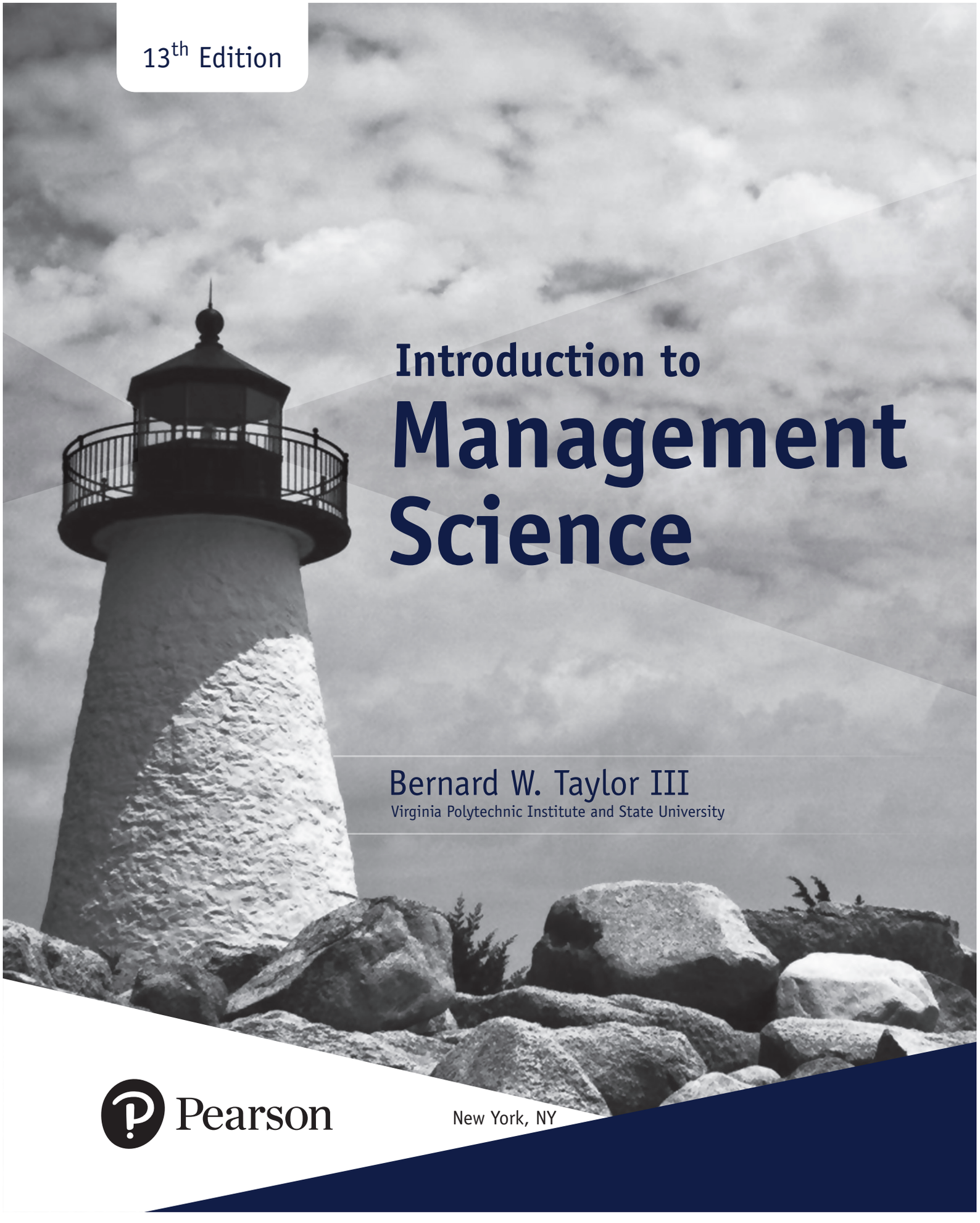
Introduction to Management Science

13th Edition



Introduction to Management Science

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To Diane, Kathleen, and Lindsey

Brief Contents

The following items can be found on the Companion Web site that accompanies this text:

Web Site Modules

Contents

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Preface

New to This Edition

Management science is the application of mathematical models and computing technology to help decision makers solve problems. Therefore, new text revisions like this one tend to focus on the latest technological advances used by businesses and organizations for solving problems, as well as new features that students and instructors have indicated would be helpful to them in learning about management science. Following is a list of the substantial new changes made for this 13th edition of the text:

- This revision incorporates the latest version of Excel® 2016 and includes more than 175 new spreadsheet screenshots.
- More than 60 new exhibit screenshots have been added to show the latest versions of Microsoft® Project 2016, QM for Windows, Excel QM, TreePlan, and Crystal Ball.
- This edition includes 20 new end-of-chapter homework problems, so it now contains more than 800 homework problems and 69 cases.
- All 800-plus Excel homework files on the Instructor's Web site have been replaced with new Excel 2016 files.
- Updated "Chapter Web links" are included for every chapter. More than 550 Web links are provided to access tutorials, summaries, and notes available on the Internet for the various topics in the chapters. Also included are links to YouTube videos that provide additional learning resources.
- Twelve of the 48 "Management Science Application" boxes are new for this edition. All of these new boxes provide applications of management science techniques by companies and organizations.

Solving Teaching and Learning Challenges

The objective of management science is to solve the decision-making problems that confront and confound managers in both the public and private sectors by developing mathematical models of those problems. These models have traditionally been solved with various mathematical techniques, all of which lend themselves to specific types of problems. Thus, management science as a field of study has always been inherently mathematical in nature, and as a result sometimes complex and rigorous. My main goal through 13 editions of this book has always been to make these mathematical topics seem less complex and thus more palatable to undergraduate business students. To achieve this goal I try to provide simple, straightforward explanations of often difficult mathematical topics. I try to use lots of examples that demonstrate in detail the fundamental mathematical steps of the modeling and solution techniques. Although in the past three decades the emphasis in management science has shifted away from strictly mathematical to mostly computer solutions, my objective has not changed. I have provided clear, concise explanations of the techniques used in management science to model problems and provided many examples of how to solve these models on the computer while still including some of the fundamental mathematics of the techniques.

The stuff of management science can seem abstract, and students sometimes have trouble perceiving the usefulness of quantitative courses in general. I remember that when I was a student, I could not foresee how I would use such mathematical topics (in addition to a lot of the other things I learned in college) in any job after graduation. Part of the problem is that the examples used in books often do not seem realistic. Unfortunately, examples must be made simple to facilitate the learning process. Larger, more complex examples reflecting actual applications would be too complex to help the student learn the modeling technique. The modeling techniques presented in this text are, in fact, used extensively in the business world, and their use is increasing rapidly because of computer and information technology, and the emerging field of business analytics. Therefore, the chances that students will use the modeling techniques that they learn from this text in a future job are very great indeed.

Even if these techniques are not used on the job, the logical approach to problem solving embodied in management science is valuable for all types of jobs in all types of organizations. Management science consists of more than just a collection of mathematical modeling techniques; it embodies a philosophy of approaching a problem in a logical manner, as does any science. Thus, this text not only teaches specific techniques but also provides a very useful method for approaching problems.

My primary objective throughout all revisions of this text is readability. The modeling techniques presented in each chapter are explained with straightforward examples that avoid lengthy written explanations. These examples are organized in a logical step-by-step fashion that the student can subsequently apply to the problems at the end of each chapter. I have tried to avoid complex mathematical notation and formulas wherever possible. These various factors will, I hope, help make the material more interesting and less intimidating to students.

Management Science Application

Management Science and Analytics

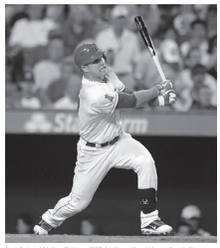
As we discussed in the section "Management Science and Business Analytics," when applied to business problems, analytics often combines the management science approach to problem solving and decision making, including model building, with the use of data. Following are a few examples of the many recent applications of analytics for problem solving in agriculture, media, urban planning, and sports.

Although the total world population is expected to grow by one-third to 9.6 billion in 2050, there will be less natural resources and land to support the necessary food production to feed an additional 2.4 billion people. Plant seed developer Syngenta is using analytics and management science models in its research and development efforts to develop and implement a plant-breeding strategy for soybeans that will improve the quality and quantity of the soybeans that farmers produce per acre. Their application of analytics enables better decisions that result in reducing the time and cost required to develop higher-productivity crops, saving Syngenta an estimated $287 million in a five-year period, while making a contribution to meeting the world's growing food needs.

iHeartMedia, Inc. (IHM) owns over 850 radio stations in more than 150 cities and provides programming (i.e., news, sports, traffic reports and weather) to over 2,250 stations. The company uses a set of management science models and sales data to maximize revenue from their inventory of radio advertising spots. Advertisers expect IHM to distribute their spots fairly and equitably across available inventory according to their order specifications, including dates, times, spot length, programs, stations, and demographic targets. IHM uses two linear programming models to assign advertising spots. The use of analytics has resulted in a more efficient use of available inventory, improved customer service, and enhanced sales from more accurate inventory visibility, resulting in a financial benefit of over a half million dollars annually.

ParkPGH is a decision analytics application that provides real-time and predictive information for garage parking space availability within the downtown Pittsburgh Cultural District. The model collects real time parking information for garage gate counts and uses historical data and event schedules to predict parking availability and provide downtown visitors with information on available parking via mobile devices and the Internet. The system has reduced parking space search times and changed the perception of downtown patrons about the downtown parking situation (including security and availability), and also helped garage operators better manage parking demand. In one year the parking application received over 300,000 inquiries.

One of the most visible applications of analytics in the sports industry has been the development and use of "sabermetrics"



San Gabriel Valley Tribune/ZUMA Press Inc/Alamy Stock Photo

in major league baseball, popularized by the book and movie *Moneyball*. It was originally defined in 1980 by Bill James (currently an analyst with the Boston Red Sox) as the "search for objective knowledge about baseball," and it is derived from the acronym SABR (e.g., Society for American Baseball Research). It has generally evolved into the application of statistical analysis of baseball records to develop predictive models and measures to evaluate and compare the in-game performance of individual players, usually in terms of runs or team wins. Sabermetrics attempts to answer questions such as, which players on a team will contribute most to the team's offense? For example, the sabermetric measure, VORP (value over replacement player), attempts to predict how much a hitter contributes offensively to his team in comparison to a fictitious average replacement player. A player might be worth 50 more runs in a season than a replacement level player at the same position (acquired at minimal cost). Currently every major league team has some employees in administrative positions dedicated to quantitative analytics for the evaluation of player performance to determine player acquisitions, trades, and contracts.

Sources: J. Byrum, C. Davis, G. Doonan, T. Doubler, D. Foster, B. Luzzi, R. Mowers, C. Zinselmeir, J. Klober, D. Culhane, and S. Mack, "Advanced Analytics for Agricultural Product Development," *Interfaces* 46, no. 1 (January–February 2016): 5–17; S. Venkatachalam, F. Wong, E. Uyar, S. Ward, and A. Aggarwal, "Media Company Uses Analytics to Schedule Radio Advertisement Spots," *Interfaces* 45, no. 6 (November–December 2015): 485–500; T. Fabusuyi, R. Hampshire, V. Hill, and K. Sasanuma, "Decision Analytics for Parking Availability in Downtown Pittsburgh," *Interfaces* 44, no. 3 (May–June 2014): 286–299.

Developing Employability Skills

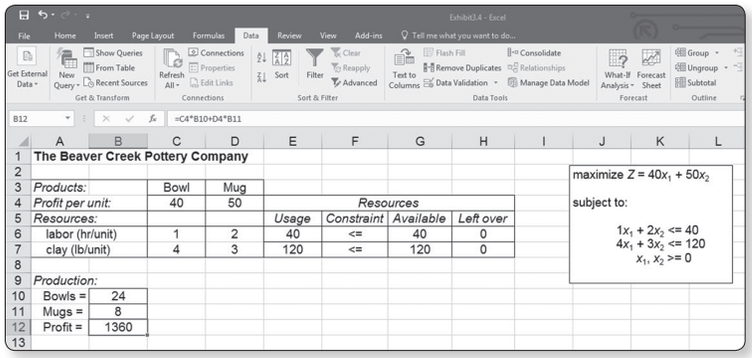
For students to succeed in a rapidly changing job market, they need to know how to develop a variety of analytical and quantitative skills that they should be aware of for their career options. In this 13th edition of *Introduction to Management Science* we focus on developing these skills in the following ways.

Management Science Applications

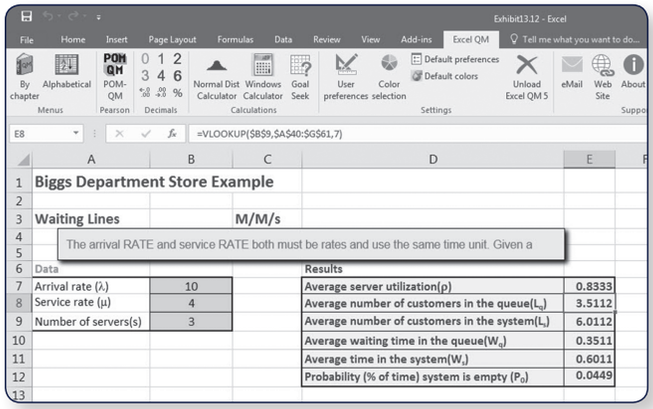
Management Science Application boxes are located in every chapter in the text. They describe how a company, an organization, or an agency uses the particular management science technique being presented and demonstrated in the chapter to compete in a global environment. There are 48 of these boxes, 12 of which are new, throughout the text. They encompass a broad range of business and public-sector applications, both foreign and domestic.

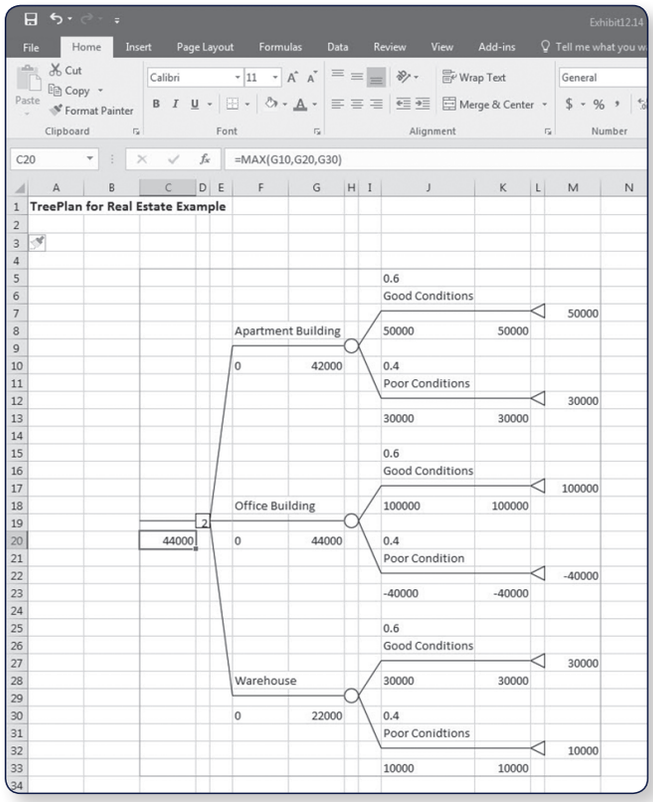
Excel Spreadsheets

This new edition continues to emphasize Excel spreadsheet solutions of problems. Spreadsheet solutions are demonstrated in all the chapters in the text (except for Chapter 2, on linear programming modeling and graphical solution) for virtually every management science modeling technique presented. These spreadsheet solutions are presented in optional subsections, allowing the instructor to decide whether to cover them. The text includes more than 140 new Excel spreadsheet screenshots for Excel 2016. Most of these screenshots include reference callout boxes that describe the solution steps within the spreadsheet. Files that include all the Excel spreadsheet



model solutions for the examples in the text (data files) are included on the Companion Web site and can be easily downloaded by the student to determine how the spreadsheet was set up and the solution derived, and to use as templates to work homework problems. In addition, Appendix B at the end of the text provides a tutorial on how to set up and edit spreadsheets for problem solution. At top left is an example of one of the Excel spreadsheet files (from Chapter 3) that is available on the Companion Web site accompanying the text.





Spreadsheet Add-Ins

Several spreadsheet add-in packages are available with this book, often in trial and premium versions. For complete information on options for downloading each package, please visit *http://www.pearsonhighered.com/taylor*.

Excel QM

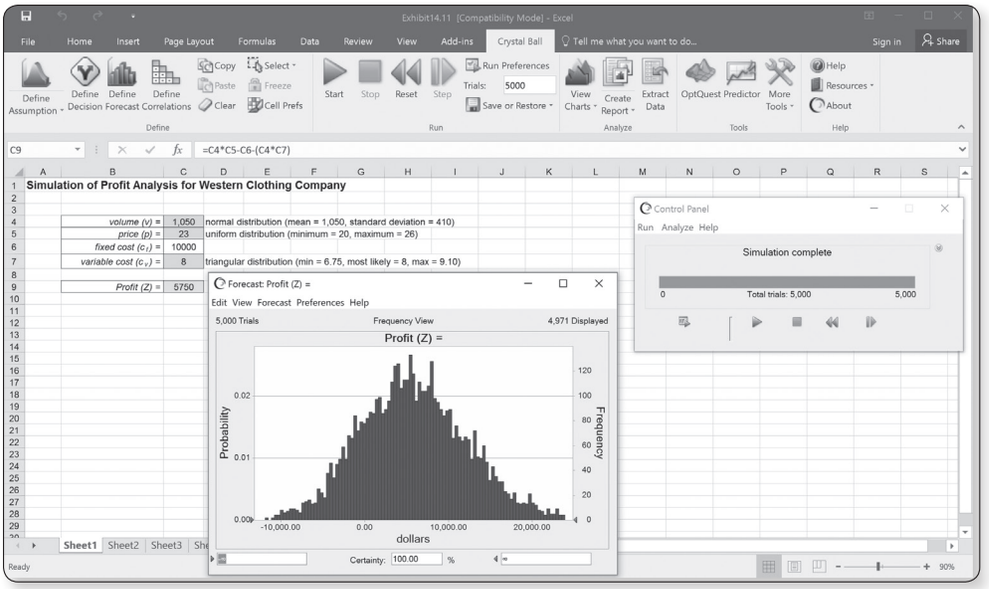
For some management science topics, the Excel formulas that are required for solution are lengthy and complex and thus are very tedious and time consuming to type into a spreadsheet. In several of these instances in the book, including Chapter 6 on transportation and assignment problems, Chapter 12 on decision analysis, Chapter 13 on queuing, Chapter 15 on forecasting, and Chapter 16 on inventory control, spreadsheet "add-ins" called Excel QM are demonstrated. These add-ins provide a generic spreadsheet setup with easy-to-use dialog boxes and all of the formulas already typed in for specific problem types. Unlike other "black box" software, these add-ins allow users to see the formulas used in each cell. The input, results, and the graphics are easily seen and can be easily changed, making this software ideal for classroom demonstrations and student explorations. At left is an example of an Excel QM file (from Chapter 13 on queuing analysis) that is on the Companion Web site that accompanies the text.

Risk Solver Platform for Education

This program is a tool for risk analysis, simulation, and optimization in Excel. The Companion Web site will direct you to a trial version of the software.

TreePlan

Another spreadsheet add-in program that is demonstrated in the text is TreePlan, a program that will set up a generic spreadsheet for the solution of decision-tree problems in Chapter 12 on decision analysis. This is also available on the Companion Web site. At left is an example of one of the TreePlan files (from Chapter 12) that is on the text Companion Web site.



Crystal Ball

Another spreadsheet add-in program is Crystal Ball by Oracle. Crystal Ball is demonstrated in Chapter 14 on simulation and shows how to perform simulation analysis for certain types of risk analysis and forecasting problems. Here is an example of one of the Crystal Ball files (from Chapter 14) that is on the Companion Web site. The Companion Web site will direct you to a trial version of the software.

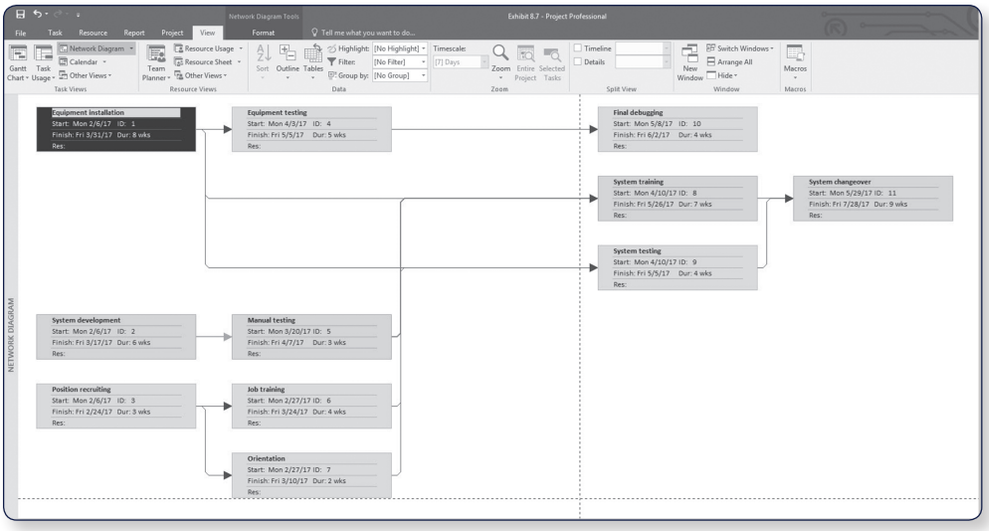
QM for Windows Software Package

QM for Windows is a computer package that is included on the text Companion Web site, and many students and instructors will prefer to use it with this text. This software is very user-friendly, requiring virtually no preliminary instruction except for the "help" screens that can be accessed directly from the program. It is demonstrated throughout the text in conjunction with virtually every management science modeling technique, except simulation. The text includes 50 QM for Windows screens used to demonstrate example problems. Thus, for most topics problem solution is demonstrated via both Excel spreadsheets and QM for Windows. Files that include all the QM for Windows solutions, for example, in the text are included on the accompanying Companion Web site. Here is an example of one of the QM for Windows files (from Chapter 4 on linear programming) that is on the Companion Web site.

Linear Programming Results

Product Mix ExampleSolution

	X1	X2	X3	X4		RHS	Dual
Maximize	90	125	45	65			
Processing time (hrs)	.1	.25	.08	.21	<=	72	233.33
Shipping capacity (boxes)	3	3	1	1	<=	1200	22.22
Budget ($)	36	48	25	35	<=	25000	0
Blank sweats (dozens)	1	1	0	0	<=	500	0
Blank T's (dozens)	0	0	1	1	<=	500	4.11
Solution	175.56	57.78	500	0		45522.22	



Microsoft Project

Chapter 8 on project management includes the popular software package Microsoft Project. Here is an example of one of the Microsoft Project files (from Chapter 8) that is available on the text Companion Web site. The Companion Web site will direct you to a trial version of the software.

Problems and Cases

Previous editions of the text always provided a substantial number of homework questions, problems, and cases for students to practice on. This edition includes more than 800 homework problems, 20 of which are new, and 69 end-of-chapter case problems.

Example Problem Solutions

As a prelude to the problems, this section presents example solutions to two linear programming problems.

Problem Statement

Moore's Meatpacking Company produces a hot dog mixture in 1,000-pound batches. The mixture contains two ingredients—chicken and beef. The cost per pound of each of these ingredients is as follows:

Ingredient	Cost/lb.
Chicken	$3
Beef	$5

Each batch has the following recipe requirements:

a. At least 500 pounds of chicken
b. At least 200 pounds of beef

The ratio of chicken to beef must be at least 2 to 1. The company wants to know the optimal mixture of ingredients that will minimize cost. Formulate a linear programming model for this problem.

Solution

Step 1: Identify Decision Variables

Recall that the problem should not be "swallowed whole." Identify each part of the model separately, starting with the decision variables:

$$x_1 = \text{lb. of chicken}$$
$$x_2 = \text{lb. of beef}$$

Step 2: Formulate the Objective Function

$$\text{minimize } Z = \$3x_1 + \$5x_2$$

where

$$Z = \text{cost per1,000-lb batch}$$
$$\$3x_1 = \text{cost of chicken}$$
$$\$5x_2 = \text{cost of beef}$$

Step 3: Establish Model Constraints

The constraints of this problem are embodied in the recipe restrictions and (not to be overlooked) the fact that each batch must consist of 1,000 pounds of mixture:

$$x_1 + x_2 = 1{,}000 \text{ lb.}$$
$$x_1 \geq 500 \text{ lb. of chicken}$$
$$x_2 \geq 200 \text{ lb. of beef}$$
$$x_1/x_2 \geq 2/1 \text{ or } x_1 - 2x_2 \geq 0$$

and

$$x_1, x_2 \geq 0$$

The Model

$$\text{minimize } Z = \$3x_1 + \$5x_2$$

subject to

$$x_1 + x_2 = 1{,}000$$
$$x_1 \geq 500$$
$$x_2 \geq 200$$
$$x_1 - 2x_2 \geq 0$$
$$x_1, x_2 \geq 0$$

Marginal Notes

Notes in the margins of this text serve the same basic function as notes that students themselves might write in the margin. They highlight certain topics to make it easier for students to locate them, summarize topics and important points, and provide brief definitions of key terms and concepts.

Examples

The primary means of teaching the various quantitative modeling techniques presented in this text is through examples. Thus, examples are liberally inserted throughout the text, primarily to demonstrate how problems are solved with the different quantitative techniques and to make them easier to understand. These examples are organized in a logical step-by-step solution approach that the student can subsequently apply to the homework problems.

Example Problem Solutions

At the end of each chapter, just prior to the homework questions and problems, is a section that provides solved examples to serve as a guide for doing the homework problems. These examples are solved in a detailed, step-by-step fashion. Here is an example from Chapter 2.

Chapter Web Links

The files on the Companion Web site contains Chapter Web links for every chapter in the text. These Web links access tutorials, summaries, and notes available on the Internet for the various techniques and topics in every chapter in the text. Also included are YouTube videos that provide additional learning resources and tutorials about many of the topics and techniques, links to the development and developers of the techniques in the text, and links to the Web sites for the companies and organizations that are featured in the "Management Science Application" boxes in every chapter. The "Chapter Web links" file includes more than 550 Web links.

Chapter Modules

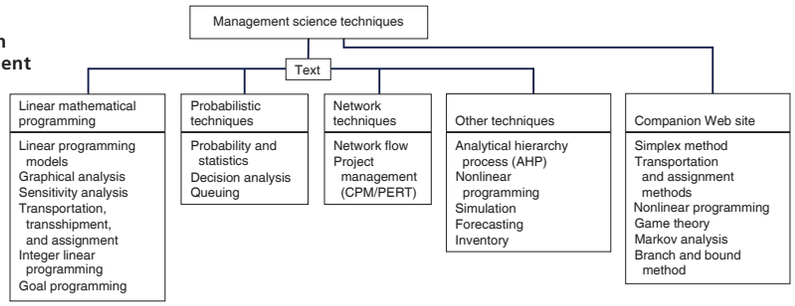
Several of the strictly mathematical topics—such as the simplex and transportation solution methods—are included as chapter modules on the Companion Web site, at *http://www.pearsonhighered.com/taylor*.

Table of Contents Overview

An important objective is to have a well-organized text that flows smoothly and follows a logical progression of topics, placing the different management science modeling techniques in their proper perspective. The following Figure 1.6 from Chapter 1 outlines the organization of topics in the book.

The first 10 chapters are related to mathematical programming that can be solved using Excel spreadsheets, including linear, integer, nonlinear, and goal programming, as well as network techniques.

FIGURE 1.6
Classification of management science techniques



Within these mathematical programming chapters, the traditional simplex procedure for solving linear programming problems mathematically is located in Module A on the Companion Web site, at *http://www.pearsonhighered.com/taylor*, that accompanies this text. It can still be covered by the student on the computer as part of linear programming, or it can be excluded, without leaving a "hole" in the presentation of this topic. The integer programming mathematical branch and bound solution method (Chapter 5) is located in Module C on the Companion Web site. In Chapter 6, on the transportation and assignment problems, the strictly mathematical solution approaches, including the northwest corner, VAM, and stepping-stone methods, are located in Module B on the Companion Web site. Because transportation and assignment problems are specific types of network problems, the two chapters that cover network flow models and project networks that can be solved with linear programming, as well as traditional model-specific solution techniques and software, follow Chapter 6 on transportation and assignment problems. In addition, in Chapter 10, on nonlinear programming, the traditional mathematical solution techniques, including the substitution method and the method of Lagrange multipliers, are located in Module D on the Companion Web site.

Chapters 11 through 14 include topics generally thought of as being probabilistic, including probability and statistics, decision analysis, queuing, and simulation. Module F on Markov analysis and Module E on game theory are on the Companion Web site. Forecasting in Chapter 15 and inventory management in Chapter 16 are both unique topics related to operations management.

Instructor Teaching Resources

This text comes with the following teaching resources.

Supplements available to instructors at *www.pearsonhighered.com/irc*	Features of the Supplement
Instructor's Solutions Manual developed by the author	• Detailed solutions for all end-of-chapter exercises and cases • One file per chapter provided in MS Word format
Excel Homework Solutions developed by the author	• A corresponding Excel solution file for almost all 840 end-of-chapter homework and case problem in the text • Organized by chapter and problem number • Also include Excel homework solution files for TreePlan, Crystal Ball, and Microsoft Project
Test Bank authored by Geoff Willis of the University of Central Oklahoma	• 2,000 questions, including true/false, multiple-choice, and problem-solving questions for each chapter • Each question followed by the correct answer, page references, main headings, difficulty rating, and key words
TestGen® Computerized Test Bank	• Pearson Education's test-generating software, PC and Mac compatible, and preloaded with all of the Test Bank questions • Can manually or randomly view test questions and drag and drop to create a test • Can add or modify test bank questions as needed
PowerPoint Presentations authored by Geoff Willis of the University of Central Oklahoma	• Available for every chapter • Features figures, tables, Excel spreadsheets and main points • They meet accessibility standards for students with disabilities. Features include, but not limited to: ◦ Keyboard and Screen Reader access ◦ Alternative text for images ◦ High color contrast between background and foreground colors
Chapter Web Links developed by the author	• Internet links to tutorials, summaries, notes and videos

Acknowledgments

As with any other large project, the revision of a textbook is not accomplished without the help of many people. The 13th edition of this book is no exception, and I would like to take this opportunity to thank those who have contributed to its preparation.

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