# *Management Science for Decision Makers*

LARRY M. AUSTIN

PARVIZ GHANDFOROUSH

# MANAGEMENT SCIENCE FOR DECISION MAKERS

LARRY M. AUSTIN
Texas Tech University

PARVIZ GHANDFOROUSH
Virginia Polytechnic Institute and State University

WEST PUBLISHING COMPANY

MINNEAPOLIS/ST. PAUL

NEW YORK

LOS ANGELES

SAN FRANCISCO

**WEST'S COMMITMENT TO THE ENVIRONMENT**

In 1906, West Publishing Company began recycling materials left over from the production of books. This began a tradition of efficient and responsible use of resources. Today, up to 95 percent of our legal books and 70 percent of our college and school texts are printed on recycled, acid-free stock. West also recycles nearly 22 million pounds of scrap paper annually—the equivalent of 181,717 trees. Since the 1960s, West has devised ways to capture and recycle waste inks, solvents, oils, and vapors created in the printing process. We also recycle plastics of all kinds, wood, glass, corrugated cardboard, and batteries, and have eliminated the use of styrofoam book packaging. We at West are proud of the longevity and the scope of our commitment to our environment.

**Composition:** Carlisle Communications
**Artwork:** Brian Betsill
**Text design:** Melinda Grosser for *silk*

Production, Prepress, Printing and Binding by West Publishing Company.



Printed in the United States of America

00 99 98 97 96 95 94 93 8 7 6 5 4 3 2 1 0

Library of Congress Cataloging-in-Publication Data

Austin, Larry M.
Management science for decision makers / Larry M. Austin, Parviz Ghandforoush.
p. cm.
Includes bibliographical references and index.
ISBN 0-314-01243-5
1. Management science. I. Ghandforoush, Parviz. II. Title.
T56.A88 1993
658.4'03—dc20 92-21119
CIP

Dedicated to **Jill** and **Terri**, who make it all worthwhile. L.M.A. and P.G.

# PREFACE

In most present texts on quantitative methods of management science/operations research (MS/OR), there is a strong emphasis on understanding the mathematical details of algorithms used to solve models introduced by the text. The traditional approach to teaching algorithms is "hand solution." Before the proliferation of computers and the availability of sophisticated software, such an emphasis was necessary so that we could solve the models.

This emphasis compromised other equally appropriate emphases, such as:

- Developing problem solving and model formulation skills
- Understanding real-world problems (instead of textbook problems whose models we can solve by hand calculation methods)
- Appreciating the assumptions that underlie the models (and their methods).

With computers and software for solving MS/OR models accessible to virtually everyone, we need to reassess the emphasis on hand solution of models.

We intend this textbook for use in graduate-level management science courses for prospective or practicing executive decision makers. Such courses typically are required in the second year of master's degree programs, such as Master of Business Administration (MBA); Master of Science (MS) in Business Administration, Economics, or Industrial Engineering; and Master of Industrial Management (MIM); etc. *For convenience, we refer to such programs in this preface and throughout the book by the generic term* "MBA."

An MBA student needs to learn how to formulate and analyze models to enhance his or her problem solving and decision-making abilities, and is much less concerned with the technical details of algorithms used to solve these models. Therefore, we geared the organization and substance of this book, toward problem formulation, model conceptualization, and problem analysis—not hand solution of small textbook models.

For all practical purposes, knowledge of management science required by the practicing manager should be identical to that required by the MBA student. Decision makers need to have substantive understanding of what models are available, how to build them, and how to use the resulting solutions as an aid to problem solving. Consequently, this text would serve equally well as an MBA textbook or as a reference book on MS/OR models for the practicing manager.

In view of the specific pedagogical needs of the MBA student and the practicing manager, we adopted the following goals and criteria for the design of this text.

- To emphasize the development of problem solving and model formulation skills, including:
  a) Recognizing how and when a particular type of model can be of value; and
  b) The ability to construct a model of the problem.
- To carefully consider the assumptions that underlie each model and its associated algorithm(s).

- To introduce the student to a variety of real-world or realistic problems and their models through the use of complex minicases.
- To articulate the art and science of decision analysis under conditions of certainty, risk, and uncertainty.
- To employ a managerial perspective that focuses on decision making rather than mathematical solution techniques.

In addition, this book places a strong emphasis on "what if" in addition to the usual "what's best." We demonstrate to MBA students how to use management science models to gain insight into problems.

In this text we do not "force" a quantitative approach to decision making and management. Rather, we include decision factors that are *intuitive, subjective, judgmental, and unquantifiable* as an inherent component of each real-world minicase. We illustrate how only a proper mix of quantifiable and nonquantifiable considerations can lead to a satisfactory solution strategy.

We treat decision making at all levels of the organizational hierarchy. At each level, modeling begins with an assessment of which factors or variables are within the decision maker's capacity to influence and which factors the decision maker can only observe. All model formulations, therefore, begin and end with a specified decision maker's perspective of the problem. Nor do we avoid the complexity that usually accompanies real-world decision making.

## MBAs AND COMPUTER SOFTWARE

It is clear that successful use of this textbook for graduate courses depends heavily upon the availability of microcomputer software that implements the various MS/OR algorithms. There are more than a dozen such packages for IBM-compatible microcomputers, to include D&D [1], Management Scientist [2], STORM [3], QSB+ [4], MSS [5], and ORS [6]. Rather than arbitrarily selecting one of these packages as our vehicle in this book, we invoke the fictitious package that we call **SAMS** (Simulated **A**lgorithms for **M**anagement **S**cience). **SAMS** is a generic approach to modeling with microcomputer software that will permit adopters of this text to select their preferred packages in the market. It has a spreadsheetlike input mechanism and report format similar to those of most available packages.

## ORGANIZATION OF THE TEXT

The text begins with a discussion of modeling as both art and science. We discuss the importance of modeling, and introduce the notation used in the text. We characterize the model building process in some generality. In detail, we discuss the criteria by which the manager classifies the problem and chooses an appropriate model to represent it. Chapter 1 presents all of these ideas. The remainder of the text consists of four parts:

### DECISION MAKING UNDER CERTAINTY

Chapters 2 through 6 are about decision making under certainty. The first four chapters address deterministic mathematical programming models—linear programming, integer programming, network programming, and nonlinear programming. Chapter 6 deals with deterministic dynamic programming.

### DECISION MAKING UNDER RISK

Chapters 7 through 12 describe models related to decision making under risk. Chapter 7 discusses matrix decision models, decision trees, expected value and opportunity loss, Bayesian analysis, and the concept of economic utility. Chapter 8 deals with queueing (waiting-line) models, while Chapter 9 describes the use of simulation in the decision environment. Chapter 10 discusses Markov chains. Chapter 11 describes the extension of probabilistic concepts to project management (PERT). Chapter 12 introduces basic principles of scientific inventory management.

### DECISION MAKING UNDER UNCERTAINTY

Chapters 13 through 15 discuss models for decision making under uncertainty. Chapter 13 covers the classical matrix decision model. Chapter 14 introduces modeling with multiple objectives and goal programming. Chapter 15 presents some useful graphical tools and multiattribute choice models that don't "fit" elsewhere in this part of the text.

### MANAGEMENT SCIENCE AND THE FUTURE

The Epilogue presents our view of the "high tech" future of 2000 A.D.

## ORGANIZATION OF EACH CHAPTER

Most chapters follow a uniform format to give continuity and coherence to the book. A typical chapter consists of the following sections:

a. **Underlying Assumptions.** Here we give managerial meaning to such concepts as linearity and multistage decision making. We also describe problem classes appropriate for this type of model.
b. **Modeling.** Here we describe the models verbally and present an intuitive description of the corresponding mathematical representations. We omit terms that have to do with the algorithm(s) used to solve the model (e.g., in linear programming—artificial variable, pivot, entering and exiting variable, revised SIMPLEX). This section devotes particular attention to how we formulate models of this type, and what the data requirements are.
c. **Solution Approaches.** Section c is an intuitive description of the algorithm(s) used to solve models of this type. In this section, we describe the algorithms by analogy or by use of graphical and tabular illustrations.
d. **Developing Alternative Solutions.** Here we deal with sensitivity studies and parametric analyses of model solutions that we can perform to assist in developing alternative solutions to the problem.
e. **State of the Art Topics.** Section e briefly describes state-of-the-art topics, such as computational considerations related to problem size and potential difficulties encountered during computer implementation. Our purpose in including these brief discussions of advanced models is to make potential and practicing managers aware that the models exist. To discuss these topics in detail would take us well beyond the scope of this book; to omit them would convey an incomplete—and therefore erroneous—impression of the dynamic nature of management science.
f. **Minicases.** In this section, we present from two to five minicases—hypothetical and actual short cases that illustrate applications of the model(s) to real or realistic problems. Several cases are adaptations of term project reports submitted by our MBA students over the years at Virginia Tech and Texas Tech. Not all minicases report successful applications—some describe *unsuccessful* applications and why the applications were unsuccessful. These minicases reflect the complexity of the real-world decision environment.
g. **Summary.** Section g summarizes the material presented in the chapter and provides an overview of the chapter contents.
h. **Problems for Analysis and Practice Models.** In this section, we first present end-of-chapter problems that will stimulate and challenge MBA students. We include "unworked" minicases that expose students to some of the complexities of problems they will encounter after graduation. Then we provide some small, unadorned practice models that MBA students can use to become familiar with available software.
i. **References and Additional Reading.** Section i contains chapter references and suggestions for additional reading.

## THE PHILOSOPHY OF THE BOOK

This book emphasizes the problem-definitional aspects of MS/OR usage, and recognizes a need for coping with the complexity of the real-world decision environment. It treats such complexity with candor, and it presents tools for characterizing and analyzing the complexity of the real world. It takes a managerial perspective of decision analysis.

Although the writing style is informal, *this is a deadly serious book*. It is not about algorithms. It is about the difficult, complex, and frustrating process of managerial decision making. If the book has a "theme," we can best describe it by the following phrase, which we repeat several times herein:

*MODELS DON'T MAKE DECISIONS—MANAGERS DO.*

## ACKNOWLEDGEMENTS

For their incisive comments on the drafts of the book and for the raw materials for several mini-cases, we are grateful to our MBA students—present and past—at Texas Tech and Virginia Tech. We wish also to thank our respective universities for their logistical support and our faculty colleagues for their help and encouragement.

In preparing this book for publication, we were extremely fortunate to have the advice and assistance of some excellent reviewers. Special thanks go to Steve Bechtold at Florida State University, Warren Boe at the University of Iowa, Mike Hanna at the University of Houston—Clear Lake, Don Harnett at Indiana University, Lori Kaplan at the University of Tennessee—Knoxville, Bill Pinney at the University of Texas—Arlington, Alan Raedels at Portland State University, Steve Replogle at Arkansas State University, and Rick Wilson at Oklahoma State University.

Special thanks are in order to the professionals at West—particularly Rick Leyh, Jayne Lindesmith, and Jessica Evans.

L.M.A., P.G.

## References

1. Anderson, D., D. Sweeney, and T. Williams. *Management Scientist*. St. Paul: West, 1991.
2. Chang, Y., and R. Sullivan. *QSB+: Quantitative Systems for Business Plus*. Englewood Cliffs, NJ: Prentice-Hall, 1989.
3. Dash, G. and N. Kajiji. *Operations Research Software*. Homewood, Ill.: Richard D. Irwin, 1988.
4. Dennis, T., and L. Dennis. *Microcomputer Models for Management Decision-Making* 2d ed.). St. Paul: West, 1988.
5. Emmons, H., and D. Flowers. *STORM Personal Version 3.0*. Englewood Cliffs, N.J.: Prentice-Hall, 1991.
6. Nelson, T. *The Management Science System*. Homewood, Ill.: Richard D. Irwin, 1988.

# CONTENTS

## 8.

## WAITING LINE (QUEUEING) MODELS 300



## 9.

## DISCRETE SIMULATION MODELS 328

## 10. MODELING WITH MARKOV CHAINS 370



## 11. PROJECT SCHEDULING 393



## 12. INVENTORY MANAGEMENT 418

# CHAPTER 1

# Problems, Models, Decisions, and Systems

This book is concerned with making decisions that solve problems. The main thesis of this book is as follows:

> The use of management science (MS) models can make us better decision makers and problem solvers.

**Models** help us to better understand problems and enable us to evaluate courses of action in making decisions. They reflect the structure of the system we use them to represent. A model is a **paradigm**—a description and explanation of the relationship of the parts of the problem to one another or of the problem to its environment.

Everyone uses models as a basis for making decisions. An oil firm executive gathers information in the form of printed data, listens to the opinions of others, and concludes that the firm must raise retail gasoline prices in accordance with increases in the price of crude. An economist reads the consumer price statistics and decides that more stringent controls on the money supply must be applied. An MBA student keeps close track of his or her course performance to determine how much effort he or she will require to achieve the desired grades. In each case, we formulate a **mental model** as a basis for making decisions. Even our interpersonal responses stem from models. Psychologists say that our mental model of ourselves—our self-image—strongly colors our personality.

Our mental concepts of a particular situation represent the model—either explicit or implicit—that we use to make decisions in both private and professional life. At times, that mental model is biased, fuzzy, incomplete, inaccurate, or just plain wrong. Obviously, the response or decision stemming from that mental model will probably be wrong also, and we must face the consequences of the misguided decision. The point is, *we make all conscious decisions on the basis of models*. The question, then, is not whether to use models but rather what kinds of models to use.

Consider a stockbroker poring over market projections on the screen of a personal computer. The broker's mental model of the stock market suggests that the market will continue to go up in the short run before dropping drastically. In light of this mental model, the stockbroker is advising clients to sell their holdings. If the stockbroker has many colleagues who share the same view of the market, the simultaneous advice those colleagues give to investors could actually cause the predicted downturn to occur. Thus, in this case, the mental model becomes self-fulfilling. Such are the hazards of forecasting models in the managerial sciences. Gloom-and-doom predictions may create the very factors responsible for drastic downward readjustments.

Clearly, models influence managerial behavior that weighs heavily upon the outcomes of the system itself. Self-image models, furthermore, tend to be consistently self-fulfilling.

This book focuses on management science (MS) models, and its premise is that such models are better decision aids than mental models alone. Actually, we use such models to influence, formalize, and concretize the mental models we use to make all decisions. An **MS model** is a model that encompasses quantitative, mathematical, or graphic forms. We distinguish it from the verbal models that make up much of the literature in business, economics, sociology, political science, and psychology.

We assert that MS models will enable us to make better decisions. We must address such questions as, What form do these models take? What data do we need? How do we formulate these models? How do we solve these models? The answers to these questions constitute most of the content of this book.

## PROBLEMS AND DECISIONS

**Problems** arise whenever there is a *perceived* difference between what is desired and what is. In the language of the economist, wherever expectations differ substantially from realizations, a problem occurs. Problems serve as motivators for doing something. Since what we do must begin with a decision about what to do, problems ultimately lead to decisions (see Figure 1.1). *The goal of* ***decision making*** *is mitigating or alleviating perceived problems.*

In Figure 1.1a, a problem leads to a **decision** about that problem without the input from an MS model. The decision could be to do nothing for now. The decision will thereafter have an impact that will either diminish or exacerbate the problem. We will observe the effect on the problem, and this will lead to further decisions about the problem in question.

The plan and purpose of this book is to insert into the decision process the use of MS models (Figure 1.1b). We study the problem in the framework of its own system to enable contextual understanding of the problem. Thereafter we can develop an MS model of the "problem system." This is the essence of the so-called systems approach popularized in recent years by Churchman [2] and others. A good problem solver should try to develop the largest possible perspective of that problem. This is tantamount to understanding the problem within the context of its own system.

## MODEL CLASSIFICATION

We can classify models in a variety of ways. For example, *purpose*, *perspective*, *degree of abstraction*, and *content* represent four classification criteria.

**FIGURE 1.1** Relationships among models, problems, and decisions