

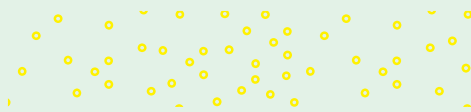
# Operations Management

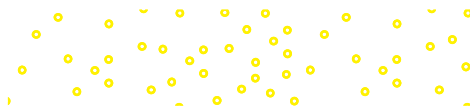
FOURTEENTH EDITION

**William J. Stevenson**

*Saunders College of Business  
Rochester Institute of Technology*

**Mc  
Graw  
Hill**





## OPERATIONS MANAGEMENT, FOURTEENTH EDITION

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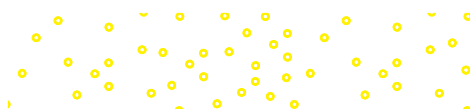
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# Preface

The material in this book is intended as an introduction to the field of operations management. The topics covered include both strategic issues and practical applications. Among the topics are forecasting, product and service design, capacity planning, management of quality and quality control, inventory management, scheduling, supply chain management, and project management.

My purpose in revising this book continues to be to provide a clear presentation of the concepts, tools, and applications of the field of operations management. Operations management is evolving and growing, and I have found updating and integrating new material to be both rewarding and challenging, particularly due to the plethora of new developments in the field, while facing the practical limits on the length of the book.

This text offers a comprehensive and flexible amount of content that can be selected as appropriate for different courses and formats, including undergraduate, graduate, and executive education.

This allows instructors to select the chapters, or portions of chapters, that are most relevant for their purposes. That flexibility also extends to the choice of relative weighting of the qualitative or quantitative aspects of the material, and the order in which chapters are covered, because chapters do not depend on sequence. For example, some instructors cover project management early, others cover quality or lean early, and so on.

As in previous editions, there are major pedagogical features designed to help students learn and understand the material. This section describes the key features of the book, the chapter elements, the supplements that are available for teaching the course, highlights of the fourteenth edition, and suggested applications for classroom instruction. By providing this support, it is our hope that instructors and students will have the tools to make this learning experience a rewarding one.

## What's New in This Edition

In many places, content has been rewritten or added to improve clarity, shorten wording, or update information. New material has been added on supply chains, and other topics. Some problems are new, and others have been revised. Many new readings and new photos have been added.

Some of the class preparation exercises have been revised. The purpose of these exercises is to introduce students to the subject matter before class in order to enhance classroom

learning. They have proved to be very popular with students, both as an introduction to new material and for study purposes. These exercises are available in the Instructor's Resource Manual. Special thanks to Linda Brooks for her help in developing the exercises.

## Acknowledgments

I want to thank the many contributors to this edition. Reviewers and adopters of the text have provided a “continuously improving” wealth of ideas and suggestions. It is encouraging to me as an author. I hope all reviewers and readers will know their suggestions were valuable, were carefully considered, and are sincerely appreciated. The list includes post-publication reviewers.

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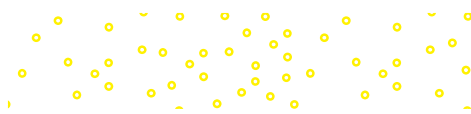
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*William J. Stevenson*



# Walkthrough

## MAJOR STUDY AND LEARNING FEATURES

A number of key features in this text have been specifically designed to help introductory students learn, understand, and apply operations concepts and problem-solving techniques.

### Examples with Solutions

Throughout the text, wherever a quantitative or analytic technique is introduced, an example is included to illustrate the application of that technique. These are designed to be easy to follow.

#### Determining a Regression Equation

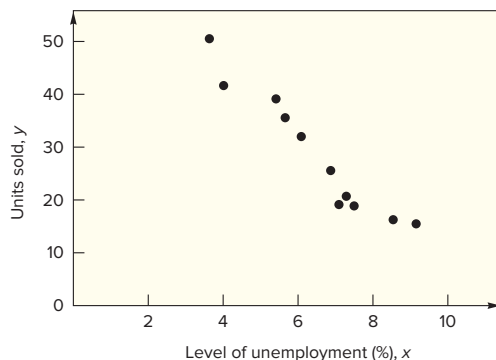
Sales of new houses and three-month lagged unemployment are shown in the following table. Determine if unemployment levels can be used to predict demand for new houses and, if so, derive a predictive equation.

Period .....	1	2	3	4	5	6	7	8	9	10	11
Units sold .....	20	41	17	35	25	31	38	50	15	19	14
Unemployment % (three-month lag)	7.2	4.0	7.3	5.5	6.8	6.0	5.4	3.6	8.4	7.0	9.0

#### EXAMPLE 8

**eXcel**  
mhhe.com/stevenson14e

1. Plot the data to see if a *linear* model seems reasonable. In this case, a linear model seems appropriate *for the range of the data*.



#### SOLUTION

2. Check the correlation coefficient to confirm that it is not close to zero using the website template, and then obtain the regression equation:

$$r = -.966$$

This is a fairly high negative correlation. The regression equation is

$$y = 71.85 - 6.91x$$

Note that the equation pertains only to unemployment levels in the range 3.6 to 9.0, because sample observations covered only that range.



## Solved Problems

At the end of chapters and chapter supplements, “Solved Problems” are provided to illustrate problem solving and the core concepts in the chapter. These have been carefully prepared to help students understand the steps involved in solving different types of problems. The Excel logo indicates that a spreadsheet is available on the text’s website.

SOLVED PROBLEMS

**Computing Productivity**  
A company that processes fruits and vegetables is able to produce 400 cases of canned peaches in one-half hour with four workers. What is labor productivity?

$$\text{Labor productivity} = \frac{\text{Quantity produced}}{\text{Labor hours}} = \frac{400 \text{ cases}}{4 \text{ workers} \times 1/2 \text{ hour/worker}}$$

$$= 200 \text{ cases per labor hour}$$

**Problem 1**  
  
mhhe.com/stevenson14e  
**Solution**

**Computing Multifactor Productivity**  
A wrapping-paper company produced 2,000 rolls of paper in one day. Labor cost was \$160, material cost was \$50, and overhead was \$320. Determine the multifactor productivity.

$$\text{Multifactor productivity} = \frac{\text{Quantity produced}}{\text{Labor cost} + \text{Material cost} + \text{Overhead}}$$

$$= \frac{2,000 \text{ rolls}}{\$160 + \$50 + \$320} = 3.77 \text{ rolls per dollar input}$$

A variation of the multifactor productivity calculation incorporates the standard price in the numerator by multiplying the units by the standard price.

**Problem 2**  
  
mhhe.com/stevenson14e  
**Solution**

**TABLE 16.5** Excel solution for Example 2a

Job Sequencing									
<Back	Notes	Clear	FCFS	SPT	DD	CR	S/O		
		Current Date:		23					
Job	Process. Time	Due Date	Remain Oper.	CR Sequence	Critical Ratio	Slack	S/O	Flow Time	Days Late
A	2	7		3		5		2	0
B	8	16		5		8		10	0
C	4	4		1		0		14	10
D	10	17		6		7		24	7
E	5	15		4		10		29	14
F	12	18		2		6		41	23
<b>Totals</b>		41	0			36		120	54

Method	FCFS
Average Flow Time	20.00
Average Tardiness	9.00
Average Number of Jobs	2.93

Days Late

A	B	C	D	E	F
---	---	---	---	---	---

See notes below.

Notes:

- Enter Job Name, Processing Time, and Due Date for each job.
- For the FCFS, SPT, and DD rules, simply press the appropriate button.
- For the CR rule, perform the following BEFORE pressing the CR button:
  - Select job with lowest Critical Ratio
  - Schedule that job next by entering next sequence number (start with 1) in the CR Sequence column.
  - Add the processing time for that job to the current date.
  - Repeat steps a, b, and c until all jobs have been scheduled (i.e. the CR Sequence column is filled in).
  - Then press the CR button.
- Fill in the Remaining Operations column and then press the S/O button.

## Excel Spreadsheet Solutions

Where applicable, the examples and solved problems include screen shots of a spreadsheet solution.



# CHAPTER ELEMENTS

Within each chapter, you will find the following elements that are designed to facilitate study and learning. All of these have been carefully developed over many editions and have proven to be successful.

## Learning Objectives

Every chapter and supplement lists the learning objectives to achieve when studying the chapter material. The learning objectives are also included next to the specific material in the margins of the text.

**4** Product and Service Design

**LEARNING OBJECTIVES**

After completing this chapter, you should be able to:

- LO4.1 Explain the strategic importance of product and service design.
- LO4.2 Describe what product and service design does.
- LO4.3 Name the key questions of product and service design.
- LO4.4 Identify some reasons for design or redesign.
- LO4.5 List some of the main sources of design ideas.
- LO4.6 Discuss the importance of legal, ethical, and sustainability considerations in product and service design.
- LO4.7 Explain the purpose and goal of life-cycle assessment.
- LO4.8 Explain the phrase "the 3 Rs."
- LO4.9 Briefly describe the phases in product design and development.
- LO4.10 Discuss several key issues in product or service design.
- LO4.11 Discuss the two key issues in service design.
- LO4.12 List the characteristics of well-designed service systems.
- LO4.13 List some guidelines for successful service design.

**CHAPTER OUTLINE**

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**Opening Vignettes**

The essence of a business organization is the products and services it offers, and every aspect of the organization and its supply chain are structured around those products and services. Organizations that have well-designed products or services are more likely to realize their goals than those with poorly designed products or services. Hence, organizations have a strategic interest in product and service design. Product or service design should be closely tied to an organization's strategy. It is a major factor in cost, quality, time-to-market, customer satisfaction, and competitive advantage. Consequently, marketing, finance, operations, accounting, IT, and HR need to be involved. Demand forecasts and projected costs are important, as is the expected impact on the supply chain. It is significant to note that an important cause of operations failures can be traced to faulty design. Designs that have not been well thought out, or are incorrectly implemented, or instructions for assembly or usage that are wrong or unclear, can be the cause of product and service failures, leading to lawsuits, injuries and deaths, product recalls, and damaged reputations.

**LO4.1** Explain the strategic importance of product and service design.

*continued*

## Chapter Outlines

Every chapter and supplement includes an outline of the topics covered.

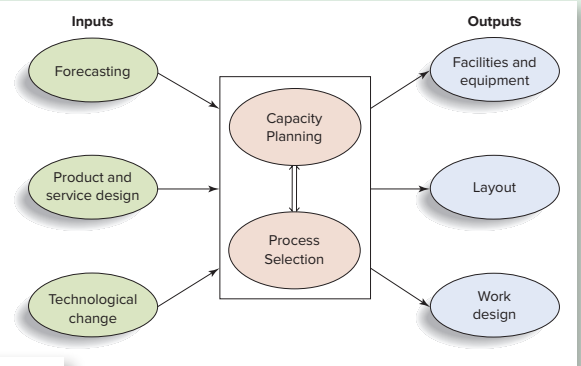
## Opening Vignettes

Each chapter opens with an introduction to the important operations topics covered in the chapter. This enables students to see the relevance of operations management in order to actively engage in learning the material.

## Figures and Photos

The text includes photographs and graphic illustrations to support student learning and provide interest and motivation. Approximately 100 carefully selected photos highlight the 14th edition. The photos illustrate applications of operations and supply chain concepts in many successful companies. More than 400 graphic illustrations, more than any other text in the field, are included and all are color coded with pedagogical consistency to assist students in understanding concepts.

**FIGURE 6.1**  
Process selection and capacity planning influence system design



A major key to Apple's continued success is its ability to keep pushing the boundaries of innovation. Apple has demonstrated how to create growth by dreaming up products so new and ingenious that they have upended one industry after another.



## 5.12 OPERATIONS STRATEGY

The strategic implications of capacity decisions can be enormous, impacting all areas of the organization. From an operations management standpoint, capacity decisions establish a set of conditions within which operations will be required to function. Hence, it is extremely important to include input from operations management people in making capacity decisions.

Flexibility can be a key issue in capacity decisions, although flexibility is not always an option, particularly in capital-intensive industries. However, where possible, flexibility allows an organization to be agile—that is, responsive to changes in the marketplace. Also, it reduces to a certain extent the dependence on long-range forecasts to accurately predict demand. And flexibility makes it easier for organizations to take advantage of technological and other innovations. Maintaining excess capacity (a capacity cushion) may provide a degree of flexibility, albeit at added cost.

Some organizations use a strategy of maintaining a capacity cushion for the purpose of blocking entry into the market by new competitors. The excess capacity enables them to produce at costs lower than what new competitors can. However, such a strategy means higher-than-necessary unit costs, and it makes it more difficult to cut back if demand slows, or to shift to new product or service offerings.

Efficiency improvements and utilization improvements can provide capacity increases. Such improvements can be achieved by streamlining operations and reducing waste. The chapter on lean operations describes ways for achieving those improvements.

Bottleneck management can be a way to increase effective capacity, by scheduling non-bottleneck operations to achieve maximum utilization of bottleneck operations.

In cases where capacity expansion will be undertaken, there are two strategies for determining the timing and degree of capacity expansion. One is the *expand-early* strategy (i.e., before demand materializes). The intent might be to achieve economies of scale, to expand market share, or to preempt competitors from expanding. The risks of this strategy include an oversupply that would drive prices down, and underutilized equipment that would result in higher unit costs.

The other approach is the *wait-and-see* strategy (i.e., until demand materializes, perhaps incrementally). Its advantages are that it allows a company to

## Operations Strategies

An Operations Strategy section is included at the end of most chapters. These sections discuss how the chapters' concepts can be applied and how they impact the operations of a company.

## Readings

Readings highlight important real-world applications, provide examples of production/operations issues, and offer further elaboration of the text material. They also provide a basis for classroom discussion and generate interest in the subject matter. Many of the end-of-chapter readings include assignment questions.

### READING



## DUTCH BOY BRUSHES UP ITS PAINTS

Sherwin-Williams' Dutch Boy Group put a revolutionary spin on paint cans with its innovative square-shaped Twist & Pour™ paint-delivery container for the Dirt Fighter interior latex paint line. The four-piece square container could be the first major change in how house paint is packaged in decades. Lightweight but sturdy, the Twist & Pour "bucket" is packed with so many conveniences, it is next to impossible to mess up a painting project.

Winning Best of Show in an AmeriStar packaging competition sponsored by the Institute of Packaging Professionals, the exclusive, all-plastic paint container stands almost 7½ in. tall and holds 126 oz., a bit less than 1 gal. Rust-resistant and moisture-resistant, the plastic bucket gives users a new way to mix, brush, and store paint.

A hollow handle on one side makes it comfortable to pour and carry. A convenient, snap-in pour spout neatly pours paint into a tray with no dripping but can be removed if desired, to allow a wide brush to be dipped into the 5¼-in.-diameter mouth. Capping the container is a large, twist-off lid that requires no tools to open or close. Molded with two lugs for a snug-finger-tight closing, the threaded cap provides a tight seal to extend the shelf life of unused paint.

While the lid requires no tools to access, the snap-off carry bail is assembled on the container in a "locked-down position" and can be pulled up after purchase for toting or hanging on a ladder. Large, nearly 4½-inch-tall label panels allow glossy front and back labels printed and UV-coated to wrap around the can's rounded corners, for an impressive display.

Jim MacDonald, co-designer of the Twist & Pour and a packaging engineer at Cleveland-based Sherwin-Williams, tells *Packaging Digest* that the space-efficient, square shape is easier to ship and easier to stack in stores. It can also be nested, courtesy of a recess



Jerry Simon

in the bottom that mates with the lid's top ring. "The new design allows for one additional shelf facing on an eight-foot rack or shelf area."

The labels are applied automatically, quite a feat, considering their complexity, size, and the hollow handle they likely encounter during application. MacDonald admits, "Label application was a challenge. We had to modify the bottle several times to accommodate the labeling machinery available."

Source: "Dutch Boy Brushes Up Its Paints," *Packaging Digest*, October 2002. Copyright ©2002 Reed Business Information. Used with permission.

## END-OF-CHAPTER RESOURCES

For student study and review, the following items are provided at the end of each chapter or chapter supplement.

associative model, 80 bias, 109 centered moving average, 96 control chart, 107 correlation, 102 cycle, 82 Delphi method, 81 error, 105 exponential smoothing, 87 focus forecasting, 88 forecast, 76	judgmental forecasts, 80 least squares line, 99 linear trend equation, 89 mean absolute deviation (MAD), 106 mean absolute percent error (MAPE), 106 mean squared error (MSE), 106 moving average, 84 naive forecast, 82 predictor variables, 98	regression, 98 seasonality, 82 seasonal relative, 94 seasonal variations, 93 standard error of estimate, 100 time series, 82 time-series forecasts, 80 tracking signal, 109 trend, 82 trend-adjusted exponential smoothing, 92
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### KEY TERMS

### Summaries and Key Points

Chapters contain summaries that provide an overview of the material covered, and the key points of the chapter are emphasized in a separate section.

### Key Terms

Key terms are highlighted in the text and then repeated in the margin with brief definitions for emphasis. They are listed at the end of each chapter (along with page references) to aid in reviewing.

### Taking Stock and Critical Thinking Exercises

These activities encourage analytical thinking and help broaden conceptual understanding. A question related to ethics is included in the Critical Thinking Exercises.

This item appears at the end of each chapter. It is intended to focus your attention on three key issues for business organizations in general, and operations management in particular. Those issues are trade-off decisions, collaboration among various functional areas of the organization, and the impact of technology. You will see three or more questions relating to these issues. Here is the first set of questions:

1. What are trade-offs? Why is careful consideration of trade-offs important in decision making?
2. Why is it important for the various functional areas of a business organization to collaborate?
3. In what general ways does technology have an impact on operations management decision making?

This item also will appear in every chapter. It allows you to critically apply information you learned in the chapter to a practical situation. Here is the first set of exercises:

1. Many organizations offer a combination of goods and services to their customers. As you learned in this chapter, there are some key differences between the production of goods and the delivery of services. What are the implications of these differences relative to managing operations?
2. Why is it important to match supply and demand? If a manager believes that supply and demand will not be equal, what actions could the manager take to increase the probability of achieving a match?
3. One way that organizations compete is through technological innovation. However, there can be downsides for both the organization and the consumer. Explain.

### TAKING STOCK

### CRITICAL THINKING EXERCISES

### Discussion and Review Questions

Each chapter and each supplement have a list of discussion and review questions. These precede the problem sets and are intended to serve as a student self-review or as class discussion starters.

### Problem Sets

Each chapter includes a set of problems for assignment. The problems have been refined over many editions and are intended to be challenging but doable for students. Short answers to most of the problems are included in Appendix A so students can check their understanding and see immediately how they are progressing.

1. Determine the utilization and efficiency for each of the following situations.
  - a. A loan processing operation that processes an average of 7 loans per day. The operation has a design capacity of 10 loans per day and an effective capacity of 8 loans per day.
  - b. A furnace repair team that services an average of four furnaces a day if the design capacity is six furnaces a day and the effective capacity is five furnaces a day.
  - c. Would you say that systems that have higher efficiency ratios than other systems will always have higher utilization ratios than those other systems? Explain.
2. In a job shop, effective capacity is only 50 percent of design capacity, and actual output is 80 percent of effective output. What design capacity would be needed to achieve an actual output of eight jobs per week?

### PROBLEMS

## Operations Tours

These provide a simple “walkthrough” of an operation for students, describing the company, its product or service, and its process of managing operations. Companies featured include Wegmans Food Markets, Morton Salt, Stickley Furniture, and Boeing.

OPERATIONS TOUR
STICKLEY FURNITURE

**Introduction**  
www.stickley.com

L. & J.G. Stickley was founded in 1900 by brothers Leopold and George Stickley. Located just outside of Syracuse, New York, the company is a producer of fine cherry, white oak, and mahogany furniture. In the 1980s, the company reintroduced the company's original line of mission oak furniture, which now accounts for nearly 50 percent of the company's sales.

Over the years, the company experienced both good and bad times, and at one point it employed over 200 people. However, by the early 1970s, the business was in disarray; there were only about 20 full-time employees, and the company was on the brink of bankruptcy. The present owners bought the ailing firm in 1974, and under their leadership, the company has prospered and grown, and now has 1,350 employees. Stickley has five retail showrooms

in New York State, two in Connecticut, one in North Carolina, and its furniture is sold nationally by some 120 dealers.

**Production**

The production facility is a large, rectangular building with a 30-foot ceiling. Furniture making is labor intensive, although saws, sanders, and other equipment are very much a part of the process. In fact, electric costs average about \$60,000 a month. The company has its own tool room where cutting tools are sharpened, and replacement parts are produced as needed.

Worker skills range from low-skilled material handlers to highly skilled craftsmen. For example, seven master cabinet makers handle customized orders.

The process (see figure below) begins with various sawing operations where large boards received from the lumber mills are cut into smaller sizes. The company recently purchased a

CASE
PROMOTIONAL NOVELTIES

Promotional Novelties provides a wide range of novelty items for its corporate customers. It has just received an order for 20,000 toy tractor-trailers that will be sold by a regional filling station company as part of a holiday promotion. The order is to be shipped at the beginning of week 8. The tree diagram shows the various components of the trucks.

```

graph TD
    TT[Tractor-trailer] --> T[Tractor]
    TT --> TR[Trailer]
    T --> WA1[Wheel assembly]
    T --> B1[Body]
    TR --> WA2[Wheel assembly]
    TR --> B2[Body]
    WA1 --> W6[Wheels (6)]
    WA1 --> BR1[Bracket]
    WA2 --> W12[Wheels (12)]
    WA2 --> BR2[Bracket]
            
```

The company can complete final assembly of the trailers at the rate of 10,000 a week. The tractor and trailer are purchased; lead time is three weeks. The wheel manager's main concern.

The company has a sufficient supply of brackets. Assembly time is one week each for tractors, trailers, and wheel assembly. However, the wheel department can only assemble wheels at the rate of 100,000 a week. The manager must use the wheel department to full capacity, starting in week 1 of the schedule, and order additional wheels from the supplier as needed. Ordered wheels come in sets of 6,400. The lead time for delivery from the supplier is expected to be three weeks. Use lot-for-lot ordering for all items except purchased wheels.

**Questions**

1. How many wheel sets should the manager order?
2. When should the wheel sets be ordered?

## Cases

The text includes short cases. The cases were selected to provide a broader, more integrated thinking opportunity for students without taking a full case approach.



## INSTRUCTOR RESOURCES

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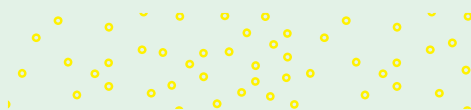
Available within Connect, instructors have access to teaching supports such as electronic files of the ancillary materials: Solutions Manual, Instructor's Manual, Test Bank, PowerPoint Lecture Slides, Digital Image Library, and accompanying Excel files.

**Instructor's Manual.** This manual, revised for the new edition by Tracie Lee, Idaho State University, includes teaching notes, chapter overview, an outline for each chapter, and solutions to the problems in the text.

**Test Bank.** Updated for the new edition by Leslie Sukup, Ferris State University, and reviewed by Nancy Lambe, University of South Alabama, the Test Bank includes over 2,000 true/false, multiple-choice, and discussion questions/problems at varying levels of difficulty. The Test Bank is available to assign within Connect, as Word files available in the Instructor Resource Library, and through our online test generator. Instructors can organize, edit, and customize questions and answers to rapidly generate tests for paper or online administration.

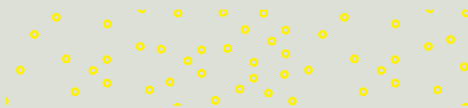
**PowerPoint Lecture Slides.** Revised by Avanti Sethi, University of Texas-Dallas, the PowerPoint slides draw on the highlights of each chapter and provide an opportunity for the instructor to emphasize the key concepts in class discussions.

**Digital Image Library.** All the figures in the book are included for insertion in PowerPoint slides or for class discussion.





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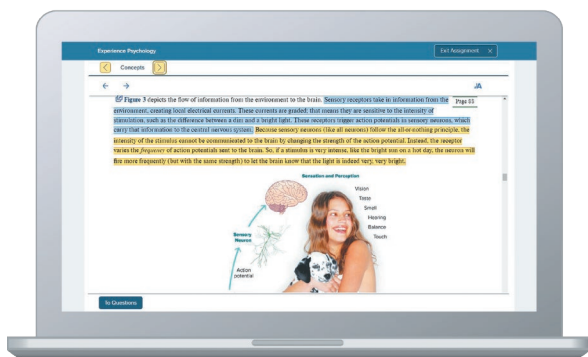
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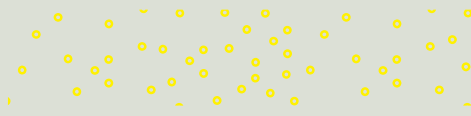
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# Note to Students

The material in this text is part of the core knowledge in your education. Consequently, you will derive considerable benefit from your study of operations management, *regardless of your major*. Practically speaking, operations is a course in *management*.

This book describes principles and concepts of operations management. You should be aware that many of these principles and concepts are applicable to other aspects of your professional and personal life. You can expect the benefits of your study of operations management to serve you in those other areas as well.

Some students approach this course with apprehension, and perhaps even some negative feelings. It may be that they have heard that the course contains a certain amount of quantitative material that they feel uncomfortable with, or that the subject matter is dreary, or that the course is about “factory management.” This is unfortunate, because the subject matter of this book is interesting and vital for all business students. While it is true that some of the material is quantitative, numerous examples, solved problems, and answers at the back of the book help with the quantitative material. As for “factory management,” there is material on manufacturing, as well as on services. Manufacturing is important, and something that you should know about for a number of reasons. Look around you. Most of the “things” you see were manufactured: cars, trucks, planes, clothing, shoes, computers, books, pens and pencils, desks, and cell phones. And these are just the tip of the iceberg. So it makes sense to know something about how these things are produced. Beyond all that is the fact that manufacturing is largely responsible for the high standard of living people have in industrialized countries.

After reading each chapter or supplement in the text, attending related classroom lectures, and completing assigned questions and problems, you should be able to do each of the following:

1. *Identify the key features of that material.*
2. *Define and use terminology.*
3. *Solve typical problems.*
4. *Recognize applications of the concepts and techniques covered.*

5. *Discuss the subject matter* in some depth, including its relevance, managerial considerations, and advantages and limitations.

You will encounter a number of chapter supplements. Check with your course syllabus to determine which ones are included.

This book places an emphasis on problem solving. There are many examples throughout the text illustrating solutions. In addition, at the end of most chapters and supplements you will find a group of solved problems. The examples within the chapter itself serve to illustrate concepts and techniques. Too much detail at those points would be counterproductive. Yet, later on, when you begin to solve the end-of-chapter problems, you will find the solved problems quite helpful. Moreover, those solved problems usually illustrate more and different details than the problems within the chapter.

I suggest the following approach to increase your chances of getting a good grade in the course:

1. Do the class preparation exercises for each chapter if they are available from your instructor.
2. Look over the chapter outline and learning objectives.
3. Read the chapter summary, and then skim the chapter.
4. Read the chapter and take notes.
5. Look over and try to answer some of the discussion and review questions.
6. Work the assigned problems, referring to the solved problems and chapter examples as needed.

Note that the answers to many problems are given at the end of the book. Try to solve each problem before turning to the answer. Remember—tests don’t come with answers.

And here is one final thought: Homework is on the Highway to Success, whether it relates to your courses, the workplace, or life! So do your homework, so you can have a successful journey!

W.J.S.

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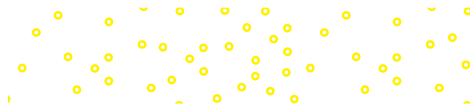
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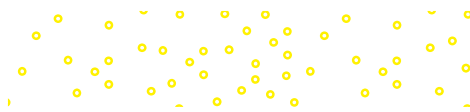
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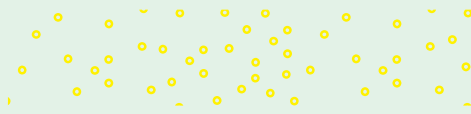
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