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Operations Management

Sustainability and Supply Chain Management

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Jay Heizer • Barry Render • Chuck Munson

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Sustainability and Supply Chain Management

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To Karen Heizer Herrmann, all a sister could ever be

J.H.

To Donna, Charlie, and Jesse

B.R.

To Kim, Christopher, and Mark Munson for their unwavering support, and to Bentonville High School teachers Velma Reed and Cheryl Gregory, who instilled in me the importance of detail and a love of learning

C.M.

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Preface

Welcome to your operations management (OM) course. In this book, we present a state-of-the-art view of the operations function. Operations is an exciting area of management that has a profound effect on productivity. Indeed, few other activities have as much impact on the quality of our lives. The goal of this text is to present a broad introduction to the field of operations in a realistic, practical manner. Even if you are not planning on a career in the operations area, you will likely be working with people in operations. Therefore, having a solid understanding of the role of operations in an organization will be of substantial benefit to you. This book will also help you understand how OM affects society and your life. Certainly, you will better understand what goes on behind the scenes when you attend a concert or major sports event; purchase a bag of Frito-Lay potato chips; buy a meal at an Olive Garden or a Hard Rock Cafe; place an order through Amazon.com; board a flight on Alaska Airlines; or enter a hospital for medical care. More than one and a half million readers of our earlier editions seem to have endorsed this premise.

We welcome comments by email from our North American readers and from students using the International edition, the Indian edition, the Arabic edition, and our editions in Portuguese, Spanish, Turkish, Indonesian, and Chinese. Hopefully, you will find this material useful, interesting, and even exciting.

New to This Edition

We've made significant revisions to this edition, and want to share some of the changes with you.

Five New *Video Case Studies* Featuring Alaska Airlines

In this edition, we take you behind the scenes of Alaska Airlines, consistently rated as one of the top carriers in the country. This fascinating organization opened its doors—and planes—so we could examine leading edge OM in the airlines industry. We observe: the quality program at Alaska Air (Chapter 6); the process analysis behind the airline's 20-minute baggage retrieval guarantee (Chapter 7); how Alaska empowers its employees (Chapter 10); the airline's use of Lean, 5s, kaizen, and Gemba walks (Chapter 16); and the complexities of scheduling (Module B).

Our prior editions focused on integrated *Video Case Studies* for the Orlando Magic basketball team, Frito-Lay, Darden Restaurants, Hard Rock Cafe, Arnold Palmer Hospital, Wheeled Coach Ambulances, and Regal Marine. These *Video Case Studies* appear in this edition as well, along with the five new ones for Alaska Airlines. All of our videos are created by the authors, with the outstanding coauthorship of Beverly Amer at Northern Arizona University, to explicitly match with text content and terminology.

Alaska Airlines: 20-Minute Baggage Process—Guaranteed! Video Case

Alaska Airlines is unique among the nine major U.S. carriers not only for its extensive flight coverage of remote towns throughout Alaska (it also covers the U.S., Hawaii, and Mexico from its primary hub in Seattle). It is also one of the smallest independent airlines, with 10,300 employees, including 3,000 flight attendants and 1,500 pilots. What makes it really unique, though, is its ability to build state-of-the-art processes, using the latest technology, that yield high customer satisfaction. Indeed, J. D. Power and Associates has ranked Alaska Airlines highest in North America for seven years in a row for customer satisfaction.

Alaska Airlines was the first to sell tickets via the Internet, first to offer Web check-in and print boarding passes online, and first with kiosk check-in. As Wayne Newton, Director of System Operation Control, states, "We are passionate about our processes. If it's not measured, it's not managed."

One of the processes Alaska is most proud of is its baggage handling system. Passengers can check in at kiosks, tag their own bags with bar code stickers, and deliver them to a customer service agent at the carousel, which carries the bags through the vast underground system that eventually delivers the bags to a baggage handler. En route, each bag passes through TSA automated screening and is manually opened or inspected if it appears suspicious. With the help of bar code readers, conveyer belts automatically sort and transfer bags to their location (called a "pier") at the tarmac level. A baggage handler then loads the bags onto a cart and takes it to

Alaska Airlines

Creating Your Own Excel Spreadsheets

We continue to provide two free decision support software programs, Excel OM for Windows and Mac and POM for Windows, to help you and your students solve homework problems and case studies. These excellent packages are found in MyOMLab and at our text's Student Download Page.

Many instructors also encourage students to develop their own Excel spreadsheet models to tackle OM issues. With this edition, we provide numerous examples at chapter end on how to do so. "Creating Your Own Excel Spreadsheets" examples now appear in Chapters 1, 2, 4, 8, 12, and 13, Supplement 6, Supplement 7, and Modules A, B, and F. We hope these eleven samples will help expand students' spreadsheet capabilities.

Using Software for Productivity Analysis

This section presents three ways to solve productivity problems with computer software. First, you can create your own Excel spreadsheets to conduct productivity analysis. Second, you can use the Excel OM software that comes with this text. Third, POM for Windows is another program that is available with this text.

CREATING YOUR OWN EXCEL SPREADSHEETS

Program 1.1 illustrates how to build an Excel spreadsheet for the data in Example 2.

	A	B	C	D	E
1	Collins Title Insurance Ltd.				
2	Productivity Increase Computations				
3					
4	Parameters	Old System	New System		
5	Length of Workday (hours)	8	8		
6	Number of Workers	4	4		
7	Labor Hours per Day	32	32		
8	Payroll Cost per Day	$640	$640		
9	Overhead Expenses	$400	$800		
10	Output (Titles per Day)	8	14		
11					
12					
13	Solutions	Old System	New System	% Increase	
14	Labor Productivity (Titles per Labor-Hour)	0.25	0.4375	75.00%	
15	Multifactor Productivity (Titles per Dollar)	0.0077	0.0092	26.39%	
16					

Enter the values for the old system in column B and the new system in Column C.

=C5*C6

=B10/B7

Productivity = Output/Input

=C10/(C8+C9)

=(C14-B14)/B14

Actions
Copy C7 to B7, Copy B14 to C14, Copy C15 to B15, and Copy D14 to D15

Create a row for each of the inputs used for the productivity measure. Put the output in the last row.

Program 1.1

USING EXCEL OM

Excel OM is an Excel "add-in" with 24 Operations Management decision support "Templates." To access the templates, double-click on the *Excel OM* tab at the top of the page, then in the menu bar choose the appropriate chapter (in this case Chapter 1), from either the "Chapter" or "Alphabetic" tab on the left. Each of Excel OM's 24 modules includes instructions for that particular module. The instructions can be turned on or off via the "instruction" tab in the menu bar.

USING POM FOR WINDOWS

POM for Windows is decision support software that includes 24 Operations Management modules. The modules are accessed by double-clicking on *Module* in the menu bar, and then double-clicking on the appropriate (in this case *Productivity*) item. Instructions are provided for each module just below the menu bar.

Expanding and Reordering Our Set of Homework Problems

We believe that a vast selection of quality homework problems, ranging from easy to challenging (denoted by one to four dots), is critical for both instructors and students. Instructors need a broad selection of problems to choose from for homework, quizzes, and exams—without reusing the same set from semester to semester. We take pride in having more problems—by far, with 807—than any other OM text. We added dozens of new problems this edition. The following table illustrates the selection by chapter.

Chapter	Number of Problems	Chapter	Number of Problems	Chapter	Number of Problems
1	18	Supplement 7	45	15	27
2	12	8	34	16	12
3	33	9	27	17	24
4	59	10	46	Module A	32
5	28	11	8	Module B	42
Supplement 5	19	Supplement 11	20	Module C	18
6	21	12	53	Module D	39
Supplement 6	55	13	26	Module E	33
7	17	14	32	Module F	25

Further, with the majority of our adopters now using the MyOMLab learning system in their classes, we have reorganized all the homework problems—both those appearing in the printed text, as well as the Additional Homework Problems that are available in MyOMLab—by topic heading. We are identifying all problems by topic (see the following example).

The list of all problems by topic also appears at the end of each boxed example, as well as in the Rapid Review that closes each chapter. These handy references should make it easier to assign problems for homework, quizzes, and exams. A rich set of assignable problems and cases makes the learning experience more complete and pedagogically sound.

Problem **5.3** *is available in* MyOMLab.

Problems 5.4–5.8 relate to Product Development

•• **5.4** Construct a house of quality matrix for a wristwatch. Be sure to indicate specific customer wants that you think the general public desires. Then complete the matrix to show how an operations manager might identify specific attributes that can be measured and controlled to meet those customer desires.

•• **5.5** Using the house of quality, pick a real product (a good or service) and analyze how an existing organization satisfies customer requirements.

•• **5.6** Prepare a house of quality for a mousetrap.

•• **5.7** Conduct an interview with a prospective purchaser of a new bicycle and translate the customer's *wants* into the specific *hows* of the firm.

•••• **5.8** Using the house of quality sequence, as described in Figure 5.4 on page 169, determine how you might deploy resources to achieve the desired quality for a product or service whose production process you understand.

Problems 5.9–5.17 relate to Defining a Product

•• **5.9** Prepare a bill of material for (a) a pair of eyeglasses and its case or (b) a fast-food sandwich (visit a local sandwich

Problems 5.21–5.28 relate to the Application of Decision Trees to Product Design

•• **5.21** The product design group of Iyengar Electric Supplies, Inc., has determined that it needs to design a new series of switches. It must decide on one of three design strategies. The market forecast is for 200,000 units. The better and more sophisticated the design strategy and the more time spent on value engineering, the less will be the variable cost. The chief of engineering design, Dr. W. L. Berry, has decided that the following costs are a good estimate of the initial and variable costs connected with each of the three strategies:

a) *Low-tech:* A low-technology, low-cost process consisting of hiring several new junior engineers. This option has a fixed cost of $45,000 and variable-cost probabilities of .3 for $.55 each, .4 for $.50, and .3 for $.45.
b) *Subcontract:* A medium-cost approach using a good outside design staff. This approach would have a fixed cost of $65,000 and variable-cost probabilities of .7 of $.45, .2 of $.40, and .1 of $.35.
c) *High-tech:* A high-technology approach using the very best of the inside staff and the latest computer-aided design technology. This approach has a fixed cost of $75,000 and variable-cost probabilities of .9 of $.40 and .1 of $.35.

What is the best decision based on an expected monetary value (EMV) criterion? (*Note:* We want the lowest EMV, as we are dealing with costs in this problem.) PX

•• **5.22** MacDonald Products, Inc., of Clarkson, New York, has the option of (a) proceeding immediately with production of

Jay, Barry, and Chuck's OM Blog

As a complement to this text, we have created a companion blog, with coordinated features to help teach the OM course. There are teaching tips, highlights of OM items in the news (along with class discussion questions and links), video tips, guest posts by instructors using our text, sample OM syllabi from dozens of colleges, and much more—all arranged by chapter. To learn more about any chapter topics, visit *www.heizerrenderOM.wordpress.com*. As you prepare your lectures and syllabus, scan our blog for discussion ideas, teaching tips, and classroom exercises.

Lean Operations

In previous editions, we sought to explicitly differentiate the concepts of just-in-time, Lean, and Toyota Production System in Chapter 16. However, there is significant overlap and interchangeability among those three concepts, so we have revised Chapter 16 to incorporate the three concepts into an overall concept of "Lean." The chapter suggests that students view Lean as a comprehensive integrated operations strategy that sustains competitive advantage and results in increased returns to all stakeholders.

Chapter-by-Chapter Changes

To highlight the extent of the revisions in this edition, here are a few of the changes, on a chapter-by-chapter basis.

Chapter 1: Operations and Productivity

We updated Table 1.4 to reflect employment in various sectors and expanded our discussion of Lean operations. Our new case, Uber Technologies, introduces productivity by discussing the disruptive nature of the Uber business model. In addition, there is a new "Creating Your Own Excel Spreadsheets" example for both labor productivity and multifactor productivity.

Chapter 2: Operations Strategy in a Global Environment

We have updated Figure 2.1 to better reflect changes in the growth of world trade and Figure 2.5 to reflect product life cycle changes. The Minute Lube case has been revised as Rapid Lube. Example 1 (National Architects) has been expanded to clarify factor rating calculations and is also demonstrated with a "Creating Your Own Excel Spreadsheets" presentation.

Chapter 3: Project Management

We rewrote and updated the Bechtel Global Company Profile and added a new section on well-defined projects with the "agile" and "waterfall" approaches. There are two new OM in Action boxes: "Agile Project Management at Mastek," and "Behind the Tour de France."

Chapter 4: Forecasting

We created a new table comparing the MAD, MSE, and MAPE forecasting error measures. There is also a new OM in Action box called "NYC's Potholes and Regression Analysis."

Chapter 5: Design of Goods and Services

We expanded our treatment of *concurrent engineering* and added two new discussion questions. Solved Problem 5.1 has been revised.

Supplement 5: Sustainability in the Supply Chain

We wrote a new introductory section on Corporate Social Responsibility. There is also a new OM in Action box called "Blue Jeans and Sustainability" and 10 new homework problems.

Chapter 6: Managing Quality

We added new material to expand our discussion of Taguchi's quality loss function. There is a new section on SERVQUAL, and a new video case study, "Quality Counts at Alaska Airlines," appears here.

Supplement 6: Statistical Process Control

We added a figure on the relationship between sample size and sampling distribution. We also added raw data to Examples S2 and S3 to illustrate how ranges are computed. There is a new Excel spreadsheet to show students how to make their own *c*-chart, and we have added three new homework problems.

Chapter 7: Process Strategy

We wrote a new section on machine technology and additive manufacturing. There are two new discussion questions and three new homework problems. Our second new video case study is called "Alaska Airlines: 20-Minute Baggage Process—Guaranteed!"

Supplement 7: Capacity and Constraint Management

We added a new Table S7.1, which compares and clarifies three capacity measurements, with an example of each. There is a new treatment of expected output and actual output in Example S2. The discussion of bottleneck time versus throughput time has also been expanded. Example S3, capacity analysis with parallel processes, has been revised. We have also added a new "Creating Your Own Excel Spreadsheets" example for a break-even model. Finally, we updated the Arnold Palmer Hospital capacity planning case with recent data.

Chapter 8: Location Strategies

We added two new OM in Action boxes: "Iowa—Home of Corn and Facebook" and "Denmark's Meat Cluster." We changed the notation for the center-of-gravity model to simplify the equation and provided a new "Creating Your Own Excel Spreadsheets" presentation for the center-of-gravity example.

Chapter 9: Layout Strategies

We created a new Muther grid for office relationship charting and added a spread of five layouts showing how offices have evolved over time. There is a new OM in Action box called "Amazon Lets Loose the Robots," and there is a new graphic example of Proplanner's Flow Path Calculator. We have included a formula for idle time as a second measure of balance assignment efficiency and added new technology issues to the Arnold Palmer Hospital video case.

Chapter 10: Human Resources, Job Design, and Work Measurement

We added a new OM in Action box, "The Missing Perfect Chair," and revised the Operations Chart as a service example. Our third new video case study is "The 'People' Focus: Human Resources at Alaska Airlines."

Chapter 11: Supply Chain Management

We added "outsourcing" as a supply chain risk in Table 11.3.

Supplement 11: Supply Chain Management Analytics

We added a major section on the topic of Warehouse Storage, with a new model for allocating inventory to storage locations. There is a new discussion question and three new homework problems.

Chapter 12: Inventory Management

New Programs 12.1 and 12.2 illustrate "Creating Your Own Excel Spreadsheets" for both the production run model and the single-period inventory model. The Excel function NORMSINV is introduced throughout the chapter. The Quantity Discount Model section is totally rewritten to illustrate the *feasible solution* shortcut. Solved Problem 12.5 is likewise redone with the new approach.

Chapter 13: Aggregate Planning and S&OP

We added a new OM in Action box, "Revenue Management Makes Disney the 'King' of the Broadway Jungle." We also provided a new "Creating Your Own Excel Spreadsheets" example for the transportation method for aggregate planning, using the Solver approach.

Chapter 14: Material Requirements Planning (MRP) and ERP

The MRP II example now includes greenhouse gasses.

Chapter 15: Short-Term Scheduling

We begin this chapter with a new Global Company Profile featuring Alaska Airlines and the scheduling issues it faces in its northern climate. We have added two new graphics to help illustrate Forward and Backward Scheduling. There is also a new section called Performance Criteria, detailing how the choice of priority rule depends on four quantifiable criteria. We now explicitly define the performance criteria for sequencing jobs as separate numbered equations. Also, we provide an explicit formula for job lateness. There is a new OM in Action box called "Starbucks' Controversial Scheduling Software."

Chapter 16: Lean Operations

This chapter saw a major reorganization and rewrite with an enhanced focus on Lean operations. There is more material on supplier partnerships and building lean organizations. A new OM in Action box describes the use of kaizen at San Francisco General Hospital, and we have added a new video case study called "Lean Operations at Alaska Airlines."

Chapter 17: Maintenance and Reliability

There are no major changes in this chapter.

Module A: Decision-Making Tools

We added a discussion of "big data" and a new "Creating Your Own Excel Spreadsheets" example on how to evaluate a decision table.

Module B: Linear Programming

There is a new section on integer and binary programming, two new homework problems, and a new video case study called "Using LP to Meet Scheduling Challenges at Alaska Airlines." The corner point method is now covered *before* the iso-profit line approach.

Module C: Transportation Models

There are no major changes to Module C.

Module D: Waiting-Line Models

The limited population model (Model D) has been replaced by the finite population model, M/M/1 with finite source. This standardizes the queuing notation to match the M/M/1, M/M/s, and M/D/1. We have also expanded the coverage of Little's Law and added six new homework problems.

Module E: Learning Curves

There are no major changes to Module E.

Module F: Simulation

We added a new "Creating Your Own Excel Spreadsheets" example for a simulation problem.

Student Resources

To liven up the course and help students learn the content material, we have made available the following resources:

- *Forty-one exciting Video Case Studies (videos located at* MyOMLab*):* These *Video Case Studies* feature real companies (Alaska Airlines, The Orlando Magic, Frito-Lay, Darden Restaurants, Regal Marine, Hard Rock Cafe, Ritz-Carlton, Wheeled Coach, and Arnold Palmer Hospital) and

allow students to watch short videos, read about the key topics, and answer questions. These case studies can also be assigned without using class time to show the videos. Each of them was developed and written by the text authors to specifically supplement the book's content. Instructors who wish to use these in class, and who don't have access to MyOMLab, should contact their Pearson Publishing Representative for access to the MyOMLab materials.

- *POM for Windows software (located at MyOMLab and at the Student Download Page, www.pearsonglobaleditions.com/heizer):* POM for Windows is a powerful tool for easily solving OM problems. Its 24 modules can be used to solve most of the homework problems in the text.
- *Excel OM problem-solving software (located at MyOMLab and at the Student Download Page, www.pearsonglobaleditions.com/heizer):* Excel OM is our exclusive user-friendly Excel add-in. Excel OM automatically creates worksheets to model and solve problems. Users select a topic from the pull-down menu and fill in the data, and then Excel will display and graph (where appropriate) the results. This software is great for student homework, what-if analysis, and classroom demonstrations. This edition includes a new version of Excel OM that is compatible with Microsoft Excel 2013 for Windows, Excel 2011 and 2016 for Mac, and earlier versions of Excel. Professor Howard Weiss, Temple University, developed both Excel OM for Windows and Mac, and POM for Windows to accompany our text and its problem set.
- *Excel OM data files (located at MyOMLab and at the Student Download Page, www.pearsonglobaleditions.com/heizer):* These data files are prepared for specific examples and allow users to solve all the marked text examples without reentering any data.
- *Active Models (located at MyOMLab and at the Student Download Page, www.pearsonglobaleditions.com/heizer):* These 28 Active Models are Excel-based OM simulations, designed to help students understand the quantitative methods shown in the textbook examples. Students may change the data in order to see how the changes affect the answers.
- *Virtual tours (located at MyOMLab):* These company tours provide direct links to companies—ranging from a hospital to an auto manufacturer—that practice key OM concepts. After touring each Web site, students are asked questions directly related to the concepts discussed in the chapter.
- *Online Tutorial Chapters (located at MyOMLab and at the Student Download Page, www.pearsonglobaleditions.com/heizer):* "Statistical Tools for Managers," "Acceptance Sampling," "The Simplex Method of Linear Programming," "The MODI and VAM Methods of Solving Transportation Problems," and "Vehicle Routing and Scheduling" are provided as additional material.
- *Additional practice problems (located at MyOMLab):* These problems provide problem-solving experience. They supplement the examples and solved problems found in each chapter.
- *Additional case studies (located at MyOMLab and at the Student Download Page, www.pearsonglobaleditions.com/heizer):* Over two dozen additional case studies supplement the ones in the text. Detailed solutions appear in the Solutions Manual.
- *Virtual office hours (located at MyOMLab):* Professors Heizer, Render, and Munson walk students through all 89 Solved Problems in a series of 5- to 20-minute explanations. These have been updated with this new edition.

Instructor Resources

At the Instructor Resource Center, *www.pearsoonglobaleditions.com/heizer*, instructors can easily register to gain access to a variety of instructor resources available with this text in downloadable format. If assistance is needed, our dedicated technical support team is ready to help with the media supplements that accompany this text. Visit *http://247.pearsoned.com* for answers to frequently asked questions and toll-free user support phone numbers.

The following supplements are available with this text:

Instructor's Resource Manual

The Instructor's Resource Manual, updated by co-author Chuck Munson, contains many useful resources for instructors—PowerPoint presentations with annotated notes, course outlines, video notes, blog highlights, learning techniques, Internet exercises and sample answers, case analysis ideas, additional teaching resources, and faculty notes.

Instructor's Solutions Manual

The Instructor's Solutions Manual, written by the authors, contains the answers to all of the discussion questions, *Ethical Dilemmas*, Active Models, and cases in the text, as well as worked-out solutions to all the end-of-chapter problems, additional homework problems, and additional case studies.

PowerPoint Presentations

An extensive set of PowerPoint presentations, created by Professor Jeff Heyl of Lincoln University, is available for each chapter. With well over 2,000 slides, this set has excellent color and clarity.

Test Bank/TestGen® Computerized Test Bank

The test bank, updated by James Roh, contains a variety of true/false, multiple-choice, short-answer, and essay questions, along with a selection of written problems, for each chapter. Test questions are annotated with the following information:

- Difficulty level
- Type: multiple-choice, true/false, short-answer, essay, problem
- Learning objective
- AACSB (see the description that follows)

TestGen®, Pearson Education's test-generating software, is PC/MAC compatible and preloaded with all the test bank questions. The test program permits instructors to edit, add, and delete questions from the test bank to create customized tests.

AACSB

The Association to Advance Collegiate Schools of Business (AACSB)

The test bank has connected select questions to the general knowledge and skill guidelines found in the AACSB Assurance of Learning standards.

AACSB is a not-for-profit corporation of educational institutions, corporations, and other organizations devoted to the promotion and improvement of higher education in business administration and accounting. A collegiate institution offering degrees in business administration or accounting may volunteer for AACSB accreditation review. The AACSB makes initial accreditation decisions and conducts periodic reviews to promote continuous quality improvement in management education. Pearson Education is a proud member of the AACSB and is pleased to provide advice to help you apply AACSB assurance of learning standards.

What are AACSB assurance of learning standards? One of the criteria for AACSB accreditation is quality of the curricula. Although no specific courses are required, the AACSB expects a curriculum to include learning experiences in the following areas:

- Written and oral communication
- Ethical understanding and reasoning
- Analytical thinking
- Information technology
- Interpersonal relations and teamwork
- Diverse and multicultural work environments
- Reflective thinking
- Application of knowledge

Questions that test skills relevant to these guidelines are appropriately tagged. For example, a question regarding clothing manufactured for U.S. firms by 10-year olds in Asia would receive the Ethical understanding and reasoning tag.

Tagged questions help you measure whether students are grasping the course content that aligns with the AACSB guidelines noted. In addition, the tagged questions may help instructors identify potential applications of these skills. This in turn may suggest enrichment activities or other educational experiences to help students achieve these skills.