21世纪高等学校经管类双语教材

QUANTITATIVE METHODS FOR BUSINESS DECISION

经济决策定量方法

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内 容 简 介

本书在遵循国际上初步形成的“经济决策定量方法”课程架构的前提下，结合我国高校教学的实际，通过大量的实际案例，系统地介绍了“经济决策定量方法”的基本原理、方法与过程。全书共分10章，即：第一章 经济决策定量方法综述；第二章 经济预测分析；第三章 存贮分析；第四章 线性规划分析；第五章 运输分析；第六章 网络计划分析；第七章 经济决策分析；第八章 博弈与对策分析；第九章 动态规划分析；第十章 随机过程分析。

“经济决策定量方法”是一门新兴的经济管理核心课程，是横跨经济预测与决策、系统规划与优化、计量经济等领域的边缘性交叉课程。本书篇幅在30万字左右，剪裁合理，详略得当，难易适中，较好地适应了我国高等院校教学的需要；采用大量实际案例，对知识的论述强调经济内涵，把数学的应用保持在中等水平上；全英文编写适应全球化人才培养的要求。

本书可作为普通高校经济管理类专业本科生和研究生双语教学或专业英语的教材，也可以作为企业全球化管理人才培训的教材或自学参考书。

图书在版编目（CIP）数据

经济决策定量方法/李军 孙彦彬编著. —广州：华南理工大学出版社，2007.3
（21世纪高等学校经管类双语教材）
ISBN 978-7-5623-2555-0

Ⅰ. 经… Ⅱ. ①李… ②孙… Ⅲ. 经济决策：定量决策-双语教学-高等学校-教材-英、汉 Ⅳ. F202

中国版本图书馆CIP数据核字（2007）第012757号

总 发 行：华南理工大学出版社（广州五山华南理工大学17号楼，邮编510640）
营销部电话：020-87113487 87111048（传真）
E-mail：scutc13@scut.edu.cn **http**：//www.scutpress.com.cn
责任编辑：黄 玲
印 刷 者：佛山市浩文彩色印刷有限公司
开 本：787mm×960mm 1/16 **印张**：16.125 **字数**：316千
版 次：2007年3月第1版 2007年3月第1次印刷
印 数：1~3000册
定 价：25.00元

PREFACE

The book is specifically designed for advanced undergraduate students with some previous coursework in Management Science & Engineering. My goal in writing Quantitative Methods for Business Decisions has been to provide a complete and modern treatment of basic management science methodology.

There are ten chapters in the text. Our principal objective is to present the material in a way that would immediately make sense to a student. We give an introduction to quantitative methods for decision making in Chapter 1. The Chapter 2 is devoted to some discussion of the forecasting using past data. In Chapter 3, 4 and 5, we present the programming problems that in general are concerned with the use or allocation of scarce resources. The part has been organized around the mathematics models. Chapter 6 introduces one of the most successful applications involving networks: PERT (Program Evaluation and Review Technique). This project management tool employs a network tying various activities. A primary objective of PERT is to provide information that managers can use in taking action to ensure that project activities are completed in a timely fashion. Chapter 7 is organized around the Decision Making to clearly delineate the decision theories and methods. In Chapter 8, we will be concerned with interactive decision making involving more than one person. The outcomes of such decision problems, sometimes referred to as games, are determined by whatever combination of actions results from the independent choices of several individual decision makers. Often decision making involves several choices that must be made at different times. Dynamic programming can cater for the situations involving sequential decision-making. Dynamic programming, described in Chapter 9, differs from the other allocation models introduced in this book in that it considers decision making over time. Chapter 10 is concerned with the techniques of modeling random processes — processes that evolve through time in a manner that is not completely predictable.

The book also highlights the limitations and pitfalls associated with various mathematical models and algorithms. It is important that you understand the techniques well enough to recognize appropriate opportunities to use them while you also appreciate their limitations enough to be conservative in their use. That is you should know when and how to use them, but also when not to use them. Individual instructors will, of course, exercise their judgment to select and to rearrange certain material. Because we know this will happen, we decided at the outset that a highly integrated text would be undesirable. Thus we have deliberately sought to maintain independence among chapters to permit maximum flexibility in their use.

It is perhaps obvious that the author is indebted to the many researchers who have developed the underlying concepts that permeate this text.

I wish to thank our colleagues who were instrumental in helping me shape the manuscript. Some of them went over the text and gave a lot of constructive suggestions. Their skill and attention to detail are most appreciated.

Jun Li, Yanbin Sun
October, 2006

CONTENTS

Chapter 1 Introduction to Quantitative Methods for Decision Making

A quiet revolution has taken place in managerial decision making over the past three decades, which is due largely to the successful implementation of *quantitative methods* and the widespread use of *computers*. The list of the types of business problems that these procedures can be employed to solve grows daily, and examples of successful applications can be found in every functional area—from marketing to production, finance and personnel—and in all major industries. Indeed, quantitative methods can be applied to decision making in general and can be used by individuals or groups, in education, in the professions, and in every type of organization, including governments and nonprofit foundations.

1.1 Quantitative Methods: A Continuing Story of Success

A few short case histories will demonstrate how useful quantitative methods have been in solving a variety of actual problems.

In the late 1950s, the U. S. Navy was faced with the monumental task of equipping its nuclear submarine fleet with Polaris ballistic missiles. A quantitative method called PERT (Program Evaluation and Review Technique) was used to establish schedules and to coordinate and control the effects of hundreds of contractors.

Banks often use quantitative analysis to decide how many tellers are needed at various times during the week, so employee workloads can be balanced and so customers spend a tolerable amount of time waiting in line.

A chemical company that produces fertilizers and pesticides employed quantitative methods to determine where to locate its warehouses. The resulting sites minimized the combined annual cost of transportation, storage, and handling.

An international oil company committed several hundred million dollars to the construction of a port facility in the Persian Gulf to service oil tankers. Alternative designs were constructed and run "on paper" for a number of years to determine a statistical pattern for future profits. Through this computer simulation, the design was selected that provided the greatest rate of return on invested capital at an acceptable level of risk.

Satellites have become an increasingly important element in worldwide communications. In 1971, the RCA Corporation decided to enter the satellite business for the private sector. Various types of quantitative methods in many different areas of application were employed to evaluate the various alternatives and to recommend the optimal strategy.

1.2 Management Science and Operations Research

This book is concerned largely with the specific techniques used in the cases just described and similar situations. These quantitative methods can be broadly categorized as techniques of **management science**—a field melding portions of business, economics, statistics, mathematics, and other disciplines into a pragmatic effort to help managers make decisions. As an area of study, these quantitative methods are often identified as **operations research**. Regardless of the label used, the techniques of management science and operations research are concerned with selecting the best alternative course of action whenever mathematics can be helpful in reaching a decision. Many problem situations can be structured so that the possible choices can be ranked on a numerical scale. Common rankings are profit or cost. In such cases, an optimal solution is the one that yields the maximum profit or minimum cost.

The beginnings of operations research can be traced to World War Two, when the United States and Great Britain employed mathematicians and physicists to analyze military operations. After the war, many of those involved in military operations research retained their interest in analyzing decision making in peace-time endeavors and developed new techniques that could be directly applied to business problems. The availability of digital computers allowed these techniques to be applied quickly to large-scale optimization problems.

1.3 The Importance of Studying Quantitative Methods

The purpose of this book is not to make you an expert in quantitative methods. Its goal is to familiarize you with the important tools of quantitative methods and to expose you to a variety of successful applications. No great skill in mathematics is required.

Three main advantages can be gained from exposure to quantitative methods. **First**, it should increase your confidence as a decision maker, largely because you will see how vast and varied the problems are that can be solved through the application of quantitative methods. **Second**, a study of quantitative methods creates problem-solving skills that will be extremely helpful when you encounter an unsolved problem, whether or not you are directly responsible for finding the answer. **A final** advantage will be your ability to cope with decisions, as a manager, as an employee, or in your personal life.

Some knowledge of quantitative methods is especially crucial to the modern manager. An effective manager must make good choices, and the ability to know where, when, and how to use quantitative methods to make optimal decisions gives managers a definite advantage. This doesn't mean that an effective manager must be mathematically skilled or must personally develop models and solutions. There are a tremendous number of opportunities for the layman to do exactly that, but experts can be hired to perform the more demanding tasks. However, it is important to know enough about this subject to guide those high-powered analysts (who too often stray into a mathematical "never-never land"). In short speaking, any exposure to quantitative methods will teach future managers to ask the right questions and to recognize when outside help may be useful.

Main words or phrases:

1. alternative: 可供选择的（方案）
2. commit: 投资
3. contractors: 承包商
4. coordinate and control: 协调与控制
5. fertilizers and pesticides: 化肥与农药
6. finance: 财务
7. handling: 处理
8. industries: 行业
9. layman: 下属
10. management science: 管理科学
11. managerial decision making: 管理决策
12. marketing: 营销
13. never-never land: 梦幻岛
14. nonprofit foundation: 非盈利性组织
15. nuclear submarine fleet: 核潜艇舰队
16. oil tankers: 油轮
17. on paper: 模拟
18. O. R. (operations research or operational research): 运筹学
19. perform the more demanding tasks: 从事更高要求的工作
20. Persian Gulf: 波斯湾
21. personnel: 人力资源
22. PERT (Program Evaluation and Review Technique): 计划评审技术，网络

计划技术

23. Polaris ballistic missiles：北极星（弹道）导弹

24. production：生产

25. professions：专业机构

26. rate of return on invested capital：投资回报率

27. storage：贮存

28. stray：迷失

29. tellers：前台服务员

30. transportation：运输

Chapter 2 Forecasting

Forecasting the future is a fundamental aspect of business decision-making. Future sale is the most important variable in business forecasts. Knowledge about sales is a prerequisite to the budgetary and planning process.

A variety of quantitative methods have been developed to forecast future values. The underlying models can be classified into three broad categories.

1. Forecasting Using Past Data

The historical patterns of a variable are identified and projected into the future. These patterns are obtained through extrapolation from time-series data.

2. Forecasting Using Causal Models

A relationship is found between the unknown variable and one or more other known variables. The values of the known variables are then used to predict the value of the variable of interest.

3. Forecasting Using Judgment

Quantitative representations are used to express judgments in terms of subjective probabilities. These methods can incorporate the forecaster's actual "batting average" and may provide a way to express collective judgments.

In this chapter, we will survey the forecasting methods commonly used in each of these three categories.

2.1 Forecasting Using Past Data: Time-series Analysis

A time series is a numerical sequence in which individual values are generated at regular intervals of time. The goal of *time-series analysis* is to identify the swings and fluctuations of a time series and then to sort them into various categories by the arithmetic manipulation of the numerical values obtained.

Several models can be used to characterize time series. The classical model used by economists provides the clearest explanation of the four components of time-series variation, which are secular trend (T_t), cyclical movement (C_t), seasonal fluctuation (S_t), and irregular variation (I_t). These components can be related to the forecast variable by mathematical equations. The forecast variable is denoted by the symbol Y_t, where the subscript t refers to a period of time.

The classical time-series model originally used by economists combines the four components of time-series variation,

$$Y_t = T_t \times C_t \times S_t \times I_t$$

This equation states that factors associated with each of these components can be multiplied to provide the value of the forecast variable. The model can be explained by means of a hypothetical time series — the sales Y_t of the novels by the Sunny book store. Figure 2-1 shows how the final time series (bottom graph) might be obtained by combining the four components. But only a hypothetical time series can be synthesized from the assumed characteristics of the four components. In actual applications, we may not know anything about T_t, C_t, S_t, or I_t. Usually, we begin with the raw time-series data and reverse the procedure, sifting the data to sort out and identify the components.

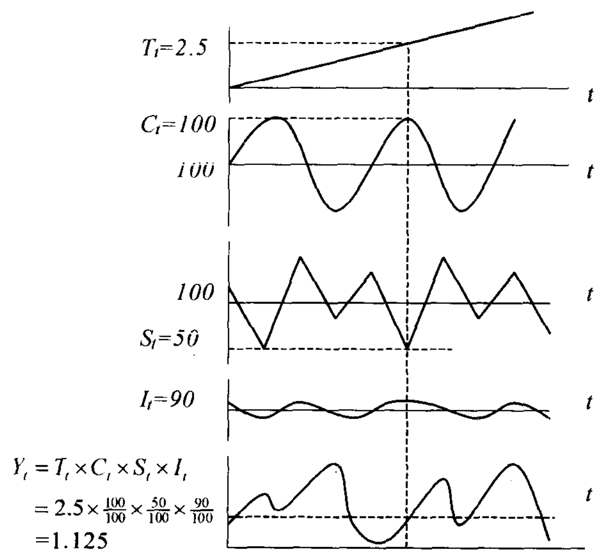

Figure 2-1 Complete time series for Sunny sales using individual components

Three major approaches are used in arriving at forecasts using past data. **Exponential smoothing** averages past time-series values in a systematic fashion. The resulting smoothed values are created using one or several averaging processes that agrees with the underlying nature of the data. Section 2-2 describes two popular procedures, each utilizing a set of parameters. Those parameters may be fine-tuned to the historical time series in order to achieve a best fit.

2.2 Exponential Smoothing

Exponential smoothing is a popular forecasting procedure that offers two basic advantages: It simplifies forecasting calculations, and its data-storage requirements are small. Exponential smoothing produces self-correcting forecasts with built-in adjustments that regulate forecast values by increasing or decreasing them in the opposite direction of earlier errors, much like a thermostat.

1. Single-parameter Exponential Smoothing

The basic exponential-smoothing procedure provides the next period's forecast directly from the current period's actual and forecast values. The following expression is used to compute the forecast value

$$F_{t+1} = \alpha Y_t + (1-\alpha) F_t$$

Where, t is the current time period, F_{t+1} and F_t are the forecast values for the next period and the current period, respectively, and Y_t is the current actual value. (the lowercase Greek letter alpha) is the **smoothing constant** — a chosen value lying between 0 and 1. Since only one smoothing constant is used, we refer to this procedure as **single-parameter exponential smoothing.**

To illustrate, we will suppose that actual sales of Harbin Beer in period 10 (October 2005) were $Y_{10} = 525$ barrels and that $F_{10} = 512$ had been forecast earlier for this period. Using a smoothing constant of $\alpha = 0.2$, the forecast for period 11 (November 2005) sales can be calculated as

$$F_{11} = 0.2Y_{10} + (1-0.2)F_{10} = 0.2(525) + 0.8(512) = 515 \qquad (\textit{barrels})$$

Elementary exponential smoothing is extremely simple, because only one number—last period's forecast—must be saved. But, in essence, the entire time series is embodied in that forecast. If we express in terms of the preceding actual and forecast values, then the equivalent expression for the next period's forecast is

$$F_{t+1} = \alpha Y_t + \alpha(1-\alpha) Y_{t-1} + (1-\alpha)^2 F_{t-1}$$

Continuing this for several earlier periods shows us that all preceding *Y's* are reflected in the current forecast. The name for this procedure is derived from the successive weights α, $\alpha(1-\alpha)$, $\alpha(1-\alpha)^2$, $\alpha(1-\alpha)^3$, $\cdots$, which *decrease exponentially*. Thus, the more current the actual value of the time series is, the greater its weight is. Progressively less forecasting weight is assigned to order *Y's*, and the oldest *Y's* are eventually wiped out. The forecasting procedure can be modified at any time by changing the value of α.

Table 2-1 Forecast of Harbin Beer sales by single-parameter exponential smoothing ($\alpha = 0.2$)

Month	Period t	Actual Sales Y_t	Forecast F_t	Error $Y_t - F_t$	Error² $(Y_t - F_t)^2$
January	1	480	—	—	—
February	2	490	480	10	100
March	3	495	482	13	169
April	4	498	485	13	169
May	5	512	508	4	16
June	6	516	509	1	1
July	7	505	510	-5	25
August	8	515	509	6	36
September	9	518	510	8	64
October	10	525	512	13	169
November	11	519	515	4	16
December	12	528	516	12	144
January	13	522	518	4	16
February	14	526	519	7	49
March	15	530	520	10	100
April	**16**	—	**522**	—	—
$MSE = 1\,074/14 \approx 76.7$					1 074

Table 2-1 provides the actual and forecast Harbin Beer sales for 15 periods when $\alpha = 0.2$. There, the actual sales figure for period 1 has been used for the initial forecast for period 2. Eventually, the same F's will be achieved in later time periods, regardless of the initial value.

The actual and forecast values may be compared in the plot provided in figure 2-2. Notice that the forecast values deviate considerably from the actual values. This reflects a poorness of fit in using this particular model and level for α. The overall forecasting quality may be assessed in terms of the forecasting errors.

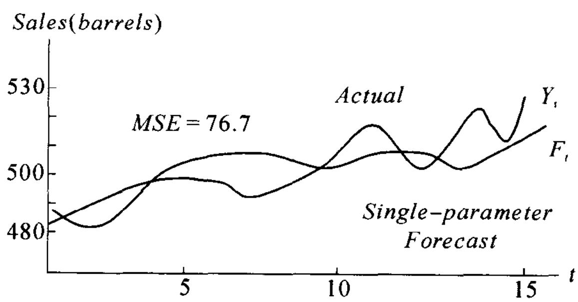

Figure 2-2 Single-parameter exponential smoothing results for Harbin Beer sales

The errors in a forecasting procedure are determined by subtracting the forecasts from their respective actual values,

$$\tau = Y_t - F_t$$

α should be set at a level that minimizes these errors. Often several separate sets of forecasts are required with different smoothing constants to past data. Large α levels assign more weight to current values, whereas small α levels emphasize past data. By trial and error, an optimal level can be found for α that minimizes *variability* in forecasting errors.

For any set of actual and forecast values, the **mean squared error**, denoted as *MSE*, is used to summarize this variability. The following expression is used to compute the

$$MSE = \frac{\sum(Y_t - F_t)^2}{n - m}$$

Here $\boldsymbol{n}$ denotes the number of time periods and $\boldsymbol{m}$ is the number of smoothing parameters. A value of $MSE = 76.7$ applies to the Harbin Beer data in table 2-1.

2. Two-parameter exponential smoothing

The forecast sales found earlier for Harbin Beer are smaller (lag behind) than the actual sales (see figure 2-2). Whenever there is a pronounced upward trend in actual data (here, increasing sales), forecasts resulting from the single-parameter exponential smoothing will be consistently low.

Two-parameter exponential smoothing eliminates such a lag by directly accounting for trend by using a second smoothing constant for the slope of the line. A total of three equations are employed in computing the forecast values,

$$T_t = \alpha Y_t + (1 - \alpha)(T_{t-1} + b_{t-1}) \quad (\textit{smooth the data to get trend})$$

$$b_t = \gamma(T_t - T_{t-1}) + (1 - \gamma) b_{t-1} (\textit{smooth the slope in trend})$$

$$F_{t+1} = T_t + b_t \quad (\textit{forecast})$$

Here, T_t represents the smoothed value for period t. This quantity conveys the underlying trend in the data. The difference between the current and the prior trend values provides the current slope in trend $T_t - T_{t-1}$. The second equation contains the slop-smoothing constant γ (the lowercase Greek letter gamma), which is used to obtain smoothed-trend line slopes, represented by b_t. The third equation provides the forecast.

Table 2-2 lists the forecasts of Harbin Beer sales when $\alpha = 0.2$ and $\gamma = 0.3$. The initial trend value of $T_2 = 480$ is the actual sales for period 1. The first slope value of $b_2 = 10$ is the difference in actual sales for period 1 and 2. The actual and forecast values