

Introduction to

MANAGEMENT SCIENCE

A Modeling and Case Studies Approach with Spreadsheets



**Mc
Graw
Hill**
Education

6e

Frederick S. Hillier

Mark S. Hillier

Introduction to

MANAGEMENT SCIENCE

A Modeling and Case Studies Approach with Spreadsheets



Mc
Graw
Hill
Education

6e

Frederick S. Hillier

Mark S. Hillier

Introduction to Management Science

A Modeling and Case Studies Approach with Spreadsheets

The McGraw-Hill/Irwin Series in Operations and Decision Sciences

SUPPLY CHAIN MANAGEMENT

Benton

Purchasing and Supply Chain Management
Second Edition

Burt, Petcavage, and Pinkerton

Supply Management
Eighth Edition

Bowersox, Closs, Cooper, and Bowersox

Supply Chain Logistics Management
Fourth Edition

Johnson and Flynn

Purchasing and Supply Management
Fifteenth Edition

Simchi-Levi, Kaminsky, and Simchi-Levi

Designing and Managing the Supply Chain: Concepts, Strategies, Case Studies
Third Edition

PROJECT MANAGEMENT

Brown and Hyer

Managing Projects: A Team-Based Approach
First Edition

Larson and Gray

Project Management: The Managerial Process
Seventh Edition

SERVICE OPERATIONS MANAGEMENT

Bordoloi, Fitzsimmons, and Fitzsimmons

Service Management: Operations, Strategy, Information Technology
Ninth Edition

MANAGEMENT SCIENCE

Hillier and Hillier

Introduction to Management Science: A Modeling and Case Studies Approach with Spreadsheets

Sixth Edition

Stevenson and Ozgur

Introduction to Management Science with Spreadsheets

First Edition

MANUFACTURING CONTROL SYSTEMS

Jacobs, Berry, Whybark, and Vollmann

Manufacturing Planning & Control for Supply Chain Management

Sixth Edition

BUSINESS RESEARCH METHODS

Cooper and Schindler

Business Research Methods

Twelfth Edition

BUSINESS FORECASTING

Keating and Wilson

Business Forecasting

Seventh Edition

LINEAR STATISTICS AND REGRESSION

Kutner, Nachtsheim, and Neter

Applied Linear Regression Models

Fourth Edition

BUSINESS SYSTEMS DYNAMICS

Sterman

Business Dynamics: Systems Thinking and Modeling for a Complex World

First Edition

OPERATIONS MANAGEMENT

Cachon and Terwiesch

Operations Management

First Edition

Cachon and Terwiesch

Matching Supply with Demand: An Introduction to Operations Management

Third Edition

Finch

Interactive Models for Operations and Supply Chain Management
First Edition

Jacobs and Chase
Operations and Supply Chain Management
Fifteenth Edition

Jacobs and Chase
Operations and Supply Chain Management: The Core
Fourth Edition

Jacobs and Whybark
Why ERP? A Primer on SAP Implementation
First Edition

Schroeder and Goldstein
Operations Management in the Supply Chain: Decisions and Cases
Seventh Edition

Stevenson
Operations Management
Thirteenth Edition

Swink, Melnyk, Hartley, and Cooper
Managing Operations Across the Supply Chain
Third Edition

BUSINESS MATH

Slater and Wittry
Practical Business Math Procedures
Twelfth Edition

Slater and Wittry
Math for Business and Finance: An Algebraic Approach
Second Edition

BUSINESS STATISTICS

Bowerman, O'Connell, and Murphree
Business Statistics in Practice
Eighth Edition

Bowerman, O'Connell, Murphree, and Orris
Essentials of Business Statistics
Fifth Edition

Doane and Seward
Applied Statistics in Business and Economics
Sixth Edition

Doane and Seward

Essential Statistics in Business and Economics

Second Edition

Lind, Marchal, and Wathen

Basic Statistics for Business and Economics

Ninth Edition

Lind, Marchal, and Wathen

Statistical Techniques in Business and Economics

Seventeenth Edition

Jaggia and Kelly

Business Statistics: Communicating with Numbers

Third Edition

Jaggia and Kelly

Essentials of Business Statistics: Communicating with Numbers

First Edition

McGuckian

Connect Master: Business Statistics Introduction to Management Science

Introduction to Management Science

A Modeling and Case Studies Approach with Spreadsheets

Sixth Edition

Frederick S. Hillier
Stanford University

Mark S. Hillier
University of Washington

Cases developed by
Karl Schmedders
University of Zurich

Molly Stephens
Quinn, Emanuel, Urquhart & Sullivan, LLP





INTRODUCTION TO MANAGEMENT SCIENCE: A MODELING AND CASE
STUDIES APPROACH WITH SPREADSHEETS, SIXTH EDITION

Published by McGraw-Hill Education, 2 Penn Plaza, New York, NY 10121. Copyright © 2019 by McGraw-Hill Education. All rights reserved. Printed in the United States of America. Previous editions © 2014, 2011, and 2008. No part of this publication may be reproduced or distributed in any form or by any means, or stored in a database or retrieval system, without the prior written consent of McGraw-Hill Education, including, but not limited to, in any network or other electronic storage or transmission, or broadcast for distance learning.

Some ancillaries, including electronic and print components, may not be available to customers outside the United States.

This book is printed on acid-free paper.

1 2 3 4 5 6 7 8 9 QVS 21 20 19 18

ISBN 978-1-259-91892-6

MHID 1-259-91892-0

Portfolio Manager: *Noelle Bathurst*

Lead Product Developer: *Michele Janicek*

Product Developer: *Tobi Phillips*

Executive Marketing Manager: *Harper Christopher*

Content Project Managers: *Erika Jordan and Jamie Koch*

Buyer: *Susan K. Culbertson*

Design: *Jessica Cuevas*

Content Licensing Specialist: *Brianna Kirschbaum*

Cover Image: ©polygraphus/Getty Images
Compositor: SPi Global

All credits appearing on page or at the end of the book are considered to be an extension of the copyright page.

Library of Congress Cataloging-in-Publication Data

Names: Hillier, Frederick S., author. | Hillier, Mark S., author.

Title: Introduction to management science : a modeling and case studies approach with spreadsheets / Frederick S. Hillier, Stanford University, Mark S. Hillier, University of Washington ; cases developed by Karl Schmedders, University of Zurich, Molly Stephens, Quinn, Emanuel, Urquhart & Sullivan, LLP.

Description: Sixth edition. | New York, NY : McGraw-Hill Education, [2019]

Identifiers: LCCN 2017048567 | ISBN 9781259918926 (acid-free paper) | ISBN 1259918920 (acid-free paper)

Subjects: LCSH: Management science. | Operations research.

Classification: LCC T56 .H55 2019 | DDC 658.4/032--dc22 LC record available at <https://lcn.loc.gov/2017048567>

The Internet addresses listed in the text were accurate at the time of publication. The inclusion of a website does not indicate an endorsement by the authors or McGraw-Hill Education, and McGraw-Hill Education does not guarantee the accuracy of the information presented at these sites.

mheducation.com/highered

To the memory of

Christine Phillips Hillier

a beloved wife and daughter-in-law

Gerald J. Lieberman

an admired mentor and one of the true giants of our field

About the Authors

Frederick S. Hillier is professor emeritus of operations research at Stanford University. Dr. Hillier is especially known for his classic, award-winning text, *Introduction to Operations Research*, co-authored with the late Gerald J. Lieberman, which has been translated into well over a dozen languages and is currently in its 10th edition. The 6th edition won honorable mention for the 1995 Lanchester Prize (best English-language publication of any kind in the field), and Dr. Hillier also was awarded the 2004 INFORMS Expository Writing Award for the 8th edition. His other books include *The Evaluation of Risky Interrelated Investments*, *Queueing Tables and Graphs*, *Introduction to Stochastic Models in Operations Research*, and *Introduction to Mathematical Programming*. He received his BS in industrial engineering and doctorate specializing in operations research and management science from Stanford University. The winner of many awards in high school and college for writing, mathematics, debate, and music, he ranked first in his undergraduate engineering class and was awarded three national fellowships (National Science Foundation, Tau Beta Pi, and Danforth) for graduate study. After receiving his PhD degree, he joined the faculty of Stanford University, where he earned tenure at the age of 28 and the rank of full professor at 32. Dr. Hillier's research has extended into a variety of areas, including integer programming, queueing theory and its application, statistical quality control, and production and operations management. He also has won a major prize for research in capital budgeting. Twice elected a national officer of professional societies, he has served in many important professional and editorial capacities. For example, he served The Institute of Management Sciences as vice president for meetings, chairman of the publications committee, associate editor of *Management Science*, and co-general chairman

of an international conference in Japan. He also is a Fellow of the Institute for Operations Research and the Management Sciences (INFORMS). He served for 20 years (until 2013) as the founding series editor for a prominent book series, the International Series in Operations Research and Management Science, for Springer Science + Business Media. He has had visiting appointments at Cornell University, the Graduate School of Industrial Administration of Carnegie-Mellon University, the Technical University of Denmark, the University of Canterbury (New Zealand), and the Judge Institute of Management Studies at the University of Cambridge (England).

Mark S. Hillier, son of Fred Hillier, is associate professor of quantitative methods at the Michael G. Foster School of Business at the University of Washington. Dr. Hillier received his BS in engineering (plus a concentration in computer science) from Swarthmore College. He then received his MS with distinction in operations research and PhD in industrial engineering and engineering management from Stanford University. As an undergraduate, he won the McCabe Award for ranking first in his engineering class, won election to Phi Beta Kappa based on his work in mathematics, set school records on the men's swim team, and was awarded two national fellowships (National Science Foundation and Tau Beta Pi) for graduate study. During that time, he also developed a comprehensive software tutorial package, *OR Courseware*, for the Hillier–Lieberman textbook, *Introduction to Operations Research*. As a graduate student, he taught a PhD-level seminar in operations management at Stanford and won a national prize for work based on his PhD dissertation. At the University of Washington, he currently teaches courses in management science and spreadsheet modeling. He has won over twenty MBA teaching awards for the core course in management science and his elective course in spreadsheet modeling, as well as a universitywide teaching award for his work in teaching undergraduate classes in operations management. He was chosen by MBA students in both 2007 and 2013 as the winner of the prestigious PACCAR award for Teacher of the Year (reputed to provide the largest monetary award for MBA teaching in the nation). He won the Ron Crocket Award for Innovation in Education in 2014. He also has been awarded an appointment to the Evert McCabe Endowed Faculty Fellowship. His research interests include issues in component commonality, inventory, manufacturing, and the design of production systems. A paper by

Dr. Hillier on component commonality won an award for best paper of 2000–2001 in *IIE Transactions*. He also has been serving as principal investigator on a grant from the Bill and Melinda Gates Foundation to lead student research projects that apply spreadsheet modeling to various issues in global health being studied by the foundation.

About the Case Writers

Karl Schmedders is professor of quantitative business administration at the University of Zurich in Switzerland and a visiting professor of executive education at the Kellogg School of Management of Northwestern University. His research interests include management science, business analytics, and computational economics and finance. He received his PhD in operations research from Stanford University, where he taught both undergraduate and graduate classes in management science, including a case studies course. He received several teaching awards at Stanford, including the universitywide Walter J. Gores Teaching Award. After a post-doc at the Hoover Institution, a think tank on the Stanford campus, he became assistant professor of managerial economics and decision sciences at the Kellogg School. He was promoted to associate professor in 2001 and received tenure in 2005. In 2008 he joined the University of Zurich, where he currently teaches courses in management science, business analytics, and computational economics and finance. He has published research articles in international academic journals such as *Management Science*, *Operations Research*, *Econometrica*, *The Review of Economic Studies*, and *The Journal of Finance*, among others. He is the area editor of the field “Computational Economics” for the INFORMS journal *Operations Research*. At Kellogg he received several teaching awards, including the L. G. Lavengood Professor of the Year Award. Most recently he won the best professor award of the Kellogg School’s European EMBA program (2011, 2012, 2013, 2014, 2015) and its EMBA program in Hong Kong (2017).

Molly Stephens is a partner in the Los Angeles office of Quinn, Emanuel, Urquhart & Sullivan, LLP. She graduated from Stanford with a BS in

industrial engineering and an MS in operations research. Ms. Stephens taught public speaking in Stanford's School of Engineering and served as a teaching assistant for a case studies course in management science. As a teaching assistant, she analyzed management science problems encountered in the real world and transformed these into classroom case studies. Her research was rewarded when she won an undergraduate research grant from Stanford to continue her work and was invited to speak at INFORMS to present her conclusions regarding successful classroom case studies. Following graduation, Ms. Stephens worked at Andersen Consulting as a systems integrator, experiencing real cases from the inside, before resuming her graduate studies to earn a JD degree with honors from the University of Texas School of Law at Austin. She is a partner in the largest law firm in the United States devoted solely to business litigation, where her practice focuses on complex financial and securities litigation. She also is ranked as a leading securities litigator by Chambers USA (2013 and 2014), which acknowledged "praise for her powerful and impressive securities litigation practice" and noted that she is "phenomenally bright, a critical thinker and great listener."

Preface

We have long been concerned that traditional management science textbooks have not taken the best approach in introducing business students to this exciting field. Our goal when initially developing this book during the late 1990s was to break out of the old mold and present new and innovative ways of teaching management science more effectively. We have been gratified by the favorable response to our efforts. Many reviewers and other users of the first five editions of the book have expressed appreciation for its various distinctive features, as well as for its clear presentation at just the right level for their business students.

Our goal for this sixth edition has been to build on the strengths of the first five editions. Co-author Mark Hillier has won over twenty schoolwide teaching awards for his spreadsheet modeling and management science courses at the University of Washington while using the first five editions, and this experience has led to many improvements in the current edition. We also incorporated many user comments and suggestions. Throughout this process, we took painstaking care to enhance the quality of the preceding edition while maintaining the distinctive orientation of the book.

This distinctive orientation is one that closely follows the recommendations in the 1996 report of the operating subcommittee of the INFORMS Business School Education Task Force, including the following extract.

There is clear evidence that there must be a major change in the character of the (introductory management science) course in this environment. There is little patience with courses centered on algorithms. Instead, the demand is for courses that focus on business situations, include prominent non-mathematical issues, use spreadsheets, and involve model formulation and assessment more than model

structuring. Such a course requires new teaching materials.

This book is designed to provide the teaching materials for such a course.

In line with the recommendations of this task force, which continue to be widely accepted today, we believe that a modern introductory management science textbook should have three key elements. As summarized in the subtitle of this book, these elements are a *modeling* and *case studies* approach with *spreadsheets*.

SPREADSHEETS

The modern approach to the teaching of management science clearly is to use *spreadsheets* as a primary medium of instruction. Both business students and managers now live with spreadsheets, so they provide a comfortable and enjoyable learning environment. Modern spreadsheet software, including Microsoft Excel used in this book, now can be used to do real management science. For student-scale models (which include many practical real-world models), spreadsheets are a much better way of implementing management science models than traditional algebraic solvers. This means that the algebraic curtain that continues to be prevalent in traditional management science courses and textbooks now can be lifted.

However, with the current enthusiasm for spreadsheets, there is a danger of going overboard. Spreadsheets are not the only useful tool for performing management science analyses. Occasional modest use of algebraic and graphical analyses still have their place and we would be doing a disservice to the students by not developing their skills in these areas when appropriate. Furthermore, the book should not be mainly a spreadsheet cookbook that focuses largely on spreadsheet mechanics. Spreadsheets are a means to an end, not an end in themselves.

A MODELING APPROACH

This brings us to the second key feature of the book, a *modeling approach*. Model formulation lies at the heart of management science methodology. Therefore, we heavily emphasize the art of model formulation, the role of a model, and the analysis of model results. We primarily (but not exclusively) use a spreadsheet format rather than algebra for formulating and presenting a

model.

Some instructors have many years of experience in teaching modeling in terms of formulating algebraic models (or what the INFORMS Task Force called “model structuring”). Some of these instructors feel that students should do their modeling in this way and then transfer the model to a spreadsheet simply to use the Excel Solver to solve the model. We disagree with this approach. Our experience (and the experience reported by many others) is that most business students find it more natural and comfortable to do their modeling directly in a spreadsheet. Furthermore, by using the best spreadsheet modeling techniques (as presented in this edition), formulating a spreadsheet model tends to be considerably more efficient and transparent than formulating an algebraic model. Another benefit is that the spreadsheet model includes all the relationships that can be expressed in an algebraic form and we often will summarize the model in this format as well.

Another break from past tradition in this book (and several contemporary textbooks) is to virtually ignore the algorithms that are used to solve the models. We feel that there is no good reason why typical business students should learn the details of algorithms executed by computers. Within the time constraints of a one-term management science course, there are far more important lessons to be learned. Therefore, the focus in this book is on what we believe are these far more important lessons. High on this list is the art of modeling managerial problems on a spreadsheet.

We believe that training business students in spreadsheet modeling will provide them with two key benefits when they later become managers. First, this will give them a powerful tool for analyzing small managerial problems without requiring outside help. Second, this will enable them to recognize when a management science team could be very helpful for analyzing more complicated managerial problems.

Formulating a spreadsheet model of a real problem typically involves much more than designing the spreadsheet and entering the data. Therefore, we work through the process step by step: understand the unstructured problem, verbally develop some structure for the problem, gather the data,

express the relationships in quantitative terms, and then lay out the spreadsheet model. The structured approach highlights the typical components of the model (the data, the decisions to be made, the constraints, and the measure of performance) and the different types of spreadsheet cells used for each. Consequently, the emphasis is on the modeling rather than spreadsheet mechanics.

A CASE STUDIES APPROACH

However, all this still would be quite sterile if we simply presented a long series of brief examples with their spreadsheet formulations. This leads to the third key feature of this book—a *case studies* approach. In addition to examples, nearly every chapter includes one or two case studies patterned after actual applications to convey the whole process of applying management science. In a few instances, the entire chapter revolves around a case study. By drawing the student into the story, we have designed each case study to bring that chapter's technique to life in a context that vividly illustrates the relevance of the technique for aiding managerial decision making. This storytelling, case-centered approach should make the material more enjoyable and stimulating while also conveying the practical considerations that are key factors in applying management science.

We have been pleased to have several reviewers of the first five editions express particular appreciation for our case study approach. Even though this storytelling approach has received little use in other management science textbooks, we feel that it is a real key to preparing students for the practical application of management science in all its aspects. Some of the reviewers have highlighted the effectiveness of the dialogue/scenario enactment approach used in some of the case studies. Although unconventional, this approach provides a way of demonstrating the process of managerial decision making with the help of management science. It also enables previewing some key concepts in the language of management.

Every chapter also contains full-fledged cases following the problems at the end of the chapter. These cases usually continue to employ a stimulating storytelling approach, so they can be assigned as interesting and challenging projects. Most of these cases were developed jointly by two talented case writers, Karl Schmedders (a faculty member at the University of Zurich in

Switzerland) and Molly Stephens (formerly a management science consultant with Andersen Consulting). The authors also have added some cases, including several shorter ones. In addition, the University of Western Ontario Ivey School of Business (the second-largest producer of teaching cases in the world) has specially selected cases from their case collection that match the chapters in this textbook. These cases are available on the Ivey website, **cases.ivey.uwo.ca/cases**, in the segment of the CaseMate area designated for this book. This website address is provided at the end of each chapter as well.

page x

We are, of course, not the first to incorporate any of these key features into a management science textbook. However, we believe that the book currently is unique in the way that it fully incorporates all three key features together.

OTHER SPECIAL FEATURES

We also should mention some additional special features of the book that are continued from the fifth edition.

Diverse examples, problems, and cases convey the pervasive relevance of management science.

A strong managerial perspective.

Learning objectives at the beginning of each chapter.

Numerous margin notes that clarify and highlight key points.

Excel tips interspersed among the margin notes.

Review questions at the end of each section.

A glossary at the end of each chapter.

Partial answers to selected problems in the back of the book.

Extensive supplementary text materials (nine supplements to book chapters and seven additional chapters) are available in the Instructor Resources of McGraw-Hill's online homework management platform, Connect, (described later) and on the website, **www.mhhe.com/Hillier6e**.

A NEW SOFTWARE PACKAGE

This edition continues to integrate Excel and its Solver (a product originally created by Front-line Systems) throughout the book. However, we are excited to also add to this edition an impressive more recent product of Frontline Systems called **Analytic Solver ® for Education** (hereafter referred to as Analytic Solver). Analytic Solver can be used with Microsoft Excel for Windows (as an add-in), or ‘in the cloud’ at **AnalyticSolver.com** using any device (PC, Mac, tablet) with a web browser. It offers comprehensive features for prescriptive analytics (optimization, simulation, decision analysis) and predictive analytics (forecasting, data mining, text mining). Its optimization features are upward compatible from the standard Solver in Excel. Analytic Solver includes:

A more interactive user interface, with the model parameters always visible alongside the main spreadsheet, rather than only in the Solver dialog box.

Parameter analysis reports that provide an easy way to see the effect of varying data in a model in a systematic way.

A model analysis tool that reveals the characteristics of a model (e.g., whether it is linear or nonlinear, smooth or nonsmooth).

Tools to build and solve decision trees within a spreadsheet.

A full range of time series forecasting and data mining models.

The ability to build and run sophisticated Monte Carlo simulation models.

An interactive simulation mode that allows simulation results to be shown instantly whenever a change is made to a simulation model.

The Solver in Analytic Solver can be used in combination with computer simulation to perform simulation optimization.

If interested in having students get individual licenses for class use, instructors should send an email to support@solver.com to get their course code and receive student pricing and access information as well as their own access information. Note that this software is no longer free with the purchase of this text, but low-cost student licenses are available.

A CONTINUING FOCUS ON EXCEL AND ITS

SOLVER

As with all the preceding editions, this edition continues to focus on spreadsheet modeling in an Excel format. Although it lacks some of the functionalities of Analytic Solver, the Excel Solver continues to provide a completely satisfactory way of solving most of the spreadsheet models encountered in this book. This edition continues to feature this use of the Excel Solver whenever either it or the Analytic Solver could be used.

Many instructors prefer this focus because it avoids introducing other complications that might confuse their students. We agree.

However, the key advantage of introducing Analytic Solver in this edition is that it provides an all-in-one complement to the Excel Solver. There are some important topics in the book (including decision analysis and computer simulation) where the Excel Solver lacks the functionalities needed to deal fully with these kinds of problems. Multiple Excel add-ins— Solver Table, TreePlan, SensIt, RiskSim, Crystal Ball, and OptQuest (a module of Crystal Ball)—were introduced in previous editions to provide the needed functionalities. Analytic Solver alone now replaces all of these add-ins.

To further enhance a continuing focus on Excel and its Solver, www.mhhe.com/Hillier6e includes all the Excel files that provide the live spreadsheets for all the various examples and case studies throughout the book. In addition to further investigating the examples and case studies, these spreadsheets can be used by either the student or instructor as templates to formulate and solve similar problems. This website also includes dozens of Excel templates for solving various models in the book as well as a Queueing Simulator for performing computer simulations of queueing systems (used in Chapter 12).

NEW FEATURES IN THIS EDITION

We have made some important enhancements to the current edition.

A New Section Describes the Relationship Between Analytics and Management Science. Recent years have seen an exciting *analytics revolution* as the business world has come to recognize the key role that *analytics* can play in managerial decision making. A new Section 1.3 fully

describes the close relationship between analytics and management science.

A New Section on the Role of Robust Optimization in What-If Analysis.

The goal of *robust optimization* is to find a solution for a model that is virtually guaranteed to remain feasible and near optimal for all plausible combinations of the actual values for the parameters of the model. A new Section 5.7 describes this key tool for performing what-if analysis for linear programming models.

A New Section on Chance Constraints. Constraints in a model usually are fully required to be satisfied, but occasionally constraints arise that actually have a little flexibility. *Chance constraints* provide a way of dealing with such constraints that actually can be violated a little bit without serious complications. A new Section 5.8 describes the role of chance constraints and how to implement them.

A Thorough Updating Throughout the Book. Given that the writing of the first edition occurred approximately 20 years ago, it is inevitable that some of that writing now is somewhat outdated. Even though the descriptions of management science techniques may still be accurate, the numbers and other details describing their application in certain problems, cases, and examples may now seem quite obsolete. Wage standards have changed. Prices have changed. Technologies have changed. Dates have changed. Although we did some updating with each new edition, we made a special effort this time to thoroughly update numbers and other details as needed to reflect conditions in 2017.

Additional Links to Articles that Describe Dramatic Real Applications.

The fifth edition included 28 application vignettes that described in a few paragraphs how an actual application of management science had a powerful effect on a company or organization by using techniques like those being studied in that portion of the book. The current edition adds five more vignettes based on recent applications (while deleting seven outdated ones) and also updates the information in nine of the other vignettes. We continue the practice of adding a link to the journal articles that fully describe these applications (except that the vignette for Chapter 1 doesn't require a link), through a special arrangement with the Institute for Operations Research and the Management Sciences (INFORMS®). Thus, the instructor now can motivate his or her lectures by having the students delve into real

applications that dramatically demonstrate the relevance of the material being covered in the lectures. The end-ofchapter problems also include an assignment after reading each of these articles.

page xii

We continue to be excited about this partnership with INFORMS, our field's preeminent professional society, to provide a link to each of these articles describing spectacular applications of management science. INFORMS is a learned professional society for students, academics, and practitioners in analytics, operations research, and management science. Information about INFORMS journals, meetings, job bank, scholarships, awards, and teaching materials is available at **www.informs.org**.

A Word-by-Word Review to Further Increase Clarity in Each Chapter.

A hallmark of each edition has been a particularly heavy use of certain techniques to maximize the clarity of the material: use cases to bring the material to life, divide sections into smaller subsections, use short paragraphs, use bullet points, set off special conclusions, use italics or boldface to highlight key points, add margin notes, never assume too much about understanding preceding material, etc. However, we have doubled down with this approach in the current edition by using a word-by-word review of each chapter to further increase clarity while also taking into special account the input provided by reviewers and others.

McGRAW-HILL CONNECT^(R) LEARN WITHOUT LIMITS!

Connect is a teaching and learning platform that is proven to deliver better results for students and instructors. Connect empowers students by continually adapting to deliver precisely what they need, when they need it, and how they need it, so your class time is more engaging and effective.

New to the 6th edition, Connect includes multiple-choice questions for each chapter to be used as practice or homework for students, SmartBook^(R), instructor resources (including the test bank), and student resources. For access, visit **connect.mheducation.com** or contact your McGraw-Hill sales representative.

SMARTBOOK^(R)

Proven to help students improve grades and study more efficiently, SmartBook contains the same content within the print book, but actively tailors that content to the needs of the individual. SmartBook's adaptive technology provides precise, personalized instruction on what the student should do next, guiding the student to master and remember key concepts, targeting gaps in knowledge and offering customized feedback, and driving the student toward comprehension and retention of the subject matter. Available on desktops and tablets, Smart-Book puts learning at the student's fingertips—anywhere, anytime.

INSTRUCTOR RESOURCES

The Instructor Resource Library within Connect is password-protected and a convenient place for instructors to access course supplements that include nine supplements to chapters in the print book and seven supplementary chapters. Resources for professors include the complete solutions to all problems and cases, PowerPoint slides which include both lecture materials for nearly every chapter and nearly all the figures (including all the spreadsheets) in the book, and an expanded Test Bank. The test bank contains almost 1,000 multiple-choice and true-false questions, all tagged according to learning objective, topic, level of difficulty, Bloom's taxonomy and AACSB category for filtering and reporting, and is delivered in the following ways:

- As a Connect assignment for online testing and automatic grading; can be used for actual exams or assigned as quizzes or practice;
- In TestGen, a desktop test generator and editing application for instructors to provide printed tests that can incorporate both McGraw-Hill's and instructors' questions;
- As Word files, with both question-only and answer files.

STUDENT RESOURCES

As described above, SmartBook provides a powerful tool to students for

personalized instruction. For the additional convenience of students, we also are providing the website, [www.mhhe.com/ Hillier6e](http://www.mhhe.com/Hillier6e), to provide the full range of resources of interest to students. In addition to providing access to supplementary text material (both supplements to book chapters and additional chapters), this website provides solutions to the “solved problems” (additional examples) that are included at the end of each chapter. For each spreadsheet example in the book, a live spreadsheet that shows the formulation and solution for the example also is provided in the website for easy reference and for use as a template. (At the end of each chapter, the page entitled “Learning Aids for This Chapter” lists the Excel files and other resources that are relevant for that chapter.) Information about accessing the book’s software is provided. In addition, the website includes a tutorial with sample test questions (different from those in the instructor’s test bank) for self-testing quizzes on the various chapters. It also provides access to the INFORMS articles cited in the application vignettes as well as updates about the book, including errata.

AN INVITATION

We invite your comments, suggestions, and errata. You can contact either one of us at the e-mail addresses given below. While giving these addresses, let us also assure instructors that *we will continue our policy of not providing solutions to problems and cases in the book to anyone* (including your students) who contacts us. We hope that you enjoy the book.

Frederick S. Hillier
Stanford University (fhillier@stanford.edu)

Mark S. Hillier
University of Washington (mhillier@uw.edu)

June 2017

Acknowledgments

This new edition has benefited greatly from the sage advice of many individuals. To begin, we would like to express our deep appreciation to the following individuals who provided formal reviews of the fifth edition:

Michael Cervertti,
University of Memphis

Danxia Chen,
Dallas Baptist University

Moula Cherikh,
Winston-Salem State University

Kelwyn A. D'Souza,
Hampton University

Jose H. Dula,
Virginia Commonwealth University

Kenneth Donald Lawrence,
New Jersey Institute of Technology

Nicoleta Maghear,
Hampton University

William P. Millhiser,
Baruch College, City University of New York

John H. Newman,

Coppin State University

David Snowden,

Thomas More College

John Wang,

Montclair State University

Norman Douglas Ward,

University of Mount Olive

We also are grateful for the valuable input provided by many of our students as well as various other students and instructors who contacted us via e-mail.

This book has continued to be a team effort involving far more than the two coauthors. As a third coauthor for the first edition, the late Gerald J. Lieberman provided important initial impetus for this project. We also are indebted to our case writers, Karl Schmedders and Molly Stephens, for their invaluable contributions. Ann Hillier again devoted numerous hours to sitting with a Macintosh, doing word processing and constructing figures and tables. They all were vital members of the team.

McGraw-Hill/Irwin's editorial and production staff provided the other key members of the team, including Noelle Bathurst, Portfolio Manager; Allison McCabe, and Tobi Philips, Product Developers, Harper Christopher, Marketing Manager, and Daryl Horrocks, Program Manager. This book is a much better product because of their guidance and hard work. It has been a real pleasure working with such a thoroughly professional staff.

Brief Contents

- 1** Introduction 1
- 2** Linear Programming: Basic Concepts 24
- 3** Linear Programming: Formulation and Applications 64
- 4** The Art of Modeling with Spreadsheets 124
- 5** What-If Analysis for Linear Programming 151
- 6** Network Optimization Problems 203
- 7** Using Binary Integer Programming to Deal with Yes-or-No Decisions 243
- 8** Nonlinear Programming 279
- 9** Decision Analysis 334
- 10** Forecasting 397
- 11** Queueing Models 446
- 12** Computer Simulation: Basic Concepts 499
- 13** Computer Simulation with Analytic Solver 536

APPENDIXES

- A** Tips for Using Microsoft Excel for Modeling 606
- B** Partial Answers to Selected Problems 612

INDEX 616

CHAPTERS available at www.mhhe.com/Hillier6e

- 14** Solution Concepts for Linear Programming
- 15** Transportation and Assignment Problems
- 16** PERT/CPM Models for Project Management
- 17** Goal Programming
- 18** Inventory Management with Known Demand
- 19** Inventory Management with Uncertain Demand
- 20** Computer Simulation with Crystal Ball



Contents

Chapter One

Introduction 1

- 1.1 The Nature of Management Science 2
- 1.2 An Illustration of the Management Science Approach: Break-Even Analysis 6
- 1.3 The Relationship Between Analytics and Management Science 12
- 1.4 The Impact of Management Science 14
- 1.5 Some Special Features of this Book 18
- 1.6 Summary 19

Glossary 20

Learning Aids for This Chapter 20

Solved Problem 21

Problems 21

Case 1-1 Keeping Time 23

Chapter Two

Linear Programming: Basic Concepts 24

- 2.1 A Case Study: The Wyndor Glass Co. Product-Mix Problem 25
- 2.2 Formulating the Wyndor Problem on a Spreadsheet 27
- 2.3 The Mathematical Model in the Spreadsheet 33
- 2.4 The Graphical Method for Solving Two-Variable Problems 35
- 2.5 Using Excel's Solver to Solve Linear Programming Problems 39

2.6	Analytic Solver	43
2.7	A Minimization Example—The Profit & Gambit Co. Advertising-Mix Problem	47
2.8	Linear Programming from a Broader Perspective	52
2.9	Summary	54
Glossary		54
Learning Aids for This Chapter		55
Solved Problems		55
Problems		55
Case 2-1	Auto Assembly	60
Case 2-2	Cutting Cafeteria Costs	61
Case 2-3	Staffing a Call Center	62
Supplement to Chapter 2: More about the Graphical Method for Linear Programming (This supplement is available at www.mhhe.com/Hillier6e).		

Chapter Three

Linear Programming: Formulation and Applications		64
3.1	A Case Study: The Super Grain Corp. Advertising-Mix Problem	65
3.2	Resource-Allocation Problems	71
3.3	Cost–Benefit–Trade-Off Problems	81
3.4	Mixed Problems	87
3.5	Transportation Problems	95
3.6	Assignment Problems	99
3.7	Model Formulation from a Broader Perspective	102
3.8	Summary	104
Glossary		104
Learning Aids for This Chapter		104
Solved Problems		105
Problems		106
Case 3-1	Shipping Wood to Market	114

Case 3-2	Capacity Concerns	115
Case 3-3	Fabrics and Fall Fashions	117
Case 3-4	New Frontiers	118
Case 3-5	Assigning Students to Schools	119
Case 3-6	Reclaiming Solid Wastes	120
Case 3-7	Project Pickings	121

Chapter Four

The Art of Modeling with Spreadsheets 124

4.1	A Case Study: The Everglade Golden Years Company Cash Flow Problem	125
4.2	Overview of the Process of Modeling with Spreadsheets	126
4.3	Some Guidelines for Building “Good” Spreadsheet Models	136
4.4	Debugging a Spreadsheet Model	142
4.5	Summary	146

Glossary 146

Learning Aids for This Chapter 146

Solved Problems 146

Problems 147

Case 4-1	Prudent Provisions for Pensions	150
-----------------	--	------------

Chapter Five

What-If Analysis for Linear Programming 151

5.1	The Importance of What-If Analysis to Managers	152
5.2	Continuing the Wyndor Case Study	154
5.3	The Effect of Changes in One Objective Function Coefficient	156
5.4	The Effect of Simultaneous Changes in Objective Function Coefficients	162
5.5	The Effect of Single Changes in a Constraint	169
5.6	The Effect of Simultaneous Changes in the Constraints	175

5.7	Robust Optimization	179
5.8	Chance Constraints with Analytic Solver	182
5.9	Summary	186
	Glossary	186
	Learning Aids for This Chapter	187
	Solved Problem	187
	Problems	188
Case 5-1	Selling Soap	197
Case 5-2	Controlling Air Pollution	198
Case 5-3	Farm Management	200
Case 5-4	Assigning Students to Schools (Revisited)	202
Supplement to Chapter 5: Reduced Costs (This supplement is available at www.mhhe.com/Hillier6e).		

Chapter Six

Network Optimization Problems		203
6.1	Minimum-Cost Flow Problems	204
6.2	A Case Study: The BMZ Co. Maximum Flow Problem	212
6.3	Maximum Flow Problems	215
6.4	Shortest Path Problems	219
6.5	Summary	229
	Glossary	229
	Learning Aids for This Chapter	230
	Solved Problems	230
	Problems	231
Case 6-1	Aiding Allies	235
Case 6-2	Money in Motion	238
Case 6-3	Airline Scheduling	240

Case 6-4 Broadcasting the Olympic Games 241

Supplement to Chapter 6: Minimum Spanning-Tree Problems (This supplement is available at www.mhhe.com/Hillier6e).

Chapter Seven

Using Binary Integer Programming to Deal with Yes-or-No Decisions 243

7.1 A Case Study: The California Manufacturing Co. Problem 244

7.2 Using BIP for Project Selection: The Tazer Corp. Problem 251

7.3 Using BIP for The Selection of Sites for Emergency Services
Facilities: The Caliente City Problem 253

7.4 Using BIP for Crew Scheduling: The Southwestern Airways
Problem 257

7.5 Using Mixed BIP to Deal with Setup Costs for Initiating Production:
The Revised Wyndor Problem 261

7.6 Summary 266

Glossary 266

Learning Aids for This Chapter 266

Solved Problems 266

Problems 268

Case 7-1 Assigning Art 273

Case 7-2 Stocking Sets 275

Case 7-3 Assigning Students to Schools (Revisited) 278

Case 7-4 Broadcasting the Olympic Games (Revisited) 278

Supplement 1 to Chapter 7: Advanced Formulation Techniques for Binary Integer Programming

Supplement 2 to Chapter 7: Some Perspectives on Solving Binary Integer Programming Problems (These supplements are available at www.mhhe.com/Hillier6e.)

Chapter Eight

Nonlinear Programming 279

- 8.1** The Challenges of Nonlinear Programming 281
- 8.2** Nonlinear Programming with Decreasing Marginal Returns 289
- 8.3** Separable Programming 299
- 8.4** Difficult Nonlinear Programming Problems 309
- 8.5** Evolutionary Solver and Genetic Algorithms 310
- 8.6** Using Analytic Solver to Analyze a Model and Choose a Solving Method 318
- 8.7** Summary 322

Glossary 323

Learning Aids for This Chapter 323

Solved Problem 324

Problems 324

Case 8-1 Continuation of the Super Grain Case Study 329

Case 8-2 Savvy Stock Selection 330

Case 8-3 International Investments 331

Chapter Nine

Decision Analysis 334

- 9.1** A Case Study: The Goferbroke Company Problem 335
- 9.2** Decision Criteria 337
- 9.3** Decision Trees 342
- 9.4** Sensitivity Analysis with Decision Trees 346
- 9.5** Checking Whether to Obtain More Information 350
- 9.6** Using New Information to Update the Probabilities 353
- 9.7** Using a Decision Tree to Analyze the Problem with a Sequence of Decisions 357
- 9.8** Performing Sensitivity Analysis on the Problem with a Sequence of Decisions 364
- 9.9** Using Utilities to Better Reflect the Values of Payoffs 367
- 9.10** The Practical Application of Decision Analysis 378

9.11 Summary 379

Glossary 379

Learning Aids for This Chapter 380

Solved Problems 381

Problems 381

Case 9-1 Who Wants to Be a Millionaire? 391

Case 9-2 University Toys and the Business Professor Action Figures 392

Case 9-3 Brainy Business 393

Case 9-4 Smart Steering Support 394

Supplement 1 to Chapter 9: Decision Criteria Supplement 2 to Chapter 9:
Using TreePlan Software for Decision Trees (These supplements are
available at www.mhhe.com/Hillier6e.)

Chapter Ten

Forecasting 397

10.1 An Overview of Forecasting Techniques 398

10.2 A Case Study: The Computer Club Warehouse (CCW) Problem 400

10.3 Applying Time-Series Forecasting Methods to the Case Study 404

10.4 The Time-Series Forecasting Methods in Perspective 423

10.5 Causal Forecasting with Linear Regression 426

10.6 Judgmental Forecasting Methods 431

10.7 Summary 433

Glossary 433

Summary of Key Formulas 434

Learning Aids for This Chapter 435

Solved Problem 435

Problems 435

Case 10-1 Finagling the Forecasts 442

Chapter Eleven

Queueing Models 446

11.1 Elements of a Queueing Model 447

11.2 Some Examples of Queueing Systems 453

11.3 Measures of Performance for Queueing Systems 455

11.4 A Case Study: The Dupit Corp. Problem 458

11.5 Some Single-Server Queueing Models 461

11.6 Some Multiple-Server Queueing Models 469

11.7 Priority Queueing Models 474

11.8 Some Insights about Designing Queueing Systems 480

11.9 Economic Analysis of the Number of Servers to Provide 485

11.10 Summary 488

Glossary 489

Key Symbols 490

Learning Aids for This Chapter 490

Solved Problem 490

Problems 491

Case 11-1 Queueing Quandary 497

Case 11-2 Reducing In-Process Inventory 498

Supplement to Chapter 11: Additional Queueing Models (This supplement is available at www.mhhe.com/Hillier6e.)

Chapter Twelve

Computer Simulation: Basic Concepts 499

12.1 The Essence of Computer Simulation 500

12.2 A Case Study: Herr Cutter's Barber Shop (Revisited) 512

12.3 Analysis of the Case Study 519

12.4	Outline of a Major Computer Simulation Study	526
12.5	Summary	529
	Glossary	529
	Learning Aids for This Chapter	530
	Solved Problem	530
	Problems	530
	Case 12-1 Planning Planers	534
	Case 12-2 Reducing In-Process Inventory (Revisited)	535
	Supplement to Chapter 12: The Inverse Transformation Method for Generating Random Observations (This supplement is available at www.mhhe.com/Hillier6e.)	

Chapter Thirteen

Computer Simulation with Analytic Solver 536

13.1	A Case Study: Freddie the Newsboy's Problem	537
13.2	Bidding for a Construction Project: A Prelude to the Reliable Construction Co. Case Study	547
13.3	Project Management: Revisiting the Reliable Construction Co. Case Study	551
13.4	Financial Risk Analysis: Revisiting the Think-Big Development Co. Problem	557
13.5	Revenue Management in the Travel Industry	562
13.6	Choosing the Right Distribution	568
13.7	Decision Making with Parameter Analysis Reports and Trend Charts	579
13.8	Optimizing with Computer Simulation Using the Solver in Analytic Solver	587
13.9	Summary	595
	Glossary	596
	Learning Aids for This Chapter	596
	Solved Problem	596

Problems 597

Case 13-1 Action Adventures 602

Case 13-2 Pricing under Pressure 603

Case 13-3 Financial Planning for Retirement 604

Appendix A: Tips for Using Microsoft Excel for Modeling 606

Appendix B: Partial Answers to Selected Problems 612

Index 616

CHAPTERS available at www.mhhe.com/Hillier6e

Chapter Fourteen

Solution Concepts for Linear Programming

- 14.1** Some Key Facts about Optimal Solutions
- 14.2** The Role of Corner Points in Searching for an Optimal Solution
- 14.3** Solution Concepts for the Simplex Method
- 14.4** The Simplex Method with Two Decision Variables
- 14.5** The Simplex Method with Three Decision Variables
- 14.6** The Role of Supplementary Variables
- 14.7** Some Algebraic Details for the Simplex Method
- 14.8** Computer Implementation of the Simplex Method
- 14.9** The Interior-Point Approach to Solving Linear Programming Problems
- 14.10** Summary

Glossary

Learning Aids for This Chapter Problems

Chapter Fifteen

Transportation and Assignment Problems

- 15.1** A Case Study: The P & T Company Distribution Problem
- 15.2** Characteristics of Transportation Problems
- 15.3** Modeling Variants of Transportation Problems
- 15.4** Some Other Applications of Variants of Transportation Problems
- 15.5** A Case Study: The Texago Corp. Site Selection Problem

page xviii

- 15.6** Characteristics of Assignment Problems
- 15.7** Modeling Variants of Assignment Problems
- 15.8** Summary

Glossary

Learning Aids for This Chapter

Problems

Case 15-1 Continuation of the Texago Case Study

Chapter Sixteen

PERT/CPM Models for Project Management

- 16.1** A Case Study: The Reliable Construction Co. Project
- 16.2** Using a Network to Visually Display a Project
- 16.3** Scheduling a Project with PERT/CPM
- 16.4** Dealing with Uncertain Activity Durations
- 16.5** Considering Time–Cost Trade-Offs
- 16.6** Scheduling and Controlling Project Costs
- 16.7** An Evaluation of PERT/CPM from a Managerial Perspective
- 16.8** Summary

Glossary

Learning Aids for This Chapter

Problems

Case 16-1 Steps to Success

Case 16-2 “School’s Out Forever . . .”

Chapter Seventeen

Goal Programming

17.1 A Case Study: The Dewright Co. Goal-Programming Problem

17.2 Weighted Goal Programming

17.3 Preemptive Goal Programming

17.4 Summary

Glossary

Learning Aids for This Chapter Problems

Case 17-1 A Cure for Cuba

Case 17-2 Remembering September 11

Chapter Eighteen

Inventory Management with Known Demand

18.1 A Case Study: The Atlantic Coast Tire Corp. (ACT) Problem

18.2 Cost Components of Inventory Models

18.3 The Basic Economic Order Quantity (EOQ) Model

18.4 The Optimal Inventory Policy for the Basic EOQ Model

18.5 The EOQ Model with Planned Shortages

18.6 The EOQ Model with Quantity Discounts

18.7 The EOQ Model with Gradual Replenishment

18.8 Summary

Glossary

Learning Aids for This Chapter

Problems

Case 18-1 Brushing Up on Inventory Control

Chapter Nineteen

Inventory Management with Uncertain Demand

- 19.1** A Case Study for Perishable Products: Freddie the Newsboy's Problem
- 19.2** An Inventory Model for Perishable Products
- 19.3** A Case Study for Stable Products: The Niko Camera Corp. Problem
- 19.4** The Management Science Team's Analysis of the Case Study
- 19.5** A Continuous-Review Inventory Model for Stable Products
- 19.6** Larger Inventory Systems in Practice
- 19.7** Summary

Glossary

Learning Aids for This Chapter

Problems

Case 19-1 TNT: Tackling Newsboy's Teachings

Case 19-2 Jettisoning Surplus Stock

Chapter Twenty

Computer Simulation with Crystal Ball

- 20.1** A Case Study: Freddie the Newsboy's Problem
- 20.2** Bidding for a Construction Project: A Prelude to the Reliable Construction Co. Case Study
- 20.3** Project Management: Revisiting the Reliable Construction Co. Case Study
- 20.4** Cash Flow Management: Revisiting the Everglade Golden Years Company Case Study
- 20.5** Financial Risk Analysis: Revisiting the Think-Big Development Co. Problem
- 20.6** Revenue Management in the Travel Industry
- 20.7** Choosing the Right Distribution
- 20.8** Decision Making with Decision Tables
- 20.9** Optimizing with OptQuest
- 20.10** Summary

Glossary

**Learning Aids for This Chapter Solved Problem
Problems**

Case 20-1 Action Adventures

Case 20-2 Pricing under Pressure

Chapter One

Introduction



Learning Objectives

After completing this chapter, you should be able to

- . Define the term *management science*.
- . Describe the nature of management science.
- . Explain what a mathematical model is.
- . Use a mathematical model to perform break-even analysis.
- . Use a spreadsheet model to perform break-even analysis.
- . Describe the relationship between analytics and management science.
- . Identify the levels of annual savings that management science sometimes can provide to organizations.
- . Identify some special features of this book.

Welcome to the field of *management science*! We think that it is a particularly exciting and interesting field. Exciting because management science is having a dramatic impact on the profitability of numerous business firms around the world. Interesting because the methods used to do this are so ingenious. We are looking forward to giving you a guided tour to introduce you to the special features of the field.

Some people approach management science with a certain amount of anxiety and skepticism. The main source of the anxiety is the reputation of the field as being highly mathematical. This reputation then generates skepticism that such a theoretical approach can have much relevance for dealing with practical managerial problems. Most traditional courses (and textbooks) about management science have only reinforced these perceptions by emphasizing the mathematics of the field rather than its practical application.

Rest easy. This is not a traditional management science textbook. We realize that most readers of this book are aspiring to become managers, not mathematicians. Therefore, the emphasis throughout is on conveying what a future manager needs to know about management science. Yes, this means including a little mathematics here and there, because it is a major language of the field. The mathematics you do see will be at the level of high school algebra plus (in the later chapters) basic concepts of elementary probability theory. We think you will be pleasantly surprised by the new appreciation you gain for how useful and intuitive mathematics at this level can be. However, managers do not need to know any of the heavy mathematical theory that underlies the various techniques of management science. Therefore, the use of mathematics plays only a strictly secondary role in the book.

One reason we can deemphasize mathematics is that powerful *spreadsheet software* is available for applying management science. Spreadsheets provide a comfortable and familiar environment for formulating and analyzing managerial problems. The spreadsheet takes care of applying the necessary mathematics automatically in the background with only a minimum of guidance by the user. This has revolutionized the use of management science. In the past, technically trained management scientists were needed to carry out significant management science studies for

management. Now spreadsheets are bringing many of the tools and concepts of management science within the reach of managers for conducting their own analyses. Although busy managers will continue to call upon management science teams to conduct major studies for them, they are increasingly becoming direct users themselves through the page 2 medium of spreadsheet software. Therefore, since this book is aimed at future managers (and management consultants), we will emphasize the use of spreadsheets for applying management science.

What does an enlightened future manager need to learn from a management science course?

Gain an appreciation for the relevance and power of management science. (Therefore, we include many *application vignettes* throughout the book that give examples of *actual applications* of management science and the *impact* they had on the organizations involved.)

Learn to recognize when management science can (and cannot) be fruitfully applied. (Therefore, we will emphasize the *kinds of problems* to which the various management science techniques can be applied.)

Learn how to apply the major techniques of management science to analyze a variety of managerial problems. (Therefore, we will focus largely on how spreadsheets enable many such applications with no more background in management science than provided by this book.)

Develop an understanding of how to interpret the results of a management science study. (Therefore, we will present many *case studies* that illustrate management science studies and how their results depend on the assumptions and data that were used.)

The objectives just described are the key teaching goals of this book.

We begin this process in the next four sections by introducing the nature of management science and the impact that it is having on many organizations. (This process will continue throughout the remaining chapters as well.) Section 1.5 then points out some of the special features of this book that you can look forward to seeing in the subsequent chapters.

1.1 THE NATURE OF MANAGEMENT SCIENCE

What is the name *management science* (sometimes abbreviated MS) supposed to convey? It does involve *management* and *science* or, more precisely, *the science of management*, but this still is too vague. Here is a more suggestive definition.

Management science is a *discipline* that attempts to *aid managerial decision making* by applying a *scientific approach* to managerial problems that involve *quantitative factors*.

Now let us see how elaborating upon each of the italicized terms in this definition conveys much more about the nature of management science.

Management Science Is a Discipline

As a discipline, management science is a whole body of knowledge and techniques that are based on a scientific foundation. For example, it is analogous in some ways to the medical field. A medical doctor has been trained in a whole body of knowledge and techniques that are based on the scientific foundations of the medical field. After receiving this training and entering practice, the doctor must diagnose a patient's illness and then choose the appropriate medical procedures to apply to the illness. The patient then makes the final decision on which medical procedures to accept. For less serious cases, the patient may choose not to consult a doctor and instead use his own basic knowledge of medical principles to treat himself. Similarly, a management scientist must receive substantial training (albeit considerably less than for a medical doctor). This training also is in a whole body of knowledge and techniques that are based on the scientific foundations of the discipline. After entering practice, the management scientist must diagnose a managerial problem and then choose the appropriate management science techniques to apply in analyzing the problem. The cognizant manager then makes the final decision as to which conclusions from this analysis to accept. For less extensive managerial problems where management science can be helpful, the manager may choose not to consult a management scientist and instead use his or her own basic knowledge of management science principles to analyze the problem.