

# QUANTITATIVE ANALYSIS FOR MANAGEMENT

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# **Quantitative Analysis for Management**

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# Preface

This book provides readers with the skills to use quantitative analysis in the decision-making process and helps them become rational and logical decision makers. We introduce a series of interesting and useful quantitative techniques ranging from simulation to PERT to linear programming to waiting line theory to decision trees. The overall orientation of the book is for future managers, not technical specialists or mathematicians.

We show how each technique works and how it can be applied in a series of real-world decision problems. One of our primary goals is to illustrate that important management problems can indeed be solved using the ideas and techniques presented here. Every chapter provides a wide selection of business, government, and organizational applications. In addition, we discuss the assumptions and limitations of each mathematical model shown. Whenever possible, we have kept the notation, terminology, and equations standard with other books, and have strived to make the text easy to understand and use. No previous background in quantitative analysis is required, but a basic understanding of algebra is a prerequisite.

This text can be used in a number of different undergraduate or graduate courses with varying titles. Some of these courses include Principles of Management Science, Introduction to Operations Research, Quantitative Methods for Management, Quantitative Approaches to Decision Making, and Quantitative Analysis for Managerial Decision Making.

We hope that the style and approach of *Quantitative Analysis for Management* will motivate readers to study quantitative analysis. A text that motivates, however, is not enough. It must also clearly *teach* the basic principles. The chapters in this book cover every major topic in the quantitative analysis/management science field. Although more material is included than could be taught in a typical first course, this was purposely done to provide flexibility in selecting topics most appropriate to particular audiences and curricula. The chapters are self-contained and, for the most part, can be presented in any convenient order.

To reinforce the learning process, we have incorporated a number of outstanding features into this book.



### Text Learning Aids

This book is student-oriented, and many of the following tools will help the effectiveness and efficiency of the learning process.

*Application boxes* provide a wide sampling of actual areas in which quantitative analysis techniques have been applied.

*Cost savings boxes* summarize published articles that actually document how quantitative analysis has saved a company money.

*Sample computer printouts* illustrate how “canned” computer programs are commonly available to solve quantitative problems.

*History boxes* tell the story of how a technique was discovered and came to be used in business.

*Key ideas* are pointed out for easy reference and review.

*Marginal notes* highlight other important points on each page and assist the reader in reviewing and studying the material.

*Glossaries* at the end of each chapter define all important terms mentioned to facilitate retention and quick review.

*Key equations* are also listed and explained at the end of each chapter to help summarize the mathematical material covered.

*Discussion questions* in each chapter test the reader’s understanding of concepts presented and can be used for review, class discussion, or homework assignments.

*A wide selection of problems* in every chapter illustrates how each technique can be used and tests the student’s ability to solve typical exam-type problems.

Cases at the end of selected chapters provide challenging management applications of the concepts and give a realistic perspective to students’ learning.

*Detailed bibliographies* provide a wide list of references. The articles listed are down-to-earth, interesting applications of quantitative analysis techniques and can be used for reviews or classroom discussions.

### Study Guide

There are several supplements available to accompany the text itself. From the student’s perspective, perhaps the most important of these is the *Study Guide*, prepared by Professor John Harpell at the West Virginia University. Each chapter of the study guide contains the following features:

- *A quick review* of the key points in the text
- *Problems and applications* providing more sample applications and illustrating problem-solving approaches
- *True-false and multiple choice questions* to highlight basic principles
- *Answers* to all questions and problems in the *Study Guide*, thus making it a self-contained study tool

The *Study Guide* has been included in the learning package for those classes in which the instructor would like the students to have more practice in problem solving and applying quantitative analysis techniques.

### Book of Cases and Readings

We have also published an accompanying paperback book called *Cases and Readings in Quantitative Analysis for Management*. Tailored specifically to this text, it provides an ideal supplement for upper-level undergraduate classes and for graduate courses. Over thirty cases, covering all techniques of quantitative analysis presented in the text, provide challenging extensions and applications to students. The readings provide a cross section of carefully selected articles published in such journals as *Interfaces*, *Decision Sciences*, and other business magazines. They allow students to discuss real-world applications of quantitative methodologies to complement the cases they must solve themselves.

### Instructor's Aids

We have tried to make the learning process easier for teachers as well as students. Our *Instructor's Resource Manual* provides the following:

- *Suggestions for chapter usage*
- *Sample course outlines for various length and level courses*
- *A test bank of questions*
- *Solutions to all problems and cases in the text*
- *A wide selection of overhead transparency masters*

The *Cases and Readings in Quantitative Analysis for Management* book is similarly accompanied by an *Instructor's Manual* for professors adopting that book.

### A Complete Teaching Package

We have tried to assemble a comprehensive, effective, and complete teaching package for classroom use. In the process we have introduced several unique text features, including cost-savings stories, history features, a discussion of careers in quantitative analysis (Chapter 1), an appendix to Chapter 9 dealing with material requirements planning, and three learning modules at the end of the book (dealing with mathematical tools, game theory, and dynamic programming). Our treatment of goal programming, integer programming, and nonlinear programming (Chapter 15) is down-to-earth and easily readable. The closing chapter, on the problems of implementing quantitative analysis, written by Professor Otto Graham, is a clear and enlightening treatment of that subject. The supplementary book, *Cases and Readings in Quantitative Analysis for Management*, and the *Study Guide* are intended to provide more flexibility, broader coverage, and emphasis on basis learning.

We have attempted to present all of the material in a lively manner that stimulates interest. Our success will be measured by the students who use this text, especially in terms of their interest in quantitative analysis for management applications.

### Acknowledgments

We would like to thank a number of organizations and individuals for their help in the preparation of this package. The Division of Business and Economic Research at the University of New Orleans and the Department of Management at the Florida State University provided support and a conducive environment for developing the text. Our Allyn and Bacon editor, Richard Carle, and sales representative, Richard Wohl, provided advice, encouragement, and helpful suggestions at all phases of the three-year project. Professors Jerry Kinard and Joe C. Iverstine of Southeastern Louisiana University assisted by contributing four fine case studies. We also gratefully acknowledge the following six individuals for their careful reviews of multiple drafts of this manuscript:

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# Introduction to Quantitative Analysis

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## *Chapter Outline*

1. Introduction
2. What Is Quantitative Analysis?
3. An Application of Quantitative Analysis: Emergency Snow Removal
4. The Quantitative Analysis Approach (The Scientific Method)
5. Quantitative Analysis in Perspective
6. The Use of Computers in Quantitative Analysis
7. Careers in Quantitative Analysis

Glossary of Terms

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## 1. Introduction

### *Successful Use of Techniques*

While people have been using mathematical tools to help solve problems for thousands of years, the formal study and application of quantitative techniques to practical decision making is largely a product of the twentieth century. The techniques we will be studying in this book have been successfully applied to an increasingly wide variety of complex problems in business, government, health care, education, and many other areas. Many successful uses will be discussed throughout this book, but we will also take a look at some failures.

The failure of a particular quantitative technique to help solve a problem is more often a result of its improper application than a fault with the technique itself. The reasons for failure can include:

### *Failure When Using Techniques*

1. Underestimating the total cost of using quantitative techniques.
2. Underestimating the total time required to develop and implement the most appropriate techniques.
3. Failure to define the real problem.
4. Overemphasis on theory and underemphasis on application.
5. Resistance to change and reluctance of managers and decision makers to trust and act upon results obtained using unfamiliar techniques.

It isn't enough just to know how a particular quantitative technique works; you must also be familiar with the limitations, assumptions, and specific applicability of the technique. The successful use of quantitative techniques usually results in a solution that is timely, accurate, flexible, economical, reliable, and easy to understand and use.

## 2. What is Quantitative Analysis?

*Quantitative analysis* is the scientific approach to managerial decision making. Whim, emotions, and guesswork are not part of the quantitative analysis approach. This approach starts with data. Like raw material for a factory, this

data is manipulated or processed into information that is valuable to people making decisions. This processing and manipulating of raw data into meaningful information is the heart of quantitative analysis.

In solving a problem, managers must consider both qualitative and quantitative factors. We might be considering several different investment alternatives, including certificates of deposit at a bank, investments in the stock market, and an investment in real estate. We can use *quantitative analysis* to determine how much our investment will be worth in the future when deposited at a bank at a given interest rate for a certain number of years. Quantitative analysis can also be used in computing financial ratios from the balance sheets for several companies whose stock we are considering. Some real estate companies have developed computer programs that use quantitative analysis to analyze cash flows and rates of return for investment property.

*Using Both Quantitative and Qualitative Analysis*

In addition to quantitative analysis, *qualitative* factors should also be considered. The weather, state and federal legislation, new technological breakthroughs, the outcome of an election, and so on may all be factors that are difficult to quantify.

Because of the importance of qualitative factors, the role of quantitative analysis in the decision-making process can vary. When there is a complete lack of qualitative factors and when the problem, model, and input data remain the same, the results of quantitative analysis can *automate* the decision-making process. For example, some companies use quantitative inventory models to determine automatically *when* to order additional new materials. In most cases, however, quantitative analysis will be an *aid* to the decision-making process. The results of quantitative analysis will be combined with other (qualitative) information in making decisions.

## History

### The Origin of Quantitative Analysis

Quantitative analysis has been in existence since the beginning of recorded history, but it was Fredrick W. Taylor who in the 1900s pioneered the principles of the scientific approach to management. During World War II, many new scientific and quantitative techniques were developed to assist the military. These new developments were so successful that after World War II many companies started using similar techniques in managerial decision making and planning. Today, many organizations employ a staff of operations research or management science person-

nel or consultants to apply the principles of scientific management to problems and opportunities. In this book, we will use the terms *management science*, *operations research*, and *quantitative analysis* interchangeably.

The origin of many of the techniques discussed in this book can be traced to individuals and organizations that have applied the principles of scientific management first developed by Taylor; they are discussed in "history boxes" scattered throughout this text.

### 3. An Application of Quantitative Analysis: Emergency Snow Removal

Perhaps a real-life case will give you an appreciation of the usefulness of the quantitative analysis approach. Let us consider an interesting problem that occurred on a Sunday in February of 1969, in New York City when Mayor John Lindsay was facing a fall reelection.<sup>1</sup> The weather forecast did not call for anything unusual. It was on this day that an abundance of crystalline H<sub>2</sub>O, better known as snow, was deposited on New York City.

#### The Problem

For the first few days after the snowstorm, residents of New York were enthralled with their new, beautifully white recreation wonderland. Skiers could be seen everywhere. By midweek, however, the city's citizens were no longer enjoying the snow, and John Lindsay was wondering if he would be mayor this time next year. Very little progress was made in clearing the streets and removing the snow. Residents of the boroughs of Queens and Brooklyn complained that Manhattan was getting better service. Sanitation workers suggested that more recruits were needed, owners of snow removal equipment suggested that more equipment was needed, and almost every special interest group had some type of solution that would directly or indirectly benefit them. At this time Mayor Lindsay asked his quantitative analysis (QA) unit to find a solution to the problem.

After carefully considering the situation, the QA unit concluded that there were four basic questions that had to be answered:

1. How much snow falls in New York City?
2. How much work has to be done to clean it up?
3. What is the city's capacity for performing this work?
4. What improvements are needed in the system?

#### The Answer

After searching U.S. Weather Bureau records, the analysts determined that a similar storm, with a snow depth of about 15 inches, occurred about once every 12 years. The number of times that a storm of this intensity would hit New York City when there was a small snow-fighting force on duty, such as on a Sunday, was about once in 84 years. And the chance of this happening during an election year was even less. They also found that the city averages slightly over 30 inches of snow a year, that there are approximately six storms per year with an inch or more of snow, and that there are only two storms per season with more than 4 inches of snow.

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<sup>1</sup>E. W. Savis, "The Political Properties of Crystalline H<sub>2</sub>O: Planning for Snow Emergencies in New York," *Management Science*, Vol. 20, No. 2, October 1973, pp. 137-45.

For any snow cleanup, three sequential procedures were required: (1) spreading salt, (2) plowing, and (3) snow removal. Collecting data on cleanup, the analysts decided that new priority areas should be developed for snow removal. These areas included about 1,600 miles of streets by parkways, bus routes, police stations, and hospitals.

Quantitative analysis also answered the third question about the city's capacity for snow removal. Since the principal snow-fighting equipment was plows and spreaders, the main emphasis was on this equipment's capacity and mobilization. After making an analysis of down times, the study unit determined that only 134 spreaders and 1,050 plows would be available. Applying quantitative analysis techniques, they learned that it would always be possible to keep the high-priority areas plowed. While there was adequate plowing equipment, the number of salt spreaders was found to be inadequate.

While the number of plows was adequate, their deployment was not. Since most of the plowing vehicles were refuse-collection trucks, they were distributed according to refuse collection and not snow removal. Because Manhattan was more densely populated, it ended up with more plows per mile than other areas. Thus, the complaint that Manhattan was receiving superior snow removal was probably correct. In addition, the analysts determined that the spreaders were not correctly located, and that new garage areas were needed. In order to improve weekend and holiday mobilization, they also suggested that the actual plow mechanisms be placed on about one-fifth of the trucks and that salt be placed in some of the salt spreaders before the weekend or holiday. To avoid flat tires, the salt had to be removed from the spreaders after the weekend or holiday.

### Implementing the Suggestions

The results of the quantitative analysis of the snow removal problem were presented to Mayor Lindsay as his reelection campaign started. The suggested solutions were implemented, and a major press conference was called to release the findings. The city's residents were assured that a snowstorm of a magnitude like the one that brought the city to its knees in February could now be quickly and effectively handled. The quantitative analysis unit happened to be at the right place, at the right time, and with the right answers. Mayor Lindsay was also reelected.<sup>2</sup>

## 4. The Quantitative Analysis Approach (The Scientific Method)

How did New York City's quantitative analysis group approach the problem that was to be analyzed? In general terms, the analysts followed seven steps, as outlined in Figure 1.1.

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<sup>2</sup>You may recall that Chicago's mayor in 1979, Michael Bilandic, was not as fortunate as Mayor Lindsay. When heavy snow was not quickly cleared during an election season, candidate Jane Byrne blamed and defeated the incumbent Bilandic.