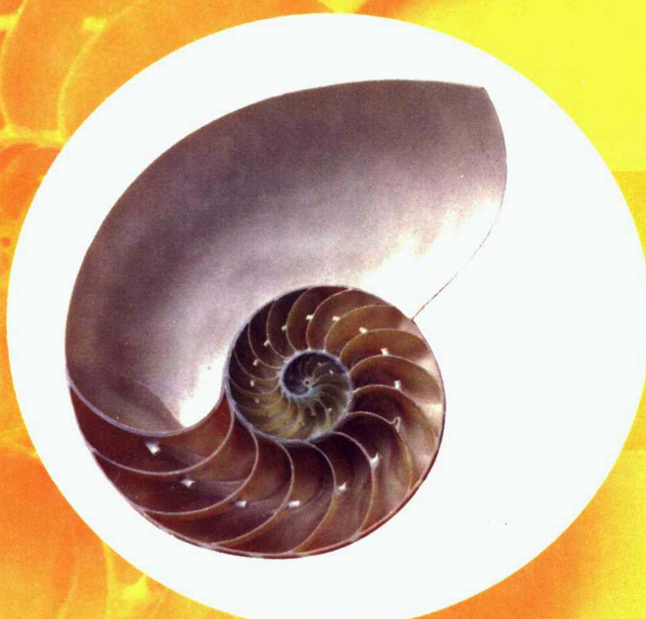
Quantitative Analysis for Management



9th Edition

Bonini

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NINTH EDITION

QUANTITATIVE ANALYSIS FOR MANAGEMENT

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For Managers and Future Managers

The first edition of this book in 1961 was the pioneering text in the application of quantitative analysis to management. It attempted to bridge the gap between the newly developed analytic methods and applied business disciplines. Over the years we have maintained this focus through eight subsequent editions.

In recent years the popularity of quantitative methods might appear to be declining. The current business press touts approaches such as *Reengineering, Total Quality Management (TQM)*, or *Supply Chain Management* as the keys to business success. But all this is somewhat misleading as it relates to the value of quantitative analysis. First of all, in many instances the implementation of these heralded approaches relies partially on using the tools and methods presented in this book. And while these new approaches have been in the limelight, the continuing success of quantitative analysis in making business and other organizations more efficient and effective has been overlooked. Because quantitative methods have been so widely utilized over the years, they have become routine and are taken for granted in many organizations. They just do not get the same press coverage as the newer ideas.

We think it is important for you, the reader, to be aware of the continuing successful use of quantitative methods. Hence we have included material in each chapter describing a recent application of the techniques in that chapter. These often involve savings of millions of dollars to the companies involved. We call these "Motivating Examples," and our aim is to make you aware that there is still ample opportunity for successful use of these methods. You should also briefly review the problems, and especially the cases, at the end of each chapter. These represent real applications—usually greatly simplified into problem format.

We authors have kept our enthusiasm for the value and role of quantitative analysis over the 36 or so years of the life of this text. We hope some of the enthusiasm will be contagious.

For Instructors

This book is the ninth edition of *Quantitative Analysis for Business Decisions*. This edition is a major revision—sufficiently major that the title has been changed to *Quantitative Analysis for Management*. Major changes include format, chapter coverage, motivating examples, and spreadsheet friendliness.

The first edition, over 35 years ago, was a pioneering approach to applying quantitative techniques to managerial problems. As stated in the original preface, one purpose of the book was to "act as a connecting force between the mathematical courses on the one hand and the applied business courses on the other." Over the years courses in Quantitative Analysis have served that role. But in recent times, business curricula have changed and that "connecting force" has often been merged into the applied courses themselves—especially into the Operations or Production course. It is with this change in mind that we undertook this revision.

The format has been altered so that each chapter is as self-contained as possible. We anticipate that some professors will use this book in its entirety but others may select a subset of chapters to be included in a "course reader", possibly with material from other Irwin texts or that of other publishers. We have eliminated virtually all chapter cross-references and have moved the "answers" section of the book, "Practice Problems," to the end of each chapter. The new one-color format has been selected with this use in mind.

We have also made most chapters substantially larger, by combining smaller chapters in the previous edition. This results in fewer chapters, more cohesion within each chapter, and again ease of use if an instructor wishes to create a unique course reader by selecting among different materials.

Each chapter now opens with one or more Motivating Examples which are brief vignettes of applications of quantitative models to real-world decision situations. These are designed to show the reader that these methods of analysis can and do have real payoff in actual business settings, hence providing motivation to undertake the effort to understand them.

The entire book has been made "spreadsheet-friendly" throughout. We have focused on Excel® and have added many examples of the use of spreadsheets in quantitative modeling. We have also added Appendixes with more detail on the use of Excel for both simulation and the solution of linear programming problems using Solver®.

We have also added a new chapter on Forecasting, covering Exponential Smoothing, Regression, New Product Forecasting, and Forecast Error Measurement.

The Decision Analysis material has been combined into two chapters, and discussion of stock options and bias in estimating probabilities has been added.

The Inventory Control and Management material has been combined into a single chapter and now includes material on Tradeoff Curves for Customer Service vs. Inventory Investment and a brief discussion of Supply Chain Management issues, including risk pooling effects.

The Queuing chapter has been extensively revised to include modern treatment of arrivals and services, focusing on the interarrival time and service time distributions and including treatment of general service times, loss systems, and a brief introduction to networks of processing systems.

Many new problems have been added to this edition. One major strength of previous editions was the quality and quantity of the problems, and we have retained the best of the best in this edition.

As always, we have attempted to make changes that are consistent with an objective described in the preface of the first edition—to make the material understandable to a reader who does not have an extensive mathematical background.

We thank the many users of previous editions who have taken the time to point out errors and inconsistencies and have offered suggestions for improvement. This assistance is greatly appreciated.

Although Lawrence Fouraker and Robert Jaedicke are no longer listed as authors, we acknowledge that a considerable percentage of the book carries forward their words and ideas.

Charles P. Bonini
Warren H. Hausman
Harold Bierman, Jr.

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EXTRACTS FROM THE PREFACE TO THE FIRST EDITION

The administration of a modern business enterprise has become an enormously complex undertaking. There has been an increasing tendency to turn to quantitative techniques and models as a potential means for solving many of the problems that arise in such an enterprise. The purpose of this book is to describe a representative sample of the models and their related quantitative techniques. It is hoped that this book will serve as a basis for a course . . . that acts as a connecting force between the mathematical courses on the one hand and the applied business courses on the other.

This is an introductory work in the application of mathematics to problems of business. It is not an introductory work to the mathematics which are being applied. We have summarized—in a rather rough and ready manner by a mathematician's standards—some of the mathematical tools employed. Our purpose is to get our notation and a few basic relationships before the reader rather than to teach him mathematics.

We have attempted to minimize the amount of mathematical training required to read this book . . . a reader who does not have formal training in these areas should not think that this book is beyond his ability.

The book is an attempt to consider techniques which treat quite sophisticated and difficult problems; so, even though we tried to choose the simplest means of exposition—avoiding proofs and much of the characteristic rigor of such treatments—the essential subtlety of the techniques remains. These attributes can be understood only by patient application of effort over a protracted period of time.

Harold Bierman, Jr.
Lawrence E. Fouraker
Robert K. Jaedicke

BRIEF CONTENTS

CONTENTS

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PART III

APPLICATION AREAS

PART

I Modeling and Optimization

Motivating Example

Modeling Coast Guard Operations[1]

The United States Coast Guard has responsibility to maintain more than 50,000 aids to navigation (including buoys, lights, and day beacons) located on U.S. waterways. Maintenance involves verifying a buoy's location, replacing missing letters or numbers, and repainting; this work is generally carried out once a year.

The Coast Guard uses two types of vessels to perform this maintenance: seagoing tenders and coastal tenders. Seagoing tenders cost nearly twice as much as coastal tenders. The entire fleet was due for replacement, and a quantitative model was developed to analyze both the scheduling of the fleet and its desired composition. The modeling effort used tools described in this book and took into account the required maintenance work, the distance to be traveled to reach each buoy, and the complete life-cycle cost (including acquisition cost of vessels and operating costs) of each type of vessel.

Various complications existed in this study. It was important to allow for the differing capabilities of each type of vessel (seagoing versus coastal tender), and the routing of vessels to buoy locations. The effects of bad weather were modeled by estimating the annual hours lost due to bad weather, depending on whether the buoys being serviced were fully exposed to weather, partially exposed, or protected. Furthermore, since these tenders were also used for other operations such as environmental response, search and rescue, and law enforcement, the Coast Guard had determined that at least 16 seagoing tenders were required.

After the modeling effort was completed, it was validated by "forecasting" current operations and comparing the model's output with actual operations. The model was then used to deal with the question of the optimal composition and operation of a replacement fleet. The model's results were that 16 seagoing tenders, 14 coastal tenders, and one stern-loading buoy boat would provide sufficient coverage, if scheduled efficiently; this configuration has 7 fewer vessels in total, with 10 fewer seagoing vessels (which are the most expensive) compared to the current fleet. Compared with a direct replacement strategy of the existing fleet, the model generated a savings of $350 million in capital acquisition costs.

[1]Mark Bucciarelli and Kip Brown, "A Desktop-OR Success: Modeling Coast Guard Buoy Tender Operations," *Interfaces*, July–August 1995, pp. 1–11.

CHAPTER

1 INTRODUCTION TO ANALYSIS AND MODEL BUILDING

This book is about managerial decision making. Managerial decision making is a process whereby management, when confronted by a problem, selects a specific course of action, or "solution," from a set of possible courses of action. Since there is often some uncertainty about the future, we cannot be sure of the consequences of the decision that is chosen, and we cannot be sure that the decision chosen will produce the best outcome. Furthermore, the problem may be quite complex because there are either a large number of alternatives to consider or many factors to take into account.

This book presents a general approach for managers to use when faced with decision problems, as well as specific quantitative tools for particular types of problems.

Decisions

A manager wants to choose that course of action that will be most effective in attaining the goals of the organization. In judging the effectiveness of different possible decisions, we must use some criterion or performance measure. The most commonly used performance measure in making decisions is a monetary unit, such as dollars, but we shall see in the following chapters that for some decisions, the use of dollars in judging the relative merits of different courses of action would not be adequate.

The following general process of solution is common to all types of decision situations:

1. Establish the *criterion* to be used. For example, in a simple situation the criterion may be to choose the act that maximizes profit.
2. Select a set of *alternatives* for consideration.
3. Determine the *model* to be used and the values of the parameters of the process. For example, we may decide that an adequate expression for total expenses is:

$$\text{Total expenses} = a + b(\text{units sold})$$

The parameters are a and b, and their values would have to be determined in order to use the model.

a = Fixed cost for the period or project
b = Variable (incremental) cost per unit

4. Determine which alternative *optimizes* (i.e., produces the best value for) the criterion established above in step 1.

Example
We can sell 1,000 units of product to the government at a price of \$50 per unit. Should the order be accepted? The firm has excess capacity.

1. We shall use the profit maximization criterion.
2. The alternatives are to (*a*) accept the order or (*b*) reject the order. In accordance with our profit criterion, we shall accept the order if it increases profit or reject the order if it does not increase profit.
3. We need to know the incremental expenses of producing the 1,000 units. The relevant expense model is:

$$E = a + 1{,}000b$$

Assume that special dies costing \$5,000 will have to be bought (a is equal to \$5,000) and that the variable costs of producing a unit are \$30 (b is equal to \$30). Then the total relevant expenses of filling the order are \$35,000 (equal to \$5,000 plus \$30,000).
4. A comparison of the incremental revenues, \$50,000, and incremental expenses, \$35,000, indicates that we should accept the order. Profit will be greater by \$15,000 if we "accept" compared with the alternative "refuse the order."

In the above example, we used basic knowledge and simple computational techniques. However, in dealing with more complex problems, we might need to use other tools of quantitative analysis, including calculus, probability, statistics, and mathematical programming.

We shall now consider some aspects of model building.

Abstraction and Simplification

Real-world problems tend to be enormously complex. There are literally an uncountable number of inherent "facts" in any empirical situation. Further, every potential course of action starts a chain of cause, effect, and interaction that logically is without end.

Consider the problem of constructing a building. An endless amount of time could be devoted to gathering factual information about this situation: for example, the precise location and physical characteristics of the building; a detailed study of the climatic conditions of the potential sites and the influence these will have on construction costs; the sources of the funds used and their cost. The decision maker might decide to consider specifically and in detail all other potential uses of the funds in this period and in future periods. If our decision maker adopts a strategy of collecting *all* the facts before acting, it follows that no action will take place. The human mind cannot consider every aspect of an empirical problem. Some attributes

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