARRIVALS, $x$ | $P(x \text{ for } T = 1 \text{ hour}) = \frac{e^{-3}3^x}{x!}$ | CUMULATIVE PROBABILITY |
|---|---|---|
| 0 | 0.0498 | 0.0498 |
| 1 | 0.1494 | 0.1992 |
| 2 | 0.2240 | 0.4232 |
| 3 | 0.2240 | 0.6472 |
| 4 | 0.1680 | 0.8152 |

By summing the probabilities for each of the arrival levels, Jay figures that he can handle the demand per hour approximately 82 percent of the time. Conversely, he figures that approximately 18 percent of the time, demand per hour will be greater than four customers, causing queues to develop.

If we assume the number of arrivals per time period is Poisson distributed with a mean arrival rate of $\lambda$, then the interarrival time (time between arrivals) is described by the negative exponential distribution, with a mean interarrival time of $1/\lambda$ (so if the mean

arrival rate is 10 per hour, then the mean interarrival time is (60 minutes/10 arrivals), or 6 minutes/arrival).

Most queuing models assume that customers stay in the queue once they join it. In other words, customers do not exhibit **balking** (refusing to join the queue once they see how long it is) or **reneging** (giving up and leaving the queue before receiving the service). Though most people have done these two things at one time or another, queuing analysis becomes much more complex when these arrival characteristics are allowed.

## The Queue Characteristics

Queuing models generally assume the length of a queue can grow to an infinite length, although for some situations this is not appropriate (e.g., a finite number of people with tickets waiting to enter a concert). Queuing configurations can contain single or multiple queues (e.g., the single winding queue at Wendy's versus the multiple queues at some McDonald's). Another queue characteristic is the **queue discipline**. The discipline describes the order in which customers are served. The most common queue discipline is first-come-first-served, although other examples include most-needy-first-served (in emergency rooms) and most-important-first-served (a VIP queue at a nightclub).

### Virtual queues

Technology is impacting queuing systems such that **virtual queues** are becoming more commonplace. Customers' places in the queue are tracked by a computerized system that allows them to roam the premises until their hand-held monitor lights up. This reduces balking and reneging while allowing customers to make better use of their time. For instance, the Lavi Industries' Qtrac system registers customers via their smart phone or computer, then lets customers know their expected waiting time. Customers are continuously updated. In hospitals in Shanghai, waiting patients can input their cell phone numbers into a computer system that sends them a text message when they become fifth in line, allowing them to leave without fear they will miss an appointment.[32]

Increasingly, companies are allowing queue-jumping, which can happen invisibly in virtual queues. Call centers for example, can prioritize callers in a telephone queue once they have been identified. Additionally, customers willing to pay extra can in many cases jump queues. Banks, airlines, and credit card companies have elite call centers, and some doctors give patients priority if they pay extra. U.K.-based Accesso operates hand-held devices (called Q-bots) and smart phone apps (called Q-smart) that allow theme park visitors in 20 theme parks worldwide, to reserve a spot in line. A premium option allows visitors to jump the queues.[33] Virtual queuing has also proved useful during the pandemic. U.K. grocer Sainsbury's has rolled out its virtual queueing system to a number of stores, to minimize the wait outside of branches under its coronavirus safety protocols (customers must queue outside stores before the (customers must queue outside stores before they are allowed to enter). The queuing app allows customers to select the store where they wish to shop. The app notifies them when they are at the 'front' of the line, without the need to physically queue.[34]

## The Service Characteristics

Services can be provided either by a single server or by multiple servers that act in series or in parallel. Multiple servers acting in parallel is referred to as a **multiple-channel queuing system**. Multiple servers acting in series is referred to as a **multiple-phase queuing system**. Figure 12.1 above shows these queuing configurations.

The *single-channel, single-phase* configuration is the most basic. For standard distribution patterns of customer arrival and service times, the formulas to evaluate this type of system are very straightforward. An example is the one-person retail shop (such as a comic book shop or gift shop). Customers encounter one server, who performs one service (accepting payment). The *single-channel, multiple-phase* queuing system is the next configuration shown. For this system, customers all contact the same servers, but receive more than one service and encounter a queue at each service. An example of this type of service is a dentist's office where customers are checked-in by a receptionist, get their teeth cleaned by a dental hygienist, get their teeth x-rayed by a dental assistant and then get a dental exam by a dentist. For each service, longer-than-average service times by the preceding customer or during one phase of the service can mean waiting line buildups within the entire system. The third configuration shown is the *multiple-channel, single-phase* system. Customers enter the system, receive one service from any one of a number of servers and then exit. Examples of this are retailers' checkout stands or banks' teller windows. These systems can have queues at each channel or one winding queue where all channels receive customers from one line. The final configuration shown is the *multiple-channel, multiple-phase* queuing system. In this example, customers all receive more than one service in sequence from more than one set or channel of servers. An example here might be a large medical clinic where patients are checked in by one of several assistants, have their vital signs recorded by one of several nurses and receive a medical consultation and service by one of several doctors.

Another characteristic of a service are the times required to complete each of the services provided. For each phase in the system, service times are described by a mean time and a probability distribution. Frequently, the negative exponential distribution is used to describe the randomness of service time distributions. To determine the probability that the service time, $t$, will be less than or equal to some specified time, $T$, the following formula can be used:

$$P(t \leq T) = 1 - e^{-\mu T}$$

where $e = 2.71828$ (natural log base), and
$\mu =$ the average service rate.

Example 12.6 illustrates the use of this formula for calculating the probability of completing service within a specified time period.

**Example 12.6 Service Times at Jay's Quick Lube Shop**

Jay's Quick Lube Shop can service an average of four customers per hour, or one customer every fifteen minutes, with a crew of three service personnel. The average customer arrival rate on Saturdays is three customers per hour, or one customer every twenty minutes. Jay is interested in calculating the probability that actual service time, $t$, will be within a specific time period, $T$, and he develops a chart showing these probabilities below, using the negative exponential distribution.

| SPECIFIC TIME PERIOD | $P(t \leq T \text{ hrs.}) = 1 - e^{-4T}$ |
|---|---|
| 15 min (0.25 hrs.) | $1 - e^{-4(.25)} = 0.6321$ |
| 20 min (0.33 hrs.) | $1 - e^{-4(.33)} = 0.7329$ |
| 30 min (0.5 hrs.) | $1 - e^{-4(.5)} = 0.8647$ |
| 40 min (0.67 hrs.) | $1 - e^{-4(.67)} = 0.9314$ |
| 45 min (0.75 hrs.) | $1 - e^{-4(.75)} = 0.9502$ |

Thus, Jay thinks that about 73 percent of the time, they will be able to service a customer in less than or equal to twenty minutes.

For single-channel systems, the average arrival and service rates can be used to calculate average capacity utilization, by dividing the customer arrival rate by the customer service rate. For example, if the arrival rate is three per hour and the service rate is four per hour, then the average capacity utilization is 75 percent. Although, as can be seen in Example 12.5, there could possibly be times when utilization for periods during the day approaches or exceeds 100 percent. Now that all of the important elements of queuing systems have been reviewed, various applications of the models can be discussed and these are presented next.

## Queuing System Applications

When using queuing models, managers collect arrival rate and service rate data by observing over time how many customers actually arrive for service and how many customers are actually served. Depending on the service, it may take a number of days or weeks to compile meaningful information. Presented below are applications of the single-channel, single-phase queuing model and the multiple-channel, single-phase queuing model. These are meant only to be introductory applications. Examples for the other queuing systems and applications can be quite complicated and are beyond the scope of this text. Interested readers are encouraged to examine management science or operations research texts for more advanced treatments of this topic. Several references are provided at the end of the chapter for this purpose.

### A single-channel, single-phase queuing system application

This is the most widely used and simplest of all queuing systems. The assumptions for the system are:

- Customers come from an infinite population and are Poisson distributed over time.
- Customers are served in first-come-first-served sequence.
- No balking or reneging occurs.
- Service times are distributed according to the negative exponential distribution.
- The average service rate is greater than the average arrival rate.

The symbols and equations used to determine the operating characteristics for the single-channel, single-phase queuing model are:

$\lambda$ = average arrival rate

$\mu$ = average service rate

$\rho$ = average server utilization = $\lambda/\mu$

$L_s$ = expected number of customers in the system = $\lambda/(\mu-\lambda)$

$L_q$ = expected number of customers in the queue = $\lambda^2/[\mu(\mu-\lambda)] = L_s - \lambda/\mu$

$W_s$ = expected waiting time in the system = $1/(\mu-\lambda) = L_s/\lambda$

$W_q$ = expected waiting time in the queue = $\lambda/[\mu(\mu-\lambda)] = L_q/\lambda$

$P_n$ = probability that there are $n$ units in the queuing system = $(\lambda/\mu)^n(1-\lambda/\mu)$

Example 12.7 illustrates the calculations of operating characteristics for a single-channel, single-phase service.

**Example 12.7 Operating Characteristics for Kathy's Sewing Shop**

Kathy's Sewing Shop can serve about five customers per hour. For the past two weeks Kathy has kept track of the customer arrival rate, and the average has been four customers per hour. Kathy is interested in calculating the operating characteristics for her store. So she asks one of her customers, a business student at the local university, to help her. The student provides the following information:

$\lambda = 4$ customers per hour
$\mu = 5$ customers per hour
$\rho = 4/5 = 0.8$ or 80% utilization
$L_s = \lambda/(\mu-\lambda) = 4/(5-4) = 4$ customers
$L_q = L_s - \lambda/\mu = 4 - 4/5 = 3.2$ customers
$W_s = L_s/\lambda = 4/4 = 1$ hour $= 60$ minutes
$W_q = L_q/\lambda = 3.2/4 = 0.8$ hours $= 48$ minutes

Kathy also wants to know how likely it will be that more than four customers will be in her shop at one time. So the student thinks about this and decides to determine the probabilities of zero, one, two, three and four customers in the shop, and then subtract their sum from 1. So, she provides the following information:

For $n = 0$ $P_0 = (4/5)^0(1-4/5) = 0.200$
$n = 1$ $P_1 = (4/5)^1(1-4/5) = 0.160$
$n = 2$ $P_2 = (4/5)^2(1-4/5) = 0.128$
$n = 3$ $P_3 = (4/5)^3(1-4/5) = 0.102$
$n = 4$ $P_4 = (4/5)^4(1-4/5) = 0.082$
For $n > 4$ $P_{n>4} = 1 - (P_0+P_1+P_2+P_3+P_4) = 1-(0.2+0.16+0.128+0.102+0.082) = 1 - 0.672 = 0.328$

So Kathy can expect that there will be more than four people in her shop about 33 percent of the time.

Kathy can also purchase a barcode scanner with an automated cash register that will increase her service rate to ten customers per hour. She wants to know how this will change the average wait time in the queue and in the system. The student then shows her the very significant change this will make:

$L_s = \lambda/(\mu-\lambda) = 4/(10-4) = 0.67$ customers
$W_q = \lambda/[\mu(\mu-\lambda)] = 4/[10(6)] = 0.067$ hours $= 4$ minutes
$W_s = 1/(\mu-\lambda) = 1/6$ hour $= 10$ minutes

## A multiple-channel, single-phase queuing system application

All of the assumptions shown above still apply for the multiple-channel, single-phase system, except that the number of servers is now greater than one, and the queuing system consists of multiple servers serving customers from multiple queues. The operating characteristics of this queuing system are as follows:

$\lambda$ = average arrival rate
$s\mu$ = average service rate, where $s$ = number of service channels
$\rho$ = average server utilization $= \lambda/s\mu$
$P_0$ = probability of zero customers in the system

$$= \frac{1}{\sum_{n=0}^{s-1}\frac{(\lambda/\mu)^n}{n!} + \frac{(\lambda/\mu)^s}{s!}\left[\frac{1}{1-(\lambda/s\mu)}\right]}, \text{ for } s\mu > \lambda$$

$P_n$ = probability of $n$ customers in the system $= P_0\dfrac{(\lambda/\mu)^n}{n!}$, for $n \le s$, or

$$= P_0\frac{(\lambda/\mu)^n}{s!s^{n-s}}, \text{ for } n > s$$

$L_q$ = expected number of customers in the queue $= P_0\dfrac{(\lambda/\mu)^s(\lambda/s\mu)}{s!(1-\lambda/s\mu)^2}$

$L_s$ = expected number of customers in the system = $L_q + \lambda/\mu$

$W_q$ = expected waiting time in the queue = $L_q/\lambda$

$W_s$ = expected waiting time in the system = $W_q + 1/\mu$

Example 12.8 extends the single-channel, single-phase shop, to the two-channel, single-phase shop, for comparison purposes.

**Example 12.8 Operating Characteristics for Kathy's Expanded Sewing Shop**

Kathy's Sewing Shop has decided to hire a second worker and buy a second checkout stand with cash register for the shop. Both Kathy and the second worker can serve five customers per hour and the average arrival rate is four customers per hour. Kathy again wants to know all of the operating characteristics of the new configuration. Once again, her student-customer helps her out:

$\rho = 4/10 = 0.4$, or 40 % utilization

$$P_0 = \frac{1}{\frac{(4/5)^0}{0!} + \frac{(4/5)^1}{1!} + \frac{(4/5)^2}{2!}\left(\frac{1}{1-(4/10)}\right)} = \frac{1}{1 + 0.8 + 0.32(1.67)} = \frac{1}{2.33} = 0.428$$

$$L_q = \frac{(4/5)^2(4/10)}{2(1-4/10)^2}(0.428) = 0.152 \text{ customers}$$

$L_s = 0.152 + 4/5 = 0.952$ customers

$W_q = 0.152/4 = 0.038$ hours, or 2.28 minutes

$W_s = 0.038 + 0.2 = 0.238$ hours, or 14.28 minutes

Note that because of the mean service time and distribution differences, having a two-channel, two-queue system serving customers with an average service rate of five customers per hour per channel is not the same as having a one-channel, one-queue system that serves at a rate of ten customers per hour.

## Managing Perceived Waiting Times

The final topic of discussion in managing queue times management of **perceived waiting times** (sometimes, customers perceive the wait time to be much longer or shorter than it really is). Even though an admirable job may be done designing a queuing system, there are still likely to be times when demand exceeds the queuing system's capacity (recall the mention earlier of the two-hour wait in a doctor's office). For these time periods, service firms must have other tools at their disposal to influence customers' perceptions of the waiting times. In a well-known paper written on the topic of waiting time, Dr. David Maister, a Harvard Business School professor and expert on business management practices, presented some very interesting observations. These are discussed below.

**First and Second Laws of Service:**[35]

*Law #1: Satisfaction = perception − expectation*

When customers expect a certain level of service, and then perceive the service they actually received to be higher, they will be satisfied. Conversely, when customers' service expectations are higher than their perceptions once the service has been completed, they are dissatisfied.

*Law #2: It's hard to play catch-up ball*

If customers start out happy when the service is first encountered, it is easy to keep them happy. If they start out disgruntled or become that way during the service, it is very difficult to turn things around.

Service Law #1 is interesting in that expectations and perceptions are not necessarily based on reality. For example, customer expectations are formed based on previous experiences, marketing campaigns, signs, information from other people, and the location, while customer perceptions can be affected during the service encounter by a friendly server, mood music, visually pleasant surroundings and a host of other things. A common practice coming out of Law #1 is to "under-promise and over-deliver." Service Law #2 is good for firms to remember when they are trying to improve service. Investments in service improvements might best be placed at the initial contact or early stages of the service to make sure the service encounter gets off to a good start.

Firms can manage both customer expectations and perceptions by observing and understanding how they are affected when customers wait for service. Waiting time management techniques resulting from this understanding include keeping customers occupied, starting the service quickly, relieving customer anxiety, keeping customers informed, grouping customers together, and designing a fair waiting system.[36] Each of these is briefly discussed next.

## Keeping customers occupied

Firms can benefit by keeping customers occupied while waiting in line. This is why magazines, televisions, coffee, and toys for children are often seen in various business waiting areas. Other attention-keepers such as music, windows, mirrors, or menus to look at keep customers' minds off the passage of time. In amusement parks such as Disneyland where long lines can be a big problem, customers waiting in line might get entertained by Mickey Mouse, a mime, or a juggler, for instance. All of these techniques try to lessen the perceived passage of time and influence customer satisfaction with the waiting experience. At Illinois-based Abt Electronics, the store's merchandise pickup area is a hub for customer activity. Abt has made it an emblem of the store's personality as well as a way to keep customers occupied during their wait for a TV or iPad. "We have a Wall of Fame there that's an interesting history of the store; nothing to do with product, just photos of a lot of famous people who've shopped there," says Billy Abt, co-president. "And that's always changing; if new people are added, we move some of the older celebrities up to the lunchroom. There is also what amounts to an appliance museum of sorts with ringer washers from the 1930s, old refrigerators with the motors on top, TVs from the 1950s, and one of the first Macintosh computers. Also added for customers' distraction three years ago were two LCD commercial screens that display a map of the Greater Chicago area, so that all of Abt's deliveries for the day can be shown. Customers find it interesting to see how many different neighborhoods we go to on an average day, and it's fun for them to find theirs," he said.[37]

## Starting the service quickly

Giving waiting customers forms to complete, menus and drinks from the bar, or programs to read all act to give customers the impression the service has started. When firms acknowledge receipt of an order via telephone, mail, or e-mail, this is another example of beginning the service. If organizations can design pre-process activities that begin quickly once a customer encounters a queue, this will act to keep customers occupied and make long waits seem much shorter. The London-based Carphone Warehouse (CPW), a mobile phone retailer, has turned to Facebook and Twitter to engage customers quickly and keep them satisfied. They have found it allows them to address complaints more quickly, offer quick feedback on problems and to positively impact customer satisfaction. If a customer wants to know whether a certain city has a retail location, CPW can tweet a link to the store; if a customer wants to know how to remove a SIM card, CPW can tweet the solution.[38]

### Relieving customer anxiety

Customer anxiety is created in many waiting situations; for example, when customers are afraid they've been forgotten, when they don't know how long their wait is going to be, when they don't know what to do, or when they fear they've entered the wrong queue. Managers need to observe customers, learn what is likely causing their anxieties, then develop plans for relieving them. These plans might include simply having employees reassure customers, announcing how much longer a caller on hold is likely to wait, announcing the lateness of a plane yet to arrive, or using signs to direct customers to the correct line.

### Keeping customers informed

Managers can derail customer anxieties before they even begin by giving customers information as their pre-process and in-process waits progress. When receptionists tell patients that their doctor is thirty minutes behind schedule, when pilots tell passengers that the plane is waiting to be cleared for gate departure, when work crews place a flashing sign on the road warning drivers to expect delays during a certain period of time, and when amusement parks place signs in the queue telling customers the waiting time from that point forward, this information makes waiting customers much more patient because they know that a delay will occur and the reasons for the delay. Consequently, they are much more willing to stay in line, remain satisfied and complete the service.

### Grouping customers

Customers generally prefer waiting together in queues, rather than waiting alone. Customers act to alleviate their own and others' anxieties, fears and problems while waiting in line by talking to each other, sharing concerns and helping out if possible. This sense of togetherness reduces perceived waiting times and may even add enjoyment to the waiting experience. Managers should think of ways to create or encourage group waiting instead of solo waiting such as closer seating, single queues instead of multiple queues and use of numbered tickets or virtual queues so people don't have to physically stand in the queue.

### Designing a fair waiting system

"Taking cuts" or queue-jumping is something that can cause significant irritation to others already waiting, particularly if it is seen as unfair. In an emergency room, most people waiting will likely accept that others coming into the queue later might be taken care of first (this queue discipline would be most-critical-first-served). Alternately, taking cuts in a long queue at a retail store or amusement park could result in grumbling and shouting from those already waiting (recall our earlier discussion about virtual queues removing some of these problems). Whenever the queue discipline is something other than first-come-first-served, managers need to be aware of the potential problems this causes and take steps to reduce the feeling of unfairness, or segment customers such that the queue discipline is not obvious. Examples include physically separating customers such as in first-class versus economy-class seating on airplanes, taking names and group sizes at a restaurant while concealing the list, and putting up signs like "six items or less" at retail checkout stands. In many cases, customers will understand and accept the reasons for using a particular queue discipline if they are informed of it. The next concern of service response logistics is the management of distribution channels.

## Managing Distribution Channels

This next topic within service response logistics describes several distribution channels and strategies a service can use to deliver their services and goods to customers.

Table 12.2 lists a number of distribution alternatives for a retailer, a bank, an auto repair facility and a university. Many of these distribution alternatives are the traditional ones everyone is used to seeing; however, services today are experimenting with other, nontraditional distribution channels as customer preferences and habits, demographics, technology, and competition change.

Some distribution channels have revolutionized the way services do business. For instance, ATMs, debit cards, and the Internet have completely changed the financial services industry; many customers almost never set foot inside a bank or stockbroker's office. Today, many people have come to expect these things, and services have responded.

Other distribution strategies have arisen because new technologies made them possible, and because customers were asking for them. In the grocery industry, Amazon's grocery delivery service through Amazon Fresh and Whole Foods Market is available in over 2000 cities in the United States. Amazon's grocery delivery service is available for two-hour delivery windows, and can also be delivered within customers' garages.[39] Several of the distribution channel alternatives and issues facing services today are discussed next.

## Eatertainment, Entertailing and Edutainment

As service distribution concepts change, new words have been coined to describe these concepts. **Eatertainment** is the combination of restaurant and entertainment elements. Many of these services incorporate elements of local culture or history into their design themes and offer the capabilities of eating, drinking, entertainment and shopping all in one venue. For over 30 years, fast food restaurants like McDonalds and Burger King have incorporated children play areas in their restaurants, and Chuck E. Cheese restaurants are

**Table 12.2 Service Distribution Channels**

| SERVICE | DISTRIBUTION CHANNEL |
|---|---|
| Retailer | • Freestanding<br>• Mall<br>• Internet<br>• Mail order |
| Bank | • Main office/headquarters<br>• Freestanding branches<br>• Sites in malls<br>• Sites in retail locations<br>• ATMs<br>• Internet<br>• Cellphone |
| Auto Repair Business | • Freestanding<br>• Attached to a large retailer<br>• Franchised outlets<br>• Mobile repair van |
| University/College | • Public<br>• Private<br>• Specialized/General<br>• Traditional/Adult education<br>• Main campus<br>• Branches<br>• Internet<br>• Day/Evening<br>• Television |

another example of the eatertainment concept that's been around for a while. Today, things are different. "Millennials really seek out and consume experiences," says Robert Thompson, CEO of Punch Bowl Social, a "social emporium" featuring everything from arcade games and ping-pong to bocce ball and bowling. Punch Bowl Social recruited "Top Chef" judge Hugh Acheson to lead its culinary operations. Thompson says Acheson's menu is a modern, Southern-inspired take on comfort food, with items like Wagyu beef hot dogs, a bologna sandwich with green olive tapenade, and chicken and waffles made with chipotle cream cheese and pecan maple syrup. Punch Bowl Social's customers expect the brand to challenge them with the culinary offerings, he adds; almost 90 percent of the company's revenue comes from food and beverage.[40]

**Entertailing** refers to retail locations with entertainment elements. Many shopping malls are designed today to offer entertainment such as ice skating, rock climbing and amusement park rides. Since opening in 1992, Bloomington, Minnesota's Mall of America boasts 4.2 million square feet of enclosed area, a theme park, an aquarium, a Lego play area, a mini-golf park, a flight simulator center, 500+ retailers, over 400 events per year, and 11,000 employees. The Body Shop in London is a prototype for a new "experience based" store. The retailer, with 3000 locations in more than 65 countries, is testing the new entertailing model that includes information and conversation areas designed to encourage customers to linger as they flow through the store. Shoppers can receive hand massages while listening to stories at the "story table" and test a variety of goods for sale, including ointments, lotions and makeup. "We found that the average amount of time a consumer spends in our prototype stores has doubled, from an average of five minutes to more than 10. This shows a depth of interaction and communication we have witnessed," says Sophie Gasperment, CEO of Body Shop International.[41]

Museums, parks, radio shows, movies and a host of service providers are also getting into the act with **edutainment** or **infotainment** to attract more customers, create a learning experience, and increase revenues. Edutainment combines learning with entertainment to appeal to customers looking for education along with play. Television shows such as "Sesame Street," "Schoolhouse Rock!" and "Mr. Rogers' Neighborhood" are examples of edutainment television programming. In the United States, state and national park employees entertain and inform tourists with indigenous animal lectures and shows or campfire stories in the evenings. For many years, documentary movies have been shown to educate and entertain, and radio shows like the U.K. radio soap opera, The Archers, have been educating its audience (in this case, on agricultural matters). Theme parks such as Legoland in San Diego offer attractions that combine fun and education aimed at the two- to twelve-year-old audience.[42]

## Franchising

**Franchising** allows services to expand quickly into dispersed geographic markets, protect existing markets and build market share. When the owners have limited financial resources, franchising is a good strategy for expansion. Franchisees are required to invest some of their own capital, while paying a small percentage of sales to the franchisor in return for the brand name, start-up help, advertising, training, and assistance in meeting specific operating standards. Many services such as fast-food restaurants, accounting and tax businesses, auto rental agencies, beauty salons, clothing stores, ice cream shops, motels and other small service businesses use franchising as a strategy for growing and competing.

Control problems are one of the biggest issues in franchising. Franchisors periodically perform financial and quality audits on the franchisees along with making frequent visits to facilities to assure that franchisees are continuing to comply with operating standards

of the company. The idea of control, however, is something that some new franchisors are experimenting with. The Massachusetts-based Wings Over franchise chain, for instance, lets franchisees make changes to their stores in order to lend an element of uniqueness to each restaurant. Harold Tramazzo and Patrick Daly created a wings delivery business at the University of Massachusetts in 1999. Finding a fairly different, yet desirable niche, the company thrived, and today there are about 40 Wings Over stores, in 13 states, primarily located on the Eastern side of the United States. The franchise in Boston is called Wings Over Boston and has a citrus chipotle sauce among others; several in North Carolina offer dry rub sauces; and in college towns, many Wings Over restaurants don't open until 4:00 p.m., and they close at 3:00 or 4:00 a.m. This gives franchisees the flexibility to compete with local businesses.[43]

The **microfranchise** is another type of franchising concept and is seen as a good way for economically disadvantaged people to make a living. It offers ready-made, low-risk starter jobs for people with little or no education and little available capital, while giving established companies additional distribution avenues. Examples are coffee kiosks, mall goods and services, food stands, and just about any other type of business that sells low-cost goods or services, primarily in high traffic areas. Drishtee, for example, is an India-based microfranchisor. Their small kiosks can be seen in over 2400 rural Indian villages serving about two million customers. Drishtee sells basic healthcare, financial, educational, and retail goods and services. The kiosks can earn the franchisees about $30 per month in profits.[44]

## International Expansion

The search for larger and additional markets has driven some services to expand globally. Since the world today has become essentially borderless because of the Internet and other communication mediums, more freedom of movement, greater use of common currencies and the expansion that has already taken place, services today compete in a global economy.

Global service expansion most likely means operating with partners who are familiar with the region's culture, markets, suppliers, competitors, infrastructure and government regulations. For instance, when McDonald's opened its first restaurant in Moscow in 1990, its entire food supply chain had to be designed and implemented. McDonald's had to train farmers to produce the type and quality of crops needed to supply the business and then find buyers for the excess food the farmers produced (e.g., Moscow hotels and embassies). By the way, over 30,000 people showed up for the grand opening.[45]

China's service sector is emerging as a key driver of the Chinese economy—the service sector has surpassed agriculture in terms of contribution to annual GDP, and is growing annually by about 13 percent. Consequently, many foreign services are looking to become involved in Chinese markets. For instance, Chinaco Healthcare, the very successful Tennessee-based hospital chain, opened its first hospital in the Chinese city of Cixi in 2014. They are operating the CHC International Hospital in a joint venture with the municipal government of Cixi. "Until 2009, the hospital industry was a nonchanging industry," says Sheldon Dorenforest, founder of Dorenforest China Healthcare Group. Today though, "the growth is unlimited. The opportunity is so great, investors are saying, now is the time," he added.[46]

Exposure to foreign currency exchange rate fluctuations can pose a problem for expanding service firms, requiring them to use financial hedging strategies to reduce exchange rate risk. Firms can operate in several different countries to offset currency problems, since economic downturns in one country can often be offset by positive economic conditions in other countries.

Language barriers, cultural problems and the varying needs of different regional cultures also must be addressed when expanding. Local management must be allowed to vary services, signage and accompanying goods to suit local tastes. Restaurants, for instance, typically add local favorites to menus to increase acceptability. Companies must become familiar with language translations in order to properly change the wording on signs and advertisements to increase readability and understanding. The Coca-Cola name in China for example, was initially rendered as "ke-kou-ke-la" on thousands of signs before it was found that the meaning of the phrase was either "bite the wax tadpole" or "female horse stuffed with wax" depending on the regional dialect. Coke personnel eventually studied 40,000 characters to find the phonetic equivalent "ko-kou-ko-le," which translates into "happiness in the mouth." Similarly, Japan's second-largest tourist agency, Kinki Nippon Tourist Co., felt compelled to change its U.S. name after they began getting requests from American customers for unusual sex-oriented trips.[47]

## Internet Distribution Strategies

Internet-based "dot com" companies exploded on the scene during the latter part of the 1990s, pushing the NASDAQ to historic highs and promising to enrich anyone with an idea, good or bad, for a website that could generate revenues on the Internet. E-commerce was touted as the coming trillion dollar revolution in retailing. But as it turned out, most of the dot-com companies of that era are gone today. Still, online retailing is growing faster than traditional brick-and-mortar retailing. In 2020, e-commerce accounted for $432 billion of U.S. retail sales, or approximately 8.8 percent of total U.S. retail sales. E-commerce sales are growing by about 8 percent per year while total retail sales are growing by about 5 percent per year.[48]

One of the primary advantages of the Internet is its ability to offer convenient sources of real-time information, integration, feedback and comparison shopping. Individual consumers use Internet search engines to look for jobs, find and communicate with businesses, find the nearest movie theater, find products, sell things and barter goods. And they can do all this in the privacy of their homes. Globally, it's estimated that Google processes 63,000 searches every second, or about 5.4 billion searches per day, or 2 trillion searches per year.[22] Businesses, too, use the Internet to communicate, find and then purchase items from suppliers, and sell or provide goods and services to individual consumers and other businesses. Today, most businesses, even small ones, either have a website or are building one. Many individuals also have their own websites, since domain names can easily be purchased. Many retailers today sell goods exclusively over the Internet (a *pure strategy*), while others use it as a supplemental distribution channel (a *mixed strategy*).

The **pure Internet distribution strategy** can have several distinct advantages over traditional brick-and-mortar services. Online companies can become more centralized, reducing labor, capital and inventory costs while using the Internet to decentralize their marketing efforts to reach a vastly distributed audience of business or individual consumers. Amazon falls into this category. Today, though, the **mixed Internet distribution strategy** of combining traditional retailing with online retailing seems to be emerging as strong business model. Firms such as Walmart and Target, among many others, sell items in retail outlets and also from Internet and store catalogs. Customers can either pick up their purchases at the store or have them delivered. Southwest Airlines was the first airline to establish a home page on the Internet, and by the end of 2016, approximately 80 percent of its passenger revenue was generated by online bookings via their industry leading website, www.southwest.com.[50]

Developing good customer service capabilities can be challenging, however. Retailer representatives, for instance, must be able to perform customer service functions over the Internet, in-person, and via mail and telephone. Companies are addressing this problem by developing sophisticated **customer contact centers**. These centers integrate their websites and traditional call centers to offer 24/7 support where customers and potential customers can contact the firm and each other using telephone, e-mail, chat rooms and e-bulletin boards. These contact centers allow firms to serve a large number of geographically dispersed customers with a relatively small number of customer service agents.

Just as services have to be concerned with managing service capacity and queues, firms must also invest in designing the necessary distribution channels to compete in today's marketplaces. The final element of the service response logistics discussion affects all elements of the service itself and the way it is distributed, and that is the management of service quality. Although this topic was initially addressed in Chapter 8, the quality management topics geared strictly toward services need further discussion, and this topic is presented below.

## Managing Service Quality

The fourth and final topic area in service response logistics is the management of service quality. For services, quality occurs during the service delivery process and typically involves interactions between a customer and service company personnel. In other words, service quality is closely tied to customer satisfaction. Customer satisfaction with the service depends not only on the ability of the firm to deliver what customers want, but on the customers' perceptions of the quality of service received. When customer expectations are met or exceeded, the service is deemed to possess high quality; and when expectations are not met, the perception of quality is poor (recall Maister's First Law of Service). Thus, service quality is highly dependent upon the ability of the firm's employees and service systems to meet or exceed customers' *varying* expectations. Because of the variable nature of customer expectations, perceptions, and happiness, services must continually be monitoring their service delivery systems using the tools described in Chapter 8 while concurrently observing, communicating with and surveying customers to adequately assess and improve quality.

### The Five Dimensions of Service Quality

Some of the most highly quoted studies of service quality are those done by Drs. Parasuraman, Zeithaml and Berry.[51] Surveying customers of a number of different services and situations, they identified **five dimensions of service quality** generally used by customers to rate service quality—reliability, responsiveness, assurance, empathy, and tangibles. Reliability was consistently reported in their study as the most important quality dimension. The five dimensions are defined below.

- *Reliability*: consistently performing the service correctly and dependably.
- *Responsiveness*: providing the service promptly or in a timely manner.
- *Assurance*: using knowledgeable, competent, courteous employees who convey trust and confidence to customers.
- *Empathy*: providing caring and individual attention to customers.
- *Tangibles*: the physical characteristics of the service including the facilities, servers, equipment, associated goods, and other customers.

Using their survey, the three researchers were able to identify any differences occurring between customer expectations in the five dimensions listed above and customer perceptions of what was actually received during the service encounter. These differences were referred to as service quality "gaps," and can thus be used in actual situations to highlight areas in need of service improvement.

What this research shows is that organizations should develop specific, measurable criteria relating to the five service quality dimensions and then collect data using customer comment cards and mailed or e-mailed surveys of customer satisfaction regarding each of the quality dimensions. This will allow managers to measure overall service quality performance. Table 12.3 presents criteria that might be used in each of the five quality dimensions. Obviously, these would vary by industry, products, and company. When weaknesses or gaps are encountered in any of the performance criteria, managers can institute improvements in the areas indicated.

World-class service companies realize they must get to know their customers, and they invest considerable time and efforts gathering information about customer expectations and perceptions. This information is used to design services and delivery systems that satisfy customers, capture market share and create profits for the firm. These organizations understand that one of the most important elements affecting long-term competitiveness and profits is the quality of their goods and services relative to their competitors.

Washington DC-based Bluemercury, a leading luxury beauty retailer, sees retailing heading a whole new direction after 2020's pandemic. "The pandemic has turned the industry on its head and has been, to say the least, incredibly disruptive. But when you have disruption, you have opportunity," said Marla Beck, CEO of Bluemercury. "Years of e-commerce penetration growth was pulled up to the spring, some estimate 10 years' worth. As we shut down over almost 200 locations, clients who shopped with us in our friendly neighborhood stores became omnichannel customers overnight," she added. Bluemercury's world-class level of tailoring and personalization to its consumers is where

**Table 12.3 Examples of Service Quality Criteria**

| SERVICE QUALITY DIMENSIONS | CRITERIA |
|---|---|
| Reliability | • billing accuracy<br>• order accuracy<br>• on-time completion<br>• promises kept |
| Responsiveness | • on-time appointment<br>• timely callback<br>• timely confirmation of order |
| Assurance | • skills of employees<br>• training provided to employees<br>• honesty of employees<br>• reputation of firm |
| Empathy | • customized service capabilities<br>• customer recognition<br>• degree of server–customer contact<br>• knowledge of the customer |
| Tangibles | • appearance of the employees<br>• appearance of the facility<br>• number of customers at facility<br>• quality of equipment and other goods used |

Beck sees the industry heading—maybe with the help of technology. "Take the concept like the mirror for workouts into the bathroom for intimate skin-care advice. Can I have Alexa for skin care and ask her what product can fix a dark spot, or a pimple that just appeared? Can we imagine technology that replicates this intimate connection with an omnichannel approach for world-class service?" she said.[52]

## Recovering from Poor Service Quality

There will undoubtedly, from time to time, be occasions when an organization's goods and services do not meet a customer's expectations. In most cases, quick recovery from these service failures can keep customers loyal and coming back, and may even serve as good word-of-mouth advertising for the firm, as customers pass on their stories of good service recoveries. Most importantly, when service failures do occur, firms must be able to recover quickly and forcefully to satisfy customers. This involves empowering front-line service personnel to identify problems and then provide solutions quickly and in an empathetic way.

Successful services offer guarantees to their customers and empower employees to provide quick and meaningful solutions when customers invoke the guarantee. In the United States, the great majority of retailers offer money-back guarantees if customers are not satisfied, and about half offer low-price guarantees where customers are refunded the price difference for a period of time after purchase.[53] In many cases, quick solutions to service problems are designed into service processes and become part of a service firm's marketing efforts. Firms that anticipate where service failures can occur, develop recovery procedures, train employees in these procedures and then empower employees to remedy customer problems, can assure they have the best service recovery system possible.

According to John Tschohl, founder and president of the Minnesota-based Service Quality Institute, less than two percent of companies unfortunately, use effective service recovery techniques. "Companies spend a fortune on marketing, but they don't spend a dime teaching front-line employees to keep the customer from defecting. Wouldn't it be better to spend that money on training employees to handle problems in the first place?," says Tschohl. "I recently ordered a DVD movie but it wouldn't play on my TV. I called Red Box and quickly realized that I ordered the Blu-ray version by mistake. Blu-ray doesn't work on my TV. Even though it was my mistake, Red Box offered me two free rentals. What's the cost of two DVD rentals to them? Nothing. They turned me into a customer for life!," he added.[54]

## Summary

Services constitute a large and growing segment of the global economy. Managing the supply chains of services is thus an important part of an overall competitive strategy for services. Since service customers are most often the final consumers of the services provided, successfully managing service encounters involves managing productive capacity, managing queues, managing distribution channels and managing service quality. These four concerns are the foundations of service response logistics and were the primary focus of this chapter.

Service companies must accurately forecast demand, design capacity to adequately meet demand, employ queuing systems to serve customers as quickly and effectively as possible, utilize distribution systems to best serve the firm's customers, and then take steps to assure service quality and customer satisfaction throughout the service process. Provided that managers have selected a good location, designed an effective layout, hired, trained and properly scheduled service personnel and then employed effective service response logistics strategies, firms and their supply chains should be able to maintain competitiveness, market share, and profitability.

## Key Terms

**arrival pattern,** 530
**back-of-the-house operations,** 515
**balking,** 531
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## Discussion Questions

1. Is your college or university a pure service? Explain.
2. Why is the service sector in the United States and other highly developed economies growing more rapidly than the manufacturing sector?
3. Describe the primary differences between goods and service firms.
4. Using the formula for productivity, describe all the ways that firms can increase productivity. Which of these ways might be considered risky?

5. Describe several single- and multiple-factor productivity measures that could be used at your college or university.
6. Define Baumol's disease and the Walmart effect, and how they affect service-oriented economies like the United States.
7. Discuss the primary issues in the management of global services.
8. What sorts of problems must services overcome as they expand into foreign markets?
9. What are the three generic strategies that services use to compete? Give examples.
10. When a service competes using a cost leadership strategy, does this mean the service is low quality? Explain.
11. When customers purchase a service, they are actually getting a bundle of service attributes. List and describe these attributes using a car-rental agency, a convenience store, and a radio station.
12. How would you characterize your college's or university's service delivery system?
13. Provide some examples of front-of-the-house and back-of-the-house service operations.
14. What are some things service firms can do to monitor customer satisfaction?
15. Why are service locations so important?
16. What strategy do you think was used in selecting the location of your college or university? Could there be a better location?
17. Discuss the principal design objectives for service layouts.
18. How do supply chain management activities differ between services and manufacturing companies? In what ways are these activities alike?
19. What are the four concerns of service response logistics?
20. Define service capacity, and provide three examples of it that were not listed in the text.
21. What is the capacity of your class' classroom?
22. Define capacity utilization. What is an ideal utilization? Can utilization ever be greater than 100 percent? Explain.
23. Describe how you would use a level and a chase demand capacity utilization strategy. Which one does your college or university use?
24. What are some alternatives to hiring and laying off workers to vary service capacity as demand varies?
25. Can customers be used to provide extra service capacity? Explain.
26. Describe some demand management techniques that are used when demand exceeds capacity, and when capacity exceeds demand. Your college or university has periods of time when both of these situations exist. What do they do?
27. How can firms make use of excess capacity?
28. What are the two elements managers must pay attention to, when managing queues, to maximize customer satisfaction?

29. What are the primary elements to consider when designing any queuing system?
30. What type of queuing system configuration is used at a restaurant? A car dealer? At Zappos?
31. Define the terms "balking" and "reneging." How could a firm minimize them?
32. What is a virtual queue? When might one be used?
33. What type of queuing system does a three-channel, four-phase system refer to?
34. What are the advantages and disadvantages of increasing the number of channels?
35. What queue discipline is used to register students at your college or university? What about seating patrons at a fancy nightclub?
36. Explain and give examples of Maister's First and Second Laws of Service. Use your personal experiences.
37. If your firm has designed an effective queuing system, why is it still necessary to practice waiting time management on some occasions?
38. What are the distribution channel alternatives for a weather service? A souvenir shop? A marriage counselor? How about your college or university?
39. What is a microfranchise? Would these be good for a developing country? For the United States ?
40. What is edutainment? Does your college or university use it? How?
41. Describe the important issues in the international expansion of services.
42. Describe and give examples of a pure Internet distribution strategy and a mixed Internet distribution strategy. Find your examples on the Internet.
43. How is service quality related to customer service and satisfaction?
44. Describe the five dimensions of service quality for a dentist's office, how performance in these dimensions might be measured and how recoveries might be handled for failures in each of the service quality dimensions.
45. Can recovery from a poor service quality incident be a good thing? Explain.

## Essay/Project Questions

1. Search the Internet for additional examples of eatertainment, entertailing and edutainment, and describe them in a report.
2. Search the Internet for examples of microfranchising and report on several.
3. Search the Internet for the terms "McDonald's carbon footprint" or "McDonald's green initiatives," and write a report on this firm's efforts.
4. Write a paper on Walmart's location and layout strategies in the United States and other countries.
5. Search for examples of virtual queuing systems and report on several of these, explaining how they work.

# Problems

1. For the previous month, the Bichsel Lounge served 1,500 customers with very few complaints. Their labor cost was $3000; material cost was $800; energy cost was $200; and the building's lease cost was $1500. They were open 26 days during the month, and the lounge has 20 seats. They are open six hours per day, and the average customer stay is one hour.

   a. Calculate the single-factor productivities and the overall multiple-factor productivity. How could they improve the productivity?

   b. Calculate the monthly capacity and the capacity utilization.

2. The Iarussi Legal Aide office assisted 126 people in June 2021, with a staff labor cost of $3240. In June 2022, the office provided assistance to 145 people with a labor cost of $3960. What was their productivity growth over this one-year period?

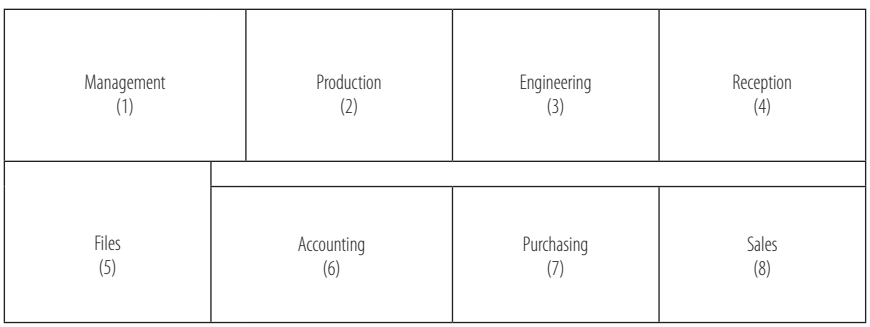
3. The Valentine Ski Company makes top-of-the-line custom snow skis for high-end ski shops and employs fifteen people at $20 per hour. Chris, the owner, wants to track several productivity performance measures using the data shown below.

| FINANCIAL INFORMATION | 2021 RESULTS |
|---|---|
| Net sales | $205,000 |
| Cost of goods sold (purchased items) | $32,000 |
| Net income after taxes | $28,200 |
| Current assets | $68,000 |
| Current liabilities | $22,000 |
| Avg. inventory value | $4500 |
| **Inputs and Outputs** | |
| Skis produced | 1000 |
| Labor hours | 10,800 |
| Lease payments | $24,000 |

   a. Calculate the labor productivity, lease productivity, and material productivity.

   b. Calculate the multiple-factor productivity. If the multiple factor productivity for 2020 was 0.004 skis/dollar, then what was the productivity growth from 2020 to 2021?

4. For the office layout shown below and the accompanying trip and distance matrices, determine the total distance traveled per day. Find another layout that results in a lower total distance traveled per day.



*Interdepartmental Trips per Day*

| | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|
| **(1)** | 6 | 5 | 2 | 1 | 7 | 6 | 15 |
| **(2)** | | 12 | 4 | 5 | 2 | 10 | 5 |
| **(3)** | | | 2 | 9 | 2 | 10 | 8 |
| **(4)** | | | | 18 | 12 | 4 | 2 |
| **(5)** | | | | | 0 | 0 | 0 |
| **(6)** | | | | | | 6 | 14 |
| **(7)** | | | | | | | 6 |

*Distances between Departments (meters)*

| | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|
| **(1)** | 15 | 30 | 45 | 10 | 20 | 35 | 50 |
| **(2)** | | 15 | 30 | 20 | 10 | 20 | 35 |
| **(3)** | | | 15 | 40 | 20 | 10 | 20 |
| **(4)** | | | | 60 | 50 | 30 | 10 |
| **(5)** | | | | | 10 | 30 | 50 |
| **(6)** | | | | | | 20 | 40 |
| **(7)** | | | | | | | 20 |

**5.** For the office layout shown in problem 4, determine the closeness desirability rating using the rating table below. Treat the hallway as if it doesn't exist (i.e., the Production and Accounting Departments touch each other). Can you find a more desirable layout? How could you use both the total distance traveled and the closeness desirability in assessing the layout alternatives? Can you find a layout resulting in relatively good scores using both types of criteria?

*Closeness Desirabilities between Departments*

| | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|
| **(1)** | 2 | 2 | -1 | 0 | 1 | 3 | 3 |
| **(2)** | | 3 | 0 | 0 | 0 | 3 | 1 |
| **(3)** | | | 0 | 2 | 0 | 2 | 3 |
| **(4)** | | | | 3 | 1 | 2 | 2 |
| **(5)** | | | | | 2 | 2 | 1 |
| **(6)** | | | | | | 0 | 2 |
| **(7)** | | | | | | | 1 |

6. Corner's Cat Care needs help in her grooming business as shown below for the five-day workweek. Determine a full- and part-time work schedule for the business using the fewest number of workers.

| | MONDAY | TUESDAY | WEDNESDAY | THURSDAY | FRIDAY |
|---|---|---|---|---|---|
| **WORKERS REQUIRED** | 2 | 3 | 3 | 4 | 5 |

7. Given an average service rate of twelve customers per hour, what is the probability the business can handle all the customers when the average arrival rate is ten customers per hour? Use the Poisson distribution to calculate the probabilities for various customer arrivals.

8. With an average service rate of twelve customers per hour and an average customer arrival rate of ten customers per hour, calculate the probability that actual service time will be less than or equal to six minutes.

9. Breann can handle about ten customers per hour at her one-person comic book store. The customer arrival rate averages about six customers per hour. Breann is interested in knowing the operating characteristics of her single-channel, single-phase queuing system.

10. How would Breann's queuing system operating characteristics change for the problem above if she added another cashier and increased her service rate to twenty customers per hour?

## Cases

### 1. Daisy Perry*

Daisy Perry is the repair shop supervisor at one of the largest automotive dealerships in Phoenix, Arizona. Daisy has been working on cars since she was 12 years old, for more than 25 years. She began by helping her father repair racecars; he raced cars as a hobby. After her graduation from high school, Daisy attended a technical school to earn her Automotive Service Excellence (ASE) certification.

Early in her career, Daisy moved around from auto maker to auto maker to get as much experience as she could. Daisy worked on all types of cars, from traditional family vans to sporty high-performance cars. Because of her experience at different dealerships, Daisy has an excellent reputation throughout Phoenix, so much so, that some customers actually switched brands when Daisy moved on to another dealership. Daisy was ready to go out on her own and open an all-purpose automotive repair shop.

One critical feature of the business is to have ASE-certified mechanics. In addition to the certification, Daisy wanted her mechanics to look professional. They would wear coveralls with her company logo and their name. She planned to give each mechanic five sets of clothing and to provide each a personal locker to keep them in. She would have a laundry service clean them so there would always be a clean set available to start each workday.

Daisy knew that customers like freebies so she planned to offer a free oil change after every fifth one. Although the type of warranty depended on the work completed and the

*Written by Rick Bonsall, D. Mgt., McKendree University, Lebanon, IL. The people and institution are fictional and any resemblance to any person or any institution is coincidental. This case was prepared solely to provide material for class discussion. The author does not intend to illustrate either effective or ineffective handling of a managerial situation.

parts provided, at a minimum, Daisy planned to provide a 30-day warranty on all work. In addition, the invoices would contain itemized charges, with no hidden costs. Prior to any repairs, the customer would receive a quote. If for some reason the repairs were more extensive than originally thought, Daisy would contact the customer and provide a revised quote before the work continued.

The waiting room would have Wi-Fi, sufficient electrical outlets to charge electronic devices, magazines to read, a TV to watch, and drink and snack machines. The waiting room would be in the center of the facility with windows looking out to all the work bays. This allowed the customer to watch the repairs and see the care given to their vehicles. Each work bay would contain state-of-the-art equipment.

One challenge Daisy was concerned about was scheduling. She believed that once she opened the doors many of her current and past customers would bring her their business. Scheduling, if business is strong, will not be an issue. However, if there are periods, whether seasonal or otherwise, where there are too many mechanics on shift, it will be difficult to manage. ASE certified mechanics are not interested in part-time work. A 40-hour per week job is expected and easy to find. Using part-time employees as a safety valve to balanced demand and capacity does not seem an option.

As Daisy reviewed her list, she felt that there were still many unanswered questions. However, Daisy felt reasonably confident, since she effectively ran the repair shop at the dealership for the last five years. Daisy had many friends in the business and decided to share her list with several of them and get feedback.

### Discussion Questions

1. Daisy decided that the main thing she should focus on is customer satisfaction. She believed that if you did that then you'd address all the other items since they drive customer satisfaction. Evaluate Daisy's list of things she believed were necessary for her business. Explain which items support the five dimensions of service quality. Has Daisy missed any of the five service quality dimensions? If so, which one(s)?
2. Which service strategy is Daisy planning to implement? Provide specifics that support your selection. Do you believe this is the best strategy? Should she consider one of the other two?
3. Daisy's concern about scheduling during non-peak periods is a serious problem. She cannot risk alienating her ASE-certified mechanics by cutting their hours because they can easily find other work. Assume the following: after the first year, Daisy determines the non-peak periods. There are very few times; however, she believes they will be consistent year after year, meaning the same general timeframe. Explain to Daisy what options or initiatives she can use to increase demand since cutting hours is not an option.

## 2. Designing a Call Center for an Express Logistics Service Provider*

E-commerce has been growing drastically in Thailand, and it provides an opportunity for an express logistics service. Bangmod is a leading logistics service provider, with headquarters based in Thailand. Its core business includes integrated logistics, international freight forwarding, and express and supply chain solutions. The company focuses mainly

*Written by Watcharapoj (Jack) Sapsanguanboon, Graduate School of Management and Innovation, King Mongkut's University of Technology, Thailand. The people and institution are fictional and any resemblance to any person or any institution is coincidental. This case was prepared solely to provide material for class discussion. The author does not intend to illustrate either effective or ineffective handling of a managerial situation.

on express logistics services in order to serve the high demand of e-commerce shipments. Many of the e-commerce entrepreneurs employ Bangmod across a wide spectrum of industries including fashion and lifestyle, cosmetics, supplement foods and beverages, and pharmaceuticals. Due to its growing customer base, Bangmod has decided it needs to also provide services through a call center, to better serve customers countrywide. Bangmod's desire is to deliver customer goods faster and more cost-effectively than anyone else.

Bangmod offers domestic express services throughout Thailand including coverage of all provinces and cities, offering same day delivery to three-day economy services. By understanding and anticipating customer express service needs, Bangmod helps create real value for their customers' businesses, ensuring delivery to customers in a smooth, cost-efficient manner. Customers normally request services from Bangmod's field sales personnel, but managers believe a lot of missed sales opportunities exist. Various service options are offered to serve different needs as follows:

- **Same Day Delivery—**Immediate pickup and door-to-door delivery in the shortest possible timeframe.
- **Next Day Delivery before 9:00 a.m.—**Nationwide door-to-door delivery by 9:00 a.m. on the next business day.
- **Next Day Delivery before 12:00 noon—**Nationwide door-to-door delivery by 12:00 noon on the next business day.
- **Next Day Delivery before 5:00 p.m.—**Nationwide door-to-door delivery by 5:00 p.m. on the next business day.
- **3-Day Economy Delivery—**Nationwide domestic delivery by the end of the next 3 business days.
- **Value-added Services—**A wide range of value-added services are also available upon request, including: home delivery, re-packing, e-commerce, web tracking, web booking, onsite services, hold at location, cash-on-delivery, invoice return, delivery by appointment, and more.

## Discussion Questions

1. Do you think a call center would benefit Bangmod at this point? What benefits could it provide?
2. From the case, identify items of importance in terms of designing a call center and rank them in terms of importance.
3. Discuss the important issues for managing the daily call center operations, including queuing management, facilitating goods, and service quality for Bangmod.

## 3. Benevolence Children Hospital*

Benevolence Children Hospital has grown steadily over the last decade. They have been fortunate to receive several large sums of charitable donations. This has enabled them to recently add a new surgical wing. This wing is actually a completely new service the hospital is providing. In the past, children were sent to other area hospitals for surgery. Now, Benevolence Children Hospital can provide surgical services specializing in children's needs.

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The new surgical wing has come at the perfect time because the population of Widow Creek has grown exponentially in the past three years. Unfortunately, the hospital wasn't prepared for the volume of surgeries. Although they have the physical capacity, such as operating rooms, staff, recovery rooms, etc., they have fallen short on customer care.

When Meredith Webb, Benevolence's CEO, read all the complaints concerning the surgical services she saw two glaring issues. When she correlated the complaints to the five service quality dimensions she knew about, Meredith believed that they were weak in responsiveness and empathy. Customers had no complaints with reliability, such as billing. Nor did they have issues with assurance, as in surgeons' skills. The tangibles, such as employee appearance and facility appearance, were always given high ratings.

As Meredith examined the data and talked with the families of the patients she began to understand the root cause of their complaints. Communications were poor. Parents didn't feel that they were kept informed in a timely manner about their children's surgeries. Their perception was that a lot of time passed before any updates were provided. Also, if they had a complaint or a compliment, they didn't know who specifically to name. Since they were extremely stressed because their child was having surgery, they didn't always remember which staff member they interacted with. Meredith talked with her senior staff and they concluded that in many ways the problem was similar to managing queue times. Many of the same emotions and reactions people felt when in a queue were similar to what waiting families were experiencing.

### Discussion Questions

1. Obviously, hospital personnel wear nametags to identify themselves. However, in the case above, the families are not remembering who they interact with because they are stressed. Recommend a solution that guarantees to eliminate this issue; thus, improving the families' sense of connection to those caring for their children.
2. What actions do you recommend the hospital take to increase the feeling of customized service thus, enhancing empathy? Hint: think about what restaurants and/or airlines do to enable better communications.
3. Besides the actions or initiatives taken to solve the specific problems mentioned in questions 1 and 2, what additional things can the hospital do to manage perceived waiting times and the issues they cause?

## PART 4 Continuing Case

Note: This case is available online only.

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# PART 5

# Integration Issues in Supply Chain Management

Chapter **13**

# Supply Chain Process Integration


*I think we are very quickly moving toward that world of instant commerce where you'll be able to buy anything you like at any time anywhere, particularly in the U.S., and be able to get it in a matter of hours. That's the kind of vision fulfillment companies are working toward and I think the COVID situation has accelerated that move, not necessarily by the end of 2020, but definitely by the end of 2021, that will be the new normal.*

**—Ben Jones, CEO, Ohi**[1]

*Over the coming years, sustainability will be a driver of development and the Brand & Retail Module assessment tool will help us invest in more sustainable products, build a supply chain that is even more respectful of the environment and workers' rights, make our stores and campus more energy efficient, and commit to reduce waste.*

**—Roberto Taiariol, internal audit and sustainability director, Benetton Group**[2]

*Beyond the price of products, the supply chain can provide data on variation in both the supply choices made by physicians and the impacts on quality and financial metrics, such as complication rates, procedural time and length of stay. Physicians, in turn, can make decisions that improve quality, which can result in lower total costs of care by reducing hospital-acquired conditions and unplanned readmissions.*

**—Karen Conway, vice president of healthcare value, GHX[3]**

## Learning Objectives

**After completing this chapter, you should be able to**

**LO 1** Discuss the overall importance of process integration in supply chain management.

**LO 2** Describe the advantages of, and obstacles to, process integration.

**LO 3** Understand the important issues of internal and external process integration.

**LO 4** Understand the role played by information systems in creating information visibility along the supply chain.

**LO 5** Describe the various processes requiring integration along the supply chain.

**LO 6** Understand the various causes of the bullwhip effect and how they impact process integration.

**LO 7** Discuss the various issues associated with supply chain risk and security.

## Chapter Outline



## SCM Profile — Centric Software Enables Process Integration in the Fashion Industry

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In the fashion industry, demand is highly variable and changes with consumer trends. Retailers were not prepared for the drastic changes in consumer buying behavior that occurred during the pandemic. For much of 2020, the major fashion item consumers were purchasing was loungewear. Today, fashion firms are moving to less physical and more digital connections, to enable better communication, process integration, and product response.

Fashion product development is historically a time-consuming and decentralized process. Digital product lifecycle management (PLM) can help businesses streamline their processes, reduce unnecessary tasks, and save time and costs. "Implementing PLM is essential to enable businesses to react to marketplace fluctuations, and not only recover successfully, but also go on to thrive in the new climate and respond rapidly if the virus resurges. Many brands are revolutionizing the way they ideate, design, and sell products with PLM acting as a digital backbone that enables them to capitalize on three key drivers: agility, efficiency, and innovation," says Lily Dong, marketing director for Centric Software, a digital PLM solution provider.

For fashion businesses to succeed in the post-pandemic world, they need to focus on reducing product development times. The use of a digital PLM solution will digitize the work flow, enabling better communication and collaboration. Other benefits include integration with planning tools, and with good data analytics, it will provide visibility into what fashions are needed. Communications with suppliers and factories can be improved by giving them an active participation in the development process. Integration is key for the success of digital PLM.

Headquartered in Campbell, California, Centric Software for example, provides a digital PLM solution for fashion and retail companies. It connects all product-related activities and product information, including the entire supply chain on one cloud-based platform, giving internal and external users a single, actionable site in real time. "What recovery looks like will vary from country to country as their situations evolve, but there is one key thing that's been made evident by this pandemic – businesses that succeed in the future will be powered by digital transformation and will heavily depend on technologies that leverage remote collaboration," says Dong. Centric's PLM enables collaborations across branding, design, merchandising, financial planning, development, specs, sourcing, manufacturing, quality control, and retailing, to cut costs and reduce time to market.[4]

## Introduction

The ultimate goal in supply chain management is to create value for the services and goods provided to end customers, which, in turn, provides benefits to the firms in the supply chain network. To accomplish this, firms in the supply chain must integrate their process activities internally and then with their trading partners. Throughout this textbook, the integration of key business processes along the supply chain has been a recurring theme. The term **process integration** (also sometimes called process collaboration) means sharing information and coordinating resources to jointly manage a process or processes. We have been introducing and discussing the various processes and issues concerning this time-consuming and somewhat daunting task throughout the text and have been alluding to the idea that key processes must somehow be coordinated, shared, or integrated among the supply chain members. In this chapter, some of these issues will be revisited and refined.

Additionally, the advantages, challenges, methods, and tools used to achieve process integration both within organizations and among their trading partners will be discussed.

Today, process integration remains a significant problem for many organizations. In fact, the global process integration software market was approximately $300 billion in 2019 and is expected to reach $582 billion by 2025. North America accounts for about one-third of the entire global market.[5] Since process integration between departments is considered to be the necessary foundation for successful external integration between trading partners, it can then be understood that any significant problems with internal integration can make external integration even more difficult to achieve.

Specifically, this chapter discusses the key business processes requiring integration, the impact of integration on the bullwhip effect, the importance of internal and external process integration in supply chain management, issues of supply chain risk and security that come about as information is shared and goods are moved significant distances, and the important role played by information technology (IT) when integrating processes.

External process integration can be an extremely difficult task because it requires proper training and preparedness, willing and competent trading partners, trust, compatible information systems, potentially a change in one or more organizational cultures, and, as mentioned above, successful internal process integration. The benefits of collaboration and information sharing between trading partners can be significant: reduced supply chain costs, greater flexibility to respond to market changes, and fewer process problems, which means less supply chain safety stock, higher quality levels, reduced time to market, and better utilization of resources. It is hoped that this chapter will allow readers to recall and consider all of the previous chapters' topics, their contributions to successful supply chain management, and the means by which information sharing and process integration must occur to make supply chain management a success.

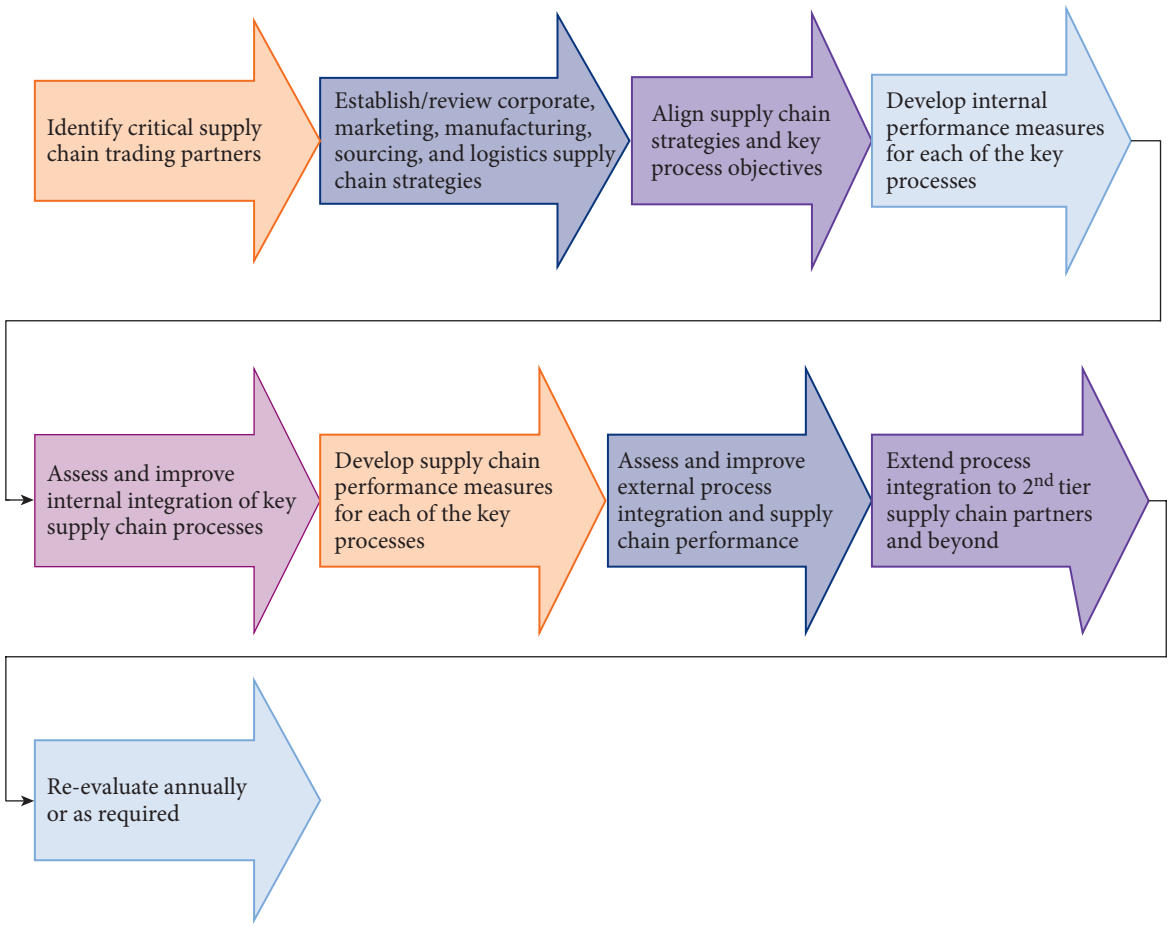
## The Supply Chain Management Integration Model

Figure 13.1 presents a supply chain integration model, starting with the identification of key trading partners, the development of supply chain strategies, aligning the strategies with key process objectives, developing internal process performance measures, internally integrating these key processes, developing external supply chain performance measures for each process, externally integrating key processes with supply chain partners, extending process integration to second-tier supply chain participants, and then, finally, reevaluating the integration model periodically. Each of the elements in the model is discussed next.

### Identify Critical Supply Chain Trading Partners

For each of the focal firm's goods and services, it is important to identify the critical or **key trading partners** that will eventually enable the successful sale and delivery of end products to the final supply chain customers. Over time, companies identify these trading partners through successful business dealings—suppliers that have come to be trusted and that provide a large share of the firm's critical goods and services; and repeat, satisfied customers that buy a significant portion of the firm's products. As the focal firm moves out to second- and third-tier suppliers and customers, trading partner numbers increase quite dramatically, which can greatly complicate integration efforts. Identifying only the first-tier primary trading partners allows the firm to concentrate its time and resources on managing important process links with these companies, enabling the overall supply chain to perform better. Including nonessential and minor supporting businesses will most likely prove counterproductive in terms of successful supply chain management. In a landmark supply chain article by Drs. Lambert, Cooper, and Pagh, they define primary or key

**Figure 13.1** The Supply Chain Integration Model




trading partners as "all those autonomous companies or strategic business units who actually perform operational and/or managerial activities in the business processes designed to produce a specific output for a particular customer or market."[6]

Depending on where within a supply chain the focal firm is physically located (close to its key suppliers, close to its primary customers, or somewhere in between), the structure of the network of primary trading partners will vary. Mapping the network of primary trading partners is something that should be done to help the firm decide which businesses to include in its supply chain management efforts. For instance, a firm with a large number of key suppliers and customers might limit the number of integrative processes, leading to fewer second-tier relationships as well. Coordinating processes with its key suppliers was seen as so important to IBM, for example, that in 2006 it moved its global procurement headquarters to Shenzhen, China, from the United States. Then, after six successful years in Shenzhen, IBM again moved its procurement headquarters to Budapest, Hungary. IBM had made sizeable investments in African growth markets and created a new procurement center in Ghana, so moving the procurement headquarters closer to suppliers in Eastern Europe and Africa allowed IBM to share its expertise and accelerate business with clients in those areas.[7]

## Review and Establish Supply Chain Strategies

On an annual basis, management should identify the basic supply chain strategies associated with each of its trading partner's goods and services. If a supply chain's end product is competing based on quality, then supply chain members should also be using strategies consistent with delivering high-quality products at competitive price and service levels. Product strategies should then translate into internal functional policies regarding the types of parts purchased and suppliers used, the manufacturing processes employed, the designs of goods and services, the warranty and return policies offered, and potentially the amount of outsourcing employed. In each of these areas, policies should be geared toward supporting the overall strategy of the supply chain.

Alternately, if end products are competing based on sustainability, then strategies and functional policies among each of the supply chain participants must be consistently aimed at achieving favorable environmental impacts or carbon footprints as intermediate goods and services are purchased, produced, and moved along the supply chain. Supply chain sustainability has become an important issue today as organizations seek better ways to compete. In 2012, for example, global food maker General Mills commissioned a study of its environmental dependence on natural resources across its supply chains and found that nearly two-thirds of the greenhouse gas emissions and almost all of the water use occurred outside of its own operations—in the growth of raw materials and the preparation of ingredients that General Mills used to produce its goods. Consequently, General Mills designed a sourcing plan to improve the sustainability of the raw materials it used and to manage the water usage across its supply chains.[8]

## Align Supply Chain Strategies with Key Supply Chain Process Objectives

Once the primary strategy has been identified for a supply chain's end product, managers need to identify the important processes linking each of the supply chain trading partners and establish process objectives to assure that resources and efforts are effectively deployed within each firm to support the end-product strategy. The key processes and the methods used to integrate and manage process links among supply chain partners will vary based on the internal structure of each firm, the prevailing economic conditions in the marketplace, the degree to which **functional silos** exist in any of the trading partners, and the nature of existing relationships within each supply chain. In some cases, it may be best to integrate only one key process with one trading partner, while with other partners, more processes could be integrated.

Based on the research of Lambert, Cooper, and Pagh, eight processes have been identified as important in supply chains. These **key supply chain processes** are shown in Table 13.1. As first described in Chapter 1, a **process** can be defined as a set of activities designed to produce a good or service for an internal or external customer. Simply put, a process is how work gets done. A discussion of each of these eight key processes follows.

### Customer Relationship Management

The **customer relationship management process** provides the firm with the structure for developing and managing customer relationships. As discussed in Chapter 10, key customers are identified, their needs are determined, and then goods and services are developed to meet their needs. Over time, relationships with these key customers are solidified through the sharing of information; the formation of cross-company teams to improve

**Table 13.1 The Eight Key Supply Chain Business Processes[9]**

| | |
|---|---|
| **Customer Relationship Management** | Identifying key customer segments, tailoring product and service agreements to meet their needs, measuring customer profitability and firm's impact on customers. |
| **Customer Service Management** | Providing information to customers such as product availability, shipping dates, and order status; administering product and service agreements. |
| **Demand Management** | Balancing customer demand with the firm's output capacity; forecasting demand and coordinating with production, purchasing, and distribution. |
| **Order Fulfillment** | Meeting customer requirements by synchronizing the firm's marketing, production, and distribution plans. |
| **Manufacturing Flow Management** | Determining manufacturing process requirements to enable the right mix of flexibility and velocity to satisfy demand. |
| **Supplier Relationship Management** | Managing product and service agreements with suppliers; developing close working relationships with key suppliers. |
| **Product Development and Commercialization** | Developing new products frequently and getting them to market effectively; integrating suppliers and customers into the process to reduce time to market. |
| **Returns Management** | Managing used product disposition, product recalls, packaging requirements, and minimizing future returns. |

product design, delivery, quality, and cost; the development of shared goals; and, finally, improved performance and profitability for the trading partners along with agreements on how to share these benefits. The firm should monitor the impact of customer relationship management (CRM) efforts in terms of both the financial impact of these efforts and with customer satisfaction. Over time, CRM has come to be associated with software applications to aid the CRM process. In fact, the global annual CRM software market is expected to grow from $50.8 billion in 2021 to almost $73 billion by 2025.[10]

## Customer Service Management

The customer service management process is what imparts information to customers while also providing ongoing management of any product and service agreements between the firm and its customers. Information can be offered through a number of communication channels including websites, personal interactions, information system linkages, and printed media. Objectives and policies are developed to assure proper distribution of goods and services to customers, to adequately respond to product and delivery failures and complaints, and to utilize the most effective means of communication to coordinate successful product, service, and information deliveries. The process also includes methods for monitoring and reporting customer service performance, allowing firms to understand to what extent their management efforts are achieving their process objectives.

## Demand Management

The **demand management process** balances customer demand and the firm's output capabilities. The specific demand management activities include forecasting demand and then utilizing techniques to vary capacity and demand within the purchasing, production, and distribution functions. Various forecasts can be used, based on the time frame, the knowledge of the forecaster, the ability to obtain point-of-sale information from customers, and the use of forecasting models contained in many ERP systems. The next step is to determine how to synchronize demand and productive capacity. As discussed in Chapters 5, 6, and 12, a number of effective techniques exist to smooth demand variabilities

and increase or decrease capacity when disparities exist between demand and supply. Contingency plans must also be ready for use when demand management techniques fail or when forecasts prove to be inaccurate. Performance measurement systems can prove quite useful here, to increase the accuracy of forecasts and to track the success of various demand management activity implementations. For example, after a terrible explosion at a Georgia-based Imperial Sugar refinery destroyed 60 percent of the plant's capacity in 2008, Imperial Sugar was able to rely on its demand management software to show everyone from production to sales, in real time, what could be delivered to which customers using available inventories. "It was our saving grace," said CIO George Muller.[11]

## Order Fulfillment

The **order fulfillment process** is the set of activities that allows the firm to fill customer orders while providing the required levels of customer service at the lowest possible delivered cost. The order fulfillment process must integrate closely with customer relationship management, customer service management, supplier relationship management, and returns management to assure that customer requirements are being met, customer service levels are being maintained, suppliers are helping to minimize order lead times, and customers are getting undamaged, high-quality products. Related order fulfillment issues are the location of suppliers, the modes of inbound and outbound transportation used, the location of production facilities and distribution centers, and the system used for entering, processing, communicating, picking, delivering, and documenting customer orders. Obviously, when these activities can be automated, fewer mistakes occur, and productivity can be increased. A 2013 survey of U.S. consumers and supply chain managers highlighted the importance of effective order fulfillment—89 percent of the consumers said they would likely shop at a different retailer if an order was delivered late, and 54 percent of the supply chain managers said that fulfillment issues have had a negative impact on their firms' revenues and profitability over the past few years.[12] The nearby SCM Profile describes the automated order fulfillment capabilities of a bakery production and distribution facility.

## Manufacturing Flow Management

The **manufacturing flow management process** is the set of activities responsible for making the actual product, establishing the manufacturing flexibility required to adequately serve markets, and designing the production system to meet cycle-time requirements. To be effective, manufacturing flow management activities must be interfaced with demand management and customer relationship management processes, using customer requirements as inputs to the process. As customers and their requirements change, so too must the supply chain and the manufacturing flow processes change to maintain a firm's competitiveness. As was shown in Chapter 8, the flexibility and rapid response requirements in many supply chains result in the firm's use of lean systems in order to continue to meet customer requirements.

Manufacturing flow characteristics also impact supplier requirements. For instance, as manufacturing batch sizes and lead time requirements are reduced, supplier deliveries must become smaller and more frequent, causing supplier interactions and supplier relationships to potentially change. The importance of an adequate material requirements planning (MRP) system should become evident here, as customer requirements must be translated into production capabilities and supplier requirements. As with other processes, a good set of performance metrics should also be utilized to track the capability of the manufacturing flow process to satisfy demand.

## SCM Profile: Automated Order Fulfillment at Kwik Trip


Aaron of L.A. Photography/Shutterstock.com

La Crosse, Wisconsin-based Kwik Trip's new baking facility uses an automated order fulfillment solution to guarantee freshness for its bakery products sold at more than 700 of its locations. Keeping its convenience stores supplied with fresh baked goods has proved very successful for Kwik Trip. Kwik Trip's approach includes a new bakery with automated order picking and storage, using a warehouse control system (WCS) application, to bake, store, and pick orders needed by stores.

The new facility repurposed its previous one, and ultimately produces and distributes four times the original output. To accomplish this, the facility incorporates automation and state-of-the-art design to handle most of the production, packaging, warehousing and distribution in an integrated fashion.

The new baking facility produces and distributes 19 types of bread and buns. The facility automates everything from raw ingredient mixing to the sprinkling of seeds on the buns. Finished goods are moved to the packaging department, where automated systems slice the bread, then bag and tie it. Once the bread is packaged it is moved to the warehouse.

The 87,000-square-foot warehouse automates product storage and retrieval. High-density storage enables the optimal use of storage space. The breads are stored in 80,000 trays stacked up to 20 trays high across the warehouse. Order picking is managed with six overhead robots that can rapidly retrieve trays, place them onto a stack, and assemble the required product quantities for each order. The WCS manages the order picks based on store and route. Orders are picked with 100% accuracy and then sent to dispatch. Inventory is held no more than 48 hours.

Kwik Trip has improved its productivity and efficiency using fully integrated automation between its manufacturing, packaging, warehousing, and distribution processes. The system also helps customer satisfaction, since the stores are stocked each day with fresh baked goods.[13]

## Supplier Relationship Management

The **supplier relationship management process** defines how the firm manages its relationships with suppliers. As was discussed in Chapters 2, 3, and 4, firms in actively managed supply chains seek out the best-performing suppliers and establish ongoing, mutually beneficial, and close supplier relationships in order to meet cost, quality, and/or customer service objectives for key materials, goods, and services. For nonessential items, firms may use reverse auctions, bid arrangements, or catalogues to select suppliers. Activities in this process include screening and selecting suppliers, negotiating product and service agreements, managing suppliers, and then monitoring supplier performance and improvement. Some companies may have a cross-functional team to manage suppliers' progress toward

meeting the firm's current and long-term requirements and establishing records of performance improvement over time, while other suppliers may be managed little or not at all, depending on supply chain, company, or product requirements. Supplier relationship management personnel routinely communicate with production personnel to obtain feedback on supplier and purchased item performances, and with marketing personnel for customer satisfaction feedback. Additionally, suppliers are frequently contacted for new product development and performance feedback purposes.

## Product Development and Commercialization

The **product development and commercialization process** is responsible for developing new goods and services to meet changing customer requirements and then getting these products to market quickly and efficiently. In actively managed supply chains, customers and suppliers are involved in the new product development process to assure that products conform to customers' needs and that purchased items meet manufacturing requirements. Activities in the product development and commercialization process include methods and incentives for generating new product ideas; the development of customer feedback mechanisms; the formation of new product development teams; assessing and selecting new product ideas based on financial impact, resource requirements, and fit with existing manufacturing and logistics infrastructure; designing and testing new product prototypes; determining marketing channels and rolling out the products; and, finally, assessing the success of each new product introduction. Successful new product development requires inputs from external customers and suppliers, and from internal manufacturing, marketing, and finance personnel.

More and more, big data analyses are being relied upon to develop new products. One of the pioneers in use of big data is the retail industry. An athletic shoe maker like Nike might use big data analysis to predict a hot sneaker model for the upcoming year. Big data analysis in this case would combine internal corporate data with other information from web browsing patterns, sneaker industry advertising, and social media perceptions. In another example, by analyzing its vast amount of search histories, Google noticed an above-average search demand for the word "flu," and some pharmaceutical company paid Google a nice sum of money for that predictive information. In yet another example, British Airways (BA) launched a program called "Know Me" which aims to get the most out of its customer data. BA marketers are able to make better decisions about how they interact with their customers, through knowing and understanding passenger needs at a deeper level.[14]

## Returns Management

The **returns management process**, discussed in Chapter 9, can be extremely beneficial for supply chain management in terms of maintaining acceptable levels of customer service and identifying product improvement opportunities. Returns management activities include environmental compliance with substance disposal and recycling, writing operating and repair instructions, troubleshooting and warranty repairs, developing material disposition guidelines, designing an effective reverse logistics process, and collecting returns data. Returns management personnel frequently communicate with customers and personnel from customer relationship management, product development and commercialization, and supplier relationship management during the returns process.

One of the goals of returns management is to reduce returns, and hence, returns costs. This is accomplished by communicating return and repair information to product development personnel, suppliers, and other potential contributors to any returns problems, to guide the improvement of future product and purchased item designs. Logistics

services may also be included in the returns feedback communication loop. In a reverse logistics survey by the Massachusetts-based business consultants Aberdeen Group, the companies best at reverse logistics were found to have a few things in common, including a standardized returns and repair process, the ability to recover costs from suppliers, real-time information reporting, and multichannel visibility.[15]

For each of the eight processes identified in Table 13.1, objectives must be developed to help guide the firm toward its supply chain strategy. Additionally, consistent objectives within each functional area of the firm, for each process, help to integrate the processes internally, as well as focus efforts and firm resources on the overall supply chain strategy. For instance, if the supply chain strategy is to compete using low pricing, marketing objectives for the customer relationship management process might be to find cheaper delivery alternatives, develop vendor managed inventory (VMI) accounts, and automate the customer order process. Production objectives might be to develop bulk packaging solutions consistent with the modes of transportation and distribution systems used, to increase mass production capabilities, and to identify the lowest total cost manufacturing sites for specific goods, while purchasing objectives might be to identify the cheapest materials and components that meet specifications, and to utilize reverse auctions whenever possible. Firms should similarly progress through each of the key processes using teams of employees, suppliers, and customers to help develop process objectives.

## Develop Internal Performance Measures for Key Process Effectiveness

As alluded to in each of the key processes above (and to be discussed at greater length in Chapter 14), procedures and metrics must be in place to collect and report internal performance data for the eight key processes. Thus, prior to measuring and comparing performance with their supply chain partners, firms must first build good internal performance measurement capabilities across functions. This can prove troublesome given that in recent surveys of performance measurement systems, about 56 percent of performance measurement implementations failed in meeting objectives.[16] Successful performance measures need to create a consistent emphasis on the overall supply chain strategy and the corresponding process objectives. To ensure that processes are supporting the overall supply chain strategy, performance should be continuously monitored using a set of metrics designed for each process.

Continuing the discussion from the previous section where competing based on low price was the supply chain strategy, performance measures for the customer relationship management process would need to be designed for each of the firm's functional areas. The responsibility for designing these measures can also be assigned to the teams developing objectives for each of the functional areas. Since the objectives in this case are cost driven, the performance measures should reflect this as well. For the customer relationship management process, performance measures in marketing might be the average delivery cost, the number of new VMI accounts, the average cost of ordering and carrying inventories for the new VMI accounts, and the number of new automated order systems over the period of time studied. For production, performance measures might be the average packaging cost per order, the average daily output capability for each product, and the average unit cost per order. For purchasing, the performance measures for the customer relationship management objectives might be the average purchasing cost for each of the items purchased and the percentage of time that reverse auctions were used over the period of time studied. Performance measures would similarly be designed for each of the key processes and their corresponding functional objectives. In this way, firms have the capability to track the progress toward meeting each of the objectives for the key processes.

## Assess and Improve Internal Integration of Key Supply Chain Processes

Successful supply chain management requires process coordination and collaboration internally between employees in the firm's functional areas as well as externally between the firm and its trading partners. Achieving process integration within the firm requires a transition from the typical functional silos to one of teamwork and cooperation across business functions. Internal integration has been shown to provide significant benefits for the firm. In a survey of 500 U.S. organizations, for instance, good interdepartmental relationships were found to result in reduced cycle times and fewer stockouts.[17] To achieve internal integration, personnel must have management support, resources, and empowerment to make meaningful organizational changes to foster the type of cooperation necessary to support the overall supply chain strategy. The formation of cross-functional teams to develop the key process objectives and accompanying performance measures is a good starting point in achieving internal process integration.

The primary enabler of integration, though, is the firm's ERP system. In Chapter 6, the importance and capabilities of ERP systems were described, along with some of the various software applications or modules that are used today. ERP systems provide a view of the entire organization, enabling decision makers within each function to have information regarding customer orders, production plans, work-in-process and finished goods inventory levels, inbound and outbound goods in-transit, purchase orders, purchased item inventories, and financial and accounting information. ERP systems thus link business processes and facilitate communication and information sharing between the firm's departments. Since the key business processes overlay each of the functional areas, the firm eventually becomes process oriented rather than functionally oriented as ERP systems are deployed. It is this visibility of information across the organization that allows processes to become integrated within the firm.

To assess the current state of internal integration, firms should first develop an understanding of their **internal supply chains**. Internal supply chains can be complex, particularly if firms have multiple divisions and global organizational structures. Thus, firms should assess the makeup of the teams used in setting process objectives and designing performance measures—do they include representatives from each of the organization's divisions or business units? These cross-functional teams should adequately represent the firm's internal supply chain. During the global pandemic starting in 2020, for example, internal integration was impacted as companies trimmed staff and transferred workers home, to cut costs and save lives. Managers then turned to team-based games to get employees working together again, once office buildings reopened. "Many employees have been shifted into new job roles because of layoffs, and employers are using team-based business games to train workers in their new responsibilities and to increase their retention of new knowledge," says Elizabeth Treher, CEO of Minnesota-based The Learning Key. "Team-based business games result in better knowledge retention, provide focused, memorable learning and a more enjoyable learning atmosphere than traditional methods," Treher adds.[18]

Once the firm has an understanding of its internal supply chain, it can begin to assess the level of information access across functional boundaries. Does the firm have a single company-wide ERP system linking the functional areas? Are all of the firm's **legacy systems** linked to its ERP system? How easy is it to extract the information needed to make effective decisions? Are centralized **data warehouses** being used to collect data from the various divisions of the firm? Firms that are successfully integrating key business processes are using global ERP systems and data warehouses to make better, informed decisions.

Data warehouses store information collected from ERP and legacy systems in one location, such that users can extract information as needed, analyze it, and use it to make decisions.

A globally linked ERP system allows the firm to use a common database from which to make product, customer, and supplier decisions. Information is captured once, reducing data input errors; information is available in real time, eliminating delays throughout the organization as information is shared; and, finally, information is visible throughout the organization—all transactions taking place can be seen and accessed by everyone on the system. As the firm moves away from its older, existing legacy systems and toward a fully integrated ERP system, as cross-functional teams are created to link key processes to supply chain strategies, and as process performance is monitored and improved, the firm will become more focused on managing the key supply chain processes in an integrated fashion. And, COVID-19 has increased the emphasis on integration. According to Nishant Manuja, Managing Director of Coats Bangladesh Ltd., "Covid has highlighted the critical need for digital adoption in our industry. At Coats we continue to develop customer-facing tools along with a fully-integrated and global ERP environment."[19]

## Develop Supply Chain Performance Measures for the Key Processes

As described earlier for internal performance measures, the firm should also develop external performance measures to monitor the links with trading partners, particularly within the key supply chain processes. And, as with the design of internal performance measures, teams composed of members from primary trading partners should be created to design these measures to be consistent with overall supply chain strategies.

Continuing with the low-cost supply chain strategy example, trading partners should monitor a number of cost-oriented performance measures that are averaged across the member firms for each of the key supply chain processes. For the customer relationship management process, examples might include the average delivery cost, rush order cost, VMI carrying cost, finished-goods safety stock costs, returned order costs, and spoilage costs. Inbound and outbound logistics costs, in particular, have come under much greater scrutiny in 2021, due to the rising cost of fuel. In the United States, the national gas price average has increased 40 percent since the start of the year, to reach the highest price in seven years.[20] Fuel prices have thus placed increased pressure on trading partners to find cheaper ways to transport goods in a timely fashion, and this can be particularly problematic for supply chains following a low-cost strategy. External performance measures should align with internal performance measures, but may vary based on purchasing, production, distribution, customer service, and other variations across the participating firms. The topic of external performance measures is discussed further in Chapter 14.

## Assess and Improve External Process Integration and Supply Chain Performance

Over time, firms eliminate poor-performing suppliers as well as unprofitable customers while placing an emphasis on developing beneficial relationships and strategic alliances with the remaining suppliers and customers. Building, maintaining, and strengthening these relationships is accomplished through use of external process integration. As process integration improves among supply chain partners, so too does supply chain performance. As a matter of fact, in a study published in 2014, supply chain process integration was found to be *the most significant predictor* of firm's competitive position.[21] When firms have

achieved a reasonably good measure of internal process integration, they are ready to move on to externally integrating key supply chain processes with trading partners.

Trading partners must be willing to share sales and forecast information, along with information on new products, expansion plans, new processes, and new marketing campaigns in order to ultimately satisfy end customers and maximize profits for all supply chain members. As with internal process integration, the teams formed to design and organize process performance measures should be viewed as a key resource for external process integration. These teams can set and revise supply chain process objectives, and the type of information that must be shared to achieve the objectives. Once the performance metrics are designed for each of the processes, they can be monitored to identify lack of process integration and supply chain weaknesses. Firms should thus periodically communicate levels of process performance and integration to their trading partners and collaborate on methods to improve both.

Once again, the way information is communicated plays an extremely important role in external process integration. Today, connecting buyers and suppliers via the Internet is the way supply chains are becoming integrated. More generally termed **knowledge management solutions**, Internet applications tied to desktop applications enable real-time collaboration and flow of information between supply chain partners, the ability to "see" into suppliers' and customers' operations, faster decision making, and the collection of supply chain performance metrics.

Supply chain communication capabilities must deal with handling the flows of goods and information between companies, negotiating and executing contracts, managing supply and demand problems, making and executing orders, and handling financial settlements, all with a high level of security. During the pandemic of 2020/2021, much of the challenge facing retailers was supply chain-related, according to a March 2020 survey of U.S. retailers conducted by Digital Commerce 360. When asked about the actions they were taking, 48 percent of the retailers cited supply chain communication as the number one item of importance.[22]

## Extend Process Integration to Second-Tier Supply Chain Partners

As supply chain relationships become more trusting and mature, and as the supply chain software used to link supply chain partners' information systems evolves and becomes more widely used and relied upon, the tendency will be to integrate processes to second-tier partners and beyond. Today, supply chain software suppliers are developing systems that integrate more easily with other applications, allowing trading partners to exchange ever more complex or detailed information on contracts, product designs, forecasts, sales, purchases, and inventories. Using these linkages, companies can, in real time, work with suppliers and customers to compare design ideas, forecasts, and order commitments; determine supply/demand mismatches; and analyze supplier performance.

Every major software developer today is trying to make its supply chain applications easier to integrate with existing systems and gather data anywhere along a firm's supply chain. One development is the **radio-frequency identification tag** (RFID), discussed in Chapters 7 and 9. These microchip devices can be attached to pallets or cases to relay information on the goods' whereabouts as they move through a supply chain. Thus, a firm's supply chain system can access real-time inventory information and instigate a replenishment order as inventories are drawn down. RFID tags have a number of applications, several of which are described in the nearby SCM Profile.

## SCM Profile RFID Tags Used for Theft, Temperature Control, and Tracking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With tag readers positioned inside a truck trailer, RFID tags can be read and reported in real time. The information can indicate items that were loaded at origin; if some tags do not respond after two hours it helps identify a cargo loss problem, which might result from goods being delivered to the wrong destination, or a cargo theft problem.

California-based Intelleflex Corp. is one company offering a temperature monitoring RFID tag that can be read from 100 meters. Placing the tags throughout a load of perishables for instance, the tags can record and report temperature variations across the load. This ability to monitor down to the pallet or container level can reduce product waste.

In one example, using tags placed in pallets of fruit coming from the field, the temperatures of the different pallets were monitored and recorded as the fruit was loaded, and during transport to the packing house. The temperatures of the pallets of fruit varied based on time of day when they were harvested and loaded and other factors. Using the data collected on the temperatures, the shelf life of the different pallets of fruit could be estimated. It was found that 70 percent of the fruit maintained an optimal shelf life of 14 days or more based on the conditions at harvest and during transport. The other 30 percent of the load had dropped below the optimal 14 days. Thus, instead of a first-in-first-out approach, the shipper was able to use a first-expiry-first-out approach so the fruit that had the shorter estimated shelf life was prioritized and shipped to closer distribution centers.[23]

San Diego's Rady Children's Hospital and IntelliGuard, a local RFID technology company, work together to distribute the COVID-19 vaccine. The tags allow the hospital to store the COVID-19 vaccine securely while also offering tracking capabilities to reduce the spread of the virus. IntelliGuard's RFID tags work by placing them directly on COVID-19 vaccine vials. IntelliGuard provides the hardware and software to secure the vaccines in the freezers used by Rady Children's Hospital for storage. Rady's staff have automated access and control, providing visibility into who accessed the vaccines and when, in real time.[24]

The prices of RFID tags vary greatly depending on whether they are *active* or *passive*. **Passive RFID tags** don't contain a power source, require power from a tag reader, and cost an average of about four cents, depending on purchase volume, packaging, and how the tag is made. **Active RFID tags** draw power from an internal battery and are priced in the $10 to $70 range depending on the volume required and battery type. Both are finding applications. The passive variety are placed on pallets, cases, and units of product and are used in many retail and warehousing environments. In retail environments, passive RFID usage is on the rise. In a study by Atlanta-based management consulting firm Kurt Salmon in 2014, 34 percent of respondents had either implemented or were currently implementing or piloting passive RFID tags. In their 2016 study, RFID usage had more than doubled to 73 percent. In 2021, RFID usage among North American retailers is about 93 percent. Part of the reason for the significant growth in RFID usage is that the technology is delivering results. One standout measure is inventory accuracy. Inventory accuracy is the most widely used RFID metric, and Kurt Salmon found an average of inventory accuracy improvement

of 25.4 percent when using RFID. Even more interesting was that retailers reported that lack of inventory accuracy accounted for an average loss of 8.7 percent of total sales.[25]

The much more costly active tags are being used, for example, to track the whereabouts of expensive equipment in a hospital or for identification of fleet vehicles and shipping containers in and out of a facility. The U.S. Marines, for example, use active tags to track container loads on international shipments. The Marines' vision is to have tags talk directly to logistics databases via network access points that will then communicate information to other locations via satellite.[26]

Prior to the development of these supply chain applications, integrating processes beyond first-tier suppliers and customers was somewhat more difficult and time-consuming. As discussed in Chapter 4, firms can develop relationships with some of their second-tier suppliers and then insist that their direct suppliers use these suppliers. They can also work closely with their key direct suppliers to solve second-tier supplier problems and help them, in turn, better manage *their* direct suppliers. To stay on the competitive edge, firms today must use a combination of information system linkages and old-fashioned customer and supplier teamwork to identify and manage second-tier relationships along the supply chain.

### Reevaluate the Integration Model Annually

In light of the dramatic and fast-paced changes occurring with the development of supply chain communication technologies and the frequent changes occurring with new products, new suppliers, and new markets, trading partners should revisit their integration model annually to identify changes within their supply chains and to assess the impact these changes are having on integration efforts. New suppliers may have entered the scene with better capabilities, more distribution choices, and better resources. Secondary, or back-up suppliers may also be desired, particularly in light of the recent pandemic, which adversely impacted most suppliers. One example is the chip shortage created by the pandemic, which was caused in part by the greatly increased demand in 2020 for personal electronics such as cell phones and laptops—the production of microchips simply could not keep up. Additionally, automakers were seeing lower demand for automobiles in early 2020, so they stopped ordering chips, to draw down inventories. When auto sales rebounded in late 2020, it created an even greater scarcity of chips. By mid-2021, distributors were out of stock, fabricators were already busy with different product mixes, and chip production had to ramp up all over again. Additionally, distributors and fabricators weren't inclined to reward customers (auto manufacturers) who had stiffed them so abruptly. Buyers that maintained good relations with these companies came out ahead.[27]

Or, perhaps the firm may be redesigning an older product, requiring different purchased components or supplier capabilities. Alternatively, the firm may be moving into a new foreign market, potentially requiring entirely different supply chains. These examples are common and should cause firms to reevaluate their supply chain strategies, objectives, processes, performance measures, and integration levels.

## Obstacles to Process Integration Along the Supply Chain

A number of factors can impede external process integration along the supply chain, causing loss of visibility, information distortion, longer cycle times, stockouts, and the bullwhip effect, all of which contribute to higher overall costs and reduced customer service capabilities. Managers must try to identify these obstacles and take steps to eliminate them to improve profitability and competitiveness for a supply chain's members. Table 13.2 summarizes these obstacles. Each of these is discussed next.

**Table 13.2 Obstacles to Supply Chain Integration**

| | |
|---|---|
| **Silo mentality** | Failing to see the big picture, and acting only in regard to a single department within a firm or a single firm within a supply chain. |
| **Lack of supply chain visibility** | The inability to easily share or retrieve trading partner information in real time, as desired by supply chain participants. |
| **Lack of trust** | Unwillingness to work together or share information because of the fear that the other party will take advantage of them or use the information unethically. |
| **Lack of knowledge** | Lack of process and information system skills and lack of knowledge regarding the benefits of SCM among management and other employees, within the firm and among partners. |
| **Activities causing the bullwhip effect:** | |
| • Demand forecast updating | Using varying customer orders to create and update forecasts, production schedules, and purchase requirements. |
| • Order batching | Making large orders for goods from suppliers on an infrequent basis to reduce order and transportation costs. |
| • Price fluctuations | Offering price discounts to customers, causing erratic buying patterns. |
| • Rationing and shortage gaming | Allocating short product supplies to customers, causing them to increase future orders beyond what they really need. |

## The Silo Mentality

Too often, firms do not consider the impact of their actions on their supply chains and long-term competitiveness and profitability. An arrogant "I win, you lose" **silo mentality** can be evidenced when using only the cheapest (or hungriest) suppliers, paying little attention to the needs of customers, and assigning few resources to new goods and services designs. Particularly with firms involved in global supply chains, silo mentalities can crop up as a result of cultural differences. The U.K. auto firm Rover is a case in point. In the 1980s, Rover formed a partnership with Japan-based Honda to provide goods for its new model program. The arrogance of Rover managers and a lack of a learning culture at Rover prevented it from realizing any benefits from the partnership. Later, when the German firm BMW bought Rover, communications with German managers and political infighting was even worse. The managerial problems that surfaced when Chrysler and Daimler-Benz got together, which ultimately led to the dissolution of that partnership, were similar.[28]

Eventually, lack of internal or external collaboration will create quality, cost, delivery timing, and other customer service problems that are detrimental to supply chains. In fact, Wayne Bourne, vice president of logistics and transportation at electronics retailer Best Buy, noted in an interview that the most significant obstacle to overcome in supply chain management was the silo mentality that exists in some companies.[29]

Internally, the silo mentality might be found between personnel of different departments. The transportation manager, for instance, may be using rail transportation to minimize transportation costs against the wishes of the firm's sales manager. The resulting delivery inconsistencies caused by continued use of the cheapest transportation providers might be deteriorating customer satisfaction and leading to a loss of customers.

To overcome these silo mentalities, firms must strive to align supply chain goals and their own goals and incentives. Functional decisions must be made while considering the impact on the firm's overall profits and those of the supply chain members. Performance

reviews of managers should include the ability of their department to integrate processes internally and externally and meet overall supply chain goals. Outside the firm, managers must work to educate suppliers and customers regarding the overall impact of their actions on their supply chains and the end customers. This should be an important part of the supply chain partnership creation and management process. Additionally, suppliers should be annually evaluated and potentially replaced if their performance vis-à-vis supply chain objectives does not improve. California-based Sutter Health, a network of physicians, hospitals, and other healthcare providers, has long believed integration among all departments is the best and most efficient way to deliver care to patients. In fact, in a study by Dartmouth Medical School's Center for the Evaluative Clinical Sciences, Sutter's hospitals, physicians, home care, and hospice services were found to represent a national benchmark.[30]

## Lack of Supply Chain Visibility

Lack of **information visibility** along a supply chain is frequently cited as a common process integration problem. In global supply chains and as noted in the chapter-opening SCM Profile, information visibility is particularly important. Product safety standards, trade agreements, and security requirements are changing almost daily, making information visibility critical for importers, shippers, and logistics providers. If trading partners have to carve out data from their information systems and then send it to one another where it then has to be uploaded to other systems prior to the data being shared and evaluated, the extra time and data transfer errors can mean higher inventories, higher costs, longer response times, and lost customers. "Visibility into inventory allows a company to do a better job accessing that inventory to fulfill a customer order, change transportation routes, and balance supply and demand using market conditions. But before that can happen, a business needs data from a number of different channels and processes: its warehouses, its stores, its finished goods supplier or manufacturer as well as freight forwarders, 3PLs, and local carriers. If this data cannot be consolidated and rationalized, a business is failing to exploit significant business value," says Scott Fenwick, senior director of product strategy at business consultant Manhattan Associates.[31]

Today, connectivity and visibility are becoming much easier with the use of **cloud-based communication platforms**. Cloud systems provide greater visibility, ensure faster time to market, and offer faster response to changing market dynamics and demands. Another key benefit to the use of cloud-based communications is speed. Customers and suppliers can be up and running in minutes to days, not months to years. California-based Del Monte Foods, one of the largest producers, distributors, and marketers of branded processed food for the U.S. retail market, enhanced its global supply chain operating platform by using a cloud-based service. Del Monte automated its inventory and document management processes with its international suppliers using a cloud-based system hosted by GT Nexus.[32] Unfortunately, many companies are still not using these types of platforms. In a September 2020 Wakefield Research survey of 900 global executives, 60 percent reported their organizations still lacked a fully integrated system to manage digital workflows. "If there are five different shared drives, databases, or programs that store similar types of information, consider cleaning house," says Jerome Huet, project manager for France-based Sandvik Rock Processing Plant Solutions.[33]

As businesses expand their supply chains to accommodate foreign suppliers and markets, and as outsourcing of manufacturing and logistics services continues, the need to use systems that provide real-time information to trading partners increases. "It's not good enough to just take the order," says Beth Enslow of Massachusetts-based research company

Aberdeen Group. "Now you have to provide a continuous stream of information about its status, feasibility, and total cost to customers and partners throughout the world. You don't want customers receiving unexpected transportation expenses or delays in shipments—or worse, receiving them without you knowing about it."[34]

RFID tags, as mentioned earlier, can be used to improve information visibility in supply chains. With the right equipment, users can determine the exact location of any product, anywhere in a supply chain, at any time. An RFID tag attached to an automobile seat or engine, for example, can be used to gather and exchange work-in-process data. Or, when a shipment of flowers drops below a safe temperature, an RFID system can alert packers to pull those cartons and send them to a closer destination. When a thief tries to break into a shipping container, an RFID-controlled monitor can send an alert to company representatives. These are all applications of RFID technology. "When you have bad data, you make bad decisions," says Kaushal Vyas, director of product development at Georgia-based Infor, a business software provider. "You must be able to source and mine data from all the different places in real time, so you can focus on the exceptions that you need to manage in order to boost your performance."[35]

## Lack of Trust

Successful process integration between trading partners requires trust, and as with the silo mentality and lack of information visibility, lack of trust is seen as a major stumbling block to process integration in supply chains. Trust develops over time between trading partners, as each organization follows through on promises made to the other firms. Even though this sounds cliché, relationships employing trust result in a win-win or win-win-win situation for the participants.

Unfortunately, old-fashioned company practices and purchasing habits don't change overnight. Until managers understand that it is in their firms' best interests to trust each other and collaborate, supply chain management will be an uphill battle. Medical treatment innovator Mayo Clinic for example, builds a collaborative culture by hiring professionals with collaborative attitudes and a common set of deeply held values regarding care for patients. At computing giant IBM, CEO Sam Palmisano transformed an extremely hierarchical culture based on individualism to one of collaboration by organizing town hall-type meetings online, involving tens of thousands of IBM employees and dozens of trading partners. Collaborative projects resulted from these meetings. IBM reinforced collaboration with "thanks awards," which were T-shirts, backpacks, and other similar gear emblazoned with the IBM logo, and given by IBM employees.[36]

Some useful advice for creating collaboration and trust is summed up nicely in an article appearing in *CIO* magazine, a business journal for IT and other business executives. They recommended six ways of "getting to yes:"[37]

1. *Start small*—Begin by collaborating on a small scale. Pick a project that is likely to provide a quick return on investment for both sides. Once you can show the benefits of trust and collaboration, then move to larger projects.
2. *Look inward*—The necessary precondition for establishing trust with outside partners is establishing trust with internal constituents. Break down the barriers to internal communication and integration.
3. *Gather 'round*—The best way to build trust is to meet face-to-face, around a table. Listen to objections, find out the agendas, and spring for lunch. Then do it all over again as people leave and as management changes.

4. *Go for the win-win*—Collaboration is a new way of doing business where the biggest companies don't bully their partners, but instead help create an environment that optimizes business for all supply chain members.
5. *Don't give away the store*—No one has to share all of their information. Some information should remain proprietary. The simple exchange of demand, purchase, and forecast information goes a long way.
6. *Just do it*—One of the best ways to build trust is to simply start sharing information. If all goes well, then success breeds trust, allowing partners to progress to bigger things.

## Lack of Knowledge

Companies have been slowly moving toward collaboration and process integration for years, and it is just within the past few years that technology has caught up with this vision, enabling collaboration and process integration across extended supply chains. Getting a network of firms and their employees to work together successfully, though, requires managers to use subtle persuasion and education to get their own firms and their trading partners to do the right things. The cultural, trust, and process knowledge differences in firms are such that firms successfully managing their supply chains must spend significant time influencing and increasing the capabilities of their own employees as well as those of their trading partners.

Training of supply chain partner employees is also known as **collaborative education** and can result in more successful supply chains and higher partner returns. As technologies change, as outsourcing increases, and as supply chains are expanded to foreign sources and markets, the pressure to extend software applications and management training to trading partners increases. As Rick Behrens, senior manager of supplier development at Boeing Company's Integrated Defense Systems unit, explains, "We look at our suppliers as an extension of Boeing. So, since we invest heavily in training and education of our employees, why wouldn't we invest in education and development for our suppliers?" Farm and construction equipment manufacturer John Deere, for example, has established a global learning and development center specifically for training its key suppliers.[38]

Change and information sharing can be threatening to people; they may fear losing control or losing their job, particularly if outsourcing accompanies process integration. Additionally, as firms construct their supply chain information infrastructure, they may find themselves with multiple ERP systems with various software applications that all need to be integrated both internally and externally. Thus, firms must realize that people using the systems should be involved early on in terms of the purchase decision, the implementation process, and training.

For all organizations, successful supply chain management requires a regimen of ongoing training. When education and training are curtailed, innovation cannot occur, and innovation fuels supply chain competitiveness. Poor decision making and other human errors can have a rippling effect in supply chains, causing loss of confidence and trust, and a magnification of the error and correction cost as it moves through the supply chain. Industry trade shows, conferences, and expos such as the Gartner Supply Chain Symposium/Xpo™, Flow 2021, and the Annual Institute for Supply Management Conference can also be valuable sources of learning, exchanging ideas, and gathering new information about supply chain management.[39]

## Activities Causing the Bullwhip Effect

As discussed in Chapter 1 of this textbook, the **bullwhip effect** can be a pervasive and expensive problem along supply chains and is caused by a number of factors that supply chain members can control. Recall that even though end item demand may be relatively constant, forecasts of trading partner demand, additions of safety stock, and the corresponding orders to suppliers as they are traced back up supply chains can become amplified, causing what is termed the bullwhip effect. These amplified demand levels cause problems with capacity planning, inventory control, and workforce and production scheduling, and ultimately result in lower levels of customer service, greater overall levels of safety stock, and higher total supply chain costs. In an early publication on the bullwhip effect, Stanford University's Dr. Hau Lee and his associates identified four major causes of the bullwhip effect. More recently, Dr. Lee commented that the 2009 economic downturn caused a number of bullwhips to again emerge, but that firms could still "tame the bullwhip" with hard work, understanding the causes of demand, gaining visibility, and investing in collaboration with partners.[40] Today, the pandemic has again caused the bullwhip effect to emerge, as inventory swings have become commonplace. Shipping delays are being caused by dock worker, truck driver, and even container shortages. "Our members can't even get empty containers. There are vessels sitting in the ports of Los Angeles and Long Beach for a week plus. And others sitting in port trying to get out of the gate. We've seen delays and supply chain issues before, but never one so global in nature. No one is being spared," says Jon Gold, vice president of supply chain and customs policy for the Washington D.C.-based National Retail Federation.[41] The causes of the bullwhip effect and the methods used to counteract it are discussed below.

### Demand Forecast Updating

Whenever a buying firm places a purchase order, its supplier uses that information as a predictor of future demand. Based on this information, suppliers update their demand forecasts, which then impact orders placed with their suppliers. If lead times grow between orders placed and deliveries, then safety stocks also grow and impact purchase orders as well, which adds to the bullwhip effect. Thus, fluctuations are magnified as orders vary from period to period, and as the review periods change, causing frequent **demand forecast updating**. These are major contributors to the bullwhip effect.

One solution to this problem is for the buyer to make its actual demand data available to its suppliers. (Recall from Chapter 5 that this activity is part of a collaborative planning, forecasting, and replenishment effort). Better yet, if all point-of-sale data is made available to the upstream tiers of suppliers, all supply chain members can then update their demand forecasts less frequently, using actual demand data. This real demand information also tends to reduce safety stocks among supply chain members, generating even less variability in supply chain orders. Thus, the importance of supply chain information visibility can again be seen.

Using the same forecasting techniques and buying practices also tends to smooth demand variabilities among supply chain members. In many cases, buyers allow some of their suppliers to observe actual demand, create a forecast, and determine their resupply schedules—a practice known as vendor managed inventory (discussed in Chapters 3 and 4). This practice can generally reduce inventories substantially.

Reducing the length of the supply chain can also lessen the bullwhip effect by reducing the number of occasions where forecasts are calculated and safety stocks are added. Examples of this are Drugstore.com, Amazon.com, and other firms that bypass distributors and

resellers and sell directly to consumers. Firms can thus see actual end-customer demand, resulting in much more stable and accurate forecasts.

Finally, reducing the lead times from order to delivery will lessen the bullwhip effect. For example, developing just-in-time ordering and delivery capabilities results in smaller, more frequent orders being placed and delivered, which more closely matches supply to demand patterns, thus decreasing the need for safety stocks.

## Order Batching

In a typical buyer–supplier scenario, demand draws down existing inventories until a reorder point is reached wherein the buyer places an order with the supplier. Inventory levels, prior delivery performance, and the desire to order full truckloads or container loads of materials may cause orders to be placed at varying time intervals. Thus, the supplier receives an order of some magnitude; then at some indeterminate future time period, another order is received from the buyer, for some quantity potentially much different in size from the prior order. This causes the supplier to hold extra safety stock. Thus, **order batching** tends to amplify demand variability, which creates greater use of safety stock, again causing the bullwhip effect.

Another type of order batching can occur when salespeople need to fill end-of-quarter or end-of-year sales quotas, or when buyers desire to fully spend budget allocations at the end of their fiscal year. Striving to meet sales quotas and making excess purchases to spend budget money causes erratic surges in consumption and production, causing, you guessed it, the bullwhip effect. If the timing of these surges is the same for many of the firm's customers, the resulting bullwhip effect can be severe.

As with forecast updating, more information visibility and frequent and smaller order sizes will reduce the order batching problem. When suppliers know that large orders are occurring because of the need to spend budgeted monies, for instance, they will not revise forecasts based on this information. Further, when using automated or computer-assisted order systems, order costs are reduced, allowing firms to order more frequently. To counteract the need to order full truckloads or container loads of an item, firms can order smaller quantities of a variety of items from a supplier, or use a freight forwarder to consolidate small shipments, to avoid the high unit cost of transporting at less-than-truckload or less-than-container load quantities.

## Price Fluctuations

When suppliers offer special promotions, quantity discounts or other special discounts, these pricing fluctuations result in significant **forward buying** activities on the part of buyers, who "stock up" to take advantage of the low price offers. Forward buying can occur between retailers and consumers, between distributors and retailers, and between manufacturers and distributors due to pricing promotions at each stage in a supply chain, all contributing to erratic buying patterns, lower forecast accuracies, and consequently the bullwhip effect. If these pricing promotions become commonplace, customers will stop buying when prices are undiscounted and buy only when the discount prices are offered, even further contributing to the bullwhip effect. To deal with these surges in demand, manufacturers may have to vary capacity by scheduling overtime and undertime for employees, finding places to store stockpiles of inventory, paying more for transportation, and dealing with higher levels of inventory shrinkage as inventories are held for longer periods.

The obvious way to reduce the problems caused by fluctuating prices is to eliminate price discounting among a supply chain's members. Manufacturers can reduce forward

buying by offering uniform wholesale prices to their customers. Many retailers have adopted this notion, termed **everyday low pricing** (EDLP), while eliminating promotions that cause forward buying. Similarly, buyers can negotiate with their own suppliers to offer EDLP. For example, big box retailer Target did not have a great year financially, in 2016. In a conference call following the release of its weaker-than-expected financial results for fiscal 2016, Brian Cornell, Target's CEO explained, "We spent a lot of time looking at the changes we had made following the [data breach of 2013], and we were very promotional, and that promotional intensity has continued. In 2017, you will see us getting back to our roots, getting back to establishing everyday low pricing in those essential categories."[42]

### Rationing and Shortage Gaming

**Rationing** can occur when demand exceeds a supplier's finished goods available—in other words, the supplier might allocate units of product in proportion to what buyers ordered. Thus, if the supply on-hand is 75 percent of total demand, buyers would be allocated 75 percent of what they ordered. When buyers figure out the relationship between their orders and what is supplied, they inflate their orders to satisfy their real needs. This strategy is known as **shortage gaming**. Of course, this further exacerbates the supply problem, as the supplier and, in turn, its suppliers, struggle to keep up with these higher demand levels. When, on the other hand, production capacity eventually equals demand and orders are filled completely, orders suddenly drop to less than normal levels as the buying firms try to unload their excess inventories. This has occurred occasionally in the United States and elsewhere around the world—for instance, with gasoline supply shortages, and in 2012 with Hostess Twinkies. As soon as consumers think a gasoline shortage is looming, demand suddenly increases as people top off their tanks and otherwise try to stockpile gasoline, which itself creates a deeper shortage. In December 2012, when Hostess Brands entered Chapter 7 liquidation, it set off a period of mass panic as fans of Twinkies, Ding Dongs, and other Hostess baked goods flew off shelves.[43] (Readers may recall the panic buying of toilet paper and other paper supplies in early 2020, due to the pandemic). When these types of shortages occur due to shortage gaming, suppliers can no longer discern their customers' true demand, and this can result in unnecessary additions to production capacity, warehouse space, and transportation costs.

One way to eliminate shortage gaming is for sellers to allocate short supplies based on the demand histories of their customers and not their customers' orders. In that way, customers are essentially not allowed to exaggerate orders. And once again, the sharing of capacity and inventory information between a manufacturer and its customers can also help to eliminate customers' fears regarding shortages and eliminate gaming. Also, sharing future order plans with suppliers allows suppliers to increase capacity if needed, thus avoiding a rationing situation.

Thus, it is seen that a number of decisions on the part of buyers and suppliers can cause the bullwhip effect in supply chains. When trading partners use the strategies discussed above to reduce the bullwhip effect, the growth of information sharing, collaboration, and process integration occurs along supply chains. Firms that strive to share data, forecasts, plans, and other information can significantly reduce the bullwhip effect.

## Managing Supply Chain Risk and Security

As supply chains grow to include more foreign suppliers and customers, there is a corresponding growth in supply chain disruptions caused by weather and traffic delays, infrastructural problems, political problems, and fears of, or actual, unlawful or terrorist-related activities. For example, in just the last few years there have been civil

rights protests across the United States, major flooding in China, the ransomware cyber attacks that hit dozens of countries across Europe, Asia, and the United States, deadly fires across the western United States, earthquakes in the Philippines, and numerous commercial airline crashes and suicide bombings. Besides the obvious impact on life and limb, these events add elements of financial, reputation, and customer service risk to global supply chains and the need for enhanced planning, change management, and security to mitigate that risk.

So, while lengthening supply chains may have resulted in cheaper labor and material costs, better product quality, and greater market coverage, it has also resulted in higher security costs and greater levels of supply risk, potentially leading to deteriorating profits and customer service levels. Managing risk and security along the supply chain is discussed in detail below.

## Managing Supply Chain Risk

Recall from Chapter 1 that **supply chain risk** is defined as the likelihood of an internal or external event that disrupts supply chain operations, causing potential reductions in service levels, product quality, and sales, along with an increase in costs. According to the Chartered Institute of Procurement & Supply Risk Index, powered by Dun & Bradstreet, global supply chain risk is increasing, which has been a trend since the global recession in 2009. And the pandemic made supply chain risk much, much worse. "There's just too much uncertainty, COVID-19 surges and variants, for anyone to accurately predict when this all returns to some level of normal," Gold, of the National Retail Federation, said. "Everyone is working through this but there is no risk mitigation strategy playbook for the pandemic."[44]

Information technology advances, for example, have made cyber attacks more and more common. "Obviously hackers and intruders can also affect the availability of a system, and that can come from any angle," says Thomas Srail, senior vice president at FINEX North America, a risk advisement service. Linda Conrad, director of strategic business risk for Zurich Global Corporate, says the effect from hackers getting access to companies' data along their supply chains can cause the loss of the data itself, reputation damage, regulatory issues, and fines. Zurich's disruption database shows that 52 percent of supply chain disruptions in a one-year period resulted from information technology or communications outages between buyer and supplier.[45]

Tom Ridge, the former governor of Pennsylvania, former secretary of Homeland Security in the United States and now CEO of risk management consulting firm Ridge Global, says that supply chains need to be vetted down to the second, third, and fourth tiers. No multinational firm "… can afford to let anybody in the supply chain, no matter how far removed, and view risk less seriously than it does," he says. The 2010 BP oil disaster in the Gulf of Mexico is a good example. Transocean was the oil rig operator, a supplier for BP in this case. Based on the finger-pointing in that disaster, Transocean was at least partially responsible for the explosion, rig destruction, worker deaths, and oil well blowout. If communication and due diligence can break down as badly as it did between BP and one of its primary direct suppliers, consider the potential financial, reputation, and customer service risks posed by the many second- and third-tier suppliers.[46]

A number of steps have been suggested for managing supply chain risk, and several good examples exist that highlight successful supply chain risk management. Table 13.3 describes a number of risk management activities, and they are discussed next.

**Table 13.3 Activities Used to Manage Supply Chain Risk[47]**

| RISK MANAGEMENT ACTIVITY | DESCRIPTION |
|---|---|
| Increase safety stocks and forward buying | Can be costly. A stopgap alternative. |
| Identify backup suppliers and logistics services | Can create ill will with current partners; requires additional time and relationship building. |
| Diversify the supply base | Use of suppliers from geographically dispersed markets to minimize the impacts of disruptions. |
| Utilize a supply chain IT system | Collection and sharing of appropriate information with supply chain partners. |
| Develop a formal risk management program | Identifies potential disruptions and the appropriate response. |

## Increase Safety Stocks and Forward Buying

If the firm fears a supply disruption, it may choose to carry some level of safety stock to provide the desired product until a suitable substitute supply source can be found. If the purchased item is readily available from other sources, the desired level of safety stock may be relatively small. On the other hand, if the item is scarce, if the supply disruption is likely to be lengthy, or if the firm fears a continued and lengthy price increase, it may decide to purchase large quantities of product, also known as forward buying. Safety stocks and forward buying should only be viewed as temporary solutions since they can dramatically increase inventory carrying costs and the bullwhip effect, particularly for firms with large numbers of purchased items.

In some cases, though, forward buying may be viewed as the only short-term solution for managing risk. In 2006, many organizations opted to stockpile the influenza drug Tamiflu to prepare for a potential avian influenza pandemic, since shortages of the drug worldwide had already been experienced. In the United States, for example, 300 firms along with the federal government itself had already been engaged in significant stockpiling by the summer of 2006. After that period, as supplies of antiviral drugs increased, the practice of forward buying decreased.[48] In 2020, during the COVID-19 pandemic, the United States and other wealthy countries did the same thing with vaccines. Once supply caught up with demand, the stockpiling subsided.[49]

## Identify Backup Suppliers and Logistics Services

Another very simple strategy for guaranteeing a continuous supply of purchased items and logistics services is to identify suppliers, transportation and warehousing services, and other third-party services to use in case the preferred supplier or service becomes unavailable. This topic was discussed in relation to the use of sole or single sources in Chapter 2. The disadvantage of this strategy is that it requires additional time to find and qualify sources and to build trusting relationships. Additionally, this strategy may tend to damage existing supplier or logistics provider relationships. The backup source may see limited value in the relationship if they are providing only a small percentage of total demand, their price for the goods or services will likely be higher, and the existing firm may view the use of backup companies as a signal that their "piece of the pie" will continue to shrink. Additionally, use of multiple sources may allow proprietary designs or technologies to be copied, creating further risk.

Backup or **emergency sourcing** and multiple sourcing, though, may be a sound strategy in specific cases. During the 2002 U.S. West Coast dockworker strikes, airfreight capacity quickly ran out, causing freight rates to skyrocket and firms to be unable to quickly move freight. Companies that had already entered into contracts for emergency airfreight service, though, were able to maintain operations during the port disruptions.[50]

In 2020, at the peak of the pandemic, New York City faced a weekly demand for personal protective equipment (PPE) that numbered in the millions of items. Under this crushing demand, supply chains broke down and the lifesaving and protective equipment and supplies hospitals and frontline workers needed were in extremely short supply. Even with nurses and doctors heavily conserving what they already had, at its worst, the city was just days away from running out. Manufacturers around the world were inundated with orders and New York's usual sources were unable to meet their needs. Prices for PPE and ventilators skyrocketed—the cost of masks and gowns for example, increased more than tenfold. Eventually, the city began fast-tracking procurement, paying suppliers in advance, and then stockpiling critical supplies.[51]

## Diversify the Supply Base

Madagascar, one-time provider of half of the world's vanilla supply, saw cyclone Hudah destroy 30 percent of its vanilla bean vines in 2000. Additionally, a political problem in Madagascar caused its primary port to be closed for many weeks in 2002. These two events caused vanilla prices to skyrocket for an extended period of time until growers in Madagascar and other countries could increase their production. Buyers with vanilla supply contracts in multiple countries were able to avoid some of this pricing problem. Eventually, the market for vanilla became more diversified, creating a situation whereby vanilla buyers today have multiple vanilla sources outside of Madagascar.[52] An earthquake and tsunami in Japan in 2011 halted automobile and parts production at a number of the country's manufacturing plants. In India, for example, Suzuki and Honda production and retail facilities had to cease operations for a time, since their Japanese parent companies and parts suppliers sustained damage from the tsunami.[53]

In the examples above, concentrating purchases with one supplier was seen as increasing supply risk, while purchasing the same or similar goods from geographically dispersed suppliers could have the effect of spreading and hence reducing the risk of supply disruptions from pandemics, political upheavals, weather-related disasters, and other widespread supply problems. Buyers, though, must also consider the impact of a geographically dispersed supply base on purchase prices, customer service, and other supply chain risks. While potentially reducing the risk associated with geographic supply disruptions, the use of suppliers in multiple countries exposes buyers to additional political, customs clearance, exchange rate, and security risks.

## Utilize a Supply Chain IT System

Chapter 6 discussed the importance of supply chain communication and information systems. As firms geographically expand their supply chains, they find customs clearance requirements and paperwork becoming increasingly complicated. Complying with these regulations requires information and data visibility among supply chain participants and involvement by all key supply chain partners. Accurate data transmissions can aid in the reduction of stockouts and the bullwhip effect caused by forecasting, order inaccuracies, and late deliveries, which also pose significant risks and costs to supply chains.

Information systems should be designed to help mitigate supply chain risk. Currently, the pandemic is hampering operations at most U.S. ports. Ports are operating at unsustainably high and imbalanced levels—for every five containers unloaded, only one full container of goods is going out. U.S. buyers are so desperate for containers in Asia, they are sending them back empty. Gene Seroka, the Port of L.A.'s executive director, believes that government intervention is needed in order to help lessen the load felt by America's port systems. "When our supply chains work well, they operate largely unnoticed, delivering essential goods, creating jobs, and driving economic growth and prosperity across the nation," he says. "Our freight system requires robust freight infrastructure investment, and importantly, this investment should include accelerated and integrated digitalization of the supply chain," the executive director added. Moreover, those systems—which are already humming across Asian and European gateways—must be bolstered in the U.S. market and interconnected to provide a means for collaborative work. "Such integrated digital platforms can equip cargo owners and service providers with the information they need to optimize their supply chains and enhance resilience to future supply chain disruption," said Mr. Seroka.[54]

## Develop a Formal Risk Management Program

By far the most proactive risk management activity is to create a formal risk management plan encompassing the firm and its supply chain participants. Risk management should become an executive-level priority. Potential risks should be identified and prioritized, and appropriate responses should be designed that will minimize disruptions to supply chains. Additionally, mechanisms should be developed to recover quickly, efficiently, and with minimal damage to the firm's reputation and customer relationships. Finally, performance measures need to be developed to monitor the firm's ongoing risk management capabilities. "Risk happens," says Dr. Kate Vitasek, supply chain faculty member at the University of Tennessee. "Plan for it. Collaborate with your partners in the supply chain to mitigate and eliminate it, and don't bury your head in the sand."[55]

A supply chain risk management office should be created to oversee and coordinate the firm's risk management efforts. The risk manager provides guidance and support to department managers, is the interface between the firm and its trading partner risk managers, and possesses the knowledge to adequately identify, prioritize, and provide a plan to reduce risks. In 2005, Tractor Supply, for example, developed a disaster recovery plan as part of its overall risk management strategy. One year later, its Waco, Texas, distribution center was struck by a tornado in the evening, leaving 2 to 3 inches of water standing in the facility and product scattered across the landscape for miles. By the time logistics VP Mike Graham made it to his office the next day, plans were already in place to repair the damage, and within several hours all of the customers served by the Waco distribution center were linked to other facilities. "We did not miss a delivery the following week and May is actually a peak season for us," said Mr. Graham.[56]

Richard Sharman, a partner in KPMG's risk advisory services group, offers his advice for developing risk management plans—"Companies almost need to ask themselves the stupid questions to think about the full spectrum of business risks, and how they would manage them," he says. Another consideration is to know who the firm is doing business with, to assure they are using an appropriate labor force, complying with product safety guidelines, and generally using practices that fit with the firm's reputation. "Know your partner. There is no substitute for that," says Brian Joseph, partner at global business consultant PricewaterhouseCoopers.[57] When outsourcing to firms in foreign locales, it is also necessary to have adequate quality controls in place, and require suppliers to report periodically to the firm to ensure their products meet design requirements.

## Managing Supply Chain Security

As supply chains become more global and technologically complex, so does the need to secure them. **Supply chain security management** is concerned with reducing the risk and impacts of intentionally created disruptions in supply chain operations including product and information theft and activities seeking to endanger personnel or sabotage supply chain infrastructure. The crash of Pan Am Flight 103 in Lockerbie, Scotland, in 1988 not only tragically illustrated the weaknesses of airline security systems at the time, but it also exposed the dependency of entire supply chains on each member's security capabilities. Pan Am's security processes did not fail in permitting a bomb onto Flight 103—it was actually Malta's Luqa Airport's security system that allowed the luggage carrying the bomb into the baggage handling system that placed the luggage on an aircraft flown to London, where the bomb was then placed aboard Flight 103.[58] In the United States, the attacks of September 11, 2001, were a wakeup call to many businesses to begin assessing their needs for supply chain security systems. Prior to that time, most executives were aware that their operations might be vulnerable to security problems; however, most firms (as well as governments) chose to put off improving security practices.

The notion that a supply chain is only as secure as its weakest link is illustrated in the Pan Am example above. It is therefore necessary today for firms to manage not only their own security but the security practices of their supply chain partners as well. Supply chain security, though, is an extremely complex problem—security activities begin at the factory where goods are packaged and loaded, and then include the logistics companies transporting goods to ports, the port terminals and customs workers, the ocean carriers, the destination ports and customs workers, additional transportation companies, distribution centers and workers, and the final delivery companies. And integrating all of these participants are various information systems that also need to be protected. The Biden administration, for example, has made supply chain security a key part of its cyber strategy. The action came after a hack of network-management company SolarWinds Corp. in 2020 gave suspected Russian hackers access to computer systems in several government agencies and dozens of U.S. businesses. "Finding a vulnerability is surprisingly hard," says Allan Liska, senior solutions architect at the cyber firm Recorded Future. "It's almost always [done] by nation-state actors, because those are the folks that are willing to spend the money." The attack was so successful, Mr. Liska said, that the attackers appeared to fumble extortion demands and negotiations. "They were just overwhelmed by the number of victims," he said, of hackers' attempts to monetize the incident. "That whole part is a complete disaster."[59]

Security management collaboration should include, for example, contractual requirements for secure systems, "standards of care" for movement and storage of goods as they move along the supply chain, and the use of law enforcement officials or consultants in security planning, training, and incident investigation. James G. Liddy, internationally recognized expert on security, CEO of Virginia-based security firm Liddy International, and the son of famous Watergate burglar and talk-show host G. Gordon Liddy, says, "Focus on what your real vulnerabilities are and have in place a safety-and-preparedness plan for all hazards. When you enhance your safety procedures and integrate them into your security, you create efficiencies."[60] Table 13.4 describes four increasing levels of supply chain security system preparedness, and these are discussed below.

### Basic Initiatives

At the most basic level, security systems should include procedures and policies for securing offices, manufacturing plants, warehouses, and other physical facilities and

**Table 13.4 Supply Chain Security System Response[61]**

| LEVEL OF SECURITY SYSTEM RESPONSE | DESCRIPTION |
|---|---|
| Basic initiatives | Physical security measures; personnel security; standard risk assessment; basic computing security; continuity plan; freight protection. |
| Reactive initiatives | Larger security organization; C-TPAT compliance; supply base analysis; supply continuity plan; limited training. |
| Proactive initiatives | Director of security; personnel with military or gov't. experience; formal security risk assessment; advanced computing security; participation in security groups. |
| Advanced initiatives | Customer/supplier collaboration; learning from the past; formal security strategy; supply chain drills, simulations, exercises; emergency control center. |

additionally should provide security for personnel, computing systems, and freight shipments. Managers should consider use of security badges and guards, conducting background checks on applicants, using antivirus software and passwords, and using shipment tracking technologies.

Today, cargo theft is a big problem for global supply chains, and some of the basic security approaches can be used to reduce this threat. Global loss estimates are tagged at $10 billion to $30 billion per year. And technology and lack of downside risk have enabled thieves to be more sophisticated and daring than ever before. Stolen goods can be moved to a warehouse, off-loaded, repackaged, remanifested, and placed on another vehicle before the theft is even discovered and reported. The existence of online marketers and auction sites even further facilitates the movement and sale of stolen merchandise.[62] The pandemic is believed to have contributed to an increase in cargo theft, which was up overall in 2020 from the previous year, according to the cargo security firm Sensitech. "COVID-19 created a perfect storm of cargo threat and vulnerability," says Johnny McCord, CEO of Loadsure, a transportation insurance provider. "Stressed and distracted workers were more vulnerable to scams, like fictitious pickups. Nonviolent offenders, like cargo thieves, were released from prison to contain the spread of the virus. Finally, those who lost jobs or had their hours slashed may have been more likely to engage in criminal activity."[63] "Cargo at rest is cargo at risk, and cargo left overnight or longer is generally at more risk," says Mike Yarwood, loss prevention expert at transportation insurer TT Club. He also noted a growth in cargo theft, and pointed out that thieves have been breaking into depots and stealing complete trailer or container loads of goods.[64]

Corruption is another potential problem organizations must begin to manage. Transparency International, a global group leading the fight against corruption, annually publishes its Corruption Perceptions Index to publicize the degree of corruption existing in 180 countries. The scale ranges from 0 (highly corrupt) to 100 (no corruption). The index combines multiple surveys of public sector employees' perceptions of the level of corruption in their countries. As in previous years, the average index was below 50, showing that most countries are failing to tackle corruption effectively. In 2020, the average score was just 43. The United Kingdom, Japan, and the United States ranked eleventh, nineteenth, and twenty-fifth, respectively. Denmark, New Zealand, and Finland continued to be the top-rated countries, while Syria, South Sudan, and Somalia were at the bottom of the list. In the past ten years, 26 countries have improved their scores while 22 have declined.[65]

## Reactive Initiatives

Reactive security initiatives represent a somewhat deeper commitment to the idea of security management compared to basic initiatives, but still lack any significant efforts to organize a cohesive and firm-wide plan for security management. Many firms in this category, for example, implemented security systems in response to the terrorist attacks of September 11, 2001. These initiatives include becoming Customs-Trade Partnership Against Terrorism (C-TPAT) compliant, assessing suppliers' security practices, developing continuity plans for various events, and implementing specific training and education programs.

**C-TPAT compliance** refers to a partnership among U.S. Customs, the International Cargo Security Council (a U.S. nonprofit association of companies and individuals involved in transportation), and Pinkerton (a global security advising company, headquartered in New Jersey), whereby companies agree to improve security in their supply chain in return for "fast lane" border crossings at both the U.S./Canadian and U.S./Mexican borders. U.S. Customs and Border Protection states that nonparticipants are about six times more likely to receive a security-related container inspection at U.S. border crossings.[66]

## Proactive Initiatives

Proactive security management initiatives venture outside the firm to include suppliers and customers, and also include a more formalized approach to security management within the firm. Security activities occurring among firms in this category include the creation of an executive-level position such as director of corporate security; the hiring of former military, intelligence, or law enforcement personnel with security management experience; a formal and comprehensive approach for assessing the firm's exposure to security risks; the use of cyber-intrusion detection systems and other advanced information security practices; the development of freight security plans in collaboration with 3PL providers; and the active participation of employees in industry security associations and conferences. Home Depot, for example, uses a computer risk modeling approach to assess its supply chains' vulnerabilities and design appropriate security measures. "We look at 35 global risk elements and one of those is threat of terrorism," explains Benjamin Cook, senior manager for global trade service for Home Depot. "We use that technique to help us roll out a strategy that is most appropriate to the country we are sourcing from."[67]

Massachusetts-based life insurance company MassMutual wanted to ensure the security of its IT system, spread across a dozen applications, including its website as well as the 12 million business and individual customer accounts it managed. It named a vice president of information security to direct its information security efforts, and it put in place a fifty-person security group that included an internal consulting team with specific security item experts, an engineering team that supported firewalls, a security assurance team that analyzed security monitoring devices, and a team responsible for identity management. Finally, it purchased a security management software application to help its security team quickly assess and prioritize risks. It creates an aggregate risk score for each application and system it uses to determine which risks need to be addressed first.[68]

## Advanced Initiatives

Firms with advanced security management systems are recognized as industry leaders with respect to their security initiatives. Activities within this category include full collaboration with key suppliers and customers in developing quick recovery and continuity plans for supply chain disruptions, consideration of past security failures of other firms in developing a more comprehensive and effective security system, the design of a complete

supply chain security management plan that is implemented by all key trading partners, the undertaking of exercises designed to train participants and test the resilience of the supply chain to security disruptions, and the use of an emergency control center to manage responses to unexpected supply chain disruptions.

Industry security leaders, such as Michigan-based Dow Chemical, see supply chain security as simply good business. According to Henry Ward, director of transportation security and safety at Dow, "We view security as one of the steps we take to make sure we remain a reliable supplier of goods to the marketplace." Dow's efforts to improve supply chain visibility and security led to a 50 percent improvement in the time it takes to identify and resolve trade transit problems, and a 20 percent inventory reduction at receiving terminals. Dow uses RFID and a global positioning system (GPS) to track large intermodal containers as they move between North America and Asia. Dow also sees collaboration with governments and with its supply chain partners as crucial to its success. "We take an integrated approach to supply chain security, which means we look at it holistically," says Ward.[69]

As described in this final section, supply chain participants are pulled by opposing objectives—one is to reduce supply chain costs and improve freight handling speed to improve competitiveness and profits; the other is to manage the risk and cost of security breaches. Unfortunately, as supply chains venture into countries in search of cheaper suppliers or new markets, or make logistics changes to reduce transit times, the security risks grow. Managers and government representatives understand the problem much better, though, today than ten years ago, and hopefully, this is leading to better management of risk and security.

## Summary

In this chapter, the topic of integrating processes within the firm and among supply chain partners was discussed, including the steps required to achieve internal and external process integration, the advantages of integration, as well as the obstacles to overcome. Process integration should be considered the primary means to achieving successful supply chain management and it is the one thing firms struggle with most when setting out to manage their supply chains. Without the proper support, training, tools, trust, and preparedness, process integration most likely will be impossible to ever fully achieve.

The supply chain integration model provides the framework for integrating processes first within the firm and then among trading partners, and this model served as the foundation of the chapter. The role played by performance measures in assessing and improving integration was also discussed. Finally, a discussion of supply chain risk and security management outlined the need for firms and their trading partners to collaborate in developing effective strategies for assessing the risk of supply chain disruptions and implementing solutions.

## Key Terms

**active RFID tags,** 573

**bullwhip effect,** 579

**C-TPAT compliance,** 588

**cloud-based communication platforms,** 576

**collaborative education,** 578

**customer relationship management process,** 564

**data warehouses,** 570

**demand forecast updating,** 579

**demand management process,** 565

**emergency sourcing,** 584

**everyday low pricing (EDLP),** 581

**forward buying,** 580

**functional silos,** 564

**information visibility,** 576

**internal supply chains,** 570

**key supply chain processes,** 564

**key trading partners,** 562

**knowledge management solutions,** 572

**legacy systems,** 570

**manufacturing flow management process,** 566

**order batching,** 580

**order fulfillment process,** 566

**passive RFID tags,** 573

**process,** 564

**process integration,** 561

**product development and commercialization process,** 568

**radio-frequency identification tag (RFID),** 572

**rationing,** 581

**returns management process,** 568

**shortage gaming,** 581

**silo mentality,** 575

**supplier relationship management process,** 567

**supply chain risk,** 582

**supply chain security management,** 586

## Discussion Questions

1. What does process integration mean, and why is it difficult to achieve?
2. What makes a supplier or customer a key or primary trading partner? Describe why it is important to begin supply chain management efforts with only these key companies.
3. Describe the linkage between supply chain strategies and internal functional strategies and policies.
4. How do functional silos prevent process integration?
5. What is a process, what are the eight key supply chain business processes, and why are they important when managing supply chains?
6. What is the difference between the customer service management process and the customer relationship management process?
7. Do you think customer service has improved over the years for retailers? Cite some examples.
8. What sort of demand management techniques would an exclusive restaurant use when demand exceeds its capacity? What about McDonald's?
9. Is it necessary to have internal performance measures for each of the supply chain business processes? Why or why not?
10. Which should come first—internal process integration or external process integration? Why?
11. Explain the differences between process integration, coordination, and collaboration.
12. Why is an ERP system important for both internal and external process integration? What other IT considerations are there?
13. Think of some supply chain external performance measures for several of the eight key supply chain business processes, assuming the overall strategy is superior customer service. What if the overall strategy is sustainability?
14. What is an internal supply chain? Do some firms not have any?
15. What are knowledge management solutions, and how can they support a firm's supply chain integration efforts? Give some examples.
16. How do organizations extend process integration to second-tier suppliers and customers?
17. How can RFID tags help to enable external process integration?
18. What is the difference between active and passive RFID tags?

19. Why is lack of trust an obstacle to supply chain management? How can we overcome this obstacle?
20. Why is visibility so important when integrating processes?
21. Define the bullwhip effect and describe how it impacts supply chain integration, or how integration impacts the bullwhip effect.
22. What is cloud-based supply chain management and how might it impact process integration?
23. What is the difference between supply chain management and supply chain process integration?
24. Define the term "collaborative education" and explain what this has to do with supply chain management.
25. Describe an incidence either personally or at work where you have been involved in shortage gaming.
26. What is order batching, and is this something that will reduce the bullwhip effect? Why or why not?
27. Why should reducing the length of the supply chain also reduce the bullwhip effect?
28. What is everyday low pricing, and how does it impact the bullwhip effect?
29. Have you ever experienced rationing and/or shortage gaming? Please describe an instance.
30. What is the difference between supply chain risk management and supply chain security management? Which do you think is most important?
31. What do most small businesses do to reduce supply chain risk? Could they do something more effective?
32. In Chapters 3 and 4, it was explained how some firms were successfully single- or sole-sourcing. Doesn't this increase supply chain risk? Discuss the advantages and disadvantages of single-sourcing.
33. What types of supply chains are most likely to be impacted by risk and security problems? Why?
34. Which is more important—risk management or security management?
35. List some steps firms can take to reduce supply chain risk and increase security.
36. What is C-TPAT, and which companies would benefit most from using it?
37. How did the pandemic impact risk and security?
38. Explain why supply chain process integration is so important to the success of supply chain trading partners.

## Essay/Project Questions

1. Go to the Institute for Supply Management website, www.ism.ws, and find the listing for the latest ISM Annual International Supply Management Conference. Then find the Conference Proceedings, and report on a paper that was presented regarding a topic covered in this chapter.

2. Find a company online that is successfully using internal and/or external process integration and report on its experiences.
3. Find the websites of several supply chain security and risk assessment firms, and report on their specialties and management experience.
4. Search on the term "Customs-Trade Partnership Against Terrorism" or "C-TPAT," and write a paper on the history of C-TPAT and how it is being used today.
5. Search on the term "supply chain security problems," and write a report on several current problems and how they are being addressed.

## Cases

### 1. 3D Printing: Will Additive Manufacturing Solve the Bullwhip Effect?*

Precision Parts (PP) was a traditional machine shop producing OEM parts for the construction equipment industry until 2017 when they began a transition to an additive manufacturer using state of the art 3D printing. Early last year, two of Precision Parts' customers representing 35 percent of their revenue and 47 percent of their profit notified PP that orders for their industrial grade fasteners would be reduced by almost 75 percent. Both manufacturing companies explained a shift in their supplier pool as part of the re-evaluation of parts supplier-partners in their second-tier integration efforts. Fortunately, the industrial fastener sales team had been working with Crane-Tech Manufacturing (C-TM) to include Precision Parts as one of their primary parts suppliers. Crane-Tech Manufacturing uses industrial fasteners for their OEM processes (crane equipment used in the construction industry) and for the aftermarket parts used for repair and replacement. The contract would triple orders and make up about 90 percent of the lost revenue. The contract was contingent on Precision Parts addressing the following requirements: collaborate in cost reduction practices in parts, inventory, and transportation; maintain adequate inventories of OEM parts and aftermarket parts for equipment sold in past 20 years; be responsive to on-demand order batches; and reduce lead times for parts.

In 2016 Precision Parts invested in three HP multi-jet fusion 4200 3D printers averaging $200,000 per printer. Each printer could produce the entire Precision Parts fastener line using digital designs and plastic materials. PP's R&D will field test and approve goods for all required product specifications starting with goods that Crane-Tech Manufacturing purchases. Precision Parts will be locating the three HP 3D printers in strategic decentralized locations in proximity to the three largest C-TM manufacturing facilities.

3D printing is an additive manufacturing process that produces three-dimensional objects from a digital file. A 3D printed item is manufactured by laying down successive layers of materials until the computer generated, designed product is produced. Materials used in 3D printing are much more diverse than metal machining and includes metals (aluminum, gold, silver, steel, etc.), ceramics, porcelain, plastic, acrylics, sandstone, and many other materials. 3D printing uses less material inputs and reduces material waste. 3D printed goods can also use alternative materials and designs (i.e. honeycomb) that reduce weight and raw material costs. 3D printing can redesign parts to consolidate part and sub-assembly components. 3D printing design capability eliminates the need to develop

*Written by Brian Hoyt, PhD, Professor of Management, Ohio University. This case was prepared solely to provide fictional material for class discussion. The author does not intend to illustrate either effective or ineffective handling of a managerial situation.

and produce tooling required in more traditional machining operations. 3D printing's digital design and single piece efficiencies are not negatively cost impacted at low production volumes. Lead times for low volume 3D parts are significantly less than traditional machined parts with the quick cycle time from design to produced part. Make-to-order parts with quick change overs will reduce labor costs and storage and handling as WIP and finished goods inventories become unnecessary. Waste at any time in the process can be recycled when 3D printing uses heat processed, recyclable plastics.

Crane-Tech Manufacturing invited Precision Parts to submit a bid to be approved in their Elite Supplier Program. Precision Parts' bid would focus on the key advantages to C-TM if they contracted with an additive manufacturer. PP would produce make-to-order parts that can be ordered, designed, produced, and shipped within three days and delivered next day if the digital design file is submitted with the order. Precision Parts will commit to a lead-time of one day production plus one day delivery when an order from Crane-Tech Manufacturing is placed with notification dates ten days, three days, and one day before the parts need to be delivered to a C-TM facility. Industry lead-time standards are four weeks for CNC machined parts. Precision Parts' make-to-order capability will enable PP to produce newly designed parts for new equipment models. PP's additive manufacturing can produce parts for discontinued equipment (old models) as needed, rather than storing these in inventory. This feature will reduce the risk of obsolescence and replace the need to maintain adequate inventories for old equipment. Precision Parts' 3D printed parts can be used in prototypes and collaborative R&D with Crane-Tech Manufacturing, replacements for broken or worn machine parts, and as needed for production runs by C-TM's OEM facilities.

## Discussion Questions

1. What are the challenges and benefits for Crane-Tech Manufacturing if they use Precision Parts' 3D printing capability to improve production of equipment and aftermarket parts orders for its customers?
2. How much warehouse space expansion should C-TM add to include the new 3D printed parts used for aftermarket sales?
3. Will the supply chain partnership with Precision Parts improve Crane-Tech Manufacturing's sustainable competitive advantage in the construction equipment and aftermarket parts industries?

## 2. Managing Supply Chain Security*

Warehouse Security Professionals (WSP) provides private security guards for warehouses, construction sites, and commercial properties. WSP has grown from a New England based private security firm with 250 security guards to providing over 10,000 highly trained private security personnel on sites across the United States within just the last five years. Early in this rapid growth period, WSP was forced to address high turnover and costly liability insurance issues. With turnover almost twice the industry average and liability insurance costs increasing yearly, WSP developed a proprietary background check system named Secure Check.

Secure Check uses an extensive screening process that includes application reviews and text analysis, interviews, criminal background checks, general background checks

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including social media searches, and it integrates other streams of data that develop a "Best Performer Profile" using big data analytics. The initial impact of Secure Check for WSP was the improved quality of their new hires including advanced technology skills in monitoring and protection.

WSP's success in reducing turnover, employee theft, and insurance claims using Secure Check developed into a new revenue stream for WSP. They began marketing Secure Check to their existing customer base of warehouses, construction companies, and commercial and industrial complexes. The marketing team for Secure Check has recently been focusing on selling Secure Check to large manufacturers of consumer electronic goods whose extensive supply chains include logistics and transportation, warehousing, wholesalers, third-party logistics firms, and retailers.

One consumer product manufacturer, Global Electronics (G-E), is developing their supply chain integration planning to integrate employee background check procedures across their supply chains as identified in their key process objectives for managing supply chain security. With the help of WSP's Secure Check implementation team, G-E has developed internal performance security measures of turnover, theft, and insurance claim losses. They will use the next six months to assess and improve their internal integration for security measures. Upon completion of G-E's internal application of Secure Check, they will develop external supply chain security performance measures for their first-tier suppliers. As part of the assessment and improvement of supplier partners' security performance, G-E will offer them Secure Check, to meet compliance with the new security performance targets.

Secure Check uses a process for collecting background information and makes use of an interactive algorithm-based model. The predictive modeling uses company specific information and data streams from a variety of sources, recommends the appropriate background check level as well as detailed information to be collected, and reports the best performer profile representing the ideal candidate. The basis for Secure Check is twofold: Secure Check is first a security risk detector for screening in human resources for a supply chain partner. The second purpose for using Secure Check is to facilitate the hiring of the best performing candidates. The system provides direction as to who not to hire as well as which candidate in the remaining pool is the best fit to hire.

Secure Check reduces the risk of a "failed hire" and a "bad hire". A failed hire is an aborted hire (i.e. a final candidate does not accept the position or does not make it through the probationary period) or a hire that leaves before full performance expectations are realized. The associated costs include increased unemployment taxes, supplementary costs for overtime or contingency workers, additional promotion, recruitment, and hiring costs, drug testing and background check fees, and orientation, training, certification, and on-boarding costs. A bad hire is an employee hired who does not meet performance expectations. Associated costs for a bad hire include reduced productivity and quality of work, increased training and overtime costs, and increased supervision costs. More significant costs that a bad hire may cause include lost time accidents (employee and others), customer property loss, and theft or other illegal activities that contribute to increased legal and insurance costs.

Both Warehouse Security Professionals and Global Electronics have calculated the average cost of a failed hire to be approximately 25-30 percent of salary and a bad hire to be almost 130 percent of salary. To mitigate the failed and bad hire risks, Secure Check inputs information about the position including risk factors (employee and customer safety, insurance and liability issues, etc.), skills (technical), and any legislative requirements including job-relatedness of conviction, time since conviction, and evidence of rehabilitation.

## Discussion Questions

1. Identify the levels of security system response Global Electronics is trying to address by collaborating with Warehouse Security Professionals and with the integration of Secure Check. Explain how the use of Secure Check would meet the level objectives.
2. What challenges will Global Electronics incur in integrating the use of Secure Check throughout its supply chain?
3. What advice would you offer to Warehouse Security Professionals to advance their supply chain security portfolio of goods and services?

## 3. Supply Chain Integration of Third-Party Logistics Providers*

Bobcat Logistical Solutions (BLS) is a third-party logistics service provider (3PL) serving the Ohio market (Columbus, Cincinnati, and Cleveland) as a non-contract partner with a broker that serves food and beverage processors and distributors, including direct relationships with large food and beverage shippers. BLS owns a fleet of trucks used to serve the "spot" markets. Spot markets are the final destinations for food and beverage deliveries to grocery stores, institutions with large food service operations (public and private school systems, colleges and universities, prisons, etc.), franchised and independent restaurants, and large entertainment venues. Large shippers use 3PLs in spot markets when they need extra capacity or when major weather events keep large truck capacities off the road. Brokers usually act as intermediaries to utilize their carrier networks (including BLS) so shippers can deliver product to market. The largest food and beverage shipper in the United States has been challenged with three severe winters in a row along with natural disasters (hurricanes, tornadoes, floods) unlike any consecutive 3-year period before. As the economy has grown, carriers who were not building assets during the 2009 global recession now suffer with capacity limitations. During the severe conditions during the recession, the use of 3PLs exploded, doubling the truck movements handled across the United States as compared to non-peak capacity requirements.

Bobcat Logistical Solutions has experienced steady growth since then, averaging 10 percent revenue growth each year. BLS has also taken advantage of the recent increase in spot markets with significant market share gains within its strategic group of 3PLs. The growth funded strategic initiatives for BLS included adding trucks to the fleet, purchasing warehouse space in key locations, integrating innovative electronic logging devices into all vehicles ahead of government mandates, and establishing a stable driver pool by collaborating with a specialized veterans recruiting and placement firm.

The increased ownership in warehouse space has established an effective distribution center model that has differentiated Bobcat Logistical Solutions from other 3PLs and brokers in their capability to handle freight. Using state and local tax incentives, BLS has been a leader in improving sustainability by reducing fuel consumption, electric bills, and greenhouse gas emissions. BLS has been working with a local university on a software project to develop a proprietary warehouse management system (WMS) to improve operations of the 24/7 distribution center using RFID technology, and to improve carbon footprints to meet sustainability targets. The WMS has added value by providing data directing changes in four areas:

1. Operating efficiencies with energy reduction gains—inventory movement analysis displays opportunities to reduce energy costs by cycling conveyer belts off during idle times and managing lighting with sensors that switch off lights in empty rack areas.

*Written by Brian Hoyt, PhD, Professor of Management, Ohio University. This case was prepared solely to provide fictional material for class discussion. The author does not intend to illustrate either effective or ineffective handling of a managerial situation.

2. Partner with energy utilities—data on energy use provides opportunities to work with local utility companies to purchase off-peak rates and make equipment scheduling adjustments.
3. Picking route scheduling—material movement scheduling can produce routes that are more efficient, save energy, and improve labor efficiencies. Efficient routing can reduce forklift usage in both numbers of forklifts needed and utilization of existing equipment, saving fuel costs and reducing emissions. Well-organized picking routes in the warehouse eliminate unnecessary travel when using a WMS picking system rather than order-based picking (pick one order at a time).
4. Reduce packaging costs—Information from the WMS can aid in reducing packaging materials by optimizing the size of the box and amount of packing materials, maximizing cube in trucks, and minimizing damage to goods.

While the increased utilization of 3PLs increased capacity to reach spot markets, the increased cost of adding broker fees and 3PL capacity has negatively influenced budgets for the large food shippers that Bobcat Logistical Solutions serves. The large food shippers across the country are re-setting strategic initiatives as it relates to using brokers and 3PLs. They need to reduce exposure to volatile spot markets, increase service consistency, more accurately forecast capacity, and reduce added or unbudgeted costs of using spot market brokers and 3PLs. Many large food and beverage shippers are setting new broker/3PL network targets with drastic cuts to the total number of brokers and 3PLs used. This initiative seeks to reign in the costs of added margins of brokers and 3PLs, geographic overlaps, and inconsistent service. A second approach for some shippers includes developing a stronger network with asset-based 3PL carriers. This initiative focuses on strategic partnerships with a smaller number of brokers who work with asset-based 3PLs or directly with the 3PLs. These partnerships are generally contract-based so that volume will be optimized and product handling and capacity secured. The most desirable 3PL partners will be in important spot markets and be more technology-based providers.

A third initiative for a few of the larger food and beverage shippers involves connecting with 3PLs who have been active in mergers or acquisitions of 3PLs in strategic geographic regions of the country. Partnering with these 3PLs provides many advantages: expanded scale of warehousing operations, broadened service offerings, expanded geographic coverage, more assets and/or technology, new management talent, new customers, more market share, greater knowledge in a targeted industry, and in some instances, reduced need for broker networks.

A large food and beverage manufacturer has approached BLS as part of their supply chain integration management effort. Midwest Food and Beverage Transportation (MFBT) is extending the process integration beyond their largest food and beverage shippers to second-tier supply chain partners and has targeted several 3PLs.

## Discussion Questions

1. Identify and briefly explain the key items that Bobcat Logistical Solution's proposal should include to secure the 3PL contract with Midwest Food and Beverage Transportation's supply chain integration efforts.
2. What are the advantages for Bobcat Logistical Solutions to be part of this potential relationship?
3. What are the advantages for Midwest Food and Beverage Transportation to partner with Bobcat Logistical Solutions as an integrated second-tier supply chain member?
4. What are the potential risks for both companies?

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# Chapter 14

# Performance Measurement Along Supply Chains


*Supply chain data is often hidden or siloed or both. Capturing that unseen data, and unlocking the insights contained [inside], give supply chain leaders enhanced end-to-end visibility into movement of vital product, and delivers the transparency and resilience required to provide quality patient care.*

**—Don Carroll, vice president, Business Development, VPL Medical**[1]

*With these new challenges, it seems like there is more of a need to get better connected, understand data, digitizing data, collecting data and sharing the same single source.*

**—Justin McCoy, general manager, Manufacturing Project Innovation Center, Toyota Motors North America**[2]

*We are particularly proud that even during the pandemic, we were able to react quickly to emerging challenges and develop the best supply chain solutions for our customers. Setting up new fulfillment operations and transport solutions – sometimes literally overnight – was only possible through our developed data analytics, well trained teams, and a right first time culture. Our progress in digitalizing supply chains has been a major contributor to our successes here.*

**—Oscar de Bok, CEO, DHL Supply Chain[3]**

## Learning Objectives

**After completing this chapter, you should be able to**

**LO 1** Discuss why managers need to assess the performance of their firms as well as their supply chains.

**LO 2** Discuss the merits of financial and nonfinancial performance measures.

**LO 3** List and describe a number of traditional and world-class performance measures.

**LO 4** Describe how the Balanced Scorecard and the SCOR models work.

**LO 5** Describe how to design a supply chain performance measurement system.

## Chapter Outline



## SCM Profile: Banner Health Expands Their Definition of Performance

Tyler Olson/Shutterstock.com

During the pandemic in 2020, Phoenix-based Banner Health used an entire shipping container of disposable isolation gowns each week, or about 1.3 million gowns per month. "We were at risk of running out, and we were determined to keep our customers, the caregivers, safe," said Doug Bowen, vice president of Supply Chain Services at Banner. "So, we migrated from disposable to reusable isolation gowns to reduce dependence on single-use, globally sourced products. The project focused on implementing reusable isolation gowns as a permanent solution to safely protect the caregivers while also being sustainable," he added.

Banner faced a lack of product, long lead times, and poor product quality, so they sourced medical grade fabric and partnered with local fabricators to manufacture Banner's gowns. "The reusable gown project team worked closely with end users to design and manufacture a product that met their specifications," Bowen said. "Then they stayed in close contact with the first pilot site hospital end users and leadership to get more feedback. The early feedback was very positive. The nurses felt better protected. So, we were thinking at that time that if the rollout to the rest of the hospitals was also positive, we could make this a permanent solution. We saw the national news stories about the nurses in New York wearing trash bags and we were determined to avoid that situation. Pivoting from disposable to reusable provided a sustainable and long-term option. The reusable isolation gowns are higher quality, better protection for the caregivers, better for the environment and—in our experience—a better value than disposables."

Bowen also noted the high ROI of the reusable gowns. "The cost of disposable isolation gowns has moved up and down, while the cost per use of the reusable gowns has been steady," he added. "Banner has experienced an average cost savings of 35 percent with the reusable isolation gowns." The program also extended Banner's on-hand inventory to more than a 90-day supply, from the original 10 days. Bowen also noted the need to move away from using cost as a primary performance measure. "If the only measure of success for the supply chain is cost savings, the supply chain will likely continue to chase pennies around the globe," he said. "However, if local sourcing, product access and availability, community benefit, agility and resiliency can be added as measures of success—along with cost savings—then the supply chain can succeed with a more balanced scorecard," said Bowen.

The pandemic motivated the entire organization to expand their thinking beyond cost. "During the pandemic, there was no discussion about saving cost," said Bowen. "The discussion was all about saving lives. To save lives, we worked to find alternate solutions for products that were not available, and we focused on listening to and caring for our caregivers—and excelled at it. This experience opened our eyes to the need for a more balanced scorecard for supply chain."[4]

## Introduction

This chapter discusses the role and importance of performance measurements for both the firm and its supply chains. The old adage "you can't improve what you aren't measuring" is certainly true for firms as well as their supply chains. **Performance measurement** is the process of quantifying the efficiency and effectiveness of various activities. When you can measure something and express it in numbers, you have adequate knowledge to make decisions. For over 15 years now, the global business research firm Gartner has published a ranking of the world's top 25 most successful supply chains. For 2021, the top three are Cisco Systems (number one for the second straight year), Colgate-Palmolive, and Johnson & Johnson. Firms with the best supply chains create hierarchies of precise performance measures at the execution level combined with a distillation of meaning at the strategic level. These organizations realize that strategic goals at the top will only succeed if there is a clear path to performance measures at the transaction level to identify execution problems.[5] While several types of performance measures have been discussed or suggested in earlier chapters of this textbook, firms need to develop an entire system of meaningful performance measures to become and then remain competitive, particularly when managing supply chains is one of the imperatives.

Performance measurement systems vary substantially from company to company. For example, some firms' performance measures concentrate solely on the firm's costs and profits. While these measures are certainly important, managers have come to realize that making decisions while relying on financial performance alone gives no indication of the underlying causes of financial performance. Designing standards and then monitoring the many activities or processes indirectly or directly impacting financial performance can provide much better information for decision-making purposes.

Indeed, during the darkest days of COVID-19 in 2020, many supply chains were helping to save the world and keep society running. In large corporate supply chains, sustainability goals are being set to align with science-based targets. And, most investments are being made to benefit both planet and business. At a strategic level, sustainability factors like carbon emissions are considered among the traditional cost and service trade-offs. Optimizing inbound supply and distribution networks to take vehicles off roads and reduce the use of carbon-intensive air freight are also becoming commonplace. Organizations are integrating green initiatives and people-related programs into a larger strategy, as customers demand higher sustainability and ethical standards from their suppliers. Many supply chain organizations have increased their focus on diversity, equity, and inclusion (DEI), and some have even linked employee bonus compensation to progress against DEI goals. Finally, many CEOs and supply chain managers are addressing social issues like racism in society and healthcare. Overall, the supply chains most able to adapt to shifting business conditions won in the marketplace. This will become a winning trait for the foreseeable future, as market disruptions now feel more like the "normal" business climate.

A survey of boards of directors in 2020 showed that nearly 70 percent of companies accelerated their digital footprint during the year. Supply chain leaders consider themselves "digital first" in the use of technology to enable more seamless customer experiences. A common trait is a shift toward ERP platforms and datasets that can be leveraged for insights and decision making. In transportation, some companies monitor and manage shipments in real-time and intercept late deliveries where necessary to maintain customer commitments.[6] Additionally, supply chain leaders are working closely with their trading partners to seek out and eliminate non-value-creating activities while identifying new customer requirements and turning these into product and service attributes. And, supporting and guiding these activities are good performance measurement systems.

Even for companies like Walmart (which by the way is a long-time member of the annual Top 25 Supply Chains published by Gartner and was ranked number eight on the 2021 list) that rely on low prices to attract customers, cost performance alone is not enough to guarantee success without assuring that products are also available when needed and at acceptable levels of quality. Attaining world-class competitive status requires managers to realize that making process decisions to create or purchase products and services customers want, and then to distribute them in ways that will satisfy customers, requires careful monitoring of cost, quality, customer service, and sustainability performance among all key supply chain trading partners. Achieving adequate performance and then continually improving on those measures are what firms aim toward. Using an adequate system of performance measures allows managers to pursue that vision.

Unfortunately, many firms and their supply chains today are not adequately measuring process performance. According to the 2021 Supply Chain Insights Global Survey from IHS Markit, 63 percent of the respondents said their companies "lacked the necessary data, platforms, and technology needed to make critical cost-saving decisions." Dick's Sporting Goods however, focused on improving data accuracy to provide visibility into the impacts of material shortages, while Wayfair gained a competitive advantage by

using data to shape its mitigation strategy during the pandemic.[7] According to a survey of Canadian manufacturing firms for instance, only about 50 percent of the firms had even moderately well-developed performance measurement systems. And in another survey of business technologists, about 75 percent said their firms mainly relied on their suppliers to furnish them with inbound performance information.[8] In other cases, organizations are busy measuring everything in sight, and in so doing, they measure the wrong things or measure things that only make the firm look good—actions that can sometimes lead to misstatements and restatements, loss of confidence, and even prove dangerous (Enron and Worldcom come to mind here). Managers need to realize the importance of creating a good, true set of performance measures, and this is the objective of the chapter.

When managing supply chains, assessing the performance of several tiers of suppliers and customers further complicates an already formidable performance measurement problem. With supply chains, performance measurement systems become much larger and are complicated by varied relationships, trust, and interactions. Performance at the end-customer level depends on the collective performance among the primary trading companies within a supply chain. Thus, performance measures must be visible and communicated to all participating members of supply chains while managers collaborate to achieve results that allow firms to plan ahead, create value, and realize benefits. Indeed, it is likely that some member costs will be higher than otherwise would be the case to permit supply chains to offer what end customers want. It is only through cooperation and shared planning and benefits that an effective supply chain-wide performance measurement system can be designed and implemented.

This chapter will discuss the basics of performance measurement including cost-based and other traditional measurements, and then move on to discuss the more effective measurement systems typical of world-class organizations. From there, the discussion will move into measuring the performance of supply chains. Finally, the Balanced Scorecard and the SCOR model methods of performance measurement, which are being utilized effectively in supply chain settings, will be presented and discussed.

## Viewing Supply Chains as a Competitive Force

The eventual and ultimate goal of all supply chains is to successfully deliver products and services to end customers. Traditionally, to meet customer service requirements, trading partners might simply load their retail shelves, warehouses, and factories with large quantities of finished goods, while hiring lots of service personnel. Today, though, this strategy would ultimately lead to inventory carrying costs and product prices so high that the firms would no longer be competitive. For companies to be successful, supply chain customers and end-product users must be satisfied. Thus, firms must invest time and effort understanding supply chain partner and end-customer requirements, and then adjust or acquire supply chain competencies to satisfy the needs of these customers. To obtain the resources to accomplish these tasks, top managers must become involved and support the firm's improvement efforts. Ultimately, well-designed performance measurement systems integrated among key trading partners must be implemented to control and enhance the capabilities of these firms and the related supply chains.

### Understanding End Customers

As discussed in Chapter 10, companies segment customers based on their service needs and then design production and distribution capabilities to meet each segment's needs. In other

words, instead of taking a one-size-fits-all approach to product design and delivery, firms and their supply chains need to look at each segment of the markets they serve and determine the needs of those customers. Companies consider customer segment needs such as:

- The variety of products required
- The quantity and delivery frequency needed
- The product quality desired
- The level of sustainability sought, and
- The pricing of products.

Obviously, depending on the range of customers the company and its supply chains serve, there will be multiple customer segments and requirements. Computer maker Dell, for example, a leader in social marketing and support, integrates Twitter data to allow brand managers and support teams to actively track what's being said in tweets. The data can be codified to show microsegments of customers who are, for example, frequent visitors to coffee shops during their work day, commute 90 minutes or more, fly internationally during the week, stay in business hotels, are passionate about football, are eco-savvy, and watch a lot of TV.[9]

## Understanding Supply Chain Partner Requirements

Once firms understand end customers' needs, the next step is determining how their supply chains can best satisfy those needs. Supply chain strategies must consider the potential trade-offs existing among the cost, quality, sustainability, and service requirements mentioned above. For instance, supply chain responsiveness (meeting changes in due dates, lead-times, and quantity requirements while providing high levels of customer service) can come at a cost. To achieve the desired level of responsiveness, companies along the supply chains may also have to become more responsive, potentially requiring investments in additional capacity and faster transportation. Likewise, supply chain quality or reliability may require investments in newer equipment, better technology, and higher-quality materials and components among participants in supply chains.

Conversely, increasing supply chain efficiency (enabling lower prices for goods) creates the need among supply chain partners to make adjustments in their purchasing, production, and delivery capabilities that will lower costs. This may include using slower transportation modes, buying and delivering in larger quantities, and/or reducing the quality of the parts and supplies purchased. Ultimately, firms within supply chains must collaborate and decide what combination of customer needs their supply chains can and should provide, both today and in the long term. For example, MANA Nutrition, a nonprofit producer of ready-to-use therapeutic food (RUTF), produces 425,000 lifesaving meals of RUTF per day, to treat severe acute malnutrition (SAM). According to UNICEF, SAM continues to result in the loss of 3 million young lives a year across the world. To extend its impact in reducing the cost of RUTF treatment across their markets, MANA needed a unified business platform that could automate manufacturing processes, improve supply chain efficiency and increase visibility into financial data. MANA selected NetSuite to accomplish this. "Our mission is simple, we're here to help end malnutrition for children around the world," said Chris Whitfield, CFO, MANA Nutrition. "NetSuite has been great. It continues to give us ever increasing levels of visibility into our operations and enabled us to dramatically and consistently reduce costs by driving efficiencies across our organization. This has helped us demonstrate our impact to benefactors and allowed us to reallocate funds to create more food and save more lives," he added.[10]

## Adjusting Supply Chain Member Capabilities

Supply chain members can audit their capabilities and those of their trading partners to determine if what they do particularly well is consistent with the needs of the end customers and other supply chain members. Some companies may be well positioned to supply the desired levels of cost, quality, and customer service performance, while others may not be as well positioned. Matching or adjusting supply chain member capabilities with end customer requirements can be a very difficult task, particularly if the communication and cooperation levels among companies are not excellent, or if companies are serving multiple supply chains and customer segments requiring different sets of capabilities.

In many cases, a dominant company within the supply chain (e.g., Walmart) can use its buying power to leverage demands for suppliers to conform to its supply chain

### SCM Profile: McDonald's Supply Chain Sustainability and Diversity Efforts

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McDonald's supply chains tie together many local and regional supply chains using strategic frameworks and policies and its Worldwide Supply Chain department. For issues related to sustainability, a global management structure was created in 2007 called the Sustainable Supply Steering Committee (SSSC). The SSSC guides McDonald's toward a more sustainable flow of supplies. McDonald's buyers of beef and potatoes for example, include sustainability initiatives in their purchasing strategies.

McDonald's announced plans in 2015 to stop using eggs from chickens raised in cages in the United States and Canada, over the following 10 years, after facing pressures from animal-rights advocates to make its supply chain more humane. "Our customers are increasingly interested in knowing more about their food and where it comes from," says Mike Andres, president of McDonald's USA. McDonald's said it would "listen, learn and collaborate with stakeholders from farm to the front counter" to move its supply chains toward more sources of sustainable beef. McDonald's created the Global Roundtable for Sustainable Beef with several stakeholders to draft principles and guidelines for sustainable beef.

McDonald's has also committed, along with more than 20 of the company's largest U.S.-based suppliers, to increasing purchases of goods and services from diverse-owned vendors by 10 percent between now and 2025, setting of goal of $3.5 billion—or a quarter—of their annual supply-chain spend. The company said that as of 2021, it has about 385 diverse-owned U.S. businesses that supply goods and services to the company. "We're proud of our leadership position and storied history in supplier diversity, dating back to the 1980s," said Marion Gross, McDonald's chief North America supply-chain officer. "McDonald's partnership with our vast network of suppliers is not only fundamental to delivering on our purpose to feed and foster communities. It's also key to realizing our diversity, equity and inclusion ambition."

In February, the company committed to leadership diversity and equity, with a goal of having 35 percent of its leadership roles, from senior director and above, filled by people from under-represented groups by 2025.[11]

requirements. As customer tastes and competition change over time, Walmart and its supply chain members can reassess and redesign their strategies for meeting end-customer requirements and remaining competitive. Use of the Internet as a marketplace, for instance, has become a significant part of many firms' competitive strategies, allowing them to offer much greater product variety and convenience than ever before.

Matching supply chain capabilities to end-customer requirements brings us back to the importance of performance measures and their ability to relay information regarding the performance of each member within a supply chain, along with the performance of the supply chain vis-à-vis the end customers. Now, more than ever before, successful supply chains are those that can continue to deliver the right combinations of cost, quality, sustainability, and customer service, as customer needs change. Weaknesses in any of these areas can mean loss of competitiveness and profits for all supply chain members. Today, the best supply chain performers are more responsive to customer needs, quicker to anticipate changes in the markets, and much better at controlling costs, resulting in greater supply chain profits. The nearby SCM Profile describes McDonald's efforts to make their supply chains more sustainable and diverse. The next section discusses traditional performance measures.

## Traditional Performance Measures

Most performance measures used by firms today continue to be the traditional cost-based and financial statistics reported to shareholders in the form of annual report, balance sheet, and income statement data. This information is relied upon by potential investors and shareholders to make stock transaction decisions and forms the basis for many managers' performance bonuses. Unfortunately, financial statements and other cost-based information don't necessarily reflect the underlying performance of the productive systems of an organization. As readers might recall with the fraudulent practices at firms like Texas-based energy company Enron, Mississippi-based long-distance phone company WorldCom, and New York-based Bernard Madoff Investment Securities, cost and profit information can be hidden or manipulated to make performance seem far better than reality.

As an example, Enron (falsely) claimed revenues of $111 billion in 2000. That year, *Fortune* magazine named Enron "America's Most Innovative Company." The very next year, high-profile managers left the company, Enron declared bankruptcy, and its fraudulent corporate and accounting practices became public, and by 2004, Enron had become one of the costliest bankruptcy cases in U.S. history. Thousands of employees lost everything, executives ended up in jail, and the Arthur Andersen accounting company, which was associated with Enron during this period, was dissolved.[12]

As illustrated above, decisions that are made solely to make the firm look good don't necessarily mean the firm is performing well or will continue to perform well in the future. Business success depends on a firm's ability to turn internal competencies into products and services that customers want, while providing desired environmental, quality, and customer service levels at a reasonable price. Financial performance measures, while important, cannot adequately capture a firm's ability to excel in various process areas.

### Use of Organization Costs, Revenue, and Profitability Measures

These might at first glance seem to be useful types of performance measures, but several problems are associated with using costs, revenues, and profits to gauge a firm's

performance. Windfall profits that occur when prices rise due to sudden demand increases or supply interruptions, as has been the case at different times in the oil industry, are one example. When sudden oil price increases occur, airlines and other transportation companies suddenly experience much higher costs and reductions in profits, while oil companies see suddenly rising profits. In 2012, for example, Exxon Mobil reported the highest *profits* in the world—$44.9 billion, while Royal Dutch Shell posted the highest sales—$481.7 billion. Exxon Mobil was also number one in profits in 2009 and 2011, while slipping to number two in 2010 and 2013. Moving to 2015, Exxon Mobil was again number two and Chevron was number five. By 2020, Exxon Mobil was the only oil company in the top 25, falling to number 14, since oil demand had fallen during the pandemic.[13] Similarly, many tourist destinations such as Las Vegas saw dramatic declines in visitor volumes during the 2008 to 2010 economic recession and the 2020 pandemic, causing hotels and theme parks to report much lower occupancies and profits during these periods. Beginning in 2008, for instance, Las Vegas saw plunges in visitor volume, gaming revenues, occupancies, and average daily room rates for the first time since the Las Vegas Convention and Visitors Authority began tracking the numbers in 1970. Las Vegas' unemployment rate, just 3.9 percent in February 2020, shot up to 34 percent in April after Governor Steve Sisolak ordered casinos and other Nevada businesses closed to help contain the virus' spread. And Nevada's gaming industry revenue in FY 2020 witnessed a 25.2 percent decrease from FY 2019.[14] Thus, profits, as described here, were not necessarily the result of something the firms did or did not do particularly well; they were caused for the most part by uncontrollable environmental conditions. In other words, changes in cost and profit statistics, in many cases, may not accurately reflect the true capabilities of the firm.

Another problem with the use of costs, revenues, or profits as performance measures is the difficulty in attributing any financial contributions to the various functional units or underlying processes of the organization. Many departments and units are interdependent and share costs, equipment, labor, and revenues, making it extremely difficult to split out costs and revenues equitably. Additionally, using costs alone as a departmental or business unit performance measure can result in actions that actually hurt the organization. For example, rewarding the purchasing department for minimizing its purchasing costs might cause increased new product return rates and warranty repairs due to low-cost but poor-quality part purchases. Minimizing transportation costs might also look great on financial reports but may result in late deliveries and lower customer service levels, causing a loss of customers. Finally, the practice of allocating overhead costs based on a department's percentage of direct labor hours causes managers to waste time trying to reduce direct labor hours to lower overhead cost allocations when, today, direct labor accounts for only a small fraction of total manufacturing costs. In essence, these overhead costs merely get transferred somewhere else in the firm, leaving the organization no better off and perhaps in worse shape due to the loss of valuable labor resources.

## Use of Performance Standards and Variances

Establishing standards for performance comparison purposes can be troublesome and particularly when the standards are unrealistic—damaging to an organization. Establishing output standards like 1000 units/day or productivity standards like 10 units/labor hour creates a goal that can drive employees and managers to do whatever it takes to reach these goals, even if it means producing shoddy work or "cooking the books." When performance expectations are not met, perfectly good products, employees, or departments can be branded as losers. Additionally, once goals are actually reached, there is no further incentive to keep improving.

When standards are not reached, a **performance variance** is created, which is the difference between the standard and actual performance. When organizations hold managers up to performance standards and the performance variances, managers can be pressured to find ways to make up these variances, resulting in decisions that may not be in the long-term best interests of the firm. Decisions like producing to make an output quota regardless of current finished goods inventory levels, or purchasing unneeded supplies just to use up department budgets, are examples of things that can happen when performance standards are applied without considering the true benefits to the organization. When applied at the functional level, standards can reinforce the idea of functional silos. Departments are then assessed on meeting their performance standards instead of optimizing firm or supply chain performance.

## Productivity and Utilization Measures

Overall **total productivity measures** such as:

$$\frac{\text{output}}{\text{costs of (labor + capital + energy + material)}},$$

and **single-factor productivity measures** such as:

$$\frac{\text{output}}{\text{cost of labor}},$$

while potentially useful, have the same problems as the use of costs and profits for performance measures. These measures, while allowing firms to view the impact of one or any number of the firm's inputs (e.g., the cost of labor) on the firm's outputs (e.g., units produced), do not allow the firm to determine the actual performance of any of the resources behind these elements. Decisions made to increase productivity may prove to actually increase a firm's costs and reduce quality or output in the long term, ultimately reducing productivity. For example, a business unit might be tempted to produce at output levels greater than demand to increase productivity, which also increases inventories and inventory carrying costs. Or managers might be inclined to lay off workers and buy the cheapest materials to decrease input costs and thus maximize their productivity without considering the longer-term impact on the firm's quality, customer service, and employee morale. In these ways, productivity measures can prove to be damaging. Example 14.1 provides a look at calculating productivity and the problems that can arise when making decisions based solely on productivity.

Labor and machine utilization can be shown as:

$$\frac{\text{actual units produced}}{\text{standard output level}} \text{ or } \frac{\text{actual hours utilized}}{\text{total hours available}}.$$

These performance measures, when used as performance goals, can encourage the firm, for instance, to reduce labor levels until everyone is overworked, causing queues of work or customers to develop, morale to suffer, and quality and customer service levels to erode. Additionally, when using the measures discussed above, there is a tendency to continue producing and adding to inventory just to keep machines and people busy. Less time is spent doing preventive maintenance, training, and projects that can lead to greater performance and profits in the future. While it is obviously beneficial to meet

### Example 14.1 Productivity Measures at the Ultra Ski Emporium

The Ultra Ski company makes top-of-the-line custom snow skis for high-end ski shops as well as its own small retail shop and employs fifteen people. The owner has been adamant about finding a way to increase productivity because their sales have been flat for the past two seasons. Given the information shown below, they have calculated the annual single-factor and total productivity values as:

Labor productivity = 1000 skis/10,800 hours = 0.093 skis per labor hour
Material productivity = 1000 skis/$18,000 = 0.056 skis per dollar of materials
Lease productivity = 1000 skis/$24,000 = 0.042 skis per lease dollar

| INPUTS AND OUTPUTS | LAST YEAR |
|---|---|
| Skis produced | 1000 |
| Labor hours | 10,800 |
| Materials purchased | $18,000 |
| Lease payments | $24,000 |

They calculate the company's total productivity by multiplying the labor hours by its average wage of $17 per hour and find:

Total productivity = 1000 skis/[10,800($17) + $18,000 + $24,000] = 0.0044 skis per dollar.

So the owner figures they can get some great improvements in productivity by finding some low-cost suppliers, moving to a cheaper location, and laying off six workers (reducing the workforce by 40 percent), making the new single-factor productivities:

Labor productivity = 1000 skis/10,800(.6) hours = 0.154 (a 66 percent increase)
Material productivity = 1000 skis/$12,000 = 0.083 (a 48 percent increase)
Lease productivity = 1000/$18,000 = 0.056 (a 33 percent increase)

and the new total productivity:

Total productivity = 1000 skis/[10,800($17)(.6) + $12,000 + $18,000]
= 0.0071 skis per dollar (a whopping 61 percent increase!)

Consequently, the owner decided to make the changes for the coming year. Unfortunately, they went out of business in six months due to poor-quality materials, a bad location, and overworked, low-morale employees.

demand and keep labor costs at optimal levels, maximizing utilization can prove to be expensive for firms.

Thus, the emphasis on overall performance in terms of generalized criteria such as the firm's financial, productivity, or utilization characteristics does not tell the entire story. While it certainly is important for firms to possess financial strength and high levels of productivity and factory utilization, these measures do not reveal in detail the firm's underlying process performance. Using general and internally focused measures like these, do not give many clues as to specific problems that may exist or how to go about solving those problems. Managers are left to guess which types of actions are needed and have no way of knowing if any corrections made actually had the intended effect. What is needed is a set of detailed performance measures throughout the organization and extending to supply chain partners that are consistent with firm and supply chain strategies, allow managers to find root causes of performance failures, and, finally, lead managers to reasonable problem solutions.

Traditional performance measures also tend to be short-term oriented. To maximize profits in the upcoming quarter, for instance, firms may focus considerable efforts on delaying capital investments, selling assets, denying new project proposals, outsourcing work, and leasing instead of purchasing equipment. These actions, while reducing short-term costs, can also significantly reduce a firm's ability to develop new products and remain competitive. New product research, new technology purchases, new facilities, and newly trained people all enhance the capabilities of the firm and position it to keep up

with ever-changing customer requirements, but these things all initially worsen the performance measures discussed above. Without this infusion of ideas and capital expenditures though, firms will ultimately perform poorly.

On the other hand, world-class organizations understand that long-term competitive advantage is created when strategies are geared toward continually meeting and exceeding customer expectations of goods and service cost, quality, deliverability, flexibility, and sustainability. These firms know that investments to improve capabilities in these areas will eventually bear fruit and position them to be successful in the long term. Effective performance measurement systems link current operating characteristics to these long-term strategies and objectives. Peoria, Arizona, for example, a city with a population of about 170,000 sitting just northwest of Phoenix, has been using performance measures for years and has won numerous awards for its efforts. Their most effective programs have used performance measures along with program descriptions and goals to tell a story. Many of the city's programs also incorporate satisfaction surveys to measure the extent to which outcomes are valued by customers. They benchmark performance with some 150 other cities in the Phoenix, Arizona area, and across the United States.[15]

## World-Class Performance Measurement Systems

Businesses respond to increased competitive and marketplace pressures by developing and maintaining a distinctive competitive advantage, which the creates the need to develop effective performance measurement systems linking firm strategies and operating decisions to customer requirements. Performance criteria that guide a firm's decision making to achieve strategic objectives must be easy to implement, understand, and measure; they must be flexible and consistent with the firm's objectives; and they must be implemented in areas that are viewed as critical to the creation of value for customers.

An effective performance measurement system should consist of the traditional financial information for external reporting purposes along with tactical-level performance criteria used to assess the firm's competitive capabilities while directing its efforts to attain other desired capabilities. In short, good performance helps firms attain their goals. A good performance measurement system should include measures that *assess what is important to customers*. In a survey of manufacturing and service company executives for example, researchers found that in firms with successful lean and Six Sigma programs, there was use of a wider variety of both financial and nonfinancial performance measures.[16]

### Developing World-Class Performance Measures

Creating an effective performance measurement system involves the following steps:[17]

- Identify the firm's strategic objectives.
- Develop an understanding of each functional area's set of requirements for achieving the strategic objectives.
- Design and document performance measures for each functional area that adequately track each required capability.
- Assure the compatibility and strategic focus of the performance measures to be used.
- Implement the new performance monitoring system.

- Identify internal and external trends likely to affect firm and functional area performance over time.
- Periodically reevaluate the firm's performance measurement system as these trends and other environmental changes occur.

In this way, world-class firms establish strategically oriented performance criteria among each of their functional areas, using the categories of quality, cost, customer service, and perhaps sustainability, and then revisit these measures as problems are solved, competition and customer requirements change, and as supply chain and firm strategies change.

For instance, the San Diego Zoo in California, a world-class leader in conservation, audits among other things, its own waste recycling performance. The Zoo initially became interested in waste recycling and other conservation efforts in response to customer and employee suggestions. Today it recovers over 90 percent of all waste generated within the facility, an improvement of 10 percent since 2013. The Zoo composts 2.6 tons of food scraps annually. Zoo patrons' eating utensils, plates, bowls and cups are also compostable. Even to-go boxes are made from recycled plastic containers. Additionally, it found that most of the unrecycled waste was compostable. As a result, new programs including the Zoo's sister location, Safari Park, have been developed that include composting to further improve its waste recovery performance. Most recently, the San Diego Zoo expanded its sustainability through adoption of a battery storage facility located on San Diego Zoo's property in Balboa Park. "This new battery storage system reduces the San Diego Zoo's need for fossil fuel, supports clean energy, and lowers our energy costs," said Adam Ringler, director of performance improvement for San Diego Zoo. "This is a great opportunity to not only support the City of San Diego's sustainability goals but it allows us to direct more resources toward our mission of saving species."[18]

Table 14.1 lists a number of world-class performance measures that might be used in different functional areas of the firm to satisfy strategic objectives, enhance the value of the firm's products and services, and increase customer satisfaction. As firms become more proactive in managing their supply chains, performance measures must be incorporated into this effort. The next section discusses performance measurement in a supply chain setting.

**Table 14.1 World-Class Performance Measures**

| CAPABILITY AREAS | PERFORMANCE MEASURES |
|---|---|
| Quality | 1. Number of defects per unit produced and per unit purchased<br>2. Number of product returns per units sold<br>3. Number of warranty claims per units sold<br>4. Number of suppliers used<br>5. Lead time from defect detection to correction<br>6. Number of workcenters using statistical process control<br>7. Number of suppliers that are quality certified<br>8. Number of quality awards applied for; number of awards won |
| Cost | 1. Scrap or spoilage losses per workcenter<br>2. Average inventory turnover<br>3. Average setup time<br>4. Employee turnover<br>5. Average safety stock levels<br>6. Number of rush orders required for meeting delivery dates<br>7. Downtime due to machine breakdowns |

**Table 14.1** (continued)

| CAPABILITY AREAS | PERFORMANCE MEASURES |
|---|---|
| Customer service | *Flexibility*<br>1. Average number of labor skills<br>2. Average production lot size<br>3. Number of customized services available<br>4. Number of days to process special or rush orders<br>*Dependability*<br>1. Average service response time or product lead time<br>2. Percentage of delivery promises kept<br>3. Average number of days late per shipment<br>4. Number of stockouts per product<br>5. Number of days to process a warranty claim<br>6. Average number of hours spent with customers by engineers<br>*Innovation*<br>1. Annual investment in R&D<br>2. Percentage of automated processes<br>3. Number of new product or service introductions<br>4. Number of process steps required per product |

## Supply Chain Performance Measurement Systems

Performance measurement systems for supply chains must effectively link supply chain trading partners to achieve breakthrough performance in satisfying end users. At the local or interfirm level, performance measures similar to the ones presented in Table 14.1 are required for high-level performance. In a collaborative supply chain setting, these measures must overlay the entire supply chain to ensure that firms are all contributing to the supply chain strategy and the satisfaction of end customers. In successful supply chains, members jointly agree on appropriate supply chain performance measures. The focus of the system should be on value creation for end customers, since customer satisfaction drives sales for all of the supply chain's members.

While challenging to implement, the best managed supply chains are indeed pulling it off. In a major study by the Massachusetts-based Performance Measurement Group that looked at firms and their supply chains from 1995 to 2000, the top supply chain performers were found to be leading the way in terms of responsiveness and reliability performance, and total supply chain costs. In a 2008 survey of 287 companies and their supply chains conducted by Connecticut-based AMR Research, the most successful supply chains were found to be more centralized, integrated, global, and focused on measuring performance. And finally, in a ranking of the "Top 25" supply chains compiled each year since 2004 by business research firm Gartner, some of the characteristics of these supply chains are a proactive use of big data, highly optimized inventory management, flexibility and speed with order fulfillment, customization with process implementation, energy sustainability, and compliance. Sustainable supply chain companies are the ones that will succeed far into the future, since these practices reduce costs and improve efficiency, in addition to preserving natural resources.[19]

## Supply Chain Environmental Performance

**Environmental sustainability** has been a recurring theme throughout this textbook, and as consumers, governments, and business leaders begin to address the need for protecting the environment and reducing greenhouse gas emissions, the demand for products

## SCM Profile — Hirschbach's Energy Efficient Trucks


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Iowa-based Hirschbach Motor Lines is a SmartWay Excellence Award winner for supply chain environmental performance and energy efficiency. Hirschbach was cited for its efforts to increase miles per gallon by 3.8 percent and reduce carbon dioxide output per mile by 3.7 percent. In its fleet of over 980 trucks and 1,600 trailers, the company has deployed the latest fuel-saving technologies, and it has adopted green policies and practices.

Hirschbach is purchasing aerodynamic tractors from Navistar and Freightliner, and it is using low rolling resistance wide-base tires along with wheel covers and fenders. The carrier has also enabled idle timers and installed equipment to reduce fuel consumption and emissions. In addition, trailers in the Hirschbach fleet are fitted with wide-base tires and an aerodynamics package. "We pay a lot of attention to trailers as there is so much to gain from reducing drag on the largest component of our equipment," said John Vesey, operations support manager at Hirschbach. "We're continually looking over data to find the best solution for fuel economy on our trailers."

Hirschbach drivers are also rewarded for helping improve the fleet's fuel economy. "Our drivers are encouraged to comply with route, fuel, and idle policies, and they are eligible for bonuses," Vesey explained. "We also empower drivers by offering coaching and fuel economy data so they can become more efficient."

To manage its fuel network, Hirschbach utilizes a fuel optimization system to determine how to buy fuel efficiently along specific routes. For instance, Vesey noted, the software helps in identifying how bypassing mpg-reducing mountain ranges and large cities, as well as staying on interstates, can provide measurable savings.[20]

and services will change, along with regulations impacting how supply chains operate. As a result, supply chain performance must begin to include assessments of environmental performance. The nearby SCM Profile for example, describes Hirschbach Motor Lines' environmental and energy performance.

Particularly during and following the COVID-19 crisis, sustainability has been shuffled down the priority list, making it even more important today to reemphasize sustainability. Zoë Beck, Sustainability Manager at HealthTrust, acknowledges the challenges the pandemic has wrought but assures that the commitment to sustainability remains steadfast. "While the healthcare industry has dealt with huge issues in terms of supply availability, facilities have been able to be innovative in the ways they conserve, obtain and stock supplies," she said. "These lessons can be useful for the future as hospitals look at ways to ensure they have a robust supply chain. They have learned ways in which they can use fewer products, reprocess products that have not traditionally been reprocessed, monitor use of products, and possibly move purchasing to more local manufacturers. While sustainability has most definitely not been the focus, the lessons learned from COVID can help health systems to be more sustainable and resilient in the future," she concluded.[21]

**Green supply chain management** (GSCM) is the objective of an effective supply chain environmental performance system. The concept of green supply chain management is to integrate environmental thinking into supply chain management. GSCM influences the total environmental impact of an organization and its supply chains, and also enhances sustainability performance. The reach of GSCM extends across the organization and its trading partners, and includes the processes involved in purchasing, manufacturing and materials management, distribution, and reverse logistics. GSCM promotes the sharing of environmental responsibility along the supply chain in each of these areas such that environmentally sound practices predominate, and adverse impacts to global environments are minimized.[22]

A good example of applying green supply chain management is the company Maersk, the world's largest container shipping company. Globally, Maersk uses about 20,000 suppliers. Maersk deems 1,500 of these suppliers as having a high environmental risk. Thus, Maersk engages with those suppliers using a combination of audits, self-assessments, and documentation reviews to ensure responsible procurement. By 2012, Maersk had reached its 2020 goal of reducing carbon dioxide emissions by 25 percent per container from 2007 levels.[23] Perhaps the world's largest GSCM initiative is being implemented by Walmart—its goals are to be supplied 100 percent by renewable energy, to produce zero waste, and to sell products that sustain health and the environment. By the end of 2013, Walmart had eliminated 7.6 million metric tons (MMT) of greenhouse gas emissions. It also implemented other projects that eliminated 18 MMT of greenhouse gas emissions by the end of 2015. In 2011, Walmart began to integrate a supplier Sustainability Index into its business by scoring vendor product offerings in terms of sustainability. It has developed scorecards to help its purchasing agents evaluate products in this way.[24]

The design of an effective green supply chain performance system should be discussed by all key supply chain members and be compatible with existing performance monitoring systems. As discussed in earlier chapters, the ISO 14000 environmental management standards, typically associated with one organization's environmental compliance, can be a good starting point for building a green supply chain strategy among trading partners. Today, organizations all realize that green supply chains are not only becoming a requirement but are also providing cost savings, additional profits, and cheaper prices to supply chain members and end-product customers. For these reasons, use of environmental sustainability assessments is a common practice.

## Triple Bottom Line Performance

The **triple bottom line (TBL)** combines several important performance measures. It is a framework incorporating social, environmental and financial dimensions. This differs from traditional performance frameworks since it includes environmental and social measures that can be difficult to assign numerical measurements. The TBL dimensions are also called the *three Ps*, for people, planet and profits. The phrase, "people, planet, and profit" to describe the triple bottom line were terms coined by John Elkington, a noted world authority on corporate responsibility and sustainable capitalism, in a paper he published in 1994.

There is no universally accepted method for calculating the TBL. There is also no agreement on the measures that are included in each of the three TBL categories. This can be viewed as a strength because it allows users to vary the measures used based on the needs of supply chain entities, the specific project, or geographic location. The set of measures used will ultimately be determined by stakeholders and the ability to collect the data required. Economic variables should use data that deal with the bottom line, such as costs or profits; environmental measurements should incorporate natural resources and things influencing

its viability, such as air and water quality or energy consumption; and social variables refer to social dimensions of the area under consideration, including measurements of education, equity, and access to social resources. Michigan-based Cascade Engineering, for example, uses the following variables (among others) for their TBL scorecard—Economic (taxes paid), Social (average hours of training/employee, charitable contributions), Environment (greenhouse gas emissions, recycled material, water consumption).[25]

Today, software is available that enables companies to analyze the **carbon footprints** of their supply chains and then evaluate design configurations and various options for reducing total carbon emissions. In many cases, this will also mean lower costs. A number of software suppliers are extending their existing software applications to measure and optimize areas such as transportation and inventory management, with explicit considerations for greening the supply chain. Several examples include carbonfootprint.com, sphera.com, and carbontrust.com.

To achieve the type of performance alluded to in this chapter, specific measures must be adopted by supply chain trading partners such that performance can be further aligned with supply chain objectives. A number of these are listed below.[26]

1. *Total Supply Chain Management Costs*: the costs to process orders, purchase materials, purchase energy, comply with environmental regulations, manage inventories and returns, and manage supply chain finance, planning, and information systems. Leading supply companies are spending from 4 to 5 percent of sales on supply chain management costs, while the average company spends about 5 to 6 percent.
2. *Supply Chain Cash-to-Cash Cycle Time*: the average number of days between paying for raw materials and getting paid for product, for the supply chain trading partners (calculated by inventory days of supply plus days of sales outstanding minus average payment period for material). This measure shows the impact of lower inventories on the speed of cash moving through firms and the supply chain. Top supply chain companies have a cash-to-cash cycle time of about thirty days, which is far less than the average company. These trading partners no longer view "slow paying" as a viable strategy.
3. *Supply Chain Production Flexibility*: the average time required for supply chain members to provide an unplanned, sustainable 20 percent increase in production. The ability for the supply chain to quickly react to unexpected demand spikes while still operating within financial targets provides tremendous competitive advantage. One common supply chain practice is to maintain stocks of component parts locally for supply chain customers to quickly respond to unexpected demand increases. Average production flexibility for best-in-class supply chains is from one to two weeks.
4. *Supply Chain Delivery Performance*: the average percentage of orders for the supply chain members that are filled on or before the requested delivery date. In the top-performing supply chains, delivery dates are being met from 94 to 100 percent of the time. For average firms, delivery performance is approximately 70 to 80 percent. Updating customers on the expected delivery dates of orders is becoming a common e-service for many supply chains.
5. *Supply Chain Perfect Order Fulfillment Performance*: the average percentage of orders among supply chain members that arrive on time, complete, and damage-free. This is quickly becoming the standard for delivery performance and represents a significant source of competitive advantage for top-performing supply chains and their member companies.
6. *Supply Chain e-Business Performance*: the average percentage of electronic orders received for all supply chain members. In 1998, only about 2 percent of all firms' purchase orders were made over the Internet. By 2018, top-performing

organizations made 98 percent of their purchase orders electronically. Today, supply chain companies are investing heavily in e-based order-receipt systems, marketing strategies, and other forms of communication and research using the Internet.

7. *Supply Chain Environmental Performance*: the percentage of supply chain trading partners that have become ISO 14000 certified; the percentage of supply chain trading partners that have created a director of environmental sustainability; the average percentage of environmental goals met; the average number of policies adopted to reduce greenhouse gas emissions; and the average percentage of carbon footprints that have been offset by sound environmental practices. While these performance indicators may certainly vary by supply chain and industry, the measures here will provide a good starting point for collaboration on supply chain environmental performance.

When combined with the world-class performance measures of Table 14.1, the measures shown above can help trading partners align themselves with supply chain strategies, creating competencies that lead to dominant positions in their markets. Most executives understand that supply chain excellence enables enhanced revenue generation, generates new cash flow, and controls the vast majority of operating cost. In fact, according to a financial analysis of the leading supply chain management companies and their closest competitors for the period 2004–2007, the analysis conclusively showed that the leading supply chain companies did, in fact, outperform their peers in most financial measures—even when accounting for other factors such as size and financial leverage. The leading supply chain companies also showed greater stock returns and economic value added, over the 2004–2007 timeframe.[27]

## The Balanced Scorecard

The **balanced scorecard** (BSC) approach to performance measurement was developed in 1992 by Drs. Robert Kaplan, David Norton, and representatives from a number of companies, as a way to align an organization's performance measures with its strategic plans and goals. The BSC thus allowed a firm to move away from reliance on merely financial measures, which effectively improved managerial decision making.[28]

Also referred to as simply **scorecarding**, the BSC has become a widely used model with more than half of the major companies in the United States, Europe, and Asia using the BSC. Its use is also growing in the Middle East and Africa. A recent global study by Bain & Co. listed the BSC fifth on the top 10 most widely used management tools around the world. BSC has also been selected by the editors of Harvard Business Review as one of the most influential business ideas of the past 75 years. BSCs were originally developed for for-profit companies, but have now been adapted for use by nonprofits. Many companies have reported notable successes with the use of the BSC including Mobil Oil, Tenneco, Brown & Root, AT&T, Intel, Allstate, Ernst & Young, and KPMG Peat Marwick.

The Balanced Scorecard Institute offers certification programs designed to provide the tools needed to help organizations increase their focus on strategy and results, improve performance, align work with strategy, and improve communication of the organization's vision and strategy. The certification is offered in association with the George Washington University Center for Excellence in Public Leadership.[29] Jennifer Reissman, chief marketing officer at Florida-based Seacoast Banking Corp., learned the balanced scorecard approach and the clarity and focus it brings while working at GE Capital, before joining Seacoast. "Banks have so many financial ratios and financial metrics that we hold ourselves accountable to," Reissman said. "It was more like, 'What are the most important ones?' And then how do we make sure that we're communicating those metrics in a way that every associate will understand?" The BSC program has been so successful in aligning employees with defined goals, that it remains a regular part of monthly strategy updates to this day.[30]

There are some indications, though, that BSC use can be problematic, expensive, and even unsuccessful. Research from the U.S.-based benchmarking company Hackett Group indicated that while 82 percent of its company database reportedly used scorecards, only 27 percent of the systems were considered "mature." They concluded that most companies were having difficulty taking BSC from concept to reality. John McMahan, senior advisor at Hackett Group, said, "Most companies get very little out of scorecards because they haven't followed the basic rules that make them effective." For example, in the United States, the average number of measures used is a very high 132, while Kaplan and Norton suggest use of 20 to 30 measures.[31] Additionally, consultants are used in many cases to help map the organization's strategy and its effect on performance, and to assist in selecting performance measures. Further, information systems may have to be modified, sometimes at great expense, to supply the information necessary for the scorecards. Other weaknesses in the BSC include its inability to show what one's competitors are doing; exclusion of employee, supplier, and alliance partner contributions; and its reliance on top-down measures.[32]

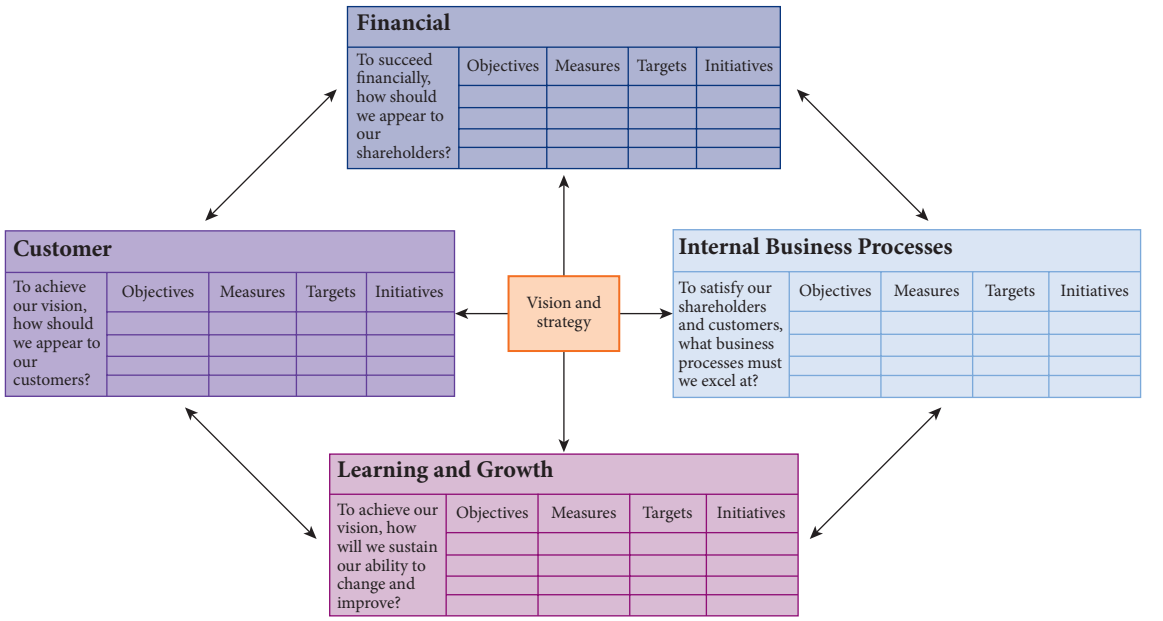
Nevertheless, the BSC is widely used in helping organizations track performance and identify areas of weakness. Performance scorecards are designed to provide managers with a formal framework for achieving a balance between nonfinancial and financial results across both short-term and long-term planning horizons. The BSC framework consists of four perspectives as shown in Figure 14.1:

- *Financial Perspective*—measures that address revenue and profitability growth, product mix, cost reduction, productivity, asset utilization, and investment strategies. Traditional financial measures are typically used.
- *Internal Business Process Perspective*—focuses on performance of the most critical internal business processes of the organization including quality, new product development, flexibility, innovative elements of processes, and time-based measures.
- *Customer Perspective*—measures that focus on customer requirements and satisfaction including customer satisfaction ratings, reliability and responsiveness, customer retention, new customer acquisition, customer-valued attributes, and customer profitability.
- *Learning and Growth Perspective*—measures concentrating on the organization's people, systems, and external environment and including retaining and training employees, enhancing information technology and systems, employee safety, and health and environmental sustainability issues.

These perspectives are all linked together using performance measures within each of the four areas. Measurements are developed for each goal in the organization's strategic plan and include both outcome measures and the performance drivers of those outcomes. In doing this, senior managers can channel the specific set of capabilities within the organization toward achieving the firm's goals. A properly constructed scorecard should support the firm's strategy and consists of a linked series of measures that are consistent and reinforcing. By developing suitable performance measures in each of the perspectives, firms can detect problem areas before they become significant, trace the problem to its root causes, and make improvements to alleviate the problem.

The process of developing a BSC begins with defining the firm's strategy. Once that strategy is understood and agreed upon by senior managers, the next step is to translate the strategy's goals into a system of relevant performance measures. Each of the four perspectives in the BSC require four to seven performance measures, resulting in a scorecard with about two dozen measures relating to one single strategy. As alluded to above, the potential for failure does exist if firms are not clear about what they are hoping to achieve and are not focused on ensuring that the best scorecards with the right performance measures linked to firm strategies are used.

**Figure 14.1** The Balanced Scorecard Framework




*Note*: Figure based on Kaplan, R. and D. Norton, "Linking the Balanced Scorecard to Strategy," *California Management Review* 39(1), 1996: 53–79.

The BSC can be also be utilized by firms in a collaborative supply chain setting by expanding the internal perspective of the scorecard to include interfunctional and partnership perspectives that characterize the supply chain. In this way, for instance, the firm's employees are motivated to view their firm's performance vis-à-vis the success of the entire supply chain. Supply chain–oriented performance measures, such as the ones described earlier, can thus be added to the more internally focused measures traditionally used in a balanced scorecard to help the firm as well as its supply chains meet their objectives.

Balanced scorecards are being used in the government and healthcare sectors, too, with many positive outcomes. One example is the U.S. Economic Development administration (EDA). The EDA used the BSC to help develop its world-class performance measurement system. After adoption of the BSC approach, it aligned the organization around a common set of goals, improved the quality of its investments, enhanced efficiencies, and created higher-quality jobs.[33]

## Web-Based Scorecards

Today, a number of software applications are available to help design scorecards, which link via the web to a firm's enterprise software system. Web-based balanced scorecard applications are also sometimes referred to as **performance dashboards**. They enable users to retrieve data easily from enterprise databases and also enable wide access by users at many locations, while providing desired security features. Performance dashboards are being used to track "big picture" corporate objectives as well as core process performance and more tactical, detailed data. Use of these web-based dashboards allows managers to see real-time progress toward organizational milestones and helps to ensure that decisions remain in sync with the firm's overall strategies.

Virtually all accounting applications, for example, provide BSC capabilities, including applications offered by Microsoft, SAP, IBM, and Oracle. Performance dashboard applications are becoming commonplace these days. For example, the U.S. Department of Veterans Affairs uses performance dashboards to give its IT employees a visual representation of its effectiveness in solving problems for customers. Some of the top supply chain companies use dashboards to compare team performances and find that this motivates teams to perform better. American energy company ConocoPhillips uses performance dashboards at a number of its oil and gas wells to let well operators know when plunger-lift operating cycles must be adjusted to eliminate fluid buildups that restrict the flow of gas. Using these dashboards has allowed production to increase by about 30 percent. The U.S. Environmental Protection Agency (EPA) uses state dashboards and comparative maps that provide the public with information about the performance of state and EPA enforcement and compliance programs across the country. "Transparency and access to information at all levels helps to drive improvements in environmental performance," says Cynthia Giles, assistant administrator for the EPA's Office of Enforcement and Compliance Assurance.[34]

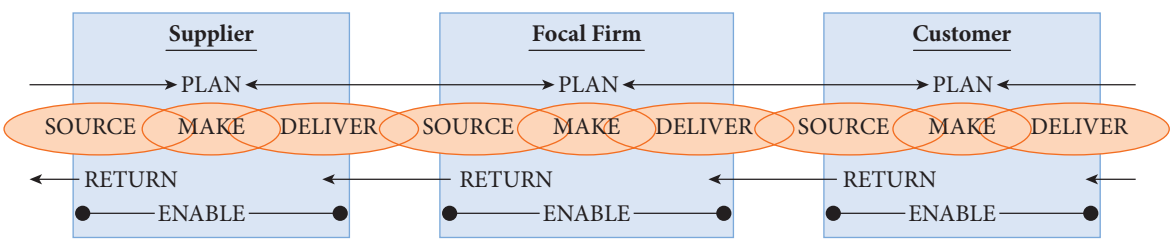
## The SCOR Model

One of the more recognized methods for integrating supply chains and measuring performance is use of the Supply Chain Operations Reference (SCOR) model developed in 1996 by supply chain consulting firms Pittiglio, Rabin, Todd & McGrath and AMR Research. These firms also founded the Texas-based Supply Chain Council (SCC) to oversee the SCOR model, a nonprofit global organization with a current membership of over 1000 profit and nonprofit organizations on six continents. In 2014, APICS, the global supply chain management association, merged with the SCC and formed APICS SCC. APICS officially changed its name to the Association for Supply Chain Management (ASCM) in 2018. Today, ASCM manages the SCOR model, while providing education opportunities for its members.[35]

The SCOR model helps to integrate the operations of supply chain members by linking the delivery operations of a seller to the sourcing operations of a buyer. Starting in 2013, members could obtain a professional certification in knowledge and methods of the SCOR model, termed a SCOR-P endorsement. Also new in 2013, was the SCOR model's new process category, ENABLE, as shown in the model in Figure 14.2.[36]

The SCOR model is used as a supply chain management diagnostic, benchmarking, and process improvement tool by manufacturing and service firms in a variety of industries around the globe. Some of the notable firms to have success using the SCOR model include Intel, IBM, 3M, Cisco, Siemens, and Bayer. Striving for the best telecommunications supply chain, Alcatel (now Alcatel-Lucent Enterprise), for example, used SCOR metrics following the economic downturn of 2001 to measure and benchmark its performance. Major

**Figure 14.2** The SCOR Model Processes and Linkages



improvements were realized in delivery performance, sourcing cycle time, supply chain management cost, and inventory days of supply.[37] Cisco set out to revamp its supply chain in 2005 using the SCOR model as a way to monitor its growing global footprint. It eventually appointed a vice president responsible for the SCOR model's functions.[38] In 2010, German semiconductor manufacturer Infineon used the SCOR model to build an agile and adaptable supply chain. Hundreds of employees, customers, suppliers, and production partners were involved in the 18-month project. Results included improved flexibility and reduction of total finished goods inventory levels, leading to improved shareholder confidence and stock price. Finally, in 2017, APICS (now ASCM), partnered with JD.com, a Chinese e-commerce company, to cross-reference the SCOR model with the JD.com database to develop a SCORmark benchmark for Chinese businesses.

The SCOR model separates supply chain operations into six process categories: plan, source, make, deliver, return, and enable, as described below, and as shown in Figure 14.2:[39]

- *PLAN*—Demand and supply planning including balancing resources with requirements; establishing/communicating plans for the supply chain; management of business rules, supply chain performance, data collection, inventory, capital assets, transportation, and regulatory requirements.
- *SOURCE*—Sourcing stocked, make-to-order, and engineer-to-order products including scheduling deliveries, receiving, verifying, and transferring product, authorizing supplier payments, identifying and selecting suppliers, assessing supplier performance, managing incoming inventory and supplier agreements.
- *MAKE*—Make-to-stock, make-to-order, and engineer-to-order production execution including scheduling production activities, producing, testing, packaging, staging, and releasing product for delivery, finalizing engineering for engineer-to-order products, managing work-in-process, equipment, facilities, and the production network.
- *DELIVER*—Order, warehouse, transportation, and installation management for stocked, make-to-order, and engineer-to-order product including all order management steps from order inquiries and quotes to routing shipments and selecting carriers, warehouse management from receiving and picking to loading and shipping product, invoicing customer, managing finished product inventories, and import/export requirements.
- *RETURN*—Returns of purchased materials to suppliers and receipt of finished goods returns from customers including authorizing and scheduling returns, receiving, verifying, and disposition of defective or excess products, return replacement or credit, and managing return inventories.
- *ENABLE*—The processes associated with establishing, maintaining, and monitoring information, relationships, resources, assets, business rules, compliance, and contracts required to operate supply chains. Enable processes support the design and management of the planning and execution processes of supply chains.

The SCOR model also uses five categories of performance attributes as shown in Table 14.2.[40] Implementing the SCOR model is no simple task. It requires a significant investment of time and open communications within the firm and among supply chain partners. In 2017, the 12th and latest version of SCOR was released. It includes updates to maturity models, best practices, and terminology. Version 12 includes more "emerging drivers of supply chain success," covering topics such as omnichannel, metadata, and blockchain. The framework was modernized so that best practices better align with digital strategies, including new training information and integrated sustainability standards using the

**Table 14.2 SCOR Performance Categories and Attributes**

| PERFORMANCE CATEGORY | PERFORMANCE ATTRIBUTE |
|---|---|
| Reliability | 1. On-time delivery performance<br>2. Order fill rates<br>3. Order accuracy rates |
| Responsiveness | 1. Order lead times or speed |
| Agility | 1. Response times for unforeseen events<br>2. Production flexibility |
| Cost | 1. Supply chain management and logistics costs<br>2. Cost of goods sold<br>3. Warranty and returns processing costs |
| Asset Management Efficiency | 1. Cash-to-cash cycle time<br>2. Inventory days of supply<br>3. Asset turns |

Global Reporting Initiative (GRI). The Digital Capabilities Model (DCM) and the SCOR digital standard (SCOR DS) were also released in 2019 to address the growing need for digitization in the SCOR model.[41]

The SCOR model is designed to enable effective communication, performance measurement, and integration of processes between supply chain members. A standardized reference model helps management focus on management issues, serving internal and external customers, and instigating improvements along the supply chain. Using the SCOR software, virtually any supply chain can be configured, evaluated, and benchmarked against best practices, leading to continuous improvements and sustainable competitive advantage for the supply chain's participating members.

SCORmark, facilitated by ASCM's alliance partner PricewaterhouseCoopers (PwC), combines the SCOR performance attributes with PwC's population data from more than 1,500 organizations and 2,500 supply chains to help firms identify gaps and make improvements. Members have access to this benchmarking based on the SCOR model metrics. Companies generally use SCOR-based benchmarking to:

- set reasonable performance goals based on the SCOR model
- calculate performance gaps against a global database
- develop company-specific roadmaps for supply chain competitive success

This has greatly reduced the time normally taken by firms to perform a benchmarking study—from months to weeks and, in some cases, days. The SCORmark portal removes cost barriers for members to obtain accurate and timely benchmark reports.

## Summary

Measuring the performance of companies and their supply chains is critical for identifying underlying problems and keeping end customers satisfied in today's highly competitive, rapidly changing marketplaces. Unfortunately, many firms have adopted performance measurement systems that measure the wrong things and are thus finding it difficult to achieve strategic goals and align their goals with those of the other supply chain members and supply chains as a whole. Good performance measures allow firms to improve their processes, making their supply chains better as well.

Financial performance, while important to the firm and its shareholders, is argued to provide too little information regarding the firm's underlying ability to provide products and services that satisfy customers. Thus, measures that say something about the firm's quality, productivity, flexibility, and customer service capabilities have begun to be used successfully in many organizations. World-class organizations realize how important it is to align strategies with the performance of their people and processes, and performance measurement systems give these firms a means for directing efforts and firm capabilities toward what the firm is trying to do over the long haul—meet strategic objectives and satisfy customers.

As was discussed throughout the chapter, performance measurement systems should be a mix of financial, nonfinancial, quantitative, qualitative, process-oriented, environmentally oriented, and customer-oriented measures that effectively link the actions of the firm to the strategies defined by its executive managers. Firms actively managing their supply chains have an added layer of performance measurement requirements—measures must be added that link the operations of member firms as well as linking the actions of the firms to the competitive strategies of the supply chain. Several performance measurement models were presented and discussed in the chapter that have been successfully used in supply chains to monitor and link supply chain members' performance—namely the Balanced Scorecard and Supply Chain Operations Reference models.

## Key Terms

**balanced scorecard,** 618

**carbon footprints,** 617

**environmental sustainability,** 614

**green supply chain management,** 616

**performance dashboards,** 620

**performance measurement,** 603

**performance variance,** 610

**scorecarding,** 618

**single-factor productivity measures,** 610

**total productivity measures,** 610

**triple bottom line (TBL),** 616

## Discussion Questions

1. How did the pandemic change the performance measures companies were monitoring in 2020?
2. Walmart's success is due to its low prices. Why would they need to monitor anything except price performance?
3. Do you think there is a relationship between performance measurement and a firm's competitiveness and profitability? Explain.
4. Why would IKEA be interested in sustainability performance measures?
5. What do customers have to do with good performance measures?
6. How should performance measures be viewed from a supply chain perspective?
7. In building supply chain competencies, what are the trade-offs that must be considered?
8. What do the best supply chains do, that is better than other supply chains?
9. What risk do managers take when they view their firm's performance solely in financial terms?
10. List some of the traditional performance measures, and describe their value in today's competitive climate.
11. Discuss the use of performance standards and performance variances. Do schools and universities use them? How can they be damaging to the organization?

**12.** How can performance standards create functional silos?

**13.** What is the difference between a total productivity measure and a single-factor productivity measure? Provide an example.

**14.** List some single-factor and multiple-factor productivity measures for a restaurant, a quick-change oil garage, and an overnight delivery service.

**15.** Using the basic formula for productivity, (outputs)/(inputs), what are all the ways that productivity can be increased?

**16.** What is the productivity growth rate right now in the United States? Explain why it is as low as it is.

**17.** What are the advantages and disadvantages of using labor utilization as a performance measure? Do these same arguments apply to machine utilization?

**18.** How could you increase labor productivity without increasing labor utilization?

**19.** Using the formulas provided for utilization, calculate the utilization of your classroom.

**20.** What do you think a good labor utilization would be for a factory? A restaurant? Why?

**21.** How do world-class performance measures differ from, say, financial performance measures?

**22.** Using the steps suggested for developing performance measures, create several world-class performance measures for a hotel's front-desk area, maintenance department, and room service personnel.

**23.** How should a firm extend its performance measures to include other supply chain members?

**24.** What are demand-driven supply networks, and what role do performance measures play in these networks?

**25.** How can you create performance measures for an entire supply chain?

**26.** What is a sustainable supply chain?

**27.** Why should supply chains begin using green performance measures? Provide some examples of green supply chain performance measures. How would these differ from green performance measures for one firm?

**28.** What is a carbon footprint, and how can firms reduce theirs? How could you measure the carbon footprint for a supply chain?

**29.** What is the triple bottom line? How is it measured/calculated for a company?

**30.** What is perfect order fulfillment? Cash-to-cash cycle time?

**31.** Describe the four perspectives of the Balanced Scorecard. How is this model different from a set of world-class performance measures?

**32.** What are the steps in developing a balanced scorecard?

**33.** What are some weaknesses of the BSC?

**34.** How is a scorecard different from a dashboard?

**35.** What are the six process categories of the SCOR model, and which one do you think is the most important?

36. In what ways is the BSC similar to the SCOR model? Different from the SCOR model?
37. Which model do you think is best suited to measure supply chain performance—the BSC or the SCOR? Why?
38. How is SCORmark beneficial for member organizations?

## Problems

1. Cindy Jo's Hair Salon is concerned about its rising costs of supplies, energy, and labor, so it is considering investing in better equipment, which hopefully will reduce the time required to perform most hairstyles as well as result in better perceived quality by its customers. It predicts that the added investment will increase output levels as well as reduce energy costs, since some of the new equipment (hair dryers) use less electricity. Using the following information, determine the current and expected single-factor and total productivity measures. What is the percentage change in total productivity? What other items should be considered before making this capital investment? Do you think the increase in output will overcome the capital costs?

| INPUTS AND OUTPUTS | CURRENT (THIS YEAR) | EXPECTED (NEXT YEAR) |
|---|---|---|
| Hairstyles per week | 250 | 300 |
| Labor costs per week | $960 | $1010 |
| Energy costs per week | $400 | $350 |
| Material costs per week | $300 | $325 |
| Capital investment | $0 | $12,000 |

2. For the four months shown, calculate the monthly labor productivities and the monthly productivity growths.

| | MARCH | APRIL | MAY | JUNE |
|---|---|---|---|---|
| Units produced | 1260 | 1340 | 1293 | 1324 |
| Labor hours | 328 | 332 | 321 | 318 |

3. Calculate the single factor productivities and the total productivity given the information below.

| OUTPUT | INPUTS |
|---|---|
| 325,000 units<br>Sales price = $1249.00/unit | 6400 labor hours @ $15.00 per hour<br>Material cost = $40,625,000<br>Utilities cost = $4400 |

## Essay/Project Questions

1. Using data obtained from the U.S. Bureau of Labor Statistics website (www.bls.gov), write a report on labor productivity in the United States compared to several other countries listed.

2. Find a company using sustainability performance measures to assess its own company as well as their suppliers, and write an essay on this company and their performance measures.
3. Pick a company from Gartner's annual listing of the Top 25 Supply Chains (see their listing at http://www.gartner.com/technology/supply-chain/top25.jsp), and discuss the performance measures it uses.
4. Find current examples of firms that are using Balanced Scorecards and the SCOR model, and report on their successes.

# Cases

## 1. Production Labor Sourcing for Supply Chain Management*

Over 75 percent of U.S. manufacturers have been reported to outsource some of their business functions. A shift in offshore outsourcing has returned some business activities to the United States even as cost reduction pressure still challenges most U.S. businesses. Brook Medical Supplies (BMS), a manufacturer of medical supplies and ambulatory kits, recently ended outsourcing operations overseas as a competitive measure to improve quality and reduce costs. BMS instead selected a cost reduction project that outsourced semi-skilled labor locally. The labor sourcing approach reduced overall costs below the offshore program, while maintaining complete oversight of product quality. The positive results in cost reduction prompted BMS to expand the labor sourcing initiative beyond its production positions. BMS now uses labor sourcing for semi-skilled labor in its material handling (shipping and receiving), staging (tow motor drivers), maintenance, and waste handlers without displacing any existing employees by moving them to other departments in the plant. With the responsibility to hire, train, and supervise this group of semi-skilled laborers, BMS has been able to increase efforts in core areas of increased quality, efficiencies, and product improvement.

Stor-Pak Distribution Center handles 90 percent of BMS' New England distribution, including assembly and kitting for their drug testing kits. In addition to their customer-supplier relationship, Stor-Pak partners with BMS as a Best in Class and benchmarking mentoring through a national association of U.S. manufacturers and distribution centers. As part of BMS's supply chain management integration efforts, they have recommended to Stor-Pak that they evaluate alternatives to expanding their labor force with permanent employees. Stor-Pak is evaluating three alternatives including hiring permanent warehouse employees, contracting with temporary employment agencies for expanded labor, and contracting with a specialized labor sourcing company similar to the contract BMS secured for their production and warehousing operation. Stor-Pak has been gathering internal data on labor costs for permanent employees and has a large pool of temporary employment agencies that responded to their RFP. Only one proposal was submitted that was identified as a specialized labor sourcing company.

Bethel Consulting Services (BCS) is a third-party labor sourcing company with expertise in screening, selection, training, and supervision of semi-skilled warehouse associates. BCS presents a "company within a company" or vendor onsite service with competencies in training for warehouse positions in material handling, pick and pack,

*Written by Brian Hoyt, PhD, Professor of Management, Ohio University. This case was prepared solely to provide fictional material for class discussion. The author does not intend to illustrate either effective or ineffective handling of a managerial situation.

assembly and kit making that reduces the learning curve time, and improves quality of work. Their proprietary competency-based hiring system and onsite supervision results in lower tardiness, turnover, and safety issues. BCS's specialized staffing system starts with an assessment of required skills and activities of the warehouse operation and then drafts Standard Operating Procedures (SOPs) for training and performance evaluations. Their data- and performance-based system allows performance incentives for BCS employees and gain sharing opportunities for contract partners.

BCS has data necessary for developing a business case that warehouses and distribution centers can use to present contracting with a specialized labor sourcing company. The business case compares BCS cost and performance measures to hiring permanent employees and contracting through temporary agencies. The business case presents data reporting productivity gains and a reduction of overall labor cost by 20–40 percent. The data reports an increased quality of work (reduced errors in storage and retrieval, assembly, and kit making), improved performance measures (picking and packing efficiencies) and improved safety (reduced liability and claims). The BCS system will allow distribution customers to redirect efforts in supervising semi-skilled labor to supervising skilled labor and focusing on core competencies and other lean cost saving priorities.

### Discussion Questions:

1. How could contracting with Bethel Consulting Services advance Stor-Pak's position as a world-class supply chain partner for Brook Medical Supplies and other customers?
2. What cost advantage perspective should Stor-Pak use to determine the differences between using a traditional temp agency versus a third-party labor source provider such as Bethel Consulting Services?
3. If the reduced costs projected by Bethel Consulting Services are realized, will there still be any risks for Stor-Pak in bringing in a third-party labor source company such as BCS?

## 2. Warehouse and Distribution Center Robotics*

Rack and Shelving Manufacturing (RSM) is an 85-year-old U.S. niche pallet rack and shelving manufacturer. RSM sells to volume resellers, direct to manufacturers with warehousing, warehouse distribution centers, and to small end users through B2B e-commerce. Major fluctuations of steel pricing, poor inventory management, and labor issues with a local union at its largest manufacturing facility, has put RSM at a financial crossroad. RSM, recognized as a high quality manufacturer with a limited product line has small market share in the growing storage equipment industry sector. Recently the shelving lines have been updated to accommodate innovations in the pick, pack, and ship fulfillment centers. The pallet rack line (Pallets Plus) is a standard selective rack system featuring two upright frames and shelf beams inserted between the frames. Their high quality rack is one of the most flexible (easy to configure racking to all layouts) and compared to more complex pallet rack systems including drive through racking and roller racks is economical with quick access to pallets. The Pallets Plus rack system is ideal for manufacturing or warehouse storage with a broad array of items but moderate to low turnover volume. Innovation of the Pallets Plus line have not been introduced to the market for over 10 years. The growth in the rack storage sector is intently focused on optimizing warehouse cubic feet with high-density racking systems that facilitate high number of items and high turnover

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volume. These rack systems, while significantly more expensive than the selective Pallets Plus rack system, increases the productive use of warehouse floor space by 60–75 percent more than selective systems.

Rack and Shelving Manufacturing attended the most recent ProMat tradeshow in Chicago, organized by the Material Handling Industry of America. The ProMat tradeshow is an international showcase of material handling, supply chain and logistics solutions in North America. The industry event offers productivity solutions and information by highlighting the products and services of leading material handling and logistics providers. At the ProMat show RSM was looking for direction relative to their next new product in pallet systems. They decided to "leapfrog" the existing high-density pallet systems (i.e., drive through, roller racks, and pallet flows) and partner with a technology firm that manufactures warehouse specific automated guided vehicles. RSM is now focusing on building a new pallet rack and shelving product line that will meet all the specifications for Automated Storage Technology's (AST) warehouse robotics line.

Rack and Shelving Manufacturing's new technology partner Automated Storage Technology is a leader in automated storage and retrieval systems (AS/RS). They were one of the first to test automated guided vehicles (AGV) and with several generations of innovations now have a prototype for a fully robotic forklift. Similar to RSM, Automated Storage Technology has evolved from systems associated with large pallet racks to automation and robotics associated with "pick, pack, and ship" fulfillment centers. AST's AGV technology supports pick up, carry and drop off loads for manufacturing plants, warehouses, and distribution centers. The guidance technologies and navigation technologies are laser guided for self-driving material handling vehicles similar to self-driving cars. AST uses a laser and light-based navigation that scans the facility to gather data to construct a detailed map of the facility floor. The reference map then can be used to navigate any route. The AGV system is a smart technology that can plan and follow its own route similar to how an auto GPS will re-route the map once the car deviates from the original mapped route. Operators can drag and drop instructions to direct the vehicle's pickups and drop-offs. AST is developing a navigation system that will allow warehouse/inventory management to control a fleet of AGVs using apps on mobile devices such as tablets, phones, and laptops.

Rack and Shelving Manufacturing is investing in a strategy where they identify and occupy a niche in the future of warehouse storage and retrieval. They must position themselves as the first to control this niche with their partnership with AST that positions the new RSM pallet and storage systems as essential to the process of automated storage and retrieval (AGV and AS/RS). The pricing strategy for the premium price of the new pallet and shelving products is based on the very small percentage of cost of the entire automated (i.e., self-guided pallet trucks) warehouse system and design. The niche is small enough and unattractive to rivals at first and Rack and Shelving Manufacturing can grow along with the projected growth of the high-tech warehouse.

## Discussion Questions

1. Defend Rack and Shelving Manufacturing's new product development strategy of tying new rack and shelving products to Automated Storage Technology's AGV/robotic innovation cycles.
2. How will product manufacturers and supply chain partners benefit in their efforts to adopt high performance supply chain measures by using RSM and AST AGV equipment and storage racks?
3. What risks do RSM and AST face that may alter (quicken or slow down) the pace of the adoption of warehouse robotics in the warehouse, storage, and logistics sectors?

Note: For pallet rack descriptions see Rack Manufacturers Institute/Material Handling Institutes SIG's (www.mhi.org) Students should also visit the ProMat tradeshow website at www.ProMatshow.com. General information on Robotics for warehousing can be found at www.dcvelocity.com.

## 3. The Balanced Scorecard Approach*

PJ Express (PJEx) is one of the largest privately owned New England business-to-consumer (B2C) carriers specializing in "last-mile" deliveries. PJEx is a company with new leadership, but also with a 2-year drop in sales and profits, and recently was contacted by a more successful competitor as an acquisition target. The overnight shipments to residential consumers have increased competitive pressures as UPS, FedEx, and Amazon have moved into smaller, Tier-two distribution hubs. Profits for all carriers of consumer products have been squeezed as major retailers have established a "free shipping" benefit that is not going away after peak shipping seasons (i.e., cyber week and holidays).

The PJEx executive team is led by a new CEO who left FedEx Ground after leading a successful turnaround of an acquired carrier. The success was attributed to a focused strategy using the Balanced Scorecard (BSC) framework. The CEO was selected in part because of his success in using the BSC and because PJEx had just recently committed to using the BSC performance measurement framework to align with its 3-year turnaround strategic plan. Last year PJEx charged four teams with developing perspectives for the BSC framework—the financial perspective team, the internal business process perspective team, the customer perspective team, and the learning and growth perspective team. To accelerate the strategic turnaround effort, the learning and growth (L&G) perspective team contracted with a BSC consulting company, Balanced Scorecard Systems (BSS). BSS is a strategic planning consulting group specializing in the logistics and transportation industry using the BSC approach. The L&G team efforts are much farther along than the other teams and BSS has presented a first draft of the learning and growth measures.

A partial L&G scorecard focused on improving organizational capacity performance and includes:

Objectives:

**a.** Establish a learning organization effort

**b.** Improve training effectiveness

Measures:

**a.** Add organizational learning components: observe, capture, store, access, disseminate, and evaluate.

**b.** Increase percent of Six Sigma program—Green Belts (by 45 percent), Black Belts (by 20 percent), and Master Black Belts (by 15 percent)

Targets:

**a.** Develop Knowledge Management System (KMS)

**b.** Build High Performance Improvement Teams (HPT)

*Written by Brian Hoyt, PhD, Professor of Management, Ohio University. This case was prepared solely to provide fictional material for class discussion. The author does not intend to illustrate either effective or ineffective handling of a managerial situation.

Initiatives:

**a.** Benchmark—learning new concepts from external sources and internal sources on KMS

- Plan—assess where new knowledge is needed as related to key performance indicators
- Find—locate a department/division (internal) or organization (external) that performs our identified process (KMS) better for comparison
- Observe—monitor performance of benchmarked KMS and note differences in performance
- Analyze—determine causes for differences in performance
- Adapt—select best practices from benchmarked organization and modify for our KMS
- Improve—integrate our new learning into other process improvements

**b.** Transition to project based training delivery for Six Sigma content

- Analyze department training needs—determine the number and level of qualified "belts" to have all employees engaged in HPT
- Analyze training task—produce a detailed description of skills required at Green Belt, Black Belt, and Master Black Belt levels
- Develop training objective measures—measures in quality tool knowledge, statistical analysis, improvement process, and improvement experiment design
- Organize training content—secure training materials and subject matter experts in Six Sigma, DMAIC, and belt requirements.
- Determine training methods—project-based training methodology where training occurs while teams are involved in actual HPT improvement projects
- Select training resources—secure Six Sigma guidebooks
- Complete training plan
- Deliver training pilot
- Assess training pilot, make adjustments and submit to HR for KMS inclusion

The transition with the new executive management team is certain to have some impact on PJEx's recent strategy and planning activities. The new CEO has indicated in preliminary discussions that he would be driving the Balanced Scorecard initiative based on his previous experience and success with BSC. A growing number of employees have been critical in open discussion meetings initiated and delivered by the new executive team. A common complaint in these meetings is that PJEx has introduced several similar companywide programs in the past that have had limited success but huge organizational investments of time and money including Total Quality Management, LEAN management, Six Sigma/Black Belt, Just in Time (JIT), Constraint Theory (TOC), etc. All of the previous programs started out with positive results but efforts, measures of effectiveness and eventually support and commitment waned. In addition, the manufacturing group assigned the internal business processes perspective (IBP) of BSC is presenting an alternative to the BSC all together as an effort to achieve the new management turnaround goals. The IBP group is proposing a shift to the Baldrige Award framework.

### Discussion Questions

1. Should the Learning & Growth team sever its relationship with Balanced Scorecard Systems before the new CEO presents the new BSC plan? Develop a Pro/Con response that the Learning & Growth team could present to the BSC steering committee.
2. What advice can you provide the new executive team for their next organizational meeting that addresses the staying power of BSC?
3. Is the Baldrige approach that the manufacturing group is presenting an alternative to the BSC or can it run parallel?

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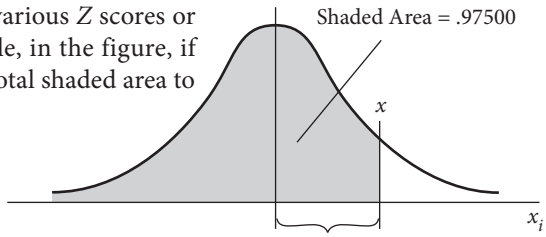
# Appendix 1

# Areas Under the Normal Curve

This table gives the area under the curve to the left of $x$ for various $Z$ scores or the number of standard deviations from the mean. For example, in the figure, if $Z = 1.96$, the value .97500 found in the body of the table is the total shaded area to the left of $x$.




| Z | .00 | .01 | .02 | .03 | .04 | .05 | .06 | .07 | .08 | .09 |
|---|---|---|---|---|---|---|---|---|---|---|
| **.0** | .50000 | .50399 | .50798 | .51197 | .51595 | .51994 | .52392 | .52790 | .53188 | .53586 |
| **.1** | .53983 | .54380 | .54776 | .55172 | .55567 | .55962 | .56356 | .56749 | .57142 | .57535 |
| **.2** | .57926 | .58317 | .58706 | .59095 | .59483 | .59871 | .60257 | .60642 | .61026 | .61409 |
| **.3** | .61791 | .62172 | .62552 | .62930 | .63307 | .63683 | .64058 | .64431 | .64803 | .65173 |
| **.4** | .65542 | .65910 | .66276 | .66640 | .67003 | .67364 | .67724 | .68082 | .68439 | .68793 |
| **.5** | .69146 | .69497 | .69847 | .70194 | .70540 | .70884 | .71226 | .71566 | .71904 | .72240 |
| **.6** | .72575 | .72907 | .73237 | .73536 | .73891 | .74215 | .74537 | .74857 | .75175 | .75490 |
| **.7** | .75804 | .76115 | .76424 | .76730 | .77035 | .77337 | .77637 | .77935 | .78230 | .78524 |
| **.8** | .78814 | .79103 | .79389 | .79673 | .79955 | .80234 | .80511 | .80785 | .81057 | .81327 |
| **.9** | .81594 | .81859 | .82121 | .82381 | .82639 | .82894 | .83147 | .83398 | .83646 | .83891 |
| **1.0** | .84134 | .84375 | .84614 | .84849 | .85083 | .85314 | .85543 | .85769 | .85993 | .86241 |
| **1.1** | .86433 | .86650 | .86864 | .87076 | .87286 | .87493 | .87698 | .87900 | .88100 | .88298 |
| **1.2** | .88493 | .88686 | .88877 | .89065 | .89251 | .89435 | .89617 | .89796 | .89973 | .90147 |
| **1.3** | .90320 | .90490 | .90658 | .90824 | .90988 | .91149 | .91309 | .91466 | .91621 | .91774 |
| **1.4** | .91924 | .92073 | .92220 | .92364 | .92507 | .92647 | .92785 | .92922 | .93056 | .93189 |
| **1.5** | .93319 | .93448 | .93574 | .93699 | .93822 | .93943 | .94062 | .94179 | .94295 | .94408 |
| **1.6** | .94520 | .94630 | .94738 | .94845 | .94950 | .95053 | .95154 | .95254 | .95352 | .95449 |
| **1.7** | .95543 | .95637 | .95728 | .95818 | .95907 | .95994 | .96080 | .96164 | .96246 | .96327 |
| **1.8** | .96407 | .96485 | .96562 | .96638 | .96712 | .96784 | .96856 | .96926 | .96995 | .97062 |
| **1.9** | .97128 | .97193 | .97257 | .97320 | .97381 | .97441 | .97500 | .97558 | .97615 | .97670 |
| **2.0** | .97725 | .97784 | .97831 | .97882 | .97932 | .97982 | .98030 | .98077 | .98124 | .98169 |
| **2.1** | .98214 | .98257 | .98300 | .98341 | .98382 | .98422 | .98461 | .98500 | .98537 | .98574 |
| **2.2** | .98610 | .98645 | .98679 | .98713 | .98745 | .98778 | .98809 | .98840 | .98870 | .98899 |
| **2.3** | .98928 | .98956 | .98983 | .99010 | .99036 | .99061 | .99086 | .99111 | .99134 | .99158 |
| **2.4** | .99180 | .99202 | .99224 | .99245 | .99266 | .99286 | .99305 | .99324 | .99343 | .99361 |
| **2.5** | .99379 | .99396 | .99413 | .99430 | .99446 | .99461 | .99477 | .99492 | .99506 | .99520 |
| **2.6** | .99534 | .99547 | .99560 | .99573 | .99585 | .99598 | .99606 | .99621 | .99632 | .99643 |
| **2.7** | .99653 | .99664 | .99674 | .99683 | .99693 | .99702 | .99711 | .99720 | .99728 | .99736 |
| **2.8** | .99744 | .99752 | .99760 | .99767 | .99774 | .99781 | .99788 | .99795 | .99801 | .99807 |
| **2.9** | .99813 | .99819 | .99825 | .99831 | .99836 | .99841 | .99846 | .99851 | .99856 | .99861 |
| **3.0** | .99865 | .99869 | .99874 | .99878 | .99882 | .99886 | .99889 | .99893 | .99896 | .99900 |
| **3.1** | .99903 | .99906 | .99910 | .99913 | .99916 | .99918 | .99921 | .99924 | .99926 | .99929 |
| **3.2** | .99931 | .99934 | .99936 | .99938 | .99940 | .99942 | .99944 | .99946 | .99948 | .99950 |
| **3.3** | .99952 | .99953 | .99955 | .99957 | .99958 | .99960 | .99961 | .99962 | .99964 | .99965 |
| **3.4** | .99966 | .99968 | .99969 | .99970 | .99971 | .99972 | .99973 | .99974 | .99975 | .99976 |
| **3.5** | .99977 | .99978 | .99978 | .99979 | .99980 | .99981 | .99981 | .99982 | .99983 | .99983 |
| **3.6** | .99984 | .99985 | .99985 | .99986 | .99986 | .99987 | .99987 | .99988 | .99988 | .99989 |
| **3.7** | .99989 | .99990 | .99990 | .99990 | .99991 | .99991 | .99992 | .99992 | .99992 | .99992 |
| **3.8** | .99993 | .99993 | .99993 | .99994 | .99994 | .99994 | .99994 | .99995 | .99995 | .99995 |
| **3.9** | .99995 | .99995 | .99996 | .99996 | .99996 | .99996 | .99996 | .99996 | .99997 | .99997 |

# Appendix 2

# Answers to Selected End-of-Chapter Problems

## CHAPTER 2

1. 8%
3. $300,000
5. a. Gross profits increase by $50,000; b. Profits before taxes increase by $50,000
7. 10 times
9. $1,280,000
13. a. 5500 units, $69,000 b. buy, $4000 c. make, $2000
15. a. Breakeven quantity = 24,700 units, if the requirement is 20,000, the firm should buy the item; cost at breakeven point = $247,600
    b. Make = $210,000; Buy = $200,600; Cost saving = $9400

## CHAPTER 3

1. The weighted score is 88.25. Supplier is classified as a certified vendor.

## CHAPTER 4

34. 50,000 second-tier suppliers. Alternately, 2000 second-tier suppliers.

## CHAPTER 5

1. b. (1) $F_{July} = (18{,}000 + 20{,}000 + 24{,}000)/3 = 20{,}667$, (2) $F_{July} = (0.2 \star 18{,}000 + 0.3 \star 20{,}000 + 0.5 \star 24{,}000) = 21{,}600$, (3) Linear regression forecast, July Forecast $= 17{,}066.667 + 7 \star 742.857 = 22{,}265.336$, (4) $F7 = F6 + a(A6 - F6) = 18{,}858 + 0.4(24{,}000 - 18{,}858) = 20{,}915$
   d. The linear regression forecast has the lowest MAD and therefore is considered the best forecasting method.
3. a. $F5 = (71{,}000 + 75{,}500 + 71{,}200)/3 = 72{,}567$
   b. $F5 = 0.4 \star 71{,}000 + 0.2 \star 75{,}500 + 0.4 \star 71{,}200 = 71{,}980$
   c. $F1 = 68{,}000$
   $F2 = F1 + a(A1 - F1) = 68{,}000 + 0.3(68{,}800 - 68{,}000) = 68{,}240$
   $F3 = F2 + a(A2 - F2) = 68{,}240 + 0.3(71{,}000 - 68{,}240) = 69{,}068$
   $F4 = F2 + a(A3 - F3) = 69{,}068 + 0.3(75{,}500 - 69{,}068) = 70{,}997.6$
   $F5 = F2 + a(A4 - F4) = 70{,}997.6 + 0.3(71{,}200 - 70{,}997.6) = 71{,}058.3$
5. Forecast 2 has the lowest MAD. Forecast 3 has the lowest MSE. Depending on which forecasting accuracy measure is selected we will arrive at a different method which is best.

7. RSFE for Model 1 = 30. Model 1 tends to under forecast demand.
RSFE for Model 2 = −17. Model 1 tends to over forecast demand.
MAPE for Model 1 = 3.29
MAPE for Model 2 = 2.08
An RSFE close to zero means that forecasts in the forecasting horizon are not consistently higher or lower than the actual demand. RSFE is a measure of bias in the forecasts.

## CHAPTER 6

2. a. Chase production strategy

| MONTH | JAN | FEB | MAR | APR | MAY | JUN |
|---|---|---|---|---|---|---|
| Demand | 2000 | 3000 | 5000 | 6000 | 6000 | 2000 |
| Production | 2000 | 3000 | 5000 | 6000 | 6000 | 2000 |
| Ending inventory | 0 | 0 | 0 | 0 | 0 | 0 |
| Workforce | 20 | 30 | 50 | 60 | 60 | 20 |

b. Level production strategy

| MONTH | JAN | FEB | MAR | APR | MAY | JUN |
|---|---|---|---|---|---|---|
| Demand | 2000 | 3000 | 5000 | 6000 | 6000 | 2000 |
| Production | 4000 | 4000 | 4000 | 4000 | 4000 | 4000 |
| Ending inventory | 2000 | 3000 | 2000 | 0 | –2000 | 0 |
| Workforce | 40 | 40 | 40 | 40 | 40 | 40 |

(–2000 indicates backlog of 2,000 in May.)

5. ATP: D

| WEEK | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| MODEL B | | | | | | | | | |
| MPS | BI = 20 | 20 | 0 | 20 | 20 | 0 | 20 | 20 | 20 |
| Committed Customer Orders | | 10 | 10 | 10 | 10 | 10 | 0 | 0 | 10 |
| ATP: D | | 20 | 0 | 10 | 0 | 0 | 20 | 20 | 10 |

8. Given the following production schedule, compute the available-to-promise quantities.

| WEEK | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| MODEL B | | | | | | | | | |
| MPS | BI = 8 | 20 | 0 | 20 | 0 | 12 | 0 | 28 | 20 |
| Committed Customer Orders | | 12 | 8 | 16 | 2 | 8 | 0 | 30 | 18 |
| ATP: D | | 8 | 0 | 2 | 0 | 2 | 0 | 0 | 2 |

10. Component B: 3 units, Component C: 2 units, Component D: 1 unit,
Component E: 4 × 2 = 8 units, Component F: 6 × 2 = 12 units

12. Given the following information, complete the planned order releases and projected on-hand balances for component part X.

| PART X | WEEK | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| Gross Requirements | | 80 | 0 | 90 | 0 | 90 |
| Scheduled Receipts | | 60 | | | | |
| Projected On-Hand Inventory | 120 | 100 | 100 | 10 | 10 | 40 |
| Planned Order Releases | | | 120 | | | |

Q = 60, LT = 3 weeks, Safety Stock = 5

15. Given the following information, compute the planned order releases and projected on-hand inventory for component part Z.

| PART A | WEEK | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | 150 | 252 | 240 | 320 | 280 | 450 |
| Scheduled Receipts | | 150 | 250 | | | | |
| Projected On-Hand Inventory | 22 | 22 | 20 | 30 | 60 | 30 | 30 |
| Planned Order Releases | | | 250 | 350 | 250 | 450 | |

Q = 50, LT = 2 weeks, Safety Stock = 20

17.

| PART D | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | 7 | 11 | 9 | 5 | 8 | 6 |
| Scheduled Receipts | | | | | | | |
| Projected On-Hand Inventory | 10 | 3 | 22 | 13 | 8 | 0 | 24 |
| Planned Order Releases | | 30 | | | | 30 | |

Q = 30; LT = 1; SS = 0

| PART E | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | 10 | 12 | 15 | 11 | 6 | 8 |
| Scheduled Receipts | | | 11 | | | | |
| Projected On-Hand Inventory | 15 | 5 | 4 | 3 | 3 | 3 | 3 |
| Planned Order Releases | | 14 | 11 | 6 | 8 | | |

Q = LFL; LT = 2; SS = 3

| | | | | | | |
|---|---|---|---|---|---|---|
| From D (1 each) | *30* | | | | *30* | |
| From E (2 each) | *28* | *22* | *12* | *16* | | |

| PART F | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | 58 | 22 | 12 | 16 | 30 | |
| Scheduled Receipts | | 60 | | | | | |
| Projected On-Hand Inventory | 20 | 22 | 0 | 48 | 32 | 2 | |
| Planned Order Releases | | | 60 | | | | |

Q = 60; LT = 1; SS = 0

19.

| **PART A** | | **1** | **2** | **3** | **4** | **5** | **6** |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | 58 | 44 | 38 | 65 | 88 | 168 |
| Scheduled Receipts | | 60 | | | | | |
| Projected On-Hand Inventory | 10 | 12 | 28 | 50 | 45 | 17 | 29 |
| Planned Order Releases | | 60 | 60 | 60 | 60 | 180 | |

Q = 60; LT = 1; SS = 8

| | | **60×2** | **60×2** | **60×2** | **60×2** | **180×2** | |
|---|---|---|---|---|---|---|---|
| **PART C** | | **1** | **2** | **3** | **4** | **5** | **6** |
| Gross Requirements | | 120 | 120 | 120 | 120 | 360 | 0 |
| Scheduled Receipts | | 90 | 120 | | | | |
| Projected On-Hand Inventory | 45 | 15 | 15 | 15 | 15 | 15 | 15 |
| Planned Order Releases | | 120 | 120 | 360 | | | |

Q = 30; LT = 2; SS = 10

| | | **120×4** | **120×4** | **360×4** | | | |
|---|---|---|---|---|---|---|---|
| **PART E** | | **1** | **2** | **3** | **4** | **5** | **6** |
| Gross Requirements | | 480 | 480 | 1440 | 0 | 0 | 0 |
| Scheduled Receipts | | 500 | | | | | |
| Projected On-Hand Inventory | 50 | 70 | 90 | 150 | 150 | 150 | 150 |
| Planned Order Releases | | 500 | 1500 | | | | |

Q = 250; LT = 1; SS = 40

| | | **120×6** | **120×6** | **360×6** | | | |
|---|---|---|---|---|---|---|---|
| **PART F** | | **1** | **2** | **3** | **4** | **5** | **6** |
| Gross Requirements | | 720 | 720 | 2160 | 0 | 0 | 0 |
| Scheduled Receipts | | 700 | | | | | |
| Projected On-Hand Inventory | 80 | 60 | 140 | 80 | 80 | 80 | 80 |
| Planned Order Releases | | 800 | 2100 | | | | |

Q = 100; LT = 1; SS = 50

21.

| BOSTON DISTRIBUTION CENTER | | **1** | **2** | **3** | **4** | **5** | **6** |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | 0 | 20 | 0 | 55 | 0 | 0 |
| Scheduled Receipts | | | | | | | |
| Projected On-Hand Inventory | 10 | 10 | 20 | 20 | 25 | 25 | 25 |
| Planned Order Releases | | 30 | | 60 | | | |

Q = 30; LT = 1; SS = 5

| DENVER DISTRIBUTION CENTER | | **1** | **2** | **3** | **4** | **5** | **6** |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | 0 | 20 | 10 | 0 | 0 | 20 |
| Scheduled Receipts | | | 11 | | | | |
| Projected On-Hand Inventory | 15 | 15 | 6 | 2 | 2 | 2 | 2 |
| Planned Order Releases | | 6 | | | 20 | | |

Q = LFL; LT = 2; SS = 2

| HOUSTON DISTRIBUTION CENTER | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Gross Requirements | | 10 | 0 | 0 | 45 | 0 | 0 |
| Scheduled Receipts | | | | | | | |
| Projected On-Hand Inventory | 20 | 10 | 10 | 10 | 25 | 25 | 25 |
| Planned Order Releases | | | | 60 | | | |

Q = 60; LT = 1; SS = 0

| | | | 30+6 | | 60+60 | 20 | | |
|---|---|---|---|---|---|---|---|---|
| LAS VEGAS CENTRAL WAREHOUSE | | 1 | 2 | 3 | 4 | 5 | 6 |
| Gross Requirements | | 36 | 0 | 120 | 20 | 0 | 0 |
| Scheduled Receipts | | | | | | | |
| Projected On-Hand Inventory | 50 | 14 | 14 | 14 | 14 | 14 | 14 |
| Planned Order Releases | | | 120 | 20 | | | |

Q = 20; LT = 1; SS = 0

## CHAPTER 7

1. 13.7 times
3. 13.3 times
4. EOQ = 1,000 units
   Annual holding cost = $7,500, Annual order cost = $7,500
   Total annual inventory cost = $15,000
5. (a) $EOQ = \sqrt{\frac{2RS}{kC}} = \sqrt{\frac{2 \times 360{,}000 \times \$120}{.12 \times \$2{,}500}} = 536.66\ units$
   (b) Annual holding cost = Q/2 × k × C = $80,498.45
   (c) Annual ordering cost = R/Q × S = $80,498.45
   (d) Annual total cost = $160,996.90
7. (a) Annual holding cost = Q/2 × k × C = 2,800/2 × .12 × $2,500 = $420,000
   (b) Annual ordering cost = R/Q × S = 360,000/2,800 × $120 = $15,428.57
   (c) Annual total cost = $420,000 + $15,428.57 = $435,428.57
   The order quantity of 2,800 is significantly larger than the EOQ quantity of 536.66 units. Indeed, it is about 5.22 times the EOQ quantity. As a result, the annual holding cost is significantly higher, annual ordering cost is significantly lower, and total cost is much higher compared to ordering at the EOQ quantity.
9. (a) Annual holding cost = Q/2 × k × C = 1,000/2 × .02 × $250 = $2,500
   (b) Annual ordering cost = R/Q × S = 49,400/1,000 × $85 = $4,199
   (c) Annual total cost = $2,500 + $4,199 = $6,699

   The order quantity of 1,000 is slightly smaller than the EOQ quantity of 1,295.99 units. It is about 77.2% (1000/1295.99) of the EOQ quantity. As a result, the annual holding cost is smaller [($2,500 − $3,239.98)/$3,239.98 = −22.8%], annual ordering cost is higher [($4,199 − $3,239.98)/$3,239.98 = 29.6%], and total cost is slightly higher [($6,699 − $6,479.96)/$6,479.96 = 3.38%] compared to ordering at the EOQ quantity.

11. Annual requirement = 1,500 × 12 months = 18,000 units
Holding cost, kC = $56

(a) $EOQ = \sqrt{\frac{2RS}{kC}} = \sqrt{\frac{2 \times 18{,}000 \times \$285}{\$56}} = 428.04$ *units*

(b) Annual holding cost = Q/2 × k × C = $11,984.99

(c) Annual ordering cost = R/Q × S = $11,984.99

(d) Annual total cost = $23,969.98

13. (a) Annual holding cost = Q/2 × k × C = 24/2 × .35 × $2,500 = $10,500

(b) Annual ordering cost = R/Q × S = 1,200/24 × $250 = $12,500

(c) Total annual inventory cost = annual holding cost + annual order cost = $10,500 + $12,500 + $23,000

Annual holding cost is 8.35% [($10,500 − $11,456.44)/$11,456.44 = −8.35%] lower, annual ordering cost is 9.11% [($12,500 − $11,456.44)/$11,456.44 = 9.11%] higher, and annual total cost is 0.38% [($23,000 − $22,912.88)/$22,912.88 = 0.38%] higher.

15. (a) 151 units, (b) $25,200,000, (c) $405,888, (d) $2,980.13, (e) $25,608,868.13
(Note: Optimal order quantity is at a price break point)

17. (If setup cost is $300):
(a) 151 units, (b) $25,200,000, (c) $190,260, (d) $2,980.13, (e) $25,393,240.13
(If setup cost is $50):
(a) 151 units, (b) $25,200,000, (c) $190,260, (d) $496.69, (e) $25,390,756.69
(Note: Optimal order quantity is at a price break point)

19. (a) D = 14,400/360 = 40 units/day

(b) $EMQ = \sqrt{\left(\frac{2RS}{kC}\right)\left(\frac{P}{P-D}\right)} = \sqrt{\left(\frac{2 \times 14{,}400 \times \$400}{.20 \times \$95}\right)\left(\frac{120}{120-40}\right)} = 953.6633$ *units*

(c) $Q_M = Q\left(1 - \frac{D}{P}\right) = 953.6633\left(1 - \frac{40}{120}\right) = 635.7755$ *units*

(d) Annual Production Cost = $R \times C = (14{,}400) \times (\$95) = \$1{,}368{,}000$

(e) Annual Holding Cost = $\left(\frac{Q_M}{2}\right)(k)(C) = \left(\frac{635.7755}{2}\right)(.20)(\$95) = \$6{,}039.87$

(f) Annual Setup Cost = $\left(\frac{R}{Q}\right)(S) = \left(\frac{14{,}400}{953.6633}\right)(\$400) = \$6{,}039.87$

(g) Total Annual Inventory Cost = $1,368,000 + $6,039.87 + $6,039.87 = $1,380,079.74

(h) $T_P = \frac{EMQ}{P} = \frac{953.6633}{120} = 7.9472$ *days*

(i) $T_C = \frac{EMQ}{D} = \frac{953.6633}{40} = 23.8416$ *days*

(j) Rate of Inventory Buildup during Prod Cycle = $(P - D) = (120 - 40)$ = 80 units/day

(k) Number of Inventory Cycles = 360/23.8416 = 15.0997 times

21.

*Std Dev of Demand during Lead Time* = $\sigma_{dLT} = \sigma_d\sqrt{LT} = 4 \times \sqrt{5} = 8.94427$ *units*

*Safety Stock* = $Z\sigma_d\sqrt{LT} = 1.6449 \times 8.94427 = 14.7124$ *units*

*Statistical ROP* = $\bar{d}_{LT} + Z\sigma_d\sqrt{LT} = 15 \times 5 + 14.7124 = 89.7124$ *units*

23.

$$Safety\ Stock = (Z)\sigma_{dLT} = (Z)\sqrt{\sigma_{LT}^2(\bar{d}^2) + \sigma_d^2(\overline{LT})} = (1.6449)\sqrt{3^2(250^2) + 40^2(10)} = 1251.10\ units$$

$$Statistical\ ROP = d \times \overline{LT} + (Z)\sigma_{dLT} = 250 \times 10 + 1251.10 = 3751.10\ units$$

27.

(a) $$EOQ = \sqrt{\frac{2RS}{kC}} = \sqrt{\frac{2 \times 5000\ units \times \$100}{0.20 \times \$20}} = 500\ units$$

(b) Total purchase cost = R × C = 5000 units × $20 = $100,000
(c) Annual holding cost = Q/2 × k × C = 500 units/2 × 20% × $20 = $1000
(d) Annual ordering cost = R/Q × S = 5000 units/500 units × $100 = $1000
(e) Annual total cost = $1000 + $1000 = $2000
(f) Reorder point (ROP) = 5000/360 × 6 = 83.33 units
(g) Number of orders placed per year = 5000/500 = 10 orders
(h) Time between orders = 360/10 = 36 days
(i) Cost Curves versus Order Quantity.

29. (a) Annual Demand, D = 120 × 360 = 43,200 units/year

(b)

$$EMQ = \sqrt{\left(\frac{2RS}{kC}\right)\left(\frac{P}{P-D}\right)} = \sqrt{\left(\frac{2 \times 43{,}200 \times \$250}{.25 \times \$85}\right)\left(\frac{252{,}000}{252{,}000 - 43{,}200}\right)} = 1011.0946\ units$$

(c) $$Q_M = Q\left(1 - \frac{D}{P}\right) = 1{,}011.0946\left(1 - \frac{43{,}200}{252{,}000}\right) = 837.7641\ units$$

(d) Annual Production Cost = $R \times C = (36{,}000)^*(\$85) = \$3{,}060{,}000$

(e) Annual Holding Cost = $\left(\frac{Q_M}{2}\right)(k)(C) = \left(\frac{837.7641}{2}\right)(.25)(\$85) = \$8901.244$

(f) Annual Setup Cost = $\left(\frac{R}{Q}\right)(S) = \left(\frac{36{,}000}{1{,}011.0946}\right)(\$250) = \$8901.244$

(g) Total Annual Inventory Cost = $3,060,000 + $8901.244 + $8901.244 + $3,077,802.49

(h) $$T_P = \frac{EMQ}{P} = \frac{1011.0946}{700} = 1.4444\ days$$

(i) $$T_C = \frac{EMQ}{D} = \frac{1011.0946}{120} = 8.4258\ days$$

(j) Rate of Inventory Buildup during Prod Cycle = $(P - D) = (700 - 120) = 580$ units/day
(k) Number of Inventory Cycles = 360/8.4258 = 42.73 times

## CHAPTER 8

2. T = 64/(14.375) = 4.45 hrs or 4 hrs and 27 minutes
4. a. D = 75 parts/hr
   b. Can double containers, reduce T to 2 hrs, or increase C to 30
6. 125 defects
8. a. variable data
   b. $UCL_x = 31.2$; $LCL_x = 23.6$; $UCL_R = 11.9$; $LCL_R = 0$
10. a. $\overline{P} = 0.1167$; b. $\sigma_p = 0.1015$; c. UCL = 0.42, LCL = 0; d. Yes
12. a. $\bar{c} = 0.733$
    b. UCL = 3.3; LCL = 0

## CHAPTER 9

2. a. S2 = 22,045 units for 9 warehouses
   b. S2 = 25,456 units for 12 warehouses
   c. 22.5% increase from 6 to 9; 41.4% increase from 6 to 12

## CHAPTER 10

1. $NPV_A$ = \$2639; $NPV_B$ = \$2362; $NPV_C$ = \$3018

## CHAPTER 11

1. Location C has the lowest total cost and is best when demand is 30,000 units.
3. City of Industry has the highest total weighted score and is the best choice for the fulfilment center.
4. The Columbus site has the highest total weighted score (84.5) and is the selected site.

## CHAPTER 12

1. a. Single-factor productivities: labor—0.5 customers/labor\$; material—1.875 customers/material\$; energy—7.5 customers/energy\$; building—1 customer/lease\$.
   Multifactor productivity—0.272 customers/total\$.
   They could improve productivity by improving capacity utilization, possibly increasing the number of hours they are open or adding seats.
   b. Capacity = 3120 customers per month. Utilization = 0.48 or 48%
3. a. Labor = 1000/10800(20) = 0.005 skis/labor\$; Lease = 1000/24000 = 0.042 skis/lease\$; Material = 1000/32000 = 0.031 skis/material\$
   b. MFP = 1000/(10800(20) + 24000 + 32000) = 0.0037 skis/\$
   Growth = (.0037 − .004)/.004 = −0.075 or −7.5% growth
4. Distance traveled = 5545 m/day; you could put Depts. 4 and 5 closer together (switch 5 and 8), so the new distance = 3805 m/day.
5. 13 points; try switching Depts. 5 and 8 = 18 points
6. Two full-time and three part-time workers to fill the requirements.
8. Probability = 0.7
9. $L_s$ = 1.5 customers; $L_q$ = 0.9 customers

## CHAPTER 14

1. Current total productivity = 250/\$ 1660 = 0.151 haircuts/dollar
   Expected total productivity = 300/\$ 1685 = 0.178 haircuts/dollar (an 18% increase)
3. Labor = 4228 \$/labor\$
   Material = 9.992 \$/mat'l\$; Utility = 92,256 \$/utility\$
   Total = 9.967 \$/input\$

# Glossary

**80/20 rule** A theory originating from Pareto analysis, which suggests that most of a firm's problem "events" (80 percent) are accounted for by just a few (20 percent) of the problems; can also be applied to other areas, such as ABC inventory control, which says that 80 percent of the inventory dollars come from 20 percent of the inventory items.

## A

**artificial intelligence** Self-learning machines.

**ABC inventory control system** A useful technique for determining which inventories should be managed more closely and which others should not (A-items are the most important).

**ABC inventory matrix** A diagram that illustrates whether a firm's physical inventory matches its inventory usage. It is derived by plotting an ABC analysis based on inventory usage classification on the vertical axis and an ABC analysis based on physical inventory classification on the horizontal axis.

**acceptance sampling** In purchasing, it is a statistical screening technique that can be used to determine whether or not a shipment will be accepted, returned to the supplier or used for billback purposes when defects are fixed or units are eliminated by the buyer.

**active RFID tags** An RFID tag that is equipped with an onboard power supply to power the integrated circuits and broadcast its signal to the tag reader.

**additive manufacturing or 3D printing** A process of making a three-dimensional solid object of virtually any shape from a digital model.

**aggregate production plan (APP)** A long-range production plan; it sets the aggregate output rate, workforce size, utilization, inventory and backlog levels for a plant.

**air carriers** For-hire airlines.

**airline security** Protection that is provided for airlines against terrorist attacks and other illegal activities.

**analytic SRM** A method that allows the company to analyze the complete supplier base.

**arrival pattern** The frequency with which customers arrive at a business.

**assignable variations** Process variations that can be traced to a specific cause. Assignable variations are created by causes that can be identified and eliminated and thus become the objective of statistical process control efforts.

**Association of Southeast Asian Nations (ASEAN)** An economic and geopolitical organization created in 1967 that today comprises the following countries in the Southeast Asian region: Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam. The primary objective of ASEAN is to promote economic, social and cultural development of the region through cooperative programs.

**attribute data** Yes/no kinds of data. These indicate the presence of some attribute such as color, satisfaction, workability or beauty (for instance, determining whether or not a car was painted the right color, if a customer liked the meal, if the lightbulb worked or if the dress was pretty).

**available-to-promise (ATP) quantity** The uncommitted portion of a firm's planned production. It is used to promise new customer orders.

## B

**back-of-the-house operations** Those services that do not require customer contact.

**backward vertical integration** Acquiring upstream suppliers.

**balanced scorecard (BSC)** A management system developed in the early 1990s by Robert Kaplan and David Norton that helps companies to continually refine their vision and strategy. The balanced scorecard uses a set of measures to provide feedback on internal business performance in order to continually improve strategic performance. Also referred to as scorecarding.

**balking** Refusing to join a queue once it is seen how long it is.

**barter** The complete exchange of goods and/or services of equal value without the exchange of currency. The seller can either consume the goods and/or services or resell the items.

**Baumol's disease** A productivity growth problem named after noted U.S. economist William Baumol in the 1960s. For most services, automation can be a troublesome issue, and the labor content per unit of output can be quite high relative to manufactured goods. These two things can lead to a declining productivity growth rate as a nation's economy becomes less manufacturing oriented and more service oriented.

**benchmarking** The practice of copying what other businesses do best; studying how things are done well in other firms to potentially make use of the same methods.

**best-of-breed solution** An ERP system that picks the best application or module for each individual function.

**bid** When suppliers respond to a buyer's invitation to bid, with an offered price for specific services or goods.

**big data** Collections of data sets that are too large and complex to be processed by traditional database management tools or data processing software applications.

**big data analytics** As the number of customers grows for large businesses, their transactions and the desire to analyze all of this information also grows, which requires big data analytics.

**billback penalty** A fee charged back to the supplier for services or products not received by the customer.

**bill of materials (BOM)** An engineering document that shows an inclusive listing of all component parts and assemblies making up the final product.

**blank check purchase order** A small value purchase order with a signed blank check attached, usually at the bottom of the purchase order.

**blanket order release** A form used to release a specific quantity against a prenegotiated blanket purchase order.

**blanket purchase order** A purchase order that covers a variety of items and is negotiated for repeated supply over a fixed time period, such as quarterly or yearly.

**break-even analysis** A tool for computing the cost-effectiveness of sourcing decisions when cost is the most important criterion. Several assumptions underlie the analysis: (1) all costs involved can be classified as either fixed or variable cost, (2) fixed cost remains the same within the range of analysis, (3) a linear variable cost relationship exists, (4) fixed cost of the make option is higher because of initial capital investment in equipment, and (5) variable cost of the buy option is higher due to supplier profits.

**bullwhip effect** A term referring to ineffective communication between buyers and suppliers and infrequent delivery of materials, combined with production based on poor forecasts along a supply chain that results in either too little or too much inventory at various points of storage and consumption. Simply, it causes an amplification of the variation in the demand pattern along the supply chain.

**business clusters** According to Dr. Michael Porter, "clusters are geographic concentrations of interconnected companies and institutions in a particular field. Clusters encompass an array of linked industries and other entities important to competition."

**business cycle** Alternating periods of expansion and contraction in economic activity.

**business ethics** The application of ethical principles to business situations.

**business process reengineering (BPR) or reengineering** The radical rethinking and redesigning of business processes to reduce waste and increase performance.

**Buy American Act** Legislation mandating that U.S. government purchases and third-party purchases that utilize federal funds must buy domestically produced goods, if the price differential between the domestic product and an identical foreign-sourced product does not exceed a certain percentage amount.

## C

**Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP)** The trade agreement includes eleven countries, which came into force on December 30, 2018. This agreement evolved from the original Trans-Pacific Partnership after the US left the group in 2017.

**climate change** Global warming problems.

**continuous improvement** A quality-oriented goal—to continuously strive for quality improvement.

**circular economy** An economic system aimed at eliminating waste and the continual use of resources

**call centers or customer contact centers** Customer service departments that integrate all of the methods customers can use to contact a business, including telephone, mail, comment cards, email, and website messages and chat rooms.

**capacity requirements planning (CRP)** A shortrange capacity planning technique that is used to check the feasibility of the material requirements plan.

**capacity utilization** The actual customers served per period divided by capacity.

**capacity** The output capabilities of a firm's labor and machine resources.

**carbon footprints** A firm's or supply chain's total carbon emissions.

**cause-and-effect diagrams** Also called fishbone diagram or Ishikawa diagram. A method that is used to aid in brainstorming and isolating the causes of a problem. Typically there are four causes of problems (the 4-Ms).

**cause-and-effect forecasting** A forecasting method that uses one or more factors (independent variables) that are related to demand to predict future demand.

**C charts** Counts the number of defects per unit of output.

**centralized/decentralized purchasing structure** A hybrid purchasing structure that is centralized at the corporate level but decentralized at the individual business unit level.

**centralized purchasing** A single purchasing department, usually located at the firm's corporate office, makes all the purchasing decisions, including order quantity, pricing policy, contracting, negotiations, and supplier selection and evaluation.

**centralized warehousing system** Fewer warehouses means that outbound transportation costs will be higher.

**chase demand strategy** A strategy that is used when the amount of capacity varies with demand. See also chase production strategy.

**chase production strategy** A production strategy that adjusts output to match the demand pattern during each production period.

**check sheets** A tool that allows users to determine the frequencies of specific problems.

**Civil Aeronautics Act of 1938** Legislation that promoted the development of the air transportation system, air safety, and airline efficiency by establishing the Civil Aeronautics Board to oversee market entry, establish routes with appropriate levels of competition, develop regional feeder airlines and establish reasonable rates. The Civil Aeronautics Administration was also established to regulate air safety.

**class rates** The transportation rates based on the particular class of the product transported; some products have higher published class rates than others. Rates are based on an evaluation of four transportation characteristics: density, stowability, handling and liability.

**clickstreams** A record of the items that a specific customer clicks on when visiting a website.

**closed-loop MRP** An MRP-based manufacturing planning and control system that incorporates aggregate production planning, master production scheduling, material requirements planning and capacity requirements planning.

**closeness desirability rating** A scale used to rate how desirable it is to have two departments close together. The objective is to design a layout that maximizes the desirability rating for the entire facility.

**cloud-based communication platforms** An Internet-based platform that provides greater visibility, ensures faster time to market, and offers faster response to changing market dynamics and demands.

**cloud-based forecasting** Using supplier-hosted or software-as-a-service (SaaS) advanced forecasting applications that are provided to companies on a subscription basis.

**cloud computing** When shared resources and other information are made available to users over the Internet, usually for a subscription fee. It allows small businesses, for example, to make use of sophisticated software without actually making the purchase; also termed *on-demand computing*.

**coal slurry** Pulverized coal that is suspended in water.

**cold chains** Refer to temperature controlled transportation, transfers, and warehousing.

**collaborative education** Providing training for supply chain partner employees.

**collaborative negotiations/integrative or win–win negotiations** The process that occurs when both sides work together to maximize the joint outcome, or to create a win-win result; also referred to as integrative negotiations.

**collaborative planning, forecasting, and replenishment (CPFR)** According to the Council of Supply Chain Professionals, "CPFR seeks cooperative management of inventory through joint visibility and replenishment of products throughout the supply chain. Information shared between suppliers and retailers aids in planning and satisfying customer demands through a supportive system of shared information. This allows for continuous updating of inventory and upcoming requirements, essentially making the end-to-end supply chain process more efficient. Efficiency is also created through the decrease expenditures for merchandising, inventory, logistics, and transportation across all trading partners."

**co-managed inventories** A somewhat more collaborative form of VMI; can also refer to JIT II buyer and supplier reach an agreement regarding how information is shared, order quantities, when an order is generated, and the delivery timing and location.

**commodity rates** Rates that apply to minimum quantities of specified products that are shipped between two specified locations.

**Common Market for Eastern and Southern Africa (COMESA)** A customs union established to foster economic growth among the member countries of Burundi, Comoros, D. R. Congo, Djibouti, Egypt, Eritrea, Ethiopia, Kenya, Libya, Madagascar, Malawi, Mauritius, Rwanda, Seychelles, Sudan, Swaziland, Uganda, Zambia, and Zimbabwe.

**consolidation warehouses** Warehouses that collect large numbers of LTL shipments from nearby regional sources of supply, then deliver in TL or CL quantities to a manufacturer.

**consumer's risk** The risk assumed when a buyer accepts a shipment of poor-quality units because the sample did meet the acceptance standard; this results in a type-II error.

**container-on-flatcar (COFC)** A form of intermodal transportation; standardized shipping containers are transported via rail flatcar, and they can also be placed on a truck chassis or on an ocean-going container ship.

**continuous review system** An inventory management system where the physical inventory levels are counted on a continuous or daily basis.

**Contracts for the International Sale of Goods (CISG)** A set of rules established by the United Nations to govern the international transactions in goods.

**contributor factory** A manufacturing facility that plays a greater strategic role than a server factory by getting involved in product development and engineering, production planning, making critical procurement decisions and developing suppliers.

**control charts** A method that monitors process variabilities and then collects and plots sample measurements of the process over time. The means of these sample measures are plotted on the control charts.

**corporate social responsibility (CSR)** The practice of business ethics.

**cost leadership strategy** Competing based on a low cost strategy.

**cost-of-service pricing** A pricing strategy used when carriers desire to establish prices that vary based on their fixed and variable costs.

**counterpurchase** A trade arrangement whereby the original exporter either buys or finds a buyer to purchase a specified quantity of unrelated goods and/or services from the original importer.

**countertrade** A global sourcing process in which goods and/or services of domestic firms are exchanged for goods and/or services of equal value or in combination with currency from foreign firms. This type of arrangement is sometimes used by countries where there is a shortage of hard currency or as a means to acquire technologies.

**critical-to-quality (CTQ) characteristics** Those characteristics related to customers and their service or product requirements that are critical to achieving customer satisfaction.

**crossdocking** A continuous replenishment logistics process at a distribution center, where incoming goods are sorted and/or consolidated, and then shipped out to their final destinations, without the need to store the goods. Cross-docking generally takes place within 24 hours, sometimes less than an hour, after shipment arrivals and is used to replenish high demand inventories.

**cross-selling** Purchasing that occurs when customers are sold additional products as the result of an initial purchase.

**C-TPAT compliance** A partnership among U.S. Customs, the International Cargo Security Council, and Pinkerton (a global security advising company), whereby companies agree to improve security in their supply chain in return for "fast lane" border crossings at both the U.S./Canadian and U.S./Mexican borders.

**customer churn** The rate at which customers leave or stop using a firm.

**customer defection analysis** Information that analyzes why customers stop using a particular business.

**customer lifetime value (CLV)/customer value or customer profitability** Assigning a profit figure to each customer by summing the margins of all the products and services purchased over time, less the cost of marketing to and maintaining that customer, such as the costs of direct mail and sales calls and the service costs for each customer. Additionally, the firm forecasts future purchased quantities, profit margins, and marketing costs for each customer, discounts these back to the current date and then adds this projected profit quantity to the current profit amount. Also known as customer value or customer profitability.

**customer relationship management** Managing a firm's customer base such that customers remain satisfied and continue to purchase goods and services. Sometimes it also refers to CRM software applications.

**customer relationship management process** Provides the firm with the structure for developing and managing customer relationships.

**customer service** The provision of information, help, and/or technical support to customers in a way that meets or exceeds customer expectations.

**customs brokers** Global logistics intermediaries that move international shipments through customs for companies as well as handle the necessary documentation required to accompany the shipments.

**Customs-Trade Partnership Against Terrorism program (C TPAT)** A partnership between U.S. Customs, the International Cargo Security Council (a U.S. nonprofit association of companies and individuals involved in transportation) and Pinkerton (a global security advising company, headquartered in New Jersey), whereby companies agree to improve security in their supply chain in return for "fast lane" border crossings.

**cycle counting** A commonly used technique in which physical inventory is counted on a periodic basis to ensure that physical inventory matches current inventory records.

## D

**demand sensing** A way of identifying short-term trends quickly so companies can better forecast what, when, and where consumers want goods.

**data warehouse** Information system structures used to store data that was collected from the various divisions of the firm.

**decentralized/centralized purchasing structure** A hybrid purchasing structure that is decentralized at the corporate level but centralized at the individual business unit level.

**decentralized purchasing** Individual, local purchasing departments, such as at the plant level, make their own purchasing decisions.

**decentralized warehousing system** Used when faster delivery service is required. As the number of warehouses used increases, the system becomes more decentralized.

**deep-sea transportation** Ocean-going water carriers. The development and use of supertankers and containerships are examples.

**defects per million opportunities (DPMO)** A Six Sigma quality metric.

**demand forecast updating** When buyers place purchase orders, suppliers use this information to revise their demand forecasts.

**demand management** A set of activities that range from determining or estimating the demand from customers through converting specific customer orders into promised delivery dates to help balance demand with supply.

**demand management process** The steps used for balancing customer demand and the firm's output capabilities.

**demand time fence** A firmed planning segment that is used with the MRP application; it usually stretches from the current period to a period several weeks into the future.

**Department of Defense (DOD)** A major public buyer within the U.S. government.

**Department of Transportation Act** Legislation that created the Department of Transportation (DOT) in 1966 to coordinate the executive functions of all government entities dealing with transportation related matters.

**dependent demand** The internal demand for parts based on the demand of the final product in which the parts are used.

**differentiation strategy** A business approach that is based on creating a product or service that is considered unique. Usually associated with high quality.

**direct costs** Costs that are directly traceable to the unit produced, such as the amount of materials and labor used to produce a unit of the finished good.

**direct offset** A form of countertrade that usually involves coproduction, or a joint venture, and exchange of related goods and/or services.

**distribution center** A warehouse that performs breakbulk activities and then forms outbound specific product assortments that are then shipped to the customer.

**distribution network** The organization of a distribution system that ensures successful product delivery.

**distribution requirements plan (DRP)** A time-phased finished goods inventory replenishment plan in a distribution network.

**Distribution requirements planning (DRP)** The time-phased net requirements from central supply warehouses and distribution centers. It links production with distribution planning by providing aggregate time-phased net requirements information to the master production schedule.

**distributive negotiations** A negotiating objective that seeks an outcome that primarily favors the interests of one side.

## E

**early supplier involvement (ESI)** Involving key suppliers during the product design and development stage to take advantage of their knowledge and technologies.

**eatertainment** The combining of restaurant and entertainment elements.

**economic manufacturing quantity (EMQ) or production order quantity (POQ) model** A variation of the classic EOQ model, used to determine the most economical number of units to produce.

**economic order quantity (EOQ) model** The classic independent demand inventory system that computes the optimal order quantity to minimize total inventory costs.

**economies of scale** A theory stating that the cost per unit decreases as the number of units purchased, produced or transported increases.

**edutainment or infotainment** The combining of learning with entertainment to appeal to customers looking for substance along with play.

**efficient consumer response (ECR)** developed by a U.S. grocery industry task force charged with making grocery supply chains more competitive. Point-of-purchase transactions at grocery stores were forwarded via computer to distributors and manufacturers, allowing the stores to keep stocks replenished while minimizing the need for safety stock inventories.

**electronic data interchange (EDI)** A computer-to-computer exchange of business documents such as purchase orders, order status inquiries and reports, promotion announcements and shipping and billing notices.

**emergency sourcing** The act of maintaining a backup source of supply available to provide purchased items when the primary source has temporarily become unavailable.

**empty miles** The trucks that return empty after their delivery; these return journeys cause big energy wastes.

**enterprise resource planning (ERP)** A packaged business software system that lets a company automate and integrate the majority of its business processes, share common data and practices across the enterprise and produce and access information in a real-time environment.

**entertailing** The combining of retail locations with entertainment elements—such as offering ice skating, rock climbing and amusement park rides at a shopping mall.

**environmental management system (EMS)** The practices put in place by a firm to try to reduce environmental waste and improve environmental performance.

**environmental sustainability** The need to continually protect the environment and reduce greenhouse gas emissions.

**equipment setups** The steps required to prepare production equipment for the next product to be produced.

**ethical and environmental certifications** Certifying companies according to ethical and environmental requirements. A number of certifying agencies can be used, such as the New York-based Rainforest Alliance and Trans-Fair USA.

**ethical and sustainable sourcing** Purchasing from suppliers that are governed by environmental sustainability and social and ethical practices.

**ethical sourcing** The practice of purchasing from suppliers that are governed by social and ethical practices.

**Ethical Trading Initiative (ETI)** An alliance of organizations seeking to take responsibility for improving working conditions and agreeing to implement the ETI Base Code, a standard for ethical practices for the firms and its suppliers.

**European Union (EU)** A European international trade organization designed to reduce tariff and nontariff barriers among member countries. Set up after the Second World War, the EU was officially launched on May 9, 1950, with France's proposal to create a European federation consisting of six countries: Belgium, Germany, France, Italy, Luxembourg, and the Netherlands. A series of accessions resulted in a total of 28 member states in 2013. Most recently, the EU has added Iceland, Montenegro, Serbia, Republic of Macedonia and Turkey.

**event-based marketing** A marketing strategy that offers the right products and services to customers at the right time.

**everyday low pricing (EDLP)** The elimination of price discounting and offering wholesale prices to customers. Helps reduce the bullwhip effect.

**exception rates** Published rates that are lower than class rates for specific origin-destination locations or volumes.

**exempt carriers** For-hire carriers that are exempt from the regulations of services and rates. They transport certain exempt products such as produce, livestock, coal, garbage, or newspapers.

**expediting** The act of contacting the supplier to speed up an overdue shipment.

## F

**fishbone diagrams** Used to aid in brainstorming and isolating the causes of a problem.

**first-tier suppliers** The direct suppliers of the focal firm.

**first-tier customers** The direct customers of the focal firm.

**facilitating products** Products such as computers, furniture, and office supplies that are not part of the services sold but rather are consumed inside the firm and must also be managed.

**fair trade products** A product manufactured or grown by a disadvantaged producer in a developing country that receives a fair price for its goods.

**Federal Acquisition Regulation (FAR)** The primary set of rules issued by the U.S. government to govern the process through which the government purchases goods and services.

**Federal Acquisition Streamlining Act (FASA)** A federal act signed by President Clinton in October 1994 to remove many restrictions on government purchases that do not exceed $100,000.

**Federal Aviation Act of 1958** Legislation that replaced the Civil Aeronautics Administration with the Federal Aviation Administration (FAA) and gave the FAA authority to prescribe air traffic rules, make safety regulations and plan the national airport system.

**five dimensions of service quality** Five categories used by customers to rate service quality: reliability, responsiveness, assurance, empathy, and tangibles.

**five-Ss** Five Japanese words, coming originally from Toyota, that relate to industrial housekeeping. The idea is that by implementing the five-Ss, the workplace will be cleaner, more organized and safer, thereby reducing processing waste and improving productivity.

**five-why** When something is found to be missing or out of place, the solution should be to repeatedly ask "why?" until the root (or most basic) cause is found and corrected. Until why is asked five times, the root cause has probably not been identified.

**fixed costs** Costs that are independent of the output quantity.

**fixed order quantity models** Independent demand inventory models that use fixed parameters to determine the optimal order quantity to minimize total inventory costs.

**flow diagrams/process diagrams/process maps** Tools that use annotated boxes representing process action elements and ovals representing wait periods, connected by arrows to show the flow of products or customers through the process. These tools are the necessary first step to evaluating any manufacturing or service process.

**FOB destination pricing** A price quotation that includes transportation to the buyer's location when products are purchased from a supplier.

**FOB origin pricing** A price quotation in which the buyer may decide to purchase goods and provide the transportation to the shipping destination; in this case, the supplier quotes are lower.

**focus strategy** A business approach incorporating the idea that a firm can serve a narrow target market or niche better than other firms that are trying to serve a broad market.

**follow-up** A proactive act to contact the supplier to ensure on-time delivery of the goods ordered.

**forecast bias** A measure of the tendency of a forecast to be consistently higher (negative bias) or lower (positive bias) than the actual demand.

**forecast error** The difference between actual demand and the forecast.

**foreign freight forwarders** Service providers that move goods for companies from domestic production facilities to foreign customer destinations, using surface and air transportation and warehouses. They consolidate small shipments into larger TL, CL or container shipments, decide what transportation modes and methods to use, handle all of the documentation requirements and then disperse the shipments at their destination.

**foreign-trade zones (FTZs)** Secure sites within the United States under the supervision of the U.S. Customs Service. These are where materials can be imported duty-free as long as the imports are used as inputs to production of goods that are eventually exported.

**forward buying** When buyers stock up to take advantage of low price offers.

**forward vertical integration** Acquiring downstream customers.

**franchising** A business practice that allows services to expand quickly in dispersed geographic markets, protect existing markets and build market share. Franchisees are required to invest some of their own capital, while paying a small percentage of sales to the franchiser in return for the brand name, start-up help, advertising, training and assistance in meeting specific operating standards.

**Free and Secure Trade program (FAST)** A U.S. Customs' security program; the overall goal is to ensure the security of international supply chains and international trucking in particular. To participate in FAST, motor carriers must become C-TPAT certified and their commercial drivers must complete an application and undergo a background check.

**freight brokers** Legally authorized intermediaries that bring shippers and transportation companies (mainly truckers) together.

**front-of-the-house operations** Operations that are involved with interactions with customers, such as front desk operations.

**functional products** MRO items and other commonly purchased items and supplies. These items are characterized by low profit margins, relatively stable demands and high levels of competition.

**functional silos** Departments in a firm that are only concerned with what is going on in their department and not what is in the best interests of the firm.

## G

**Government travel charge card** A travel P-card that provides government employees with a safe, effective, and convenient method to pay for expenses related to official travel.

**general freight carriers** The carriers transporting the majority of goods shipped in theUnited States; includes common carriers.

**General Services Administration (GSA)** A U.S. federal agency that is responsible for most federal purchases. It is based in Washington, D.C., and has 11 regional offices throughout the United States.

**global sourcing** Purchasing from non-domestic suppliers.

**global supply chains** Supply chains with foreign trading partners.

**global trade management systems** Software that enables shippers and carriers to submit the correct import/export documents as goods are moved between countries.

**green development** The implementation of environmentally friendly development.

**green purchasing** A practice aimed at ensuring that purchasing personnel include environmental considerations and human health issues when making purchasing decisions; also termed *green sourcing* and *sustainable procurement*.

**green reverse logistics programs** Systems that focus on reducing the environmental impact of certain modes of transportation used for returns, reducing the amount of disposed packaging and product materials by redesigning products and processes, and making use of reusable totes and pallets.

**green supply chain management (GSCM)** An organizational approach that extends the concept of green logistics to include activities related to environmentally responsible product design, acquisition, production, distribution, use, reuse and disposal by partners within the supply chain.

## H

**high-speed trains** Passenger trains that typically average 70 miles per hour or greater.

**holding or carrying costs** The costs incurred for holding inventory in storage.

**horizontal collaboration** Two or more companies cooperating at the same level on a certain activity to realize benefits they could not achieve independently.

**hybrid purchasing organization** A firm that uses either a centralized–decentralized or decentralized–centralized purchasing structure.

## I

**integrative negotiations** Both sides work together to maximize the joint outcome or to create a joint optimal result.

**ICC Termination Act of 1995** Legislation that eliminated the Interstate Commerce Commission.

**implosion** When demand information is gathered from a number of field distribution centers and aggregated in the central warehouse, and eventually passed onto the manufacturing facility.

**import broker or sales agent** A firm that is set up to import goods for customers for a fee. An import broker does not take title to the goods.

**import merchant** A firm that imports and takes title to the good, and then resells them to a buyer.

**incoterms (International Commercial Terms)** A uniform set of rules created by the International Chamber of Commerce to simplify international transactions of goods with respect to shipping costs, risks and responsibilities of the buyer, seller and shipper.

**indented bill of materials** Indentations are used to present the level number within the bill of materials; also known as the multilevel bill of materials.

**independent demand** The demand for final products and service parts. It has a demand pattern that is affected by trends, seasonal patterns and general market conditions.

**indirect costs** Those costs that cannot be traced directly to the unit produced and are synonymous with manufacturing overhead.

**indirect offset** A form of countertrade that involves an exchange of goods and/or services unrelated to the initial purchase.

**industrial buyers** Buyers with a primary responsibility of purchasing raw materials for conversion purposes.

**information visibility** The degree that information is communicated and made available to various constituents, typically on the Internet.

**innovative products** Newly developed products characterized by short product life cycles, volatile demand, high profit margins and relatively less competition.

**intermediately positioned strategy** A location strategy that places warehouses midway between the sources of supply and the customers.

**intermediate or medium-range planning horizon** A planning horizon that covers six to eighteen months.

**intermodal marketing companies (IMCs)** Companies that act as intermediaries between intermodal railroad companies and shippers.

**intermodal transportation** Two or more modes of transportation that combine to deliver a shipment of goods.

**internal supply chains** An organization's network of internal suppliers and internal customers. Internal supply chains can be complex, particularly if the firm has multiple divisions and organizational structures around the globe.

**inventory turnover** The number of times a firm's inventory is utilized and replaced over an accounting period, such as a year.

**inventory turnover ratio or inventory turnovers** A widely used measure to analyze how efficiently a firm uses its inventory to generate revenue.

**inventory visibility** The ability of supply chain companies to see inventory quantities of the various members, typically using the Internet.

**invitation for bid (IFB)** A request for qualified suppliers to submit bids for a contract. Suppliers are asked to bid, given certain opening and closing dates of the bid. The basis for awarding a contract is preset and binding.

**ISO 14000** A family of international standards for environmental management developed by the International Organization for Standardization (ISO).

## J

**just-in-time (JIT)** Originally associated with Toyota managers like TaiichiOhno and his kanban system, JIT encompasses continuous problem solving to eliminate waste. Today it is also referred to as lean or lean thinking.

## K

**kaizen** Ways to reduce supplier delivery and quality problems, solve movement problems, visibility problems, machine breakdown problems, machine setup problems, and internal quality problems.

**kaizen blitz** A rapid improvement event or workshop, aimed at finding big improvements.

**kanban** A Japanese word for "card"; it is a visual tool used in lean production.

**keiretsu relationships** Partnership arrangements between Japanese manufacturers and suppliers.

**key supply chain processes** The eight processes that are most important to integrate in the supply chain.

**key trading partners** Suppliers that have come to be trusted and that provide a large share of the firm's critical products and services; and repeat, satisfied customers that buy a significant portion of the firm's products.

**knowledge management solutions** A system that uses Internet applications tied to desktop applications that enable real-time collaboration and flow of information between supply chain partners.

**knowledge management system** A system that is able to capture the accumulated knowledge of experienced sales staff and other skilled personnel if they leave an organization.

## L

**load board** A site where shippers can post loads for motor carriers to see, and motor carriers can post truck availabilities and locations for shippers to see.

**lag capacity strategy** A reactive approach that adjusts capacity in response to demand.

**lead capacity strategy** A proactive approach that adds or subtracts capacity in anticipation of future market condition and demand.

**lead factory** A source of product and process innovation and competitive advantage for the entire organization.

**lead management system** A tool that allows sales reps to follow prescribed sales tactics when dealing with sales prospects or opportunities, to aid in closing the deal with a client.

**lean layouts** Arrangements that reduce wasted movements of workers, customers and/or work-in-process (WIP), and achieve smooth product flow through the facility.

**lean production/lean manufacturing/lean thinking** Organizing work and analyzing the level of waste existing in operating machinery, warehouses and systems to fit a lean process flow. The goals are to reduce production throughput times and inventory levels, cut order lead times, increase quality and improve customer responsiveness with fewer people and other assets.

**lean production system** Also known as a pull system, where parts are placed in standardized containers, and kanbans exist for each container.

**Lean Six Sigma/Lean Six** A new term used to describe the melding of lean production and Six Sigma quality practices.

**lean supply chain relationships** The relationships that occur when the focal firm, its suppliers and its customers begin to work together to identify customer requirements, remove waste, reduce cost and improve quality and customer service.

**lean warehousing** When warehousing, crossdocking, packaging and freight consolidation is offered to companies who are looking to increase speed and reduce costs as much as possible to compete.

**legacy MRP system** A broad label used to describe an older information system that usually works at an operational level to schedule production within a single facility.

**legacy systems** A firm's existing software applications.

**less-than-truckload (LTL) carriers** Carriers that move small packages or shipments taking up less than one truckload; the shipping fees are higher per hundred weight (cwt) than TL fees, since the carrier must consolidate many small shipments into one truckload, then break the truckload

back down into individual shipments at the destination for individual deliveries.

**level demand strategy** A theory for managing capacity that occurs when a firm utilizes a constant amount of capacity regardless of demand variations.

**level production strategy** Using a constant output rate and capacity while varying inventory and backlog levels to handle the fluctuating demand pattern.

**leveraging purchase volume** The concentration of purchase volume to create quantity discounts, less-costly volume shipments and other more favorable purchase terms.

**linear trend forecast** A forecasting method in which the trend can be estimated using simple linear regression to fit a line to a time series of historical data.

**line haul rates** The charges for moving goods to a nonlocal destination; these can be further classified as class rates, exception rates, commodity rates and miscellaneous rates.

**logistics** The practice of moving and storing goods to meet customer requirements for the minimum cost.

**logistics brokers** Legally authorized intermediaries that bring shippers and transportation companies (mainly truckers) together.

**long-range planning horizon** A planning horizon that covers a year or more.

## M

**mixed production strategy** A strategy that strives to maintain a stable core workforce while using other short-term means such as overtime, an additional shift, subcontracting, or the hiring of part-time and temporary workers to meet short-term high demand.

**machine learning** Self-learning machines.

**multi-channel fulfillment** Allowing consumers to shop for what they want, where they want, and when they want, and then have their purchases delivered quickly and consistently.

**make or buy decision** A strategic one that can impact an organization's competitive position. It is obvious that most organizations buy their MRO and office supplies rather than make the items themselves.

**make-to-order manufacturing firms** Firms that make custom products based on orders from customers, resulting in long lead times and higher unit costs.

**make-to-stock** Firms that typically emphasize immediate delivery of off-the-shelf, standard goods at relatively low prices compared to the chase strategy.

**manufacturing cells or work cells** Cells that are designed to process similar parts or components, saving duplication of equipment and labor as well as centralizing the area where units of the same purchased part are delivered.

**manufacturing flow management process** The set of activities responsible for making the actual product, establishing the manufacturing flexibility required to adequately serve the markets, and designing the production system to meet cycle time requirements.

**manufacturing resource planning (MRP-II)** An outgrowth and extension of the original closed loop MRP system.

**market positioned strategy** A location strategy that places warehouses close to customers, to maximize customer service and to allow the firm to generate transportation economies by using inbound TL and CL deliveries to each warehouse location.

**master production schedule (MPS)** A medium range production plan that is more detailed than the aggregate production plan.

**match or tracking capacity strategy** A moderate strategy that adjusts capacity in small amounts in response to demand and changing market conditions.

**material requirements plan (MRP)** A software application that has been available since the 1970s; it performs an analysis of the firm's existing internal conditions and reports back what the production and purchase requirements are for a given finished product manufacturing schedule.

**material requirements planning** Use of the MRP.

**material requisition (MR)** An internal document initiated by the material user to request materials from the warehouse or purchasing department.

**maximize competition** The competition that is designed for ensuring the purchases of goods and services that are in strict compliance with statutes and policies, public procurement procedures.

**merchant buyers** Firms that buy goods in large quantities for resale purposes. Wholesalers and retailers are examples of merchants.

**microfranchise** A type of franchising concept that offers ready-made, low-risk starter jobs to people with no education and little available capital while giving established companies additional distribution avenues.

**micro-purchases** Government purchases of less than $2,500.

**miscellaneous rates** Contract rates that are negotiated between two parties involving shipments containing a variety of products (in the typical case, the rate is based on the overall weight of the shipment).

**mixed Internet distribution strategy** The combining of traditional retailing with Internet retailing.

**mobile marketing** An advertising technique that places advertising messages on mobile phones.

**Motor Carrier Act of 1935** Legislation that brought motor carriers under ICC control, thus controlling entry into the market, establishing motor carrier classes of operation, setting reasonable rates, requiring ICC approval for any mergers or acquisitions, and controlling the issuance of securities.

**motor carriers** Trucks; the most flexible mode of transportation, accounting for almost one-third of all U.S. for-hire transportation.

**muda** A Japanese word meaning waste or anything that does not add value.

**multiple-channel queuing system** A system in which multiple servers act in parallel.

**multiple-factor productivity** Inputs that can be represented by the sum of labor, material, energy and capital costs.

**multiple-phase queuing system** A system in which multiple servers act in series.

**multiple regression forecast** A forecast technique using multiple regression.

## N

**naïve forecast** A forecasting approach where the actual demand for the immediate past period is used as a forecast for next period's demand.

**natural variations** Variations that are random and uncontrollable with no specific cause; also termed *environmental noise* or *white noise*.

**near field communication (NFC)** A secure form of data exchange between an NFC tag or Android-powered device with another Android-powered device. NFC is a specialized subset of RFID technology.

**negotiated pricing** Transportation pricing that is agreed upon by both parties.

**nontariff barriers** Import quotas, licensing agreements, embargoes, laws, and other regulations imposed on imports and exports.

**non-vessel operating common carriers (NVOCC)** Carriers that operate very similarly to international freight forwarders but normally use scheduled ocean liners.

## O

**operations management** Managing the processes of buying, making, and delivering goods and services.

**Ocean Shipping Reform Act of 1998** Legislation that eliminated the requirement for ocean carriers to file rates with the Federal Maritime Commission.

**offset** An exchange agreement for industrial goods and/or services as a condition of military- related export. It is also commonly used in the aerospace and defense sectors.

**offshore factory** A firm that manufactures products at low cost with minimum investment in technical and managerial resources in low labor cost countries, then exports all of its finished goods.

**open-end purchase order** A purchase order that covers a variety of items and is negotiated for repeated supply over a fixed time period, such as quarterly or yearly. Additional items and expiration dates can be renegotiated in an open-end purchase order.

**opportunities for a defect to occur (OFD)** The number of activities or steps in a product wherein a defect could occur. Used in the DPMO calculation.

**option overplanning** Raising the final requirements of component parts beyond 100 percent in a super bill of materials to cover uncertainty.

**order batching** A type of inventory control that occurs when small orders are combined into one large order. This amplifies demand variability and adds to the use of safety stock, creating the bullwhip effect.

**order costs** Direct variable costs associated with placing an order with a supplier.

**order fulfillment process** The set of activities that allows a firm to fill customer orders while providing the required levels of customer service at the lowest possible delivered cost.

**original equipment manufacturers (OEM)** The companies that make the final products.

**outpost factory** A manufacturing facility that is set up in a location with an abundance of advanced suppliers, competitors, research facilities and knowledge centers to get access to the latest information on materials, components, technologies and products.

**outsource** The process that occurs when a firm purchases materials or products instead of producing them in-house.

## P

**performance measurement** The process of quantifying the efficiency and effectiveness of various activities.

**Pareto analysis** A graphic technique that prioritizes the most frequently occurring problems or issues. The analysis recommends that problems falling into the most frequently occurring category be assigned the highest priority and managed closely.

**Pareto charts** A useful method for organizing applications of data in many formats; based on the work of Vilfredo Pareto, a nineteenth-century economist.

**Pareto principle** Refers to the observation that 20 percent of something is typically responsible for 80 percent of the results.

**part families** Similarly processed parts in a manufacturing cell.

**passive RFID tags** RFID tags that are without an internal power source and require power from a tag reader.

**payment bonds** Bonds posted by the bidders to protect the buyer against any third-party liens not fulfilled by the successful bidder.

**P charts** Monitors the percent defective in each sample.

**perceived waiting times** An aspect of queue management that occurs when customers think the wait time is much longer or shorter than it really is.

**perfect order** An order that did arrive on time, complete and damage free.

**performance bonds** Bonds posted by the bidders to guarantee that the work done by the successful bidder meets specifications and is completed in the time specified.

**performance dashboards** Web-based balanced scorecard applications.

**performance variance** The difference between the standard and actual performance.

**periodic review system** A review of physical inventory at specific points in time.

**petty cash** A small cash reserve maintained by a midlevel manager or clerk.

**piggyback service** A type of intermodal transportation involving the loading of shipping containers or truck trailers on a rail flatbed car; also known as container-on-flat-car (COFC) and trailer-on-flat-car (TOFC).

**pipeline carriers** One of the five modes of transportation; carries oil, natural gas, coal slurry and other liquids/gases.

**place utility** A situation that is created when customers get things delivered to the desired location.

**planned order releases** The bottom line of an MRP part record. It designates when the specific quantity is to be ordered from the supplier or to begin being processed. These quantities also determine the gross requirements of the dependent or "children" parts going into this higher level part or product.

**planning factor** A calculation showing the number of units of a specific component required to make one unit of a higher-level part.

**planning time fence** A period typically stretching from the end of the firmed segment to several weeks farther into the future; also known as the tentative segment.

**poka-yoke** Error- or mistake-proofing.

**posttransaction costs** Costs are incurred after the goods are in the possession of the company, agents, or customers.

**posttransaction elements** Customer service activities that occur after a sale.

**pretransaction costs** Costs that are incurred prior to order and receipt of the purchased goods.

**pretransaction elements** Customer service activities that occur before a sale.

**price break point** The minimum quantity required to receive a quantity discount.

**private carrier** A form of transportation owned by a company, such as a fleet of trucks, which is used to ship that company's goods only.

**private warehouses** Warehouses that are owned by the firm storing the goods.

**process integration** The sharing of information and coordinating resources to jointly manage a process.

**process** A set of steps to accomplish a task or get work done.

**procurement credit cards or corporate purchasing cards (P-cards)** Credit cards with a predetermined credit limit, usually not more than $5,000 depending on the organization, issued to authorized personnel of the buying organization to make low-dollar purchases.

**producer's risk** The risk that occurs when a buyer rejects a shipment of good-quality units because the sample quality level did not meet the acceptance standard.

**product development and commercialization process** The development of new products to meet changing customer requirements and then getting these products to market quickly and efficiently.

**product family** A group consisting of different products that share similar characteristics, components or manufacturing processes.

**production kanban** A visual signal such as a light, flag or sign that is used to trigger production of certain components.

**production strategy** Consists of a chase, level, or mixed strategy.

**product positioned strategy** A location strategy that places warehouses close to the sources of supply, to enable the firm to collect various goods and then consolidate these into TL or CL quantities for shipment to customers.

**profit-leverage effect** A purchasing performance measure that calculates the impact of a change in purchase spend on a firm's profit before taxes, assuming gross sales and other expenses remain unchanged.

**public procurement or public purchasing** The management of the purchasing and supply management function of the government and nonprofit sector, such as educational institutions, charitable organizations and the federal, state and local governments.

**public warehouses** An independent warehouse that is operated as a for-profit business.

**pull system** An operating system where synchronized work takes place only upon authorization from another downstream user in the system rather than strictly to a forecast. JIT systems or lean systems are typically referred to as pull systems.

**purchase requisition** An internal document initiated by the material user to request the purchasing department to buy specific goods or services.

**purchase spend** The money a firm spends on goods and services.

**purchasing spend** The amount of money purchasing has spent on materials, supplies, and services in a period.

**pure Internet distribution strategy** Selling goods or services strictly over the Internet.

**pure services** Services that offer few, if any, tangible products to customers.

## Q

**QR codes** A form of mobile marketing that involves the use of the camera function on a smart phone and installing a QR (quick response) code reader on the phone.

**qualitative forecasting methods** Forecasts based on opinions and intuition.

**quality-of-life factors** Those issues that contribute to "a feeling of well-being, fulfillment or satisfaction resulting from factors in the external environments."

**quantitative forecasting methods** Forecasts based on mathematical models and relevant historical data.

**quantity discount model or price-break model** A variation of the classic EOQ model, wherein purchase price is allowed to vary with the quantity purchased.

**queue discipline** The order in which customers are served.

**queue management** A demand management strategy that is used to deal with excess customers.

**queue times** The time that people or goods have spent waiting in line.

**queuing systems** The processes used to align, prioritize and serve customers.

**quick response (QR)** "Developed by the U.S. textile industry in the mid-1980s as an offshoot of JIT and was based

on merchandisers and suppliers working together to respond more quickly to consumer needs by sharing information, resulting in better customer service and less inventory and waste."

## R

**Regional Comprehensive Economic Partnership (RCEP)** The first trade agreement between Asia's three largest economies of China, Japan, and Korea.

**radio frequency identification (RFID)** A technology that enables huge amounts of information to be stored on chips (called tags) and read at a distance by readers, without requiring line of-sight scanning.

**radio frequency identification tag** The chips used to store information about a specific product or carton using RFID.

**rail carriers** Trains or railroads.

**Railroad Revitalization and Regulatory Reform Act** Commonly known as the 4-R Act; this legislation was passed in 1976 and made several regulatory changes to help the railroads.

**Railway Passenger Service Act** Legislation passed in 1970 that created Amtrak.

**rationing** A strategy that can occur when demand exceeds a supplier's finished goods available. In such cases, the supplier may allocate product in proportion to what buyers ordered.

***R* chart** Used to track sample ranges, or the variation of the measurements within each sample.

**real-time location systems (RTLSs)** WiFi-enabled radio frequency identification (RFID) tags used on rail cars to allow tracking of rail cars (and their assets) in real-time.

**Reed-Bulwinkle Act** Legislation passed in 1948 that gave groups of carriers the ability to form rate bureaus or conferences wherein they could propose rate changes to the ICC.

**relationship marketing or permission marketing** An extension of target marketing; letting customers select the type and time of communication with organizations.

**reneging** Leaving a queue before receiving the service.

**reorder point (ROP)** The lowest inventory level at which a new order must be placed to avoid a stockout during the order cycle time period.

**request for proposal (RFP)** A formal request for a project or product proposal issued by the buyer to qualified suppliers. The use of RFPs allows the supplier to develop part specifications based on their own knowledge of the materials and technology needed.

**request for quotation (RFQ)** A formal request for pricing from a supplier; commonly used when the purchasing requirements are clear.

**resource requirements planning (RRP)** A long range capacity planning module that is used to check whether aggregate resources are capable of satisfying the aggregate production plan.

**return on assets (ROA)/return on investment (ROI)** A financial ratio of a firm's net income in relation to its total assets.

**returns management process** A process that manages product returns. This can be extremely beneficial for supply chain management in terms of maintaining acceptable levels of customer service and identifying product improvement opportunities.

**reverse logistics/returns management** Returning products, warranty repairs, and recycling or disposing items. Also referred to as returns management.

**rewarding suppliers** Giving suppliers more business when their performance is deemed to be excellent.

**rights and duties** A theory stating that some actions are right in themselves without regard for the consequences.

**right-shoring** The combining of on-shore, near-shore and far-shore operations into a single, flexible, low-cost approach to supply chain management.

**right-to-work laws** State legislation that provides employees with the right to decide whether to join or support a union financially.

**risk pooling** The relationship between the number of warehouses, inventory and customer service; it can be explained intuitively as follows: when market demand is random, it is very likely that higher-than-average demand from some customers will be offset by lower-than-average demand from other customers. As the number of customers served by a single warehouse increases, these demand variabilities will tend to offset each other more often, thus reducing overall demand variance and the likelihood of stockouts.

**road trains** Trucks pulling more than two trailers; these are commonly seen in Australia where trucks are used instead of railroads in low population areas.

**root causes** The most significant/potential cause of a problem that impacts the process.

**ROROs** Roll-on-roll-off containerships that allow truck trailers and containers to be directly driven on and off the ship, without use of cranes.

**rough-cut capacity plan (RCCP)** A plan that is used to check the feasibility of the master production schedule.

## S

**sales activity management system** Software tools that give sales personnel a sequence of activities guiding them through their sales processes with customers. These standardized steps assure the proper sales activities are performed and also put forth a uniform sales process across the entire organization.

**sales force automation (SFA)** Software products used for documenting field activities, communicating with the home office, and retrieval of sales history and other company-specific documents in the field.

**sales order** A supplier's offer to sell goods and services at the supplier's terms and conditions. The sales order becomes a legally binding contract when accepted by the buyer.

**sales territory management systems** Software applications that allow sales managers to obtain current information and reporting capabilities regarding each salesperson's activities on each customer's account, total sales in general for each sales rep, their sales territories and any ongoing sales initiatives.

**scorecarding** A performance measure design technique such as the Balanced Scorecard that uses the scorecard model.

**sealed bids** A bid for business by a supplier in response to an invitation for bid sent by a buyer. The bid is kept sealed until all bids are received, whereupon they are opened and the low bidder is typically awarded the purchase contract.

**second-tier customers** A customer's customers.

**second-tier suppliers** A supplier's suppliers.

**segment customers** Placing customers in a behavioral class, such as males/females, age brackets and profitability, so as to better design marketing campaigns for each segment.

**server factory** A manufacturing facility that is set up primarily to take advantage of government incentives, minimize exchange risk, avoid tariff barriers and reduce taxes and logistics costs to supply the regional market where the factory is located.

**service bundles** A group of attributes that are offered to customers when purchasing services, including the explicit service itself, the supporting facility, facilitating goods and implicit services. Successful services are designed to deliver this bundle of attributes in the most efficient way, while still satisfying customer requirements.

**service capacity** The number of customers per day that a firm's service delivery systems are designed to serve, although it could also be some other period of time such as customers per hour or customers per shift.

**service delivery systems** A continuum of services that may range from mass-produced, low-customer-contact systems at one extreme (such as ATMs) to highly customized, high customer- contact systems at the other (such as expensive beauty salons).

**service layout strategies** A method that works in combination with location decisions to further support the overall business strategies of differentiation, low cost or market focus. Office layouts tend to be departmentalized; commercial airliner layouts segment customers; casino layouts are designed to get customers in quickly and then keep them there by spacing out the attractions; and self-serve restaurant buffet layouts are designed to process customers quickly.

**service level** The in-stock probability.

**service response logistics** The management and coordination of an organization's activities that occur while the service is being performed.

**setup costs** The costs associated with setting up machines and equipment to produce a batch of product; the term is often used in place of order costs.

**Seven Rs Rule** Having the right product, in the right quantity, in the right condition, at the right place, at the right time, for the right customer, at the right cost.

**seven wastes** A concept that encompasses things such as excess wait times, inventories, material and people movements, processing steps, variabilities and any other non-value-adding activity.

**shippers' associations** Nonprofit membership cooperatives that make domestic or international arrangements for the movement of members' cargo.

**Shipping Act of 1984** Legislation that allowed ocean carriers to pool or share shipments, assign ports, publish rates and enter into contracts with shippers.

**shortage gaming** A strategy that occurs when buyers figure out the relationship between their orders and what is supplied, and they then tend to inflate their orders to satisfy their real needs.

**short-range planning horizon** A planning horizon that covers a weekly, daily, or hourly basis.

**sigma drift** A theory that assumes process variations will grow over time, as process measurements drift off target.

**silo effect/silo mentality** An I-win-you-lose organizational issue that causes a firm to be reactive and short-term-goal oriented. At this stage, no internal functional integration is occurring.

**simple moving average forecast** A method that uses historical data to generate a forecast; it works well when the demand is fairly stable over time.

**simplification** A reduction of the number of components, supplies, or standard materials used in a product or process.

**simplified acquisition threshold** U.S. government agencies can now use simplified procedures that require fewer administrative details, lower approval levels, and less documentation for soliciting and evaluating bids.

**single-factor productivity measures** The output measure divided by a single input measure, such as labor cost.

**single integrator solution** An ERP system that uses all the desired applications from the same vendor.

**single sourcing** "Refers to the deliberate practice of concentrating purchases of an item with one source from a pool of viable suppliers."

**Six Sigma** A system that stresses a commitment by top management to enable a firm to identify customer expectations and excel in meeting and exceeding those expectations. A type of TQM method devised by Motorola.

**Six Sigma quality management** A commitment by the firm's top management to help the firm identify customer expectations and excel in meeting and exceeding those expectations.

**sole sourcing** Refers to the situation when the supplier is the only available source.

**source factory** A manufacturing facility that has a broader strategic role than an offshore factory, with plant management heavily involved in supplier selection and production planning.

**Southern Common Market (MERCOSUR)** A regional trade agreement among Argentina, Brazil, Paraguay and Uruguay, formed in March 1991.

**specialized carriers** Carriers that transport liquid petroleum, household goods, agricultural commodities, building materials and other specialized items.

**square root rule** A rule suggesting that the system average inventory (impacted by adding or deleting warehouses) is equal to the old system inventory times the ratio of the square root of the new number of warehouses to the square root of the old number of warehouses.

**Staggers Rail Act of 1980** Legislation aimed at improving finances for the rail industry.

**state utility** A situation that occurs when services do something to things that are owned by the customer, such as transport and store their supplies, repair their machines, cut their hair or provide their healthcare.

**statistical process control (SPC)** A method that allows firms to visually monitor process performance, compare the performance to desired levels or standards and take corrective steps quickly before process variabilities get out of control and damage products, services and customer relationships.

**stockless buying or system contracting** An extension of the blanket purchase order.

**strategic alliance development** Improving the capabilities of key trading partners.

**strategic partnerships** A close working relationship that develops among trading partner relationships.

**strategic sourcing** Strategically managing a firm's external resources and services to improve cost, quality, delivery, performance and competitive advantage.

**strategic supplier alliances** The creation of partnerships with key suppliers.

**subcontracting** The process of entering into a contractual agreement with a supplier to produce goods and/or services according to a specific set of terms and conditions.

**super bill of materials** Another type of bill of materials that is useful for planning purposes.

**supplier certification** Defined by the Institute of Supply Management as "an organization's process for evaluating the quality systems of key suppliers in an effort to eliminate incoming inspections."

**supplier development** The efforts of a buying firm to improve the capabilities and performance of specific suppliers to better meet its needs.

**supplier evaluation** Determining the current capabilities of suppliers.

**supplier management** One of the most crucial issues within the topic of supply management—getting suppliers to do what the buyer's firm wants them to do.

**supplier relationship management process** A process by which the firm manages its relationships with suppliers.

**supplier relationship management (SRM)** Accenture defines SRM as "the systematic management of supplier relationships to optimize the value delivered through the relationship over their life cycle."

**supply base or supplier base** Refers to the list of suppliers that a firm uses to acquire its materials, services, supplies, and equipment.

**supply base rationalization, supply base optimization, or supply base reduction** Getting rid of poorly performing suppliers.

**supply chain** A network of trading partners that make products and services available to consumers, including all of the functions enabling the production, delivery and recycling of materials, components, end products and services.

**Supply chain analytics** Tools that harness data from internal and external sources to produce breakthrough insights that can help supply chains reduce costs and risk.

**supply chain management (SCM)** The integration of key business processes regarding the flow of materials from raw material suppliers to the final customer.

**supply chain performance measurement** Determining the performance of an entire supply chain.

**supply chain process integration** Supplier, producers, and customers working together to make purchasing, inventory, production, quality, and logistics decisions that impact the overall costs and profits of the supply chain.

**supply chain risk** The likelihood of an internal or external event that disrupts supply chain operations, causing potential reductions in service levels, product quality, and sales, along with an increase in costs.

**supply chain security management** A method that is concerned with reducing the risk of intentionally created disruptions in supply chain operations including product and information theft and activities seeking to endanger personnel or sabotage supply chain infrastructure.

**supply chain visibility** The ability of suppliers, manufacturers, business partners, and customers to know exactly where products are, at any point in the supply chain.

**supply management** The identification, acquisition, access, positioning and management of resources the organization needs or potentially needs in the attainment of its strategic objectives.

**surety bonds** Bonds posted by bidders to ensure that the successful bidder will accept the contract.

**sustainability** A commitment to environmental responsibility.

**sustainable development** A development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

**sustainable sourcing** A process of purchasing goods and services that takes into account the long-term impact on people, profits, and the planet.

**system nervousness** A situation where a small change in the upper- level production plan causes a major change in the lower-level production plan.

## T

**target marketing** Targeting specific customer segments, with respect to promotional efforts.

**tariff** An official list or schedule showing the duties, taxes or customs imposed by a host country on imports or exports.

**the 4 M's** The standard classifications of problem causes and represent a very thorough list for problem–cause analyses. In almost all cases, problem causes will be in one or more of these four areas: Material, Machine, Methods, and Manpower.

**third-party logistics providers (3PLs)** For-hire outside agents that provide transportation and other services including warehousing, document preparation, customs clearance, packaging, labeling and freight bill auditing.

**third-party logistics services** For-profit logistics companies.

**three P's** Refers to people, planet, and profit.

**tier-1 suppliers** A company's direct suppliers.

**tier-2 suppliers** The suppliers' suppliers of a company.

**tier-3 suppliers** The suppliers' suppliers' suppliers of a company.

**time fence system** Separates the planning horizon into two segments: a firmed and a tentative segment.

**time series forecasting** A prediction technique based on the assumption that the future is an extension of the past

and that historical data can thus be used to forecast future demand.

**time utility** A state of well-being that is created when customers get products delivered at precisely the right time, not earlier and not later.

**total cost of ownership (TCO) or total cost of acquisition** Considers the unit price of the material, payment terms, cash discount, ordering cost, carrying cost, logistical costs, maintenance costs and other more qualitative costs that may not be easy to assess.

**total productivity measures** A measure of total outputs divided by total inputs.

**total quality management (TQM)** A focus on the customer, performance measurement, and formal training in quality control methods. Six Sigma embodies an organizational culture wherein everyone from CEO, to production worker, to frontline service employee is involved in quality assessment and improvement.

**Toyota Production System** A methodology created by Toyota Motor Company in the 1950s. The idea is to make the best use of an organization's time, assets and people in all processes in order to optimize productivity. Also known as JIT and lean production.

**tracking signal** A tool used to check the forecast bias.

**trading companies** A firm that puts buyers and sellers from different countries together and handles all of the export/import arrangements, documentation and transportation for both goods and services.

**trailer-on-flatcar service or TOFC service** Railroads that offer flatcars used to carry truck trailers.

**transactional SRM** A system that enables an organization to track supplier interactions such as order planning, order payment and returns. The volume of transactions involved may result in independent systems maintained by geographic region or business lines. Transactional SRM tends to focus on short-term reporting.

**transaction costs** Costs include the cost of the goods/services and cost associated with placing and receiving the order.

**transaction elements** Activities that occur during the sale of a product or service.

**Transportation Act of 1920** Legislation that instructed the ICC to ensure that rates were high enough to provide a fair return for the railroads each year.

**Transportation Act of 1940** Legislation that further extended the Interstate Commerce Act of 1887, establishing ICC control over domestic water transportation.

**Transportation Act of 1958** Legislation that established temporary loan guarantees to railroads, liberalized control over intrastate rail rates, amended the rule of rate making to ensure more intermodal competition and clarified the differences between private and for hire motor carriers.

**transportation brokers** Legally authorized intermediaries that bring shippers and transportation companies (mainly truckers) together.

**transportation deregulation** The laws that seek to reduce government regulation in the transportation industry, allowing market forces to dictate services offered.

**transportation intermediaries** For-hire agencies that bring shippers and transportation providers together.

**transportation management systems** Software applications that allow firms to select the best mix of transportation services and pricing to determine the best use of containers or truck trailers, to better manage transportation contracts, to rank transportation options, to clear customs and to track fuel usage, product movements and carrier performance.

**transportation regulation** The laws that protect consumers in areas of transportation monopoly pricing, safety and liability.

**transportation security** Protection that is provided to transportation companies against unlawful activities such as terrorism.

**Transportation Worker Identification Credential (TWIC)** A transportation security initiative for transportation workers mandated by the Maritime Transportation Security Act of 2002 and the Safe Port Act of 2006.

**traveling requisition** A material requisition that is used for materials and standard parts that are requested on a recurring basis.

**triple bottom line** A broad term that includes protecting the environment and some aspects of social responsibility, as well as financial performance.

**truckload (TL) carriers** For-hire trucks that move shipments that take up one full truckload.

**Type-I error** When a process is mistakenly thought to be out of control and an improvement initiative is undertaken unnecessarily.

**Type-II error** When a process is thought to be exhibiting only natural variations and no improvement is undertaken, even though the process is actually out of control.

## U

**United States–Mexico–Canada Agreement (USMCA)** The U.S. renegotiated the North American Free Trade Agreement, replacing it with an updated and rebalanced agreement, which is now called the USMCA and which came into force on July 1, 2020.

**U.S. Baldrige Quality Award** Legislation enacted in 1987, named in honor of Malcolm Baldrige, President Ronald Reagan's Secretary of Commerce, that seeks to recognize U.S. companies for service or product quality.

**Uniform Commercial Code (UCC)** Legislation that governs the purchase and sale of goods.

**utilitarianism** A theory that maintains an ethical act creates the greatest good for the greatest number of people.

## V

**value engineering** Designing better quality and cost savings into the products originally.

**value-of-service pricing** A strategy that allows carriers to price their services at competitive levels the market will bear.

**variable costs** Expenses that vary as a function of the output level.

**variable data** Measurable data, such as weight, time and length (as in the weight of a box of cereal, the time to serve a customer or the length of a steel girder).

**vendor managed inventory (VMI)** A progressive partner-based approach to controlling inventory and reducing supply chain costs. Customers provide information to the key supplier, including historical usage, current inventory levels, minimum and maximum stock levels, sales forecasts and upcoming promotions, who then takes on the responsibility and risk for planning, managing and monitoring the replenishment of inventory. The supplier may even own the inventory until the product is sold.

**virtual queues** A queuing system in which customers' places in the queue are tracked by a computerized system that allows customers to roam the premises until their names are called.

## W

**walk-through service audits** A method of monitoring a service system that is performed by management and covers service system attributes from the time customers initially encounter the service until they leave.

**Walmart effect** A theory postulating that the booming growth in information technology has allowed many big-box retailers such as Wal-Mart to realize large productivity growth rates.

**warehouse management systems** Software applications facilitating the proper storage and movement of inventory and minor manufacturing such as assembly or labeling activities within the warehouse, and movement of shipments onto the transportation carrier.

**waste elimination** Includes reducing excess inventories, material movements, production steps, scrap losses, rejects, and rework.

**water carrier** A carrier using ships for transportation.

**weighted-factor rating model** A method commonly used to compare the attractiveness of several locations along a number of quantitative and qualitative dimensions.

**World Trade Organization (WTO)** The only international organization dealing with the rules of trade between nations. Its functions include administering the WTO agreements, providing a forum for trade negotiations, handling trade disputes, monitoring national trade policies, providing technical assistance and training programs for developing countries and cooperating with other international organizations.

## X

**$\bar{x}$ chart** When measuring and plotting variable process data, the x-bar chart is used to track the central tendency of the sample means.

## Y

**yokoten** A Japanese term meaning "across everywhere." In lean terminology, it is used to mean the sharing of best practices.

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