

Operations and Supply Chain Management

FIFTEENTH EDITION

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OPERATIONS AND SUPPLY CHAIN MANAGEMENT, 2024 RELEASE

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Modern Business Analytics
First Edition



Preface

I am pleased to announce that a co-author will be joining on the upcoming edition. He is Thomas Kull, a professor of operations and supply chain management at Arizona State University. Thomas is a former supply chain manager, and has written numerous papers on supply chains. He brings a wealth of knowledge to the book, not only on supply chains, but also on the entire field of operations management. I am looking forward to working with him.

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.

Our purpose in revising this book continues to be to provide a clear presentation of the concepts, tools, and applications in the field of operations management. Operations management is evolving and growing, and we 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 2024 Release, 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. 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.

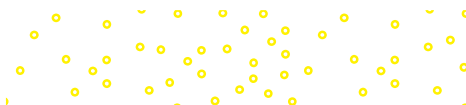
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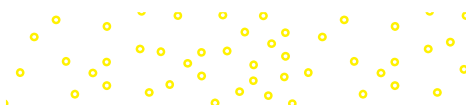


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William J. Stevenson

Thomas J. Kull



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 web-site 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 of 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?

$$\text{Labor productivity} = \frac{\text{Quantity produced}}{\text{Labor hours}} = \frac{400 \text{ cases}}{4 \text{ workers} \times 1/2 \text{ hour/worker}} = 200 \text{ cases per labor hour}$$

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.

$$\text{Multifactor productivity} = \frac{\text{Quantity produced}}{\text{Labor cost} + \text{Material cost} + \text{Overhead}} = \frac{2,000 \text{ rolls}}{\$160 + \$50 + \$320} = 3.77 \text{ rolls per dollar input}$$

Problem 1

mhhe.com/stevenson14e
Solution

Problem 2

mhhe.com/stevenson14e
Solution

TABLE 16.5 Excel solution for Example 2a

Job Sequencing		Clear	FCFS	SPT	DD	CR	S/O
<Back		Notes		Current Date: 23			
Job	Process. Time	Due Date	Remain Oper.	CR Sequence	Critical Ratio	Slack	S/O
A	2	7		3		5	
B	8	16		5		8	
C	4	4		1		0	
D	10	17		6		7	
E	5	15		4		10	
F	12	18		2		6	
Totals		41	0			36	
Method		FCFS					
Average Flow Time		20.00					
Average Tardiness		9.00					
Average Number of Jobs		2.93					

See notes below.

Notes:

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

Days Late

Job	Days Late
A	2
B	10
C	0
D	7
E	14
F	23

Excel Spreadsheet Solutions

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

Logical Connection among Chapters

Chapter topics were selected with the intention to provide content at multiple levels (i.e., strategic, tactical, and operational) and process steps (i.e., inputs and outputs), as well as across concepts of universal applicability (i.e., analytics and principles) throughout the operations management system.

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

CHAPTER

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 List 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 three Rs."
- LO4.9 Discuss several key issues in product or service design.
- LO4.10 Briefly describe the phases in product design and development.
- 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

4.1 Introduction to Product and Service Design 142 What Does Product and Service Design Do? 142 Objectives of Product and Service Design 143 Key Questions 143 Reasons for Product and Service Design (or Redesign) 143	4.5 Cultural Factors 147 4.6 Global Product and Service Design 147 4.7 Environmental Factors: Sustainability 148 Cradle-to-Grave Assessment 148 End-of-Life Programs 149 The Three Rs: Reduce, Reuse, and Recycle 149 Reduce: Value Analysis 149 Reuse: Remanufacturing 149 Recycle 151	4.8 Other Design Considerations 153 Strategies for Product or Service Life Stages 153 Product Life Cycle Management 155 Degree of Standardization 155 Involving Supply Chain Partners and Customers 156 Designing for Mass Customization 156 Reliability 158 Robust Design 159
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OM Is Personal
A Strategic Approach to Design Is Crucial to Operations Managers



Fernando is a little anxious. For the past few years, he has been leading the architectural team that designs plans for an apartment builder in the metro area. He has noticed more and more frustration in his team members. In addition, the company's online ratings have dropped, and tenants have been complaining about excessive noise and poor internet service in their buildings. Construction crews have complained about the difficulties involved in building some of the newer apartment complexes with important but challenging environmental standards. Fernando knows that his supervisor will be expecting him to have a formal plan in the next day or so to resolve these problems.

Question to Consider

1. What formal method might Fernando use to help his team translate tenants' needs and wishes into improved building designs and better construction plans?

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4.10 Designing for Production 165
Concurrent Engineering 165
Computer-Aided Design (CAD) 166

4.11 Service Design 168
Overview of Service Design 168
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Service Blueprinting 170

4.12 Design Strategy 172
Guidelines for Successful Service Design 171
Operations Tour: High Acres Landfill 177
Chapter Supplement: Reliability 178

Chapter Outlines

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

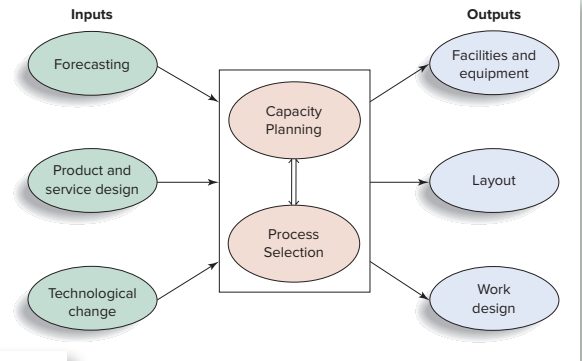
OM Is Personal

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, often with familiar examples, in order to motivate learning. Also, the end-of-chapter Taking Stock section includes a related question that further encourages a holistic view.

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 2024 Release. 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 CAPACITY 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 advantage is more accurate matching of supply and demand.

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 cases include assignment questions.

READING

KRAFT FOODS' RECIPE FOR SUSTAINABILITY

The threat of global warming and the desire to protect the environment have many companies embracing sustainability initiatives. Along the way, they are finding that, in many instances, there are cost savings in doing so.

Among them has been the **Kraft Foods Company**, which spun off of its North American grocery business, known as **Mondelez**, and merged with the **H. J. Heinz Company** to become the **Kraft Heinz Company**, now one of the largest food and beverage companies in the world. Its brands include Kraft, Heinz, ABC, Capri Sun, Jell-O, Kool-Aid, Lunchables, Maxwell House, Ore-Ida, Oscar Mayer, Philadelphia, Planters, Quero, Weight Watchers Smart Ones, and Velveeta. According to the company's website, it "is dedicated to the sustainable health of our people, our planet and our Company" (kraftheinzcompany.com).

Both **Kraft Foods** and the **H. J. Heinz Company** were recognized for their sustainability efforts, which provides insight into some of the cost savings that can stem from sustainability efforts and serve as examples that others might wish to follow.

Some of Kraft's successes have come from redesigned packaging. The goal of the redesign required more efficient packaging and a reduction in the amount of packaging material used. Kraft believed that the greatest opportunity to reduce the environmental impact of a package is early in the design phase. Its packaging designers worldwide critically considered the amount of packaging used, how much post-consumer material could be used, how much energy was used to create the packaging materials, how much CO₂ was generated as the materials were created and formed, and how well the package fit the product physically. According to Kraft's press releases at the time, examples and benefits of some packaging redesigns included:

- DiGiorno and California Pizza Kitchen pizzas: Using slimmer cartons that allow shipment of two extra pizza boxes per case and 14 percent more pizzas per pallet. This design change

- Kraft salad dressing: Using 19 percent less plastic per bottle translated to 3 million fewer pounds annually. Additionally, the new design allowed more bottles to be shipped per truckload, leading to an 18 percent increase in transportation efficiency.

The company has reduced water pollution/soil erosion and to support biodiversity. Considering those successes, Kraft's recipe for sustainability is one that other companies should emulate.



END-OF-CHAPTER RESOURCES

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

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, as well as a final question related to the **OM Is Personal** story from the chapter introduction.

1. What are the major trade-offs in capacity planning?
2. Who needs to be involved in capacity planning?
3. In what ways does technology have an impact on capacity planning?
4. **OM Is Personal:** Assume Claudia chose a wait-and-see approach for capacity planning. What capabilities must her operation have for that strategy to be successful?

TAKING STOCK

1. A computer repair service has a design capacity of 80 repairs per day. Its effective capacity, however, is 64 repairs per day, and its actual output is 62 repairs per day. The manager would like to increase the number of repairs per day because demand is higher than 70 repairs per day, creating a backlog of orders. Which factors would you recommend that the manager investigate? Explain your reasoning.
2. Compared to manufacturing, service requirements tend to be more time dependent, location dependent, and volatile. In addition, service quality is often directly observable by customers. Find a recent article in a business publication that describes how a service organization is struggling with one or more of these issues and make recommendations on what an organization needs to do to overcome these difficulties.
3. Identify four potential unethical actions or inactions related to capacity planning, and the ethical principle each violates (see Chapter 1).
4. Any increase in efficiency also increases utilization. Although the upper limit on efficiency is 100 percent, what can be done to achieve still higher levels of utilization?

CRITICAL THINKING EXERCISES

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 many 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 capacity. 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 HIGH ACRES LANDFILL

The High Acres Landfill is located on a 218-acre site outside Fairport, New York. Opened in 1971, it is licensed to handle residential, commercial, and industrial nonhazardous waste. According to its website, the landfill receives approximately 100,000 tons of waste a year.

The public has certain preconceived notions about a landfill, chief among them that landfills are dirty and unpleasant. However, a visit to the landfill by citizens dispelled some of those misconceptions. The entrance is nicely landscaped, and most of the site is planted with grass and a few trees. Although unpleasant odors can emanate from arriving trucks or at the dump site, the remainder of the landfill is relatively free of noxious smells.

A major portion of the landfill consists of a large hill, within which the waste is buried. Initially, the landfill began not as a hill but as a large hole in the ground. After a number of years of depositing waste, the hole eventually was filled. From that point on, as additional layers were added, the landfill began to take the shape

The construction and operation of landfills are subject to numerous state and federal regulations. For example, nonpermeable liners must be placed on the bottom and sides of the landfill to prevent leakage of liquids into the groundwater. (Independent firms monitor groundwater to determine if there is any leakage into wells placed around the perimeter of the hill.) The High Acres Landfill is mindful of public opinion, and it makes every effort to minimize the amount of time that waste is left exposed. At the end of each day, the waste that has been deposited in the landfill is compacted and covered with six inches of soil.

The primary source of income for the landfill is the fees it charges users. The landfill generates income from methane gas, a by-product of organic waste decomposition, that accumulates within the landfill. According to its website, a collection system is in place to capture and extract the gas from the landfill, enough to power 10,000 homes, which is then sold to the local power company. Also, the landfill has a composting operation in which leaves

and wastes are converted into mulch.

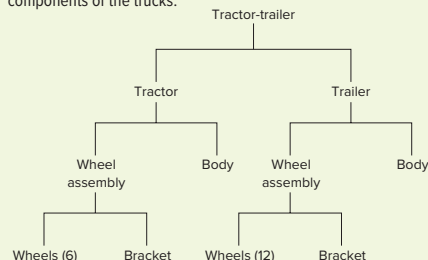
For more information, see <https://www.wm.com/us/en/landfill>.

There is local opposition to locating landfills in the vicinity

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.



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

The company has a sufficient supply of brackets on hand. Assembly time is one week each for tractors, trailers, and wheel assembly. However, the wheel department can only produce wheels at the rate of 100,000 a week. The manager plans to use the wheel department to full capacity, starting in week 2 of the schedule, and order additional wheels from a supplier as needed. Ordered wheels come in sets of 6,400. The lead time for delivery from the supplier is expected to be two to three weeks. Use lot-for-lot ordering for all items except the 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

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, Boise 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, and through our online test generator, Test Builder. 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.

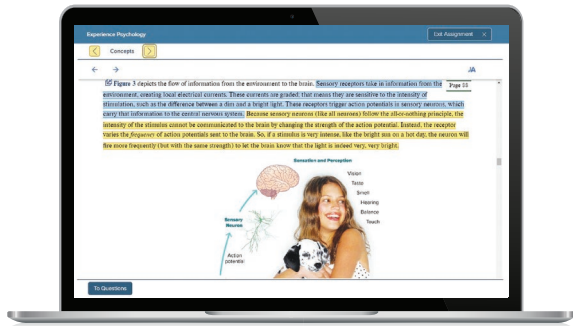




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Note to Students

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 and supply chain management 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 to problems. 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. 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 and solutions 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.

T.J.K.

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