

**5th  
EDITION**

# **INTRODUCTORY MANAGEMENT SCIENCE**

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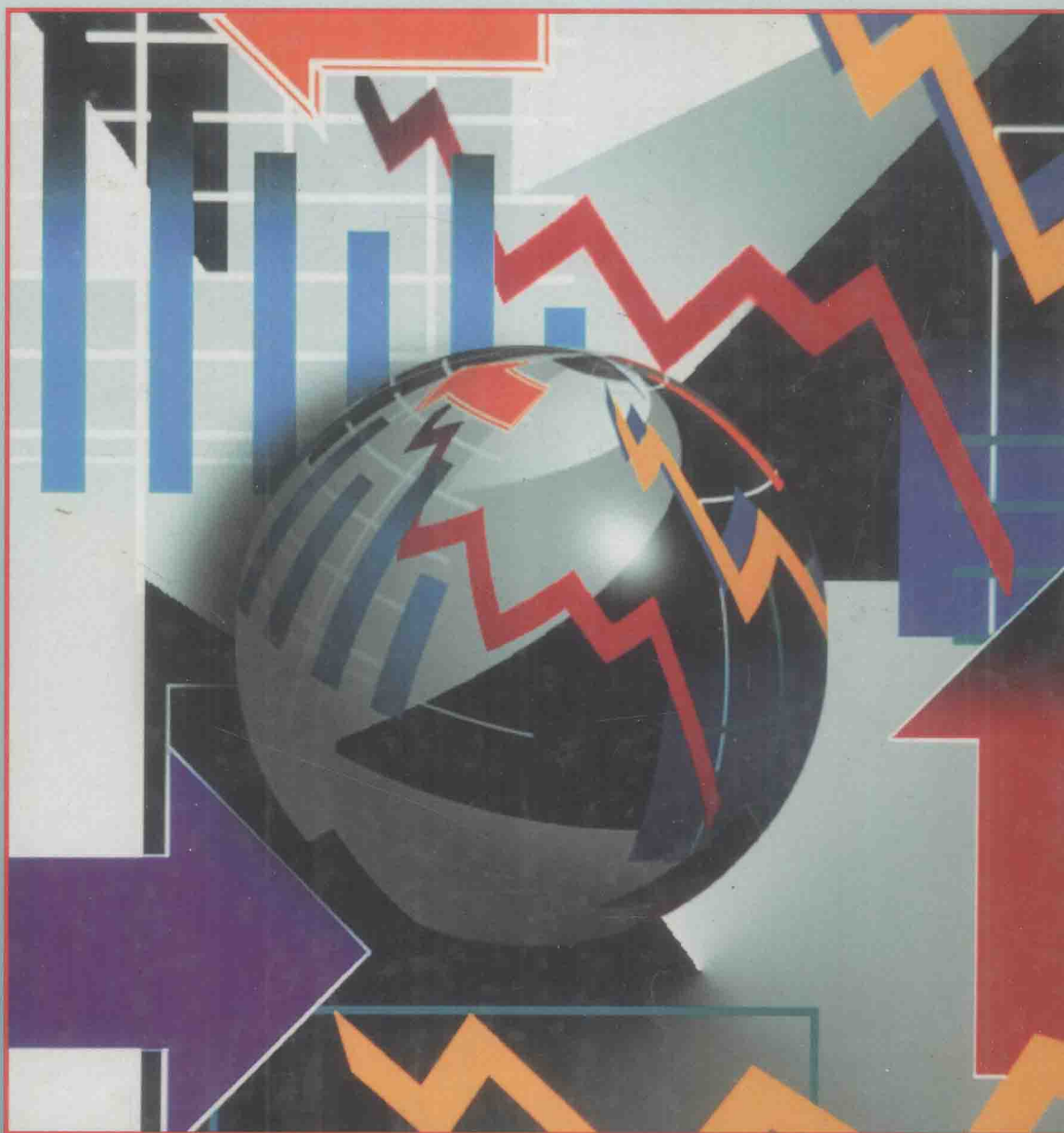
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**Decision Modeling with Spreadsheets**

INTRODUCTORY

# Management Science

FIFTH EDITION

Decision Modeling  
with  
Spreadsheets

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University of Chicago

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He has worked on several courseware projects to introduce Excel for modeling and decision support to graduate level MBA's and executives. This has included work under several grants from Microsoft, IBM, and Hewlett Packard, and early work with Frontline Systems in the testing and development of Excel's Solver, particularly the linear optimization options. In 1978-79 he pioneered one of the first courses to use spreadsheet modeling in a business school, and soon thereafter, orchestrated Stanford's conversion of its Decision Science core course to spreadsheets, the first major business school to do so. Since that time, he has been involved in the development of modeling and statistical applications of spreadsheets, and has developed GLP, Stanford's Graphical LP Optimizer, and Regress, an Excel-based regression package now used at Stanford and elsewhere.

In 1995-96 he served on the INFORMS Business School Educational Task Force which surveyed more than 300 university instructors in the teaching of management science and has made presentations at its conferences on the important role

spreadsheets should play in management education. Currently, he is the Director of TELL, the Stanford Business School's Technology Educational Learning Laboratory, a new facility devoted to understanding the use of technology in management and in management education.

In 1996, he received Stanford's Sloan Teaching Excellence Award for his core course in Decision Support Modeling.

Dr. Moore holds a BSEE with specialty in digital circuit design from the University of Cincinnati, a joint MBA/CS degree from Texas A&M University, and a Ph.D. in Business from the University of California at Berkeley. He also holds a Professional Engineer certification (E.E., Ohio).



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ceived the Outstanding Teaching Award for the College of Business in his first year as a professor. In the ensuing years he has also earned the "Outstanding Faculty Member" award by Alpha Kappa Psi, the Outstanding Junior Research Award for the College of Business, and most recently the University-wide Ellbogen Meritorious Classroom Teaching Award. He has published several scholarly articles in such journals as *Operations Research*, *Decision Sciences*, *Transportation Science*, *Naval Research Logistics*, *Cornell Hotel and Restaurant Administration Quarterly*, *International Journal of Technology Management*, *Journal of Combinatorial Optimization* and *Omega*.

On the practitioner side, he was featured in the "Questions and Answers" section of *Scorecard* (the Revenue Management Quarterly) in the second quarter of 1994. He also wrote the technical brief section of *Scorecard* for the same issue. Larry has made presentations of his research to the Yield Management study group of AGIFORS and the IATA International Revenue Management conference the past several years. He has worked on revenue management projects with several major airline and hotel corporations.

On the personal side, Larry is married to the lovely Jenny and they have 6 children (yes, they are all from the same union)! Most of his outside interests are centered in his family and church. Any other spare time is spent playing racquetball or golf or reading a fun book.

# Preface

## To the Student of Management

Congratulations! By learning Microsoft Excel you have joined the 35 million users who have made spreadsheets the *lingua franca* of management, a revolution in management that is barely a decade old. This book is not about Excel; it is about how you can use Excel for the analysis of management situations. Our approach will consist of developing and then analyzing an Excel model of the situation. From this analysis, recommended decisions to improve the situation will be considered. A wide range of models will be developed along with the appropriate concepts to allow you to generalize these examples to the variety of situations that you will encounter in your career as a manager.

The building of explicit models for analysis and managerial decision making has traditionally been called *management science*.

Webster's New World Dictionary defines *oxymoron* as "a figure of speech in which opposite or contradictory ideas or terms are combined." Common examples include sweet sorrow, thunderous silence, jumbo shrimp, sport sedan, bureaucratic efficiency, proprietary standard . . . you can probably think of many more. And management science?

The same dictionary says that *management* is "the act, art, or manner of managing, or handling, controlling, directing, and so on." If management is an art, is management science then an oxymoron—a contradiction in terms?

Not to us!

Science is the process of using observation and testing to establish principles and then using these principles to answer questions. Much of business is based on the same approach. Actuaries use statistical models to set insurance rates. Organizations use discounted cash flow models to make decisions on capital expenditures. Sales executives use models based on demand elasticity to determine prices, and pension fund managers use investment models to control their investment portfolios.

This book is devoted to models that may appear in many different management situations. Indeed, many of the models we will study are *generic* models. Just as the model for discounting cash flows can be used for problems with different time periods, different interest rates, and different cash flows, so can the models studied in this text be used in widely different situations.

We believe that you will find this book interesting (to say nothing of useful) to the extent that you (1) focus upon *real-world situations* and the role of spreadsheet models in addressing such situations, and (2) engage in the hands on building and analysis of these models. For our part, we have tried to keep the focus on *the relationship between management and model*. Much of the responsibility for maintaining this focus, however, rests with you. As you work your way through this text, you will find that it is full of specific models. It is easy to become so immersed in the technical details of the models and their Excel representation that you lose track of the general skills that you must develop to be either a good manager or a good modeler. Here are four ideas that are fundamental to effective decision making. It will be useful to keep them in mind and to see how the specific models you will work with contribute to your understanding of them.

**Framing.** To model a situation, you first have to “frame” it. That is, you must develop an organized way of thinking about the situation. Remember, most management problems come to us in the form of symptoms, not as clear problem statements. Your sales representative in Spokane tells you that your chief competitor is beating you by offering direct sales transaction processing over the Internet. In the everyday sense of the word, that’s a management problem. In our language, that’s a symptom. A problem involves possible decisions and a method for measuring their effectiveness. The art of moving from a symptom to a crisp problem statement is called framing. It is an essential skill of an effective manager.

*Constrained optimization* and *decisions under risk* are two important and useful frames we will cover that apply to a wide variety of management situations. Unfortunately, it does not seem possible merely to describe the frames and assume that you can then use them correctly. You have to understand how the models are created and the relationships between decisions and results before you can advance to using the frames in an intuitive way. You have to learn about the models and how they are used in various situations before you can make the ideas your own. This requires taking the time to critically review the works of others and practice on your own. Thus the book is full of examples and their spreadsheet representation, and cases and problems for you to sharpen your own spreadsheet modeling skills.

**Optimality and Sensitivity.** In this text you will encounter many business models, and you will see that analysis of these models produces “optimal” decisions. That sounds great—what could be better than an “optimal” decision? But language can be deceptive if you do not have a thorough understanding of the concepts behind it. In this context, an *optimal decision* is one that gives the best answer to the abstract problem formulated in the model—for example, an answer that maximizes profits. But is it the best answer to the real-world situation that prompted you to make the model in the first place? This is what you must decide—preferably, *before* implementing the recommendations of the model. Whether or not to implement a particular recommendation is always a judgment call, but the quality of this judgment will depend heavily on how well you understand the relationship between the model and the real situation it is designed to mirror.

It is also important to assess the *sensitivity* of the answer—that is, how much the answer given by a model depends on the particular numerical values used for the model’s inputs. Managers are usually most comfortable with decisions that hold for a wide range of input values, so that a good decision cannot suddenly be transformed into a bad one by a small change in one model input. Sensitivity analysis is thus an important topic throughout this text.

**Cost Concepts.** This text deals with individual business decisions, such as how many items to order or where to build a new factory. One of the basic building blocks for the models you will construct is costs. You will have the opportunity to work with the concepts of fixed, marginal, and opportunity costs. Determining the proper cost relationships in a model is crucial to arriving at good decisions. It is a skill that will stand you in good stead in your career.

**Healthy Skepticism.** It is important to be skeptical. Learn to beware of experts, of solutions provided by computer models—yours and especially another’s—and certainly of your own intuition. Our most valuable associates are those who say, “You can’t be right! If you were right, then we would know that the following condition must be true, and it obviously isn’t and thus you are wrong.” Working directly with models—hands on—enhances your ability to analyze and dissect the route from assumptions to conclusions. The end-chapter cases are specifically designed to illustrate this concept. Asking the right question is the first step in reaching a good decision. You will have the opportunity to work on developing this skill.

The key ingredient in successfully modeling management situations is you. Remember, you are in “competition” with the 35 million others who preceded you in this revolution by mastering spreadsheet mechanics. But how many of them can use a spreadsheet to successfully model a challenging management situation and defend their analysis on sound conceptual grounds? It is clearly possible to do the work assignments in this text, get a passing grade in the course, and still have the material make no impact on you or your career. To avoid this tragic result, you have to *own* these modeling ideas, which means you must make them a part of your intuition. The text can help, your teacher can help, but ultimately you have to do it on the basis of your own “hands on” work with Excel modeling. Learning something is, after all, a personal experience, and you can achieve it only with personal effort.

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## To the Instructor

As evident in our message above, spreadsheet based management science has a lot to offer your students. We believe a good textbook coupled with your teaching and enthusiasm can play a critical role in helping to shape the attitudes of tomorrow's managers towards the proper use of quantitative modeling in business. Certainly, spreadsheets have become the near-exclusive tool used by millions of managers in analyzing business problems. They now contain many powerful tools that can be used to analyze more sophisticated models and make better decisions. Given the pervasive use of spreadsheets in management, our task is to focus students upon developing their modeling skills—how to “paint” onto the blank canvas of the worksheet to develop helpful, practical business models—and not upon algorithms or mathematical puzzles.

With this in mind, the fifth edition was revised entirely by the new authors, Jeff Moore and Larry Weatherford, top to bottom, to make it state-of-the-art in the spreadsheet tools that it teaches and to help you make it more relevant to the management careers your students face. With this in mind, content has shifted away from solution procedures and other mathematical details toward additional case material. For example, new cases from the Stanford and Darden Graduate Schools of Business have been added in almost all chapters. We also think that it is very important for the student to be aware of the continuing successful use of these quantitative methods by actual businesses and thus have included updated chapter-opening vignettes and application capsules that demonstrate payoffs, often on the order of millions of dollars, by well-known businesses who have applied these modeling techniques.

This textbook is designed for introductory courses in applying the Microsoft Excel spreadsheet to management decision modeling at the undergraduate or MBA level. It introduces students to the key ideas of modeling and management decision making that will be important to them throughout their careers. Addressing the needs of readers interested in either general management or more specialized decision science careers, the book emphasizes

- the importance of strong conceptual foundations for all topics, as opposed to “cook-book” spreadsheet prescriptions
- role of spreadsheet modeling in the larger context of management decision-making, as opposed to algorithmic techniques.

We have adopted a very “hands on” approach to modeling many different challenges a business may face in the areas of operations, finance, human resources, marketing, and the public sector, to name a few. Students strongly prefer this approach because (1) they learn marketable skills they will use immediately in their careers, and more importantly, (2) they develop valuable modeling habits and insights of longer term benefit. Many students have called us to say that this was one of the most valuable courses they took in college.



The revised book has a strong focus on models—what they are, how they are created, how they are used, what kinds of insights they provide—and on the critical importance of managerial judgment in utilizing those insights. At the same time, for readers interested in the more technical aspects of the subject, there is an unparalleled treatment of optimization and decision analysis techniques.

Spreadsheet applications and examples in Microsoft Excel, including the use of popular spreadsheet add-ins (Solver, Crystal Ball, @Risk, and TreePlan), are integrated throughout as the modeling paradigm.

Considerable attention has been paid to the procedural (almost tutorial) steps to build and analyze decision-making models in Excel. The emphasis again is “hands on” use of Excel and its add-ins. The book provides many screen “shots” of Excel models and includes four software application packages students will use long after the course is completed:

- A new graphic visualization program, GLP, for interactive optimization of linear programming models—software included with the textbook.
- *Exclusive* student version of the Monte Carlo simulation add-in, Crystal Ball—software included with the textbook.
- Decision analysis add-in software, TreePlan—software included with the textbook.
- Excel templates for queuing models—software included with textbook.

We have also expanded the introductory coverage of modeling philosophy and added a new chapter on general spreadsheet modeling techniques that introduces students to the application of spreadsheets to managerial modeling. We have also significantly revised two chapters—the chapter on Multi-objective Decision Making has added a new section on analytic hierarchy process (AHP), and the chapter on Forecasting has expanded the coverage of time-series forecasting models, and added the treatment of seasonality in data, as well as a case on forecasting at Marriott hotels.

This edition features new material on applying models in the service sector of the economy, in addition to the traditional manufacturing examples in previous editions. Continuing the fine tradition of previous editions, the text offers unequalled coverage of optimization.

The text is divided into three parts; the first deals with general modeling issues; the second with optimization models; and the third with probabilistic (stochastic) models. This provides a logical organizational framework for the material while allowing for greater emphasis on and enhanced coverage of currently “hot” areas such as AHP, Monte Carlo simulation, multi-objective decision making, and the general use of spreadsheets in modeling. There is more material than can be covered in a typical first course. We believe our organization of topics allows each instructor the flexibility to tailor their course to different audiences and needs.

Appendices on the Solver and the special features of Excel for modeling not normally covered in mechanics-of-spreadsheets courses have been added to enable the student to improve their spreadsheet skills and gain a greater appreciation for the modeling capability of Excel.

## ACCOMPANYING MATERIALS

New copies of the book include a CD-ROM containing the following software and courseware at no extra charge:

- New graphic visualization program, GLP, for interactive optimization of linear programming models for the material in Chapters 4 and 7.
- *Exclusive* student version of the Monte Carlo simulation add-in, Crystal Ball, for the material in Chapter 11. Compatible with Excel 97 (version 8.0).
- Decision analysis add-in software, TreePlan, for the material in Chapter 10. Compatible with Excel 97 (version 8.0).
- Excel templates for queuing models for the material in Chapter 12. Compatible with Excel 97 (version 8.0).

- Voice annotated “playback” demonstrations on use of the major Excel add-ins.
- Excel spreadsheet files for all in-text examples and any relevant data for end-of-chapter problems and cases.

### SUPPLEMENTARY ITEMS FOR TEXT ADOPTERS

- Excel Solutions (for the Instructor) to every example, problem and case in the book. Instructors may use these as is, take out some of the detail, or modify them as desired.
- Presentation slides for each chapter in PowerPoint with the appropriate Excel spreadsheets (013-904780-8).
- Access to protected Web Page for more timely supplementary materials ([www.prenhall.com/eppen](http://www.prenhall.com/eppen))
- Instructor’s Solutions Manual (013-904756-5)
- Test Item File (013-904764-6)
- Custom Test for Windows (013-904772-7)

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We would like to thank our editor, Tom Tucker, for his patience in bringing this revision to pass. We believe if it wasn’t for his guidance, and direction, the book would not be nearly the product that it is.

We would like to thank our many reviewers of this edition (see the list below) for their insightful comments and ideas. This is a much better book because of them. We also thank the contributors to the expanded case studies of this edition, C.P. Bonini, Evan Porteus, Robert Wilson, Haim Mendelson, Krishnan Anand, and Sam Bodily.

We thank the more than 300 instructors who participated in the extensive INFORMS Management Science Teaching Survey. Their comments and suggestions have validated many of the changes made in this edition.

We would also like to thank our secretaries, Heather Harper, Vonda Barnes and Marge Holford, for the long hours of dedicated service in scanning in the old edition of the book and editing. We are also indebted to Kevin Lewis’ eagle eyes for spotting any mistakes that had slipped through the cracks to that point, as well as to the University of Wyoming MBA Decision Modeling class of the Fall 1997 for class-testing the book.

We are grateful to Professor David Ashley for the queuing templates and to Professor Mike Middleton for the TreePlan software.

Finally, we would like to thank Daniel Fylstra and John Watson of Frontline Systems and Software Engines for making Solver a reality. They have been a joy to work with. Also, at Microsoft, Lewis Lewin, and former Stanford business students, Steve Ballmer and Pete Higgins, deserve thanks for their instrumental roles in creating the Excel tools that have made it the preferred choice for modeling and analysis by managers. Their cooperation with and receptivity to suggestions from academics in determining Excel’s and Solver’s product design and feature set is a model that we wish more software developers would follow.

We hope you find that this text and its supporting materials enhance your teaching efforts. We always like to hear from you—especially when it's to pass along your ideas for how the text can be improved—so, please feel free to send along your reactions.

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