PREFACE

When Jerry Lieberman and I started working on the first edition of this book 45 years ago, our goal was to develop a pathbreaking textbook that would help establish the future direction of education in what was then the emerging field of operations research. Following publication, it was unclear how well this particular goal was met, but what did become clear was that the demand for the book was far larger than either of us had anticipated. Neither of us could have imagined that this extensive worldwide demand would continue at such a high level for such an extended period of time.

The enthusiastic response to our first eight editions has been most gratifying. It was a particular pleasure to have the field's leading professional society, the international Institute for Operations Research and the Management Sciences (INFORMS), award the 6th edition honorable mention for the 1995 INFORMS Lanchester Prize (the prize awarded for the year's most outstanding English-language publication of any kind in the field of operations research).

Then, just after the publication of the eighth edition, it was especially gratifying to be the recipient of the prestigious 2004 INFORMS Expository Writing Award for this book, including receiving the following citation:

> Over 37 years, successive editions of this book have introduced more than one-half million students to the field and have attracted many people to enter the field for academic activity and professional practice. Many leaders in the field and many current instructors first learned about the field via an edition of this book. The extensive use of international student editions and translations into 15 other languages has contributed to spreading the field around the world. The book remains preeminent even after 37 years. Although the eighth edition just appeared, the seventh edition had 46 percent of the market for books of its kind, and it ranked second in international sales among all McGraw-Hill publications in engineering.
>
> Two features account for this success. First, the editions have been outstanding from students' points of view due to excellent motivation, clear and intuitive explanations, good examples of professional practice, excellent organization of material, very useful supporting software, and appropriate but not excessive mathematics. Second, the editions have been attractive from instructors' points of view because they repeatedly infuse state-of-the-art material with remarkable lucidity and plain language. For example, a wonderful chapter on metaheuristics was created for the eighth edition.

When we began work on the book 45 years ago, Jerry already was a prominent member of the field, a successful textbook writer, and the chairman of a renowned operations research program at Stanford University. I was a very young assistant professor just starting my career. It was a wonderful opportunity for me to work with and to learn from the master. I will be forever indebted to Jerry for giving me this opportunity.

Now, sadly, Jerry is no longer with us. During the progressive illness that led to his death nine years ago, I resolved that I would pick up the torch and devote myself to subsequent editions of this book, maintaining a standard that would fully honor Jerry. Therefore, I took early retirement from my faculty responsibilities at Stanford in order to work full time on textbook writing for the foreseeable future. This has enabled me to spend far more than the usual amount of time in preparing each new edition. It also has enabled me

to closely monitor new trends and developments in the field in order to bring this edition completely up to date. This monitoring has led to the choice of the major revisions outlined below.

■ THE MAJOR REVISIONS

- **A Greatly Increased Emphasis on Real Applications.** Unbeknownst to the general public, the field of operations research is continuing to have an increasingly dramatic impact on the success of numerous companies and organizations around the world. Therefore, a special goal of this edition has been to tell this story much more forcefully, thereby exciting students about the great relevance of the material they are studying. We have pursued this goal in four ways. One is the *addition of 29 application vignettes* separated from the regular textual material that describe in a few paragraphs how an actual application of operations research had a powerful impact on a company or organization by using techniques like those being studied in that portion of the book. A second is the *addition of 71 selected references of award winning OR applications* given at the end of various chapters. A third is the *addition of a link to the journal articles that fully describe these 100 applications*, through a special arrangement with INFORMS. The final way is the *addition of many problems that require reading one or more of these articles*. 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.
- **Approximately 200 New or Revised Problems.** The new problems include the ones involving real applications mentioned above. Other new problems also have been added, including a considerable number that support the new or revised topics mentioned later. Two new cases have been added for the chapter on decision analysis that are less complex than the two that already were there. In addition, many of the problems from the eighth edition have been revised. Therefore, an instructor who does not wish to assign problems that were assigned in previous classes has a substantial number from which to choose.
- **An Updating of the Software Accompanying the Book.** The next section will outline the wealth of software options that are provided with this new edition. The main difference from the eighth edition is that new, improved versions of several of the software packages now are available. For example, *Excel 2007* represents by far the most major revision of Excel and its user interface in many, many years, so this new version of Excel and its Solver has been fully integrated into the book (while pointing out differences for those still using old versions). Another important example is that, for the first time in 10 years, new versions of *TreePlan* and *SensIt* have just now become available and have been fully integrated into the decision analysis chapter. The latest versions of all the other software packages also are being provided with this new edition.
- **A New Section on Revenue Management.** A hallmark of new editions of this book has been the addition of substantial coverage of dramatic, recent developments that are beginning to revolutionize how certain areas of operations research are being practiced. For example, the eighth edition added a new chapter on metaheuristics, a new section on the incorporation of constraint programming, and a new section on multiechelon inventory models for supply chain management. This edition is adding another key new topic with the *addition of a complete section on revenue management in the chapter on inventory theory*. This is a timely addition because of the dramatic impact that revenue management has been having in the airline industry and now is beginning to have in several other industries.

- **A Reorganization of the Chapter on the Theory of the Simplex Method.** Some instructors do not wish to take the time to cover the revised simplex method but may still want to introduce the matrix form of the simplex method and may still want to cover what we call the "fundamental insight" regarding the simplex method. Therefore, rather than covering the revised simplex method in Section 5.2 before turning to the fundamental insight in Section 5.3—as in the eighth edition—we now simply introduce the matrix form of the simplex method in Section 5.2, which flows directly into the fundamental insight in Section 5.3, after which we focus on the revised simplex method as an optional topic in Section 5.4.

- **A Simplified Method for Determining Utilities.** Among the various other smaller revisions throughout the book, perhaps the most noteworthy is a simplified presentation in Section 15.6 of how to determine utilities. This is done through outlining a simple "equivalent lottery method."

- **A Reorganization to Reduce the Size of the Book.** An unfortunate trend with early editions of this book was that each new edition was significantly larger than the previous one. This continued until the seventh edition had become considerably larger than is desirable for an introductory survey textbook. Therefore, I worked hard to substantially reduce the size of the eighth edition and adopted the goal of avoiding any growth in subsequent editions. The goal has been achieved for the current edition. This was accomplished through a variety of means. One was being careful not to add too much new material. Another was deleting two sections on real applications that had been in the eighth edition but no longer were needed because of the addition of application vignettes. Another was moving both the long Appendix 3.1 on the LINGO modeling language and the section on optimizing with OptQuest to the supplements on the book's website. (This decision regarding OptQuest was made easy by the fact that a new version is due out momentarily, but not in time for this edition, so it will be added later as a supplement.) Finally, a considerable number of sections were shortened. Otherwise, I have stuck closely to what I hope has become the familiar organization of the eighth edition after having made major changes for that edition.

- **Updating to Reflect the Current State of the Art.** A special effort has been made to keep the book completely up to date. This has included carefully updating both the selected references at the end of each chapter and the various footnotes referencing the latest research on the topics being covered.

A WEALTH OF SOFTWARE OPTIONS

A wealth of software options is being provided on the book's website www.mhhe.com/hillier as outlined below.

- Excel spreadsheets: state-of-the-art spreadsheet formulations are displayed in Excel files for all relevant examples throughout the book.
- Several Excel add-ins, including Premium Solver for Education (an enhancement of the basic Excel Solver), TreePlan (for decision analysis), SensIt (for probabilistic sensitivity analysis), RiskSim (for simulation), and Solver Table (for sensitivity analysis).
- A number of Excel templates for solving basic models.
- Student versions of LINDO (a traditional optimizer) and LINGO (a popular algebraic modeling language), along with formulations and solutions for all relevant examples throughout the book.
- Student versions of MPL (a leading algebraic modeling language) and its prime solver CPLEX (the most widely used state-of-the-art optimizer), along with an MPL Tutorial and MPL/CPLEX formulations and solutions for all relevant examples throughout the book.

- Student versions of several additional MPL solvers, including CONOPT (for convex programming), LGO (for global optimization), LINDO (for mathematical programming), CoinMP (for linear and integer programming), and BendX (for some stochastic models).
- Queueing Simulator (for the simulation of queueing systems).
- OR Tutor for illustrating various algorithms in action.
- Interactive Operations Research (IOR) Tutorial for efficiently learning and executing algorithms interactively, implemented in Java 2 in order to be platform independent.

Numerous students have found OR Tutor and IOR Tutorial very helpful for learning algorithms of operations research. When moving to the next stage of solving OR models automatically, surveys have found instructors almost equally split in preferring one of the following options for their students' use: (1) Excel spreadsheets, including the Excel Solver and other add-ins, (2) convenient traditional software (LINDO and LINGO), and (3) state-of-the-art OR software (MPL and CPLEX). For this edition, therefore, I have retained the philosophy of the last couple of editions of providing enough introduction in the book to enable the basic use of any of the three options without distracting those using another, while also providing ample supporting material for each option on the book's website.

We have elected to no longer include the Crystal Ball software package that was bundled with the eighth edition. Fortunately, many universities now have a site license for Crystal Ball and the package currently can also be downloaded for a free 30-day trial period, so it still is feasible to have students use this software, at least for a limited time. Therefore, this edition continues to use Crystal Ball in Section 20.6 and certain supplements to illustrate the exciting functionality that is now available for analyzing simulation models.

Additional Online Resources

- Several examples for nearly every book chapter are included in a *Worked Examples section* of the book's website to provide additional help to occasional students who need it without disrupting the flow of the text and adding unneeded pages for others. (The book uses boldface to highlight whenever an additional example on the current topic is available.)
- A *glossary* for every book chapter.
- *Data files* for various cases are included to enable students to focus on analysis rather than inputting large data sets.
- An abundance of supplementary textual material (including eight complete chapters).
- A *test bank* featuring moderately difficult questions that require students to show their work is being provided to instructors. Most of the questions in this test bank have previously been used successfully as test questions by the authors.
- Also available to instructors are a solutions manual and image files.

Electronic Textbook Option

This text is offered through CourseSmart for both instructors and students. CourseSmart is an online resource where students can purchase access to this and other McGraw-Hill textbooks in a digital format. Through their browser, students can access the complete text online for one year at almost half the cost of a traditional text. Purchasing the eTextbook also allows students to take advantage of CourseSmart's web tools for learning, which include full text search, notes and highlighting, and e-mail tools for sharing notes between classmates. To learn more about CourseSmart options, contact your sales representative or visit www.CourseSmart.com.

■ THE USE OF THE BOOK

The overall thrust of all the revision efforts has been to build upon the strengths of previous editions to more fully meet the needs of today's students. These revisions make the book even more suitable for use in a modern course that reflects contemporary practice in the field. The use of software is integral to the practice of operations research, so the wealth of software options accompanying the book provides great flexibility to the instructor in choosing the preferred types of software for student use. All the educational resources accompanying the book further enhance the learning experience. Therefore, the book and its website should fit a course where the instructor wants the students to have a single self-contained textbook that complements and supports what happens in the classroom.

The McGraw-Hill editorial team and I think that the net effect of the revision has been to make this edition even more of a "student's book"—clear, interesting, and well-organized with lots of helpful examples and illustrations, good motivation and perspective, easy-to-find important material, and enjoyable homework, without too much notation, terminology, and dense mathematics. We believe and trust that the numerous instructors who have used previous editions will agree that this is the best edition yet.

The prerequisites for a course using this book can be relatively modest. As with previous editions, the mathematics has been kept at a relatively elementary level. Most of Chaps. 1 to 14 (introduction, linear programming, and mathematical programming) require no mathematics beyond high school algebra. Calculus is used only in Chaps. 12 (Nonlinear Programming) and in one example in Chap. 10 (Dynamic Programming). Matrix notation is used in Chap. 5 (The Theory of the Simplex Method), Chap. 6 (Duality Theory and Sensitivity Analysis), Sec. 7.4 (An Interior-Point Algorithm), and Chap. 12, but the only background needed for this is presented in Appendix 4. For Chaps. 15 to 20 (probabilistic models), a previous introduction to probability theory is assumed, and calculus is used in a few places. In general terms, the mathematical maturity that a student achieves through taking an elementary calculus course is useful throughout Chaps. 15 to 20 and for the more advanced material in the preceding chapters.

The content of the book is aimed largely at the upper-division undergraduate level (including well-prepared sophomores) and at first-year (master's level) graduate students. Because of the book's great flexibility, there are many ways to package the material into a course. Chapters 1 and 2 give an introduction to the subject of operations research. Chapters 3 to 14 (on linear programming and on mathematical programming) may essentially be covered independently of Chaps. 15 to 20 (on probabilistic models), and vice-versa. Furthermore, the individual chapters among Chaps. 3 to 14 are almost independent, except that they all use basic material presented in Chap. 3 and perhaps in Chap. 4. Chapter 6 and Sec. 7.2 also draw upon Chap. 5. Sections 7.1 and 7.2 use parts of Chap. 6. Section 9.6 assumes an acquaintance with the problem formulations in Secs. 8.1 and 8.3, while prior exposure to Secs. 7.3 and 8.2 is helpful (but not essential) in Sec. 9.7. Within Chaps. 15 to 20, there is considerable flexibility of coverage, although some integration of the material is available.

An elementary survey course covering linear programming, mathematical programming, and some probabilistic models can be presented in a quarter (40 hours) or semester by selectively drawing from material throughout the book. For example, a good survey of the field can be obtained from Chaps. 1, 2, 3, 4, 15, 17, 18, and 20, along with parts of Chaps. 9 to 13. A more extensive elementary survey course can be completed in two quarters (60 to 80 hours) by excluding just a few chapters, for example, Chaps. 7, 14, and 19. Chapters 1 to 8 (and perhaps part of Chap. 9) form an excellent basis for a (one-quarter)

course in linear programming. The material in Chaps. 9 to 14 covers topics for another (one-quarter) course in other deterministic models. Finally, the material in Chaps. 15 to 20 covers the probabilistic (stochastic) models of operations research suitable for presentation in a (one-quarter) course. In fact, these latter three courses (the material in the entire text) can be viewed as a basic one-year sequence in the techniques of operations research, forming the core of a master's degree program. Each course outlined has been presented at either the undergraduate or graduate level at Stanford University, and this text has been used in the manner suggested.

The book's website will provide updates about the book, including an errata. To access this site, visit www.mhhe.com/hillier.

■ ACKNOWLEDGMENTS

I am indebted to an excellent group of reviewers who provided sage advice for the revision process. This group included

Chun-Hung Chen, George Mason University
Mary Court, University of Oklahoma
Todd Easton, Kansas State University
Samuel H. Huang, University of Cincinnati
Ronald Giachetti, Florida International University
Mary E. Kurz, Clemson University
Wooseung Jang, University of Missouri-Columbia
Shafiu Jibrin, Northern Arizona University
Roger Johnson, South Dakota School of Mines & Technology
Emanuel Melachrinoudis, Northeastern University
Clark A. Mount-Campbell, The Ohio State University
Jose A. Ventura, Pennsylvania State University
John Wu, Kansas State University

I also am grateful to Garrett Van Ryzin for his expert advice regarding the new section on revenue management, to Charles McCallum, Jr., for providing lists of typos in the 8th edition three times, and to Bjarni Kristjansson for providing up-to-date information on the sizes of problems being solved successfully by the latest optimization software. In addition, thanks go to those instructors and students who sent email messages to provide their feedback on the 8th edition.

This edition was very much of a team effort. Our case writers, Karl Schmedders and Molly Stephens (both graduates of our department), wrote 24 elaborate cases for the 7th edition, and all of these cases continue to accompany this new edition. One of our department's current PhD students, Pelin Canbolat, did an excellent job in preparing the solutions manual. She went above and beyond the call of duty by typing nearly all of the solutions that had been handwritten for preceding editions, as well as providing helpful input for this edition. One of our former PhD students, Michael O'Sullivan, developed OR Tutor for the 7th edition (and continued here), based on part of the software that my son Mark Hillier had developed for the 5th and 6th editions. Mark (who was born the same year as the first edition, earned his PhD at Stanford, and now is a tenured Associate Professor of Quantitative Methods at the University of Washington) provided both the spreadsheets and the Excel files (including many Excel templates) for this edition, as well as the Solver Table and Queueing Simulator. He also gave helpful advice on both the textual material and software for this edition, and contributed greatly

to Chapters 21 and 28 on the book's website. Another Stanford PhD graduate, William Sun (CEO of the software company Accelet Corporation), and his team did a brilliant job of starting with much of Mark's earlier software and implementing it anew in Java 2 as IOR Tutorial for the 7th edition. They again did a masterful job of further enhancing IOR Tutorial for the 8th and subsequent editions. Linus Schrage of the University of Chicago and LINDO Systems (and who took an introductory operations research course from me 45 years ago) provided LINGO and LINDO for the book's website. He also supervised the further development of LINGO/LINDO files for the various chapters as well as providing tutorial material for the book's website. Another long-time friend, Bjarni Kristjansson (who heads Maximal Software), did the same thing for the MPL/CPLEX files and MPL tutorial material, as well as arranging to provide student versions of MPL, CPLEX, and various other solvers for the book's website. My wife, Ann Hillier, devoted numerous long days and nights to sitting with a Macintosh, doing word processing and constructing many figures and tables. They all were vital members of the team.

In addition to Accelet Corporation, LINDO Systems, and Maximal Software, we are deeply indebted to several other companies for providing software to accompany this edition. These include Frontline Systems (for providing Premium Solver for Education), ILOG (for providing the CPLEX solver used with the MPL Student Edition), ARKI Corporation (for providing the CONOPT convex programming solver used with the MPL Student Edition), and PCS Inc. (for providing the LGO global optimization solver used with the MPL Student Edition). We also are grateful to Professor Michael Middleton for providing newly improved versions of TreePlan and SensIt, as well as RiskSim. Finally, we appreciate the cooperation of INFORMS in providing a link to the articles in *Interfaces* that describe the applications of OR that are summarized in the application vignettes and other selected references of award winning OR applications provided in the book.

It was a real pleasure working with McGraw-Hill's thoroughly professional editorial and production staff, including Debra Hash (Sponsoring Editor) and Lora Kalb-Neyens (Developmental Editor).

Just as so many individuals made important contributions to this edition, I would like to invite each of you to start contributing to the next edition by using my email address below to send me your comments, suggestions, and errata to help me improve the book in the future. In giving my email address, let me also assure instructors that I will continue to follow the policy of not providing solutions to problems and cases in the book to anybody (including your students) who contacts me.

Enjoy the book.

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May 2008