

OPERATIONS AND SUPPLY CHAIN MANAGEMENT

fifteenth edition



F. ROBERT JACOBS
RICHARD B. CHASE

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OPERATIONS AND SUPPLY CHAIN MANAGEMENT

fifteenth edition

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To my father, Forest

*To my wife, Harriet, and to our children
Laurie, Andy, Glenn, Robb, and Christine*

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Operations and supply chain management (OSCM) is a key element in the improvement in productivity in business around the world. Establishing a *competitive advantage* through operations requires an understanding of how the operations and supply chain functions contribute to productivity growth. However, our intent in this book is to do more than just show you what companies are doing to create a competitive advantage in the marketplace by conveying to you a set of skills and tools that you can actually apply.

Hot topics in business today that relate to operations and supply chain management are reducing the cost of supply chain processes, integration and collaboration with customers and suppliers, sustainability, and minimizing the long-term cost of products and processes. These topics are studied in the book with up-to-date, high-level managerial material to clarify the “big picture” of what these topics are and why they are so important to business today.

A significant feature of this book is the organization of each chapter by concise learning objectives. Each objective relates to a block of knowledge that should be studied as a unit. The objectives are carried through the end-of-chapter material that includes Concept Connections, Discussion Questions, Objective Questions, and a Practice Exam. The material is organized to ease understanding of each topic.

Success in OSCM requires a data-driven view of a firm’s business. Every chapter in the book has *analytic* content that ties decisions to relevant data. Mathematical models are used to structure the data for making decisions. Given the facts that are supported by data, success in OSCM requires using a *strategy* that is consistent with the operations-related priorities of a firm. Different approaches can often be used, and usually trade-offs related to cost-and-flexibility-related criteria exist. Strategies are implemented through *processes* that define exactly how things are done. Processes are executed over and over again as the firm conducts business, so they must be designed to operate efficiently to minimize cost while meeting quality-related standards. Great managers are analytic in their approach to decision making; they understand and select the appropriate strategy, and then execute the strategy through great processes. We develop this pattern throughout the topics in this book.

The reality of global customers, global suppliers, and global supply chains has made the global firm recognize the importance of being both lean and green to ensure competitiveness. Applications that range from high-tech manufacturing to high-touch service are used in the balanced treatment of the traditional topics of the field. Success for companies today requires successfully managing the entire supply flow, from the sources of the firm, through the value-added process of the firm, and on to the customers of the firm.

Each chapter includes information about how operations and supply chain-related problems are solved. There are concise treatments of the many decisions that need to be made in designing, planning, and managing the operations of a business. Many spreadsheets are available from the book website to help clarify how these problems are quickly solved. We have indicated those spreadsheets with an Excel icon in the margin.

OSCM should appeal to individuals who want to be directly involved in making products or providing services. The entry-level operations specialist is the person who determines how best to design, supply, and run the processes. Senior operations managers are responsible for setting the strategic direction of the company from an operations and supply chain standpoint, deciding what technologies should be used and where facilities should be located, purchasing the resources needed, and managing the facilities that make the products or provide the services. OSCM is an interesting mix of managing people and applying sophisticated technology. The goal is to efficiently create wealth by supplying quality goods and services.

Features to aid in your understanding of the material include the following:

- OSCM at Work boxes provide short overviews of how leading-edge companies are applying OSCM concepts today.
- Solved problems at the end of chapters to serve as models that can be reviewed prior to attempting problems.
- Concept Connections section in each chapter that summarizes the concepts in each learning objective, has definitions of the key terms, and lists the equations where appropriate.
- Discussion questions that are designed to review concepts and show their applicability in real-world settings. These are included in each chapter and organized by learning objectives.
- Objective questions at the end of chapters that cover each concept and problem. These are organized by the chapter learning objectives.
- Practice exam questions at the end of each chapter. These are special questions designed to require a deeper understanding of the material in the chapter. They are similar to the type of short-answer questions that might be given on a test.
- Answers to selected problems are in Appendix D.
- Available as a supplement to the book is the super-innovative Connect smart-learning system. Connect includes LearnSmart, a study system that uses automated intelligent drills to test and ensure your mastery of the material. Connect also includes PowerPoint slide outlines of each chapter, Excel spreadsheets for the solved problems and other examples, practice quizzes, ScreenCam tutorials, Internet links, and video segments that illustrate the application of operations concepts in companies such as Xerox, Zappos, Six Flags, Caterpillar, Burton Snowboards, Honda, Disney, Ford, and many others.

Our aim is to cover the latest and the most important issues facing OSCM managers, as well as basic tools and techniques. We supply many examples of leading-edge companies and practices and have done our best to make the book an interesting read and give you a competitive advantage in your career.

We hope you enjoy it.

PLAN OF THE BOOK

This book is about methods to effectively produce and distribute the goods and services sold by a company. To develop a better understanding of the field, this book is organized into five major sections: Strategy, Products, and Capacity; Manufacturing and Service Processes; Supply Chain Processes; Supply and Demand Planning and Control; and Special Topics. In the following paragraphs, we quickly describe the major topics in the book.

Strategy and sustainability are important and recurring topics in the book. Any company must have a comprehensive business plan that is supported by a marketing strategy, operations strategy, and financial strategy. It is essential for a company to ensure that the three strategies support each other. Strategy is covered from a high-level view in Chapter 2 (Strategy), and more details that relate to economies of scale and learning are covered in Chapters 5 and 6.

The lifeline of the company is a steady stream of innovative products that are offered to the marketplace at the lowest cost possible. Design of Products and Services (Chapter 3) includes a view of how products are designed in the context of having to actually produce and distribute the product over its life cycle. The chapter includes material on how to manage and analyze the economic impact of a stream of products that are developed over time. Projects (Chapter 4) are used to implement change in a firm, be it a change in strategy, a new product introduction, or a new process.

The second section of the book, titled Manufacturing and Service Processes, focuses on the design of internal processes. Chapters 7 and 9 cover the unique characteristics of production and service processes. Important technical material that relates to design activities is covered in Chapters 8 (Facility Layout) and 10 (Waiting Line Analysis and Simulation).

Chapter 11, Process Design and Analysis, is a nuts-and-bolts chapter on process flow charting and static process analysis using some easily understood real-life examples.

An essential element of process design is quality. Six Sigma Quality is the topic of Chapter 12. Here we cover total quality management concepts, Six Sigma tools, and ISO 9000 and 14000. Technical details covering all the statistical aspects of quality are in Chapter 13 (Statistical Quality Control).

The third section of the book, titled Supply Chain Processes, expands our focus to the entire distribution system from the sourcing of material and other resources to the distribution of products and services. We discuss the concepts behind lean manufacturing and just-in-time processes in Chapter 14. These are ideas used by companies throughout the world and are key drivers for efficient and quick-responding supply systems. Many different transformation processes are needed to put together a supply chain. There are critical decisions such as: Where should we locate our facility? What equipment should we buy or lease? Should we outsource work or do it in-house? These are the topics of Chapters 15 and 16 that relate to sourcing, procurement, location of facilities, and distribution. All of these decisions have a direct financial impact on the firm.

Section Four, titled Supply and Demand Planning and Control, covers the techniques required to actually run the system. This is at the heart of OSCM. The basic building blocks are Forecasting (Chapter 18), Sales and Operations Planning (Chapter 19), Inventory Management (Chapter 20), Material Requirements Planning (Chapter 21), and Workcenter Scheduling (Chapter 22). These daily processes are often partially automated with computer information systems. Coverage of Enterprise Resource Planning Systems is the topic of Chapter 17.

In the final section of the book, titled Special Topics, we show how the concepts in the book are applied to special business situations. Here we have selected two types of businesses, Health Care (Chapter 24) and Operations Consulting (Chapter 25). We know that many of you may be interested in working for hospitals and similar specialized care facilities, a growing segment of the world economy. In addition, we know that many of those interested in OSCM are also interested in consulting as a profession.

Making fact-based decisions is what OSCM is all about, so this book features extensive coverage of decision-making approaches and tools. One useful way to categorize decisions is by the length of the planning horizon, or the period of time that the decision maker must consider. For example, building a new plant would be a long-term decision that a firm would need to be happy with for 10 to 15 years into the future. At the other extreme, a decision about how much inventory for a particular item should be ordered for tomorrow typically has a much shorter planning horizon of a few months or, in many cases, only a few days. Such short-term decisions are usually automated using computer programs. In the intermediate term are decisions that a company needs to live with for only 3 to 12 months. Often these decisions correspond to yearly model changes and seasonal business cycles.

As you can see from this discussion, this material is all interrelated. A company's strategy dictates how operations are designed. The design of the operation dictates how it needs to be managed. Finally, because businesses are constantly being presented with new opportunities through new markets, products, and technologies, a business needs to be very good at managing change.

Many very talented scholars have made major contributions to specific chapters in this edition of the book. We are pleased to thank the following individuals:

Rhonda Lummus of Indiana University for her many ideas for improving the material in the book. Ronny Richardson of Kennesaw State University and Matthew Drake of Duquesne University, who spent countless hours checking problems and improving Connect.

Chris Albright, Goker Aydin, Doug Blocher, Kyle Cattani, Seb Hesse, Ash Soni, Gilvan Souza, and Wayne Winston of the ODT department at the Kelley School of Business, Indiana University, for all the time spent discussing ideas.

Supplements are a great deal of work to write, and we appreciate the efforts that make teaching the course easier for everyone who uses the text. John Kros of East Carolina University created the Connect guided examples. P. Sundararaghavan of University of Toledo updated the test bank. Ronny Richardson of Kennesaw State University updated the Power-Point decks and revised Smartbook.

We also want to thank former doctoral students who have contributed to the book over the years, including Mahesh Nagarajan, *University of British Columbia*; Hiroshi Ochiumi, Wayne Johannson, and Jason Niggley, *USC*; Douglas Stewart, *University of New Mexico*; Anderas Soteriou, *University of Cyprus*; Arvinder Loomba, *University of Northern Iowa*; Deborah Kellogg, *University of Colorado–Denver*; Blair Berkeley, *California State University–Los Angeles*; and Bill Youngdahl, *Thunderbird American Graduate School of International Management*.

We also want to thank the following individuals for their thoughtful reviews of the previous edition and suggestion for this text: Gladys Simpson, *Florida International University*; Scott Swenseth, *University of Nebraska*; Mohsen El Hafsi, *University of California Riverside*; Joel Wisner, *University of Nebraska*; Kim Roberts, *Athens State University*; Chris Kiscaden, *University of New Mexico*; Steven Yourstone, *University of New Mexico*; Mark Ippolito, *Indiana University*; Frank Armstrong, *Ferris State University* and *Lansing Community College*.

Thanks to the McGraw-Hill Education team who make this possible—Chuck Synovec, director; Michele Janicek, lead product developer; Trina Maurer, senior marketing manager; Kathryn Wright and Kristin Bradley, project managers; Mark Christianson, program manager; Sandy Ludovissy, senior buyer; Egzon Shaqiri, designer; and Melissa Homer and Jacob Sullivan, content licensing specialists.

Finally, I want to thank my past co-authors Dick Chase and Nick Aquilano for giving me the opportunity to work with them on their book for the past 16 years. I had the opportunity to work with Nick Aquilano on two editions of the book and with Dick Chase on six editions. Both Nick and Dick have now retired from writing the book, but they are still engaged in many creative activities. They have been an inspiration to me and are wonderful colleagues. Enjoy your retirement, you both deserve it.

F. Robert Jacobs



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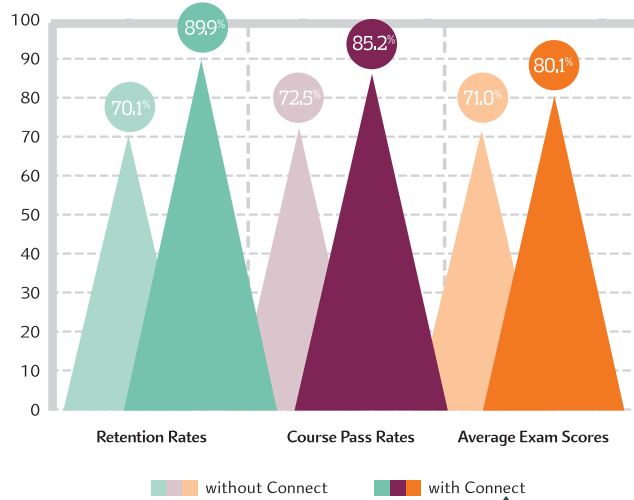
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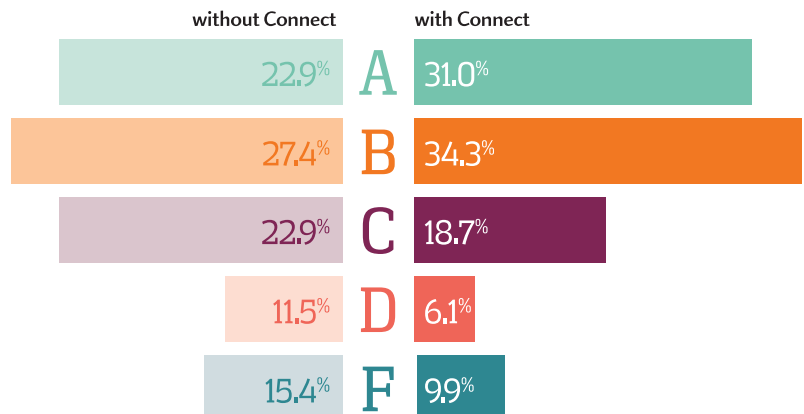
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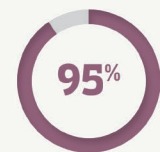
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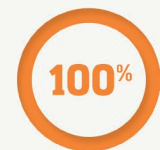
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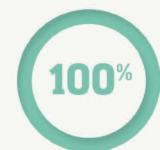
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NOTE TO INSTRUCTORS

DISCUSSION OF FIFTEENTH EDITION REVISIONS

The revisions to the fifteenth edition are a refinement of major changes made in the last edition. Each chapter is organized around a short set of learning objectives. These learning objectives define the major sections of each chapter. A complete set of Discussion Questions together with Objective Questions, which include concepts and problems, are included.

The many questions now included in each chapter are all available for use in *Connect*, the automated assignment grading system available to adopters of the book.

Much work has been put into *Connect* to make it an easy to use and reliable tool. The Objective Question problems are available and many have both static versions (these are identical to the problem in the book) and scenario versions. In the scenario versions of the problem, the parameters have been changed, but the problem is essentially the same, thus allowing students to see different examples of the same problem. The instructor can select predefined or set up custom problem sets that students can complete. These are automatically graded with the results available in a spreadsheet that can be easily downloaded by the instructor. There are many options for how these problem sets can be used, such as allowing the students multiple tries, giving the students help, and timed exams.

In this edition, we have increased our focus on supply chain analytics. Supply chain analytics involve the analysis of data to better solve business problems. We recognize that this is not really a new concept because data has always been used to solve business problems. But what is new is the reality that there is so much more data now available for decision making.

In the past, most analysis involved the generation of standard and ad hoc reports that summarized the current state of the firm. Software allowed query and “drill down” analysis to the level of the individual transaction, useful features for understanding what happened in the past. Decision making was typically left to the decision maker, based on their judgment or simply because they were aware of the rules. The new “analytics” movement takes this to a new level using statistical analysis, forecasting to extrapolate what to expect in the future, and even optimization, possibly in real time, to support decisions.

In this edition, our goal is to capture this spirit of using integrated analytic and strategic criteria in making operations and supply chain decisions. We have done this in two major ways. First, we have reorganized the material in the book by integrating the strategic and analytic material. Next, we have refined our series of 11 Analytics Exercises spread throughout the chapters. In this edition, many small changes designed to increase clarity, simplify assumptions, and make the exercises better learning tools have been made.

These new Analytics Exercises use settings that are modern and familiar to students taking the course. They include Starbucks, cell phones, notebook computers, Taco Bell Restaurant, Toyota, a retail website-based company, and industrial products that are sourced from China/Taiwan and sold globally. The book has been reorganized into five major sections: Strategy, Products, and Capacity; Manufacturing and Service Processes; Supply Chain Processes; Supply and Demand Planning and Control; and Special Topics. Our strategy is to weave analytics into the managerial material so students see the important role of data analysis in making operations and supply chain management decisions.

In the first section, Strategy, Products, and Capacity, our chapters cover Strategy, the Design of Products and Services, Project Management, Strategic Capacity Management, and Learning Curves. The key themes of operations strategy, product design to support the strategy, and strategic capacity are a good foundation for learning about operations and supply chain management. Because most strategic plans are implemented using projects, we include this topic in the first section as well. In the project management chapter, we introduce a good amount of material on product design through examples and exercises, emphasizing the strategic importance of these projects to the success of the firm.

The second section, Manufacturing and Service Processes, gets into the nuts and bolts of operations management. The section introduces the ways manufacturing and service systems are organized and includes new Analytics Exercises for assembly line design and queuing. The Six Sigma and Statistical Quality Control chapters cover topics that would be appropriate for a green-belt program and include good coverage of the popular value-stream mapping technique.

The third section, Supply Chain Processes, discusses processes that source material for internal operations and then distribute products to the customers. The analytic models involved with location/transportation are included here. The topics are tied together in the Lean Supply Chain chapter, which now stresses the cost versus disruption risk trade-offs that are involved in such tactics as single sourcing and just-in-time inventory.

The fourth section, Supply and Demand Planning and Control, covers the techniques typically implemented in Enterprise Resource Planning Systems. These include Forecasting, Sales and Operations Planning, Inventory Management, Material Requirements Planning, and Workcenter Scheduling. We also include a chapter on the Theory of Constraints, a set of thought-provoking concepts.

Finally, the fifth section, titled Special Topics, covers two industries where operations and supply chain management concepts are being applied with great success. The first is health care, with the majority of our material on hospital and special care facilities. We also discuss operations consulting because this is an area where many of our students find jobs.

The following are a list of the major revisions in selected chapters:

- *Chapter 1* Introduction—The opening vignette has been changed to highlight “Efficiency at Southwest Airlines.” Exhibit 1.4 the “Good-Services Continuum” has been changed to make it more relevant to today. A number of new key terms were added that relate to major concepts that define OSCM. These are from the timeline. Exhibit 1.7 has been updated and is now a comparison of Toyota, GM, and Ford.
- *Chapter 2* Strategy—The new opening vignette features the innovative car company Tesla Motors. Exhibit 2.2 “Formulating an Operations and Supply Chain Strategy” is new. A new definition of the key term *order winner* now indicates that there can be more than one order winner. Exhibit 2.4 “Risk Mitigation Strategies” has been updated.
- *Chapter 3* Design of Products and Services—The opening vignette has been updated. It still features IDEO but now captures their new process, Overlapping Thought Spaces. Tesla has been added as an example of an innovative and highly successful company. Exhibit 3.7 (“Process Alternatives for a Family Restaurant”) has been updated to be more in tune with today. Exhibit 3.11 has been replaced with measures related to product development success, focusing on the terms: time-to-market, productivity, and quality. These terms have all been changed to keywords.
- *Chapter 4* Project Management—The opening vignette that describes how a Chinese construction company builds 30-story hotels in only 15 days was updated.
- *Chapter 5* Strategic Capacity Management—The opening vignette was updated. Rewrote Example 5.1 to explain how this planning example fits into a hierarchical planning process. Also, clarified some terminology.
- *Chapter 6* Learning Curves—The opening vignette was updated.
- *Chapter 8* Facility Layout—The opening vignette was updated. The description of assembly line task times was updated to reflect the usual focus on labor task time. Efficiency calculation was also updated to reflect this. The Retail Service Layout section was rewritten and updated to reflect current trends. The Analytic Exercise discussion questions were updated for clarity.
- *Chapter 9* Service Processes—The opening vignette was updated. Exhibit 9.4 was updated to reflect current thought. Updated material on service guarantees. Updated examples to reflect current times. The “Three Contrasting Service Design” section was extensively rewritten to reflect current thought.
- *Chapter 10* Waiting Line Analysis and Simulation—The opening vignette was completely rewritten. The “Waiting Line Problem” section was rewritten. The new Exhibit 10.9

for multi-server (Model 3) analysis now includes many more values. This is needed to support the *Connect* scenario-based problems.

- *Chapter 11* Process Design and Analysis (title changed)—A new opening vignette was added featuring Amazon Air Prime. In Example 11.2, the solution was rewritten and clarified. The material describing cycle time and flow time was rewritten and clarified. Object question 21 was rewritten to clarify assumptions.
- *Chapter 12* Sigma Quality—Here, a new case “Tesla’s Quality Challenge” was added. This replaced the old Toyota case.
- *Chapter 13* Statistical Quality Control—The notation for the standard deviation (S_c) for the c-chart was changed from S_p to S_c to prevent any confusion with S_p , the standard deviation for the p-chart. The “Hot Shot Plastics Company” was changed to an analytics exercise. “Quality Management—Toyota” was also changed to an analytics exercise.
- *Chapter 14* Lean Supply Chains—The section that describes “minimized setup time” was rewritten.
- *Chapter 15* Logistics, Distribution, and Transportation—The opening vignette was rewritten to reflect the current status and thoughts related to the Panama Canal project. Many other updates have been made to make the material up-to-date. The OSCM at Work box about Boeing was rewritten.
- *Chapter 16* Global Sourcing and Procurement—Exhibit 16.6 was rewritten and updated to current thought.
- *Chapter 17* Enterprise Resource Planning Systems—Updated OSCM at Work box titled Open Information Warehouse. Updated “Supply Chain Council” section to show current association with APICS.
- *Chapter 18* Forecasting—Changed the definition of MAPE and how it is calculated. It is the average of the percent errors associated with each forecast. This does not impact any problems, but it does impact the analytics exercise section (only slightly) at the end of the chapter.
- *Chapter 20* Inventory Management—Here the exhibits in Big10Sweaters were updated to make them clearer.
- *Chapters 23* Theory of Constraints—Updated Eli Goldratt’s Theory of Constraints section to reflect current thinking. The Lahey Clinical OSCM at Work box was removed.
- *Chapter 24* Health Care—Exhibit 24.2 was updated and Exhibit 24.6 was replaced with better material. Exhibit 24.7 was updated. The description of DRGs was updated. Exhibit 24.8 was removed and its material was inserted into the text.

F. Robert Jacobs
July 2016

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Walkthrough

The following section highlights the key features developed to provide you with the best overall text available. We hope these features give you maximum support to learn, understand, and apply operations concepts.

Chapter Opener

Opening Vignettes

Each chapter opens with a short vignette to set the stage and help pique students' interest in the material about to be studied. A few examples include:

- Boeing, Chapter 6
- United Parcel Service (UPS), Chapter 11
- Starbucks, Chapter 18

7

Manufacturing Processes

Learning Objectives

- LO 7-1** Understand what a manufacturing process is.
- LO 7-2** Explain how manufacturing processes are organized.
- LO 7-3** Analyze simple manufacturing processes.

THREE-DIMENSIONAL PRINTING—THE TECHNOLOGY COULD BE USED TO MAKE PARTS THAT PERFORM BETTER AND COST LESS



THIS RATCHET WRENCH WAS MADE USING A 3-D PRINTER ON THE INTERNATIONAL SPACE STATION IN ABOUT FOUR HOURS.
© NASA/Spa USA/
Newscom

The technology for printing three-dimensional objects has existed for decades, but its application has been largely limited to novelty items and specialized custom fabrication, such as making personalized prosthetics. The technology has now improved to the point where these printers can make intricate objects out of durable materials, including ceramics and metals (such as titanium and aluminum), with a resolution on the scale of tens of micrometers.

The impact of advanced manufacturing technology on productivity is dramatic. Every year, U.S. manufacturing firms invest millions of dollars to convert manufacturing plants into computerized environments in an effort to improve the firm's competitive position. Companies in other major manufacturing countries such as Germany, Japan, and South Korea are making similar investments. Chinese companies, though, are the productivity leaders, with the country's combination of advanced technology and low labor costs.

AMAZON—THE MASTER OF EFFICIENCY AND LOGISTICS

How does the world's largest online retailer run the fulfillment centers that process the thousands of orders received by the company each hour? They employ more than 120,000 full-time and part-time workers around the world and use an optimized combination of humans and machines to efficiently process each order.

The fulfillment centers use conveyor belts to transport items and employ machines to print and stick mailing labels on them. The company's computers track every item using bar codes. All of this happens with the assistance of workers who are as efficient as the machines.

The company's amazingly efficient process allows them to offer free two-day delivery for its Prime membership customers. In major cities, Amazon even offers same day delivery to some areas.

Amazon is experimenting with the use of drones that may someday deliver packages within 30 minutes. Amazon calls the service Prime Air. With no human intervention, a small plastic package containing your items are loaded under the drone, which then automatically flies to your home. It may be a few years before the Prime Air is operational, but it offers an intriguing opportunity for Amazon.

This wildly efficient infrastructure is what sets Amazon apart and ahead of competitors such as Walmart, Target, and the Chinese Alibaba.com.



AMAZON'S PRIME AIR SERVICE MAY SOMEDAY ALLOW SMALL PACKAGES TO BE DELIVERED IN 30 MINUTES.
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OSCM AT WORK

Remote Doctor Consultation!

You broke your ankle playing tennis yesterday afternoon. What a mess—the whole joint dislocated and three broken bones. The doctor says that it might be a year before you are back to normal. Your surgery was performed last night. No pain right now, but the medication coming through that tube connected to your arm may be the reason for that.

The doctor wanted to get the surgery done last night since he was leaving for vacation early this morning. Just prior to going under the knife, he assured you that everything would be fine and that he would talk to you in the morning. He is 700 miles away by now, so how could this be?



The Remote Presence Robot (RP-7) from InTouch Health is a mobile telemedicine unit that connects physicians and specialists with patients and other doctors in real time through computers equipped with cameras and microphones.

© Patrick Farrell/Miami Herald/MCT/Getty Images

The nurse comes in and asks how things are going. She says the doctor wants to talk and asks if I am up for that. "Sure," I say, but I am still unsure how this can be done. "No problem, I'll be right in with the doctor" says the nurse. The nurse rolls in a device like I had never seen before. It looks to be a little over 5 feet high and has a computer monitor on top.

I hear a voice say, "Hi, how are you doing?" I look up and sure enough there is my doctor on the screen. He tells me about how well the surgery went. He describes how he put a plate in my ankle and seven screws to hold everything together. He explains that it is going to take time for all of this to heal and that after six months he would probably do another surgical procedure and take the plate and screws out. It is all part of the process. He said he would check in with me again tomorrow morning and that it might be four or five days before I could leave the hospital. Also, I should let the nurses know if I am feeling any pain. He assured me that he was connected to the gadget through an app and that the nurses could contact him quickly, even better than if he were at the local office.

This type of electronic physician assistant gives the doctor direct access to current data related to the patient—heart rate, blood pressure, sleep and active periods, and current drugs being administered. In many ways, this is even better than the old way of doing hospital rounds. Everything is at the doctor's finger tips; the information is in real-time and accurate.

The "Remote Presence Robot" is a reality and is being used by many hospitals today. Physician-to-patient communication is now possible regardless of whether a physician is out of town or out of the country. Doctors can now make rounds off-site or from their office any time of the day via an app on the physician's cell phone. Patients are still monitored by the hospital nursing staff, but now they have a direct link to the doctor via the app with real-time ability to communicate.

Many patients are impressed with the new technology as it gives doctors the ability to provide better coverage to patients, rather than everything being done face-to-face. For example, the doctor is now able to connect and see the patient when family members are visiting. This is so much better when the need to communicate with the family is critical.

OSCM at Work Boxes

The boxes provide examples or expansions of the topics presented by highlighting leading companies practicing new, breakthrough ways to run their operations. Examples include:

- Efficiency: It's the Details That Count, Chapter 1
- What's It Like Working on an Assembly Line?, Chapter 8
- J.D. Power and Associates Initial Quality Study of New Cars, Chapter 12
- Mr. Rounder Is On-Call at Hackensack University Medical Center, Chapter 24

Excel

Excel icons point out concepts where Excel templates are available on the text website.

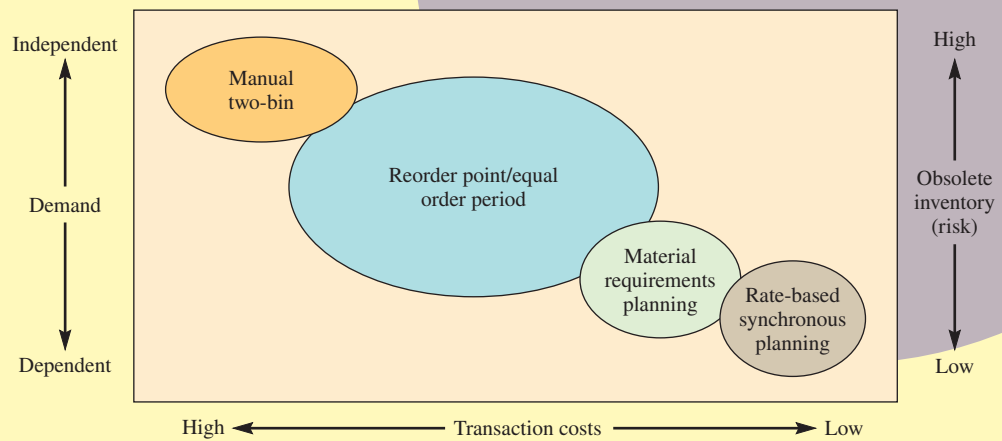


ge time for two units is the average time of the sum of the time for three units is the average time for the sum of the play could have almost any starting shape, not necessarily on the stream of random numbers. What we can be sure of hile until they settle down as units are finished and smooth

age time that parts spend in the system. At the start, the it of time in the system. This can be expected because the no interruptions for parts passing from Bob to Ray. Often, ve to wait between stages as work-in-process; this causes ds to the waiting time. As time goes on, however, stability

Photos and Exhibits

Over 60 photos and 200 exhibits are included in the text to enhance the visual appeal and clarify text discussions. Many of the photos illustrate additional examples of companies that utilize the operations and supply chain concepts in their business.



Key Ideas

Important points in the text are called out and summarized in the margins.

KEY IDEA



Drawing a picture is always the first step in analyzing a process. Keep the drawing simple to start with.

Solved Problems

Representative problems are placed at the end of appropriate chapters. Each includes a worked-out solution, giving students a review before solving problems on their own.

SOLVED PROBLEM 2

American Vending Inc. (AVI) supplies vended food to a large university. Because students kick the machines out of anger and frustration, management has a constant repair pro machines break down on an average of three per hour, and the breakdowns are distributed in a Poisson manner. Downtime costs the company \$25 per hour per machine, and each machine worker gets \$16 per hour. One worker can service machines at an average rate of five machines per hour, distributed exponentially; two workers working together can service seven per hour, distributed exponentially; and a team of three workers can do eight per hour, distributed exponentially.

What is the optimal maintenance crew size for servicing the machines?

Solution

Case 1—One worker:

$\lambda = 3/\text{hour}$ Poisson, $\mu = 5/\text{hour}$ exponential

The average number of machines in the system is

$$L_s = \frac{\lambda}{\mu - \lambda} = \frac{3}{5 - 3} = \frac{3}{2} = 1\frac{1}{2} \text{ machines}$$

Downtime cost is $\$25 \times 1.5 = \37.50 per hour; repair cost is \$16.00 per hour; and per hour for 1 worker is $\$37.50 + \$16.00 = \$53.50$.

Concept Connections

The Concept Connections grid appears at the end of every chapter. This tool draws students' attention to the main points, key terms, and formulas for each learning objective. The organization of the Concept Connections gives students a quick and effective reference when applying the chapter content.

Concept Connections

LO 10–1 Understand what a waiting line problem is.

Summary

- The study of waiting in line is the essence of this problem. Queuing theory is the mathematical analysis of the waiting line.
- A queuing (or waiting line) system is composed of three major parts: (1) the customers arriving to the system, (2) the servicing of the customers, and (3) how customers exit the system.
- Queuing theory assumes that customers arrive according to a Poisson arrival distribution and are serviced according to an exponential service time distribution. These are specific probability distributions that match well with actual situations.

Key Terms

Queues A line of waiting persons, jobs, things, or the like.

Queuing system A process where customers wait in line for service.

Arrival rate The expected number of customers that arrive each period.

Exponential distribution A probability distribution associated with the time between arrivals.

Poisson distribution Probability distribution for number of arrivals during each time period.

Service rate The number of customers a server can handle during a given time period.

Practice Exams

The Practice Exams are designed to allow students to see how well they understand the material using a format that is similar to what they might see in an exam. This feature includes many straightforward review questions, but also has a selection that tests for mastery and integration/application level understanding, i.e., the kind of questions that make an exam challenging. The practice exams include short answers at the bottom so students can see how well they have answered the questions.

Practice Exam

Answer the following questions. Answers are listed at the end of this section.

1. The queuing models assume that customers are served in what order?
2. Consider two identical queuing systems except for the service time distribution. In the first system, the service time is random and Poisson distributed. The service time is constant in the second system. How would the waiting time differ in the two systems?
3. What is the average utilization of the servers in a system that has three servers? On average, 15 customers arrive every 15 minutes. It takes a server exactly three minutes to wait on each customer.
4. What is the expected waiting time for the system described in question 3?
5. Firms that desire high service levels where customers have short wait times should target server utilization levels at no more than this percentage.
6. In most cases, if a firm increases its service capacity by 10 percent, it would expect waiting times to be reduced by what percentage? Assume customer arrivals and service times are random.
7. An ice cream stand has a single window and one employee to serve customers. During their busy season, 30 customers arrive each hour, on average. It takes 1.5 minutes, on average, to serve a customer. What is the utilization of the employee?
8. How long would customers have to wait in line, on average, at the ice cream shop discussed in question 7?
9. Random service times can be modeled by this.
10. A bank teller takes 2.4 minutes, on average, to serve a customer. What would be the hourly service rate used in the queuing formulas?
11. There are three teller windows in the bank described in the prior question. On average, 60 customers per hour arrive at the bank. What will be the average number of customers in line at the bank?

Answers to Practice Exam 1. First come, first served 2. Waiting time in the first system is two times the second. 3. 100% 4. Infinite 5. 70–80% 6. Greater than 10% 7. 75% 8. .075 hours, or 4.5 minutes 9. Exponential distribution 10. 25 customers per hour 11. 2.5888 (from Exhibit 10.9)

Strategy, Products, and Capacity

SECTION **ONE**

1. Introduction
2. Strategy
3. Design of Products and Services
4. Project Management
5. Strategic Capacity Management
6. Learning Curves

TWENTY-FIRST-CENTURY OPERATIONS AND SUPPLY CHAIN MANAGEMENT

Managing a modern supply chain involves specialists in manufacturing, purchasing, and distribution, of course. However, today it is also vital to the work of chief financial officers, chief information officers, operations and customer service executives, and chief executives. Changes in operations and supply management have been truly revolutionary, and the pace of progress shows no sign of slowing.

In the first section of *Operations and Supply Chain Management*, we lay a foundation for understanding the dynamic field of operations and supply management. This book is about designing and operating processes that deliver a firm's goods and services in a manner that matches customers' expectations.