

Introduction to Management Science



13th Edition

Introduction to Management Science

Bernard W. Taylor III
Virginia Polytechnic Institute and State University



New York, NY

Vice President, Business Publishing: Donna Battista
Director of Portfolio Management: Stephanie Wall
Director, Courseware Portfolio Management: Ashley Dodge
Senior Sponsoring Editor: Neeraj Bhalla
Editorial Assistant: Linda Albelli
Vice President, Product Marketing: Roxanne McCarley
Senior Product Marketer: Kaylee Claymore
Product Marketing Assistant: Marianela Silvestri
Manager of Field Marketing, Business Publishing: Adam Goldstein
Executive Field Marketing Manager: Thomas Hayward
Vice President, Production and Digital Studio, Arts and Business:
Etain O'Dea
Director of Production, Business: Jeff Holcomb
Managing Producer, Business: Melissa Feimer
Content Producer: Sugandh Juneja
Operations Specialist: Carol Melville

Design Lead: Kathryn Foot
Manager, Learning Tools: Brian Surette
Content Developer, Learning Tools: Lindsey Sloan
Managing Producer, Digital Studio and GLP, Media Production and Development: Ashley Santora
Managing Producer, Digital Studio: Diane Lombardo
Digital Studio Producer: Regina DaSilva
Digital Studio Producer: Alana Coles
Digital Content Team Lead: Noel Lotz
Digital Content Project Lead: Courtney Kamauf
Project Managers: Roberta Sherman and Sree Meenakshi.R, SPi Global
Cover Designer: SPi Global
Cover Art: Margaret Macleod/EyeEm/Getty Images
Printer/Binder: Courier/DigitalSolutions/Kendallville
Cover Printer: Courier/DigitalSolutions/Kendallville

Microsoft and/or its respective suppliers make no representations about the suitability of the information contained in the documents and related graphics published as part of the services for any purpose. All such documents and related graphics are provided "as is" without warranty of any kind. Microsoft and/or its respective suppliers hereby disclaim all warranties and conditions with regard to this information, including all warranties and conditions of merchantability, whether express, implied or statutory, fitness for a particular purpose, title and non-infringement. In no event shall Microsoft and/or its respective suppliers be liable for any special, indirect or consequential damages or any damages whatsoever resulting from loss of use, data or profits, whether in an action of contract, negligence or other tortious action, arising out of or in connection with the use or performance of information available from the services.

The documents and related graphics contained herein could include technical inaccuracies or typographical errors. Changes are periodically added to the information herein. Microsoft and/or its respective suppliers may make improvements and/or changes in the product(s) and/or the program(s) described herein at any time. Partial screen shots may be viewed in full within the software version specified.

Microsoft® and Windows® are registered trademarks of the Microsoft Corporation in the U.S.A. and other countries. This book is not sponsored or endorsed by or affiliated with the Microsoft Corporation.

Copyright © 2019, 2016, 2013 by Pearson Education, Inc. or its affiliates. All Rights Reserved. Manufactured in the United States of America. This publication is protected by copyright, and permission should be obtained from the publisher prior to any prohibited reproduction, storage in a retrieval system, or transmission in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise. For information regarding permissions, request forms, and the appropriate contacts within the Pearson Education Global Rights and Permissions department, please visit www.pearsoned.com/permissions/.

Acknowledgments of third-party content appear on the appropriate page within the text, which constitutes an extension of this copyright page.

PEARSON and ALWAYS LEARNING are exclusive trademarks owned by Pearson Education, Inc. or its affiliates in the U.S. and/or other countries.

Unless otherwise indicated herein, any third-party trademarks logos, or icons that may appear in this work are the property of their respective owners, and any references to third-party trademarks, logos, or other trade dress are for demonstrative or descriptive purposes only. Such references are not intended to imply any sponsorship, endorsement, authorization, or promotion of Pearson's products by the owners of such marks, or any relationship between the owner and Pearson Education, Inc. or its affiliates, authors, licensees, or distributors.

Library of Congress Cataloging-in-Publication Data on File

To Diane, Kathleen, and Lindsey



Brief Contents

<i>Preface</i>	<i>xiii</i>	12 Decision Analysis	553
1 Management Science	1	13 Queuing Analysis	614
2 Linear Programming: Model Formulation and Graphical Solution	33	14 Simulation	654
3 Linear Programming: Computer Solution and Sensitivity Analysis	76	15 Forecasting	706
4 Linear Programming: Modeling Examples	114	16 Inventory Management	773
5 Integer Programming	187	Appendix A	
6 Transportation, Transshipment, and Assignment Problems	240	Normal and Chi-Square Tables	815
7 Network Flow Models	299	Appendix B	
8 Project Management	350	Setting Up and Editing a Spreadsheet	817
9 Multicriteria Decision Making	422	Appendix C	
10 Nonlinear Programming	493	The Poisson and Exponential Distributions	821
11 Probability and Statistics	518	<i>Solutions to Selected Odd-Numbered Problems</i>	823
		<i>Glossary</i>	832
		<i>Index</i>	837
		The following items can be found on the Companion Web site that accompanies this text:	
		Web Site Modules	
		Module A: The Simplex Solution Method	A-1
		Module B: Transportation and Assignment Solution Methods	B-1
		Module C: Integer Programming: The Branch and Bound Method	C-1
		Module D: Nonlinear Programming Solution Techniques	D-1
		Module E: Game Theory	E-1
		Module F: Markov Analysis	F-1
		vii	

Contents

<i>Preface</i>	<i>xiii</i>		
1 Management Science	1		
The Management Science Approach to Problem Solving	2		
Time Out: for Pioneers in Management Science	5		
Management Science Application: Room Pricing with Management Science and Analytics at Marriott	6		
Management Science and Business Analytics	7		
Model Building: Break-Even Analysis	8		
Computer Solution	13		
Management Science Modeling Techniques	16		
Management Science Application: Management Science and Analytics	17		
Business Usage of Management Science Techniques	19		
Management Science Application: Management Science in Health Care	20		
Management Science Models in Decision Support Systems	21		
<i>Summary 23 • Problems 23 • Case Problem</i>	<i>30</i>		
2 Linear Programming: Model Formulation and Graphical Solution	33		
Model Formulation	34		
A Maximization Model Example	34		
Time Out: for George B. Dantzig	35		
		Management Science Application: Allocating Seat Capacity on Indian Railways Using Linear Programming	38
		Graphical Solutions of Linear Programming Models	38
		Management Science Application: Renewable Energy Investment Decisions at GE Energy	50
		A Minimization Model Example	50
		Management Science Application: Determining Optimal Fertilizer Mixes at Soquimich (South America)	54
		Irregular Types of Linear Programming Problems	56
		Characteristics of Linear Programming Problems	59
		<i>Summary 60 • Example Problem Solutions 60 • Problems 64 • Case Problem 73</i>	
		3 Linear Programming: Computer Solution and Sensitivity Analysis	76
		Computer Solution	77
		Management Science Application: Scheduling Air Ambulance Service in Ontario (Canada)	82
		Management Science Application: Improving Profitability at Norske Skog with Linear Programming	83
		Sensitivity Analysis	84
		<i>Summary 95 • Example Problem Solutions 95 • Problems 98 • Case Problem 111</i>	

<p>4 Linear Programming: Modeling Examples 114</p> <hr/> <p>A Product Mix Example 115</p> <p>Time Out: for George B. Dantzig 120</p> <p>A Diet Example 120</p> <p>An Investment Example 123</p> <p>A Marketing Example 128</p> <p>Management Science Application: Scheduling Radio Ads with Analytics and Linear Programming 129</p> <p>A Transportation Example 133</p> <p>A Blend Example 136</p> <p>A Multiperiod Scheduling Example 140</p> <p>Management Science Application: Linear Programming Blending Applications in the Petroleum Industry 141</p> <p>Management Science Application: Employee Scheduling with Management Science 143</p> <p>A Data Envelopment Analysis Example 145</p> <p>Management Science Application: Evaluating American Red Cross Chapters Using DEA 147</p> <p><i>Summary 149 • Example Problem Solutions 150 • Problems 152 • Case Problem 182</i></p> <p>5 Integer Programming 187</p> <hr/> <p>Integer Programming Models 188</p> <p>Management Science Application: Selecting Volunteer Teams at Eli Lilly to Serve in Impoverished Communities 191</p> <p>Integer Programming Graphical Solution 191</p> <p>Computer Solution of Integer Programming Problems with Excel and QM for Windows 193</p> <p>Time Out: for Ralph E. Gomory 194</p> <p>Management Science Application: Scheduling Appeals Court Sessions in Virginia with Integer Programming 197</p> <p>Management Science Application: Forming Business Case Student Teams at Indiana University 202</p> <p>0–1 Integer Programming Modeling Examples 202</p>	<p>Management Science Application: A Set Covering Model for Determining Fire Station Locations in Istanbul 211</p> <p><i>Summary 211 • Example Problem Solution 212 • Problems 212 • Case Problem 230</i></p> <p>6 Transportation, Transshipment, and Assignment Problems 240</p> <hr/> <p>The Transportation Model 241</p> <p>Time Out: for Frank L. Hitchcock and Tjalling C. Koopmans 243</p> <p>Management Science Application: Reducing Transportation Costs in the California Cut Flower Industry 244</p> <p>Computer Solution of a Transportation Problem 244</p> <p>Management Science Application: Analyzing Container Traffic Potential at the Port of Davisville (RI) 250</p> <p>The Assignment Model 254</p> <p>Computer Solution of an Assignment Problem 254</p> <p>Management Science Application: Supplying Empty Freight Cars at Union Pacific Railroad 257</p> <p>Management Science Application: Assigning Umpire Crews at Professional Tennis Tournaments 258</p> <p><i>Summary 259 • Example Problem Solution 259 • Problems 260 • Case Problem 290</i></p> <p>7 Network Flow Models 299</p> <hr/> <p>Network Components 300</p> <p>The Shortest Route Problem 301</p> <p>The Minimal Spanning Tree Problem 309</p> <p>Management Science Application: Determining Optimal Milk Collection Routes in Italy 312</p> <p>The Maximal Flow Problem 313</p> <p>Time Out: for E. W. Dijkstra, L. R. Ford, Jr., and D. R. Fulkerson 314</p>
--	---

	Management Science Application: Distributing Railway Cars to Customers at CSX	315
	<i>Summary</i> 320 • <i>Example Problem Solution</i> 320 • <i>Problems</i> 322 • <i>Case Problem</i> 342	
8	Project Management	350
	The Elements of Project Management	351
	Management Science Application: The Panama Canal Expansion Project	353
	Time Out: for Henry Gantt	357
	Management Science Application: Transportation Construction Projects	359
	CPM/PERT	360
	Time Out: for Morgan R. Walker, James E. Kelley, Jr., and D. G. Malcolm	362
	Probabilistic Activity Times	369
	Management Science Application: Salvaging the Costa Concordia Cruise Ship	375
	Microsoft Project	377
	Project Crashing and Time–Cost Trade-Off	380
	Management Science Application: Reconstructing the Pentagon after 9/11	384
	Formulating the CPM/PERT Network as a Linear Programming Model	385
	<i>Summary</i> 393 • <i>Example Problem Solution</i> 393 • <i>Problems</i> 396 • <i>Case Problem</i> 419	
9	Multicriteria Decision Making	422
	Goal Programming	423
	Graphical Interpretation of Goal Programming	427
	Computer Solution of Goal Programming Problems with QM for Windows and Excel	430
	Management Science Application: Workforce Planning for the U.S. Army Medical Department with Goal Programming	430
	Time Out: for Abraham Charnes and William W. Cooper	434
	The Analytical Hierarchy Process	437

	Management Science Application: Selecting Sustainable Transportation Routes Across the Pyrenees Using AHP	437
	Management Science Application: Ranking Twentieth-Century Army Generals Using AHP	444
	Scoring Models	447
	Management Science Application: A Scoring Model for Determining U.S. Army Installation Regions	449
	<i>Summary</i> 449 • <i>Example Problem Solutions</i> 450 • <i>Problems</i> 453 • <i>Case Problem</i> 488	
10	Nonlinear Programming	493
	Nonlinear Profit Analysis	494
	Constrained Optimization	497
	Solution of Nonlinear Programming Problems with Excel	499
	A Nonlinear Programming Model with Multiple Constraints	503
	Management Science Application: Making Solar Power Decisions at Lockheed Martin with Nonlinear Programming	504
	Nonlinear Model Examples	505
	<i>Summary</i> 510 • <i>Example Problem Solution</i> 511 • <i>Problems</i> 511 • <i>Case Problem</i> 516	
11	Probability and Statistics	518
	Types of Probability	519
	Fundamentals of Probability	521
	Management Science Application: Treasure Hunting with Probability and Statistics	523
	Statistical Independence and Dependence	524
	Expected Value	531
	Management Science Application: A Probability Model for Analyzing Coast Guard Patrol Effectiveness	532
	The Normal Distribution	533
	<i>Summary</i> 543 • <i>Example Problem Solution</i> 543 • <i>Problems</i> 545 • <i>Case Problem</i> 551	

12 Decision Analysis	553	Continuous Probability Distributions	669
Components of Decision Making	554	Statistical Analysis of Simulation Results	674
Decision Making Without Probabilities	555	Management Science Application: Predicting Somalian Pirate Attacks Using Simulation	675
Management Science Application: Planning for Terrorist Attacks and Epidemics in Los Angeles County with Decision Analysis	562	Crystal Ball	676
Decision Making with Probabilities	562	Verification of the Simulation Model	683
Decision Analysis With Additional Information	576	Areas of Simulation Application	683
Utility	582	<i>Summary</i> 684 • <i>Example Problem Solution</i> 685 • <i>Problems</i> 688 • <i>Case Problem</i> 702	
<i>Summary</i> 584 • <i>Example Problem Solutions</i> 584 • <i>Problems</i> 587 • <i>Case Problem</i> 610		15 Forecasting	706
13 Queuing Analysis	614	Forecasting Components	707
Elements of Waiting Line Analysis	615	Management Science Application: Forecasting Advertising Demand at NBC	709
The Single-Server Waiting Line System	616	Time Series Methods	710
Time Out: for Agner Krarup Erlang	617	Management Science Application: Forecasting Empty Shipping Containers at CSAV (Chile)	714
Management Science Application: Using Queuing Analysis to Design Health Centers in Abu Dhabi	624	Management Science Application Forecasting Trends for Denim Jeans	719
Undefined and Constant Service Times	625	Forecast Accuracy	722
Finite Queue Length	628	Time Series Forecasting Using Excel	726
Management Science Application: Providing Telephone Order Service in the Retail Catalog Business	631	Management Science Application: Demand Forecasting at Zara	727
Finite Calling Population	631	Regression Methods	730
The Multiple-Server Waiting Line	634	Management Science Application: An Airline Passenger Forecasting Model	734
Management Science Application: Making Sure 911 Calls Get Through at AT&T	637	Data Mining	739
Additional Types of Queuing Systems	639	<i>Summary</i> 740 • <i>Example Problem Solutions</i> 740 • <i>Problems</i> 743 • <i>Case Problem</i> 769	
<i>Summary</i> 640 • <i>Example Problem Solutions</i> 640 • <i>Problems</i> 642 • <i>Case Problem</i> 651		16 Inventory Management	773
14 Simulation	654	Elements of Inventory Management	774
The Monte Carlo Process	655	Management Science Application: Inventory Optimization at Procter & Gamble	776
Time Out: for John Von Neumann	660	Inventory Control Systems	777
Computer Simulation with Excel Spreadsheets	660	Time Out: for Ford Harris	778
Simulation of a Queuing System	665	Economic Order Quantity Models	778
Management Science Application: Planning for Catastrophic Disease Outbreaks Using Simulation	668	The Basic EOQ Model	779

The EOQ Model with Noninstantaneous Receipt	784	Appendix C	
The EOQ Model with Shortages	787	The Poisson and Exponential Distributions	821
Management Science Application: Inventory Management at Zara	790	Solutions to Selected Odd-Numbered Problems	823
EOQ Analysis with QM for Windows	790	Glossary	832
EOQ Analysis with Excel and Excel QM	791	Index	837
Quantity Discounts	792		
Management Science Application: Quantity Discount Orders at Mars	795	The following items can be found on the Companion Web site that accompanies this text:	
Reorder Point	796	Web Site Modules	
Determining Safety Stock by Using Service Levels	798	Module A: The Simplex Solution Method	A-1
Order Quantity for a Periodic Inventory System	800	Module B: Transportation and Assignment Solution Methods	B-1
<i>Summary</i> 802 • <i>Example Problem Solution</i> 802 • <i>Problems</i> 804 • <i>Case Problem</i> 812		Module C: Integer Programming: The Branch and Bound Method	C-1
Appendix A		Module D: Nonlinear Programming Solution Techniques	D-1
Normal and Chi-Square Tables	815	Module E: Game Theory	E-1
Appendix B		Module F: Markov Analysis	F-1
Setting Up and Editing a Spreadsheet	817		

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.

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

Management Science Application

Management Science and Analytics

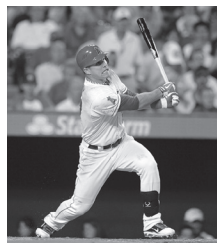
As we discussed in the section “Management Science and Business Analytics,” when applied to business problems, analytics often combines the management science approach to problem solving and decision making, including model building, with the use of data. Following are a few examples of the many recent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

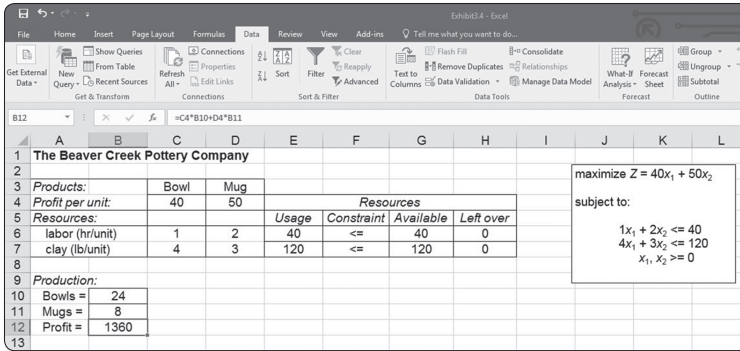
One of the most visible applications of analytics in the sports industry has been the development and use of “sabermetrics”



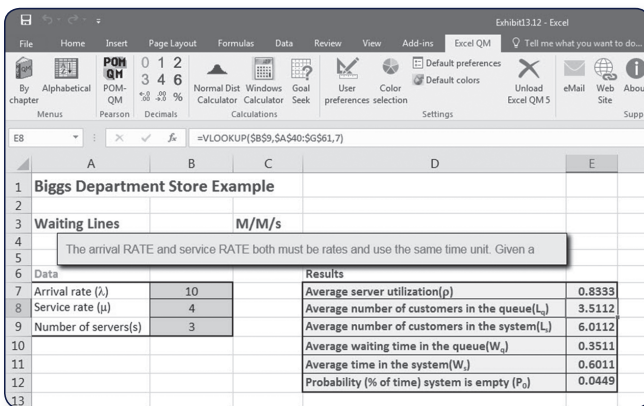
San Gabriel Valley Tribune/ZUMA Press Inc./Alamy Stock Photo

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. Zinselmeier, J. Klober, D. Culhane, and S. Mack, “Advanced Analytics for Agricultural Product Development,” *Interfaces* 46, no. 1 (January–February 2016): 5–17; S. Venkateshram, 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. Fabussuyi, R. Hampshire, V. Hill, and K. Sasamma, “Decision Analytics for Parking Availability in Downtown Pittsburgh,” *Interfaces* 44, no. 3 (May–June 2014): 286–299.



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

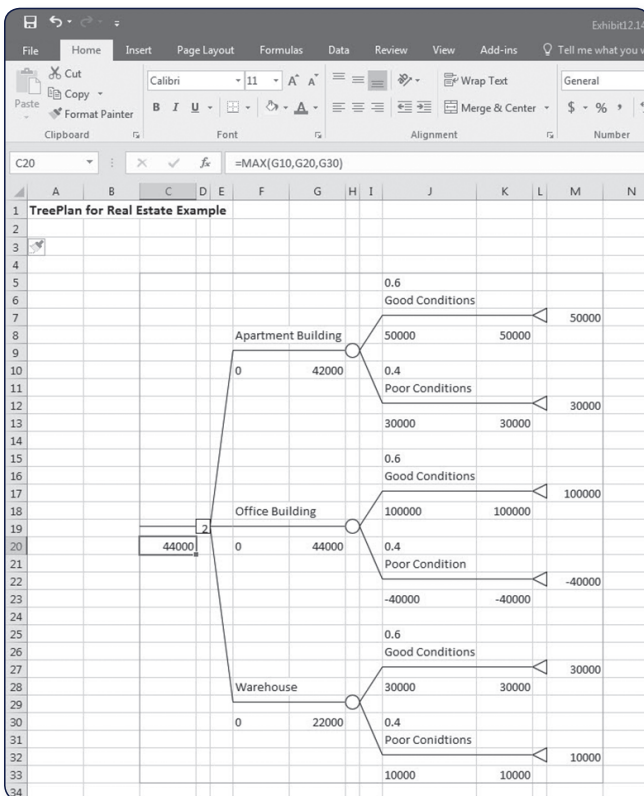
For some management science topics, the Excel formulas that are required for solution are lengthy and complex and thus are very tedious and time consuming to type into a spreadsheet. In several of these instances in the book, including Chapter 6 on transportation and assignment problems, Chapter 12 on 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.

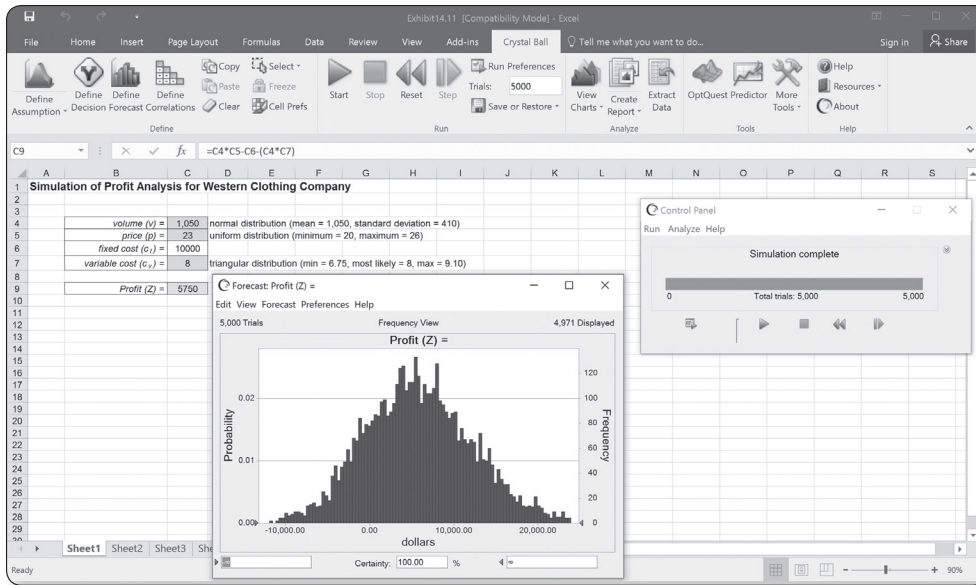
Risk Solver Platform for Education

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

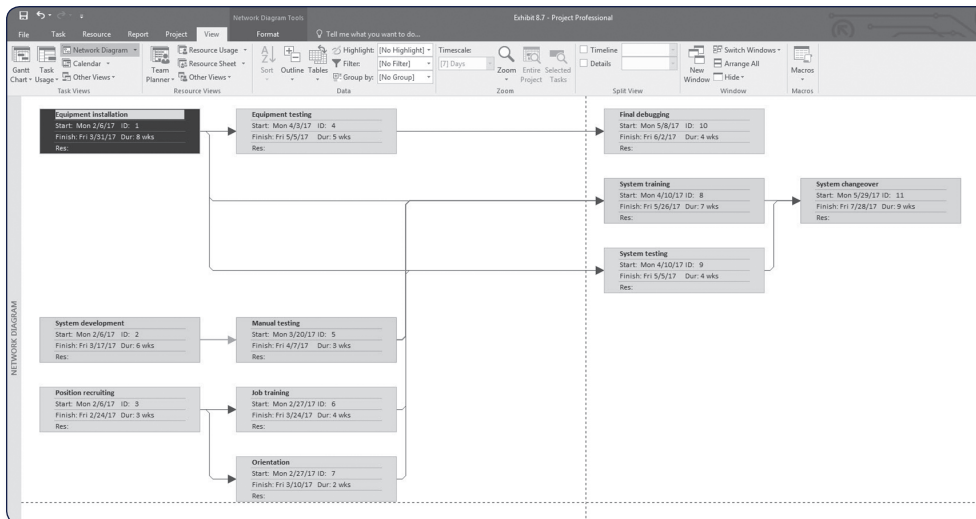
Another spreadsheet add-in program is Crystal Ball by Oracle. Crystal Ball is demonstrated in Chapter 14 on simulation and shows how to perform simulation analysis for certain types of risk analysis and forecasting problems. Here is an example of one of the Crystal Ball files (from Chapter 14) that is 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 Example Solution							
	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:

- At least 500 pounds of chicken
- 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

$$Z = \text{cost per 1,000-lb batch}$$

$$\$3x_1 = \text{cost of chicken}$$

$$\$5x_2 = \text{cost of beef}$$

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

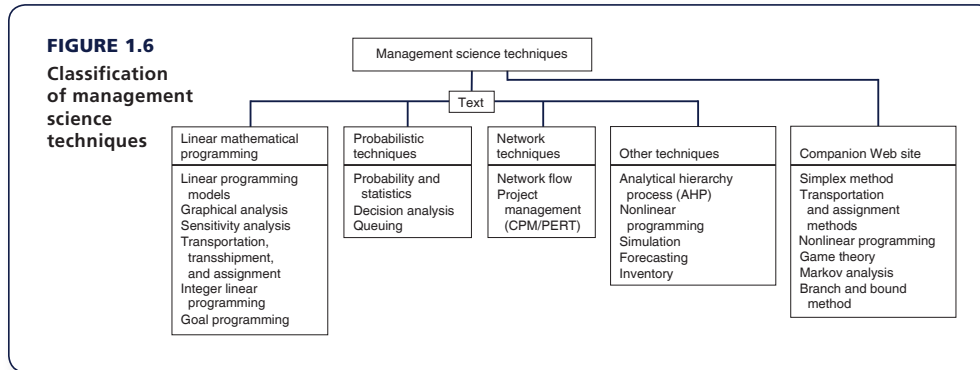
Several of the strictly mathematical topics—such as the simplex and transportation solution methods—are included as chapter modules on the Companion Web site, at <http://www.pearsonhighered.com/taylor>.

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.

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	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • 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: <ul style="list-style-type: none"> ◦ Keyboard and Screen Reader access ◦ Alternative text for images ◦ High color contrast between background and foreground colors
Chapter Web Links developed by the author	<ul style="list-style-type: none"> • 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.

I thank the reviewers of this and previous editions: Dr. B. S. Bal, Nagraj Balakrishnan, Edward M. Barrow, Ali Behnezhad, Weldon J. Bowling, Rod Carlson, Petros Christofi, Yar M. Ebadi, Richard Ehrhardt, Warren W. Fisher, James Flynn, Wade Furgeson, Soumen Ghosh,

James C. Goodwin, Jr., Richard Gunther, Dewey Hemphill, Ann Hughes, Shivaji Khade, David A. Larson, Sr., Shao-ju Lee, Robert L. Ludke, Peter A. Lyew, Robert D. Lynch, Dinesh Manocha, Mildred Massey, Russell McGee, Abdel-Aziz Mohamed, Anthony Narsing, Thomas J. Nolan, Susan W. Palocsay, David W. Pentico, Cindy Randall, Christopher M. Rump, Michael E. Salassi, Roger Schoenfeldt, Jaya Singhal, Charles H. Smith, Lisa Sokol, Daniel Solow, Dothang Truong, John Wang, Edward Williams, Barry Wray, Kefeng Xu, Hulya Julie Yazici, Ding Zhang, and Zuopeng Zhang.

I am also very grateful to Tracy McCoy at Virginia Tech for her valued assistance. I would like to thank my Content Producer, Sugandh Juneja, at Pearson, for her valuable assistance and patience. I very much appreciate the help and hard work of Roberta Sherman and all the folks at SPi Global, who produced this edition, and the text's accuracy checker, M. Khurram S. Bhutta. Finally, I would like to thank my editors, Dan Tylman and Neeraj Bhalla, at Pearson, for their continued help and patience.