PEARSON
Prentice Hall

（影印版）

工程经济学

（第9版）

Engineering Economy

(Ninth Edition)

Gerald J. Thuesen
W. J. Fabrycky

清华大学出版社

（影印版）

工程经济学

（第9版）

Engineering Economy (Ninth Edition)

Gerald J. Thuesen
W. J. Fabrycky

清华大学出版社
北京

图书在版编目(CIP)数据

工程经济学=Engineering Economy，英文，第 9 版/（美） 图森（Thusen, G.J.）等著. —影印本. —北京：清华大学出版社，2005.1
ISBN 7-302-10240-6

Ⅰ. 工… Ⅱ. 图… Ⅲ. 工程经济学–教材–英文 Ⅳ. F40

中国版本图书馆 CIP 数据核字（2004）第 141814 号

出 版 者： 清华大学出版社
http://www.tup.com.cn
社总机：（010）6277 0175
地 址： 北京清华大学学研大厦
邮 编： 100084
客户服务：（010）6277 6969
责任编辑： 徐晓飞
印 装 者： 北京鑫海金澳胶印有限公司
发 行 者： 新华书店总店北京发行所
开 本： 185×230 **印张：** 40.75
版 次： 2005 年 1 月第 1 版 2005 年 1 月第 1 次印刷
书 号： ISBN 7-302-10240-6/F · 1046
印 数： 1~3000
定 价： 58.00 元

Preface

This ninth edition of *Engineering Economy* emphasizes that the essential prerequisite of successful engineering application is economic feasibility. We present the concepts and technique of analysis useful in evaluating the economic feasibility of systems, products, and services. Our objective is to help the reader understand the significance of the economic aspects of engineering and to become proficient in the evaluation of engineering proposals in terms of worth and cost.

For the increasingly competitive global marketplace, economic feasibility is a consideration of primary importance. The engineering approach to problem solution has advanced and broadened to the extent that success often depends upon the ability to deal with both economic and physical factors. Down through history, the limiting factor has been predominantly physical, but with the development of science and technology, goods and services that may not have utility have become physically possible. Fortunately, engineers can readily extend their inherent ability for analysis to embrace economic factors. To aid them in so doing is a primary aim of this book.

A secondary aim of this book is to acquaint the engineer with operations and operational feasibility. Economic factors in the operation of systems and equipment can no longer be left to chance but must be considered in the design process. A basic understanding of mathematical modeling of operations is becoming more important as complex operational systems require the attention of larger numbers of engineers.

This text contains more than enough material for a three-semester-hour course. For a course of shorter duration some material will have to be omitted. This may be easily done, since the foundation topics are concentrated in the first ten chapters.

We have had no difficulty in teaching this material to engineering sophomores as well as to upper division students in management, economics, and the physical sciences who want an introduction to engineering from the economic point of view. Elementary calculus is the only mathematical background required.

A significant reorganization of Part Three has occurred with the inclusion of a revised chapter on evaluating production operations. This chapter now combines all the material directed at this important area in an integrated manner. Additionally, there is a new chapter in Part Five dealing with decisions involving multiple criteria, featuring the decision evaluation display.

Accompanying this book are computer packages and internet links available at the web site (http://www.prenhall.com/thuesen). These packages included software for the solution of a wide variety of engineering economy problems and a multimedia presentation that highlights the important principles of the field including the fundamental role of engineering economy in engineering design. It is intended that students avail themselves of this supplementary material as they progress through the book. Course instructors may also assign particular elements of these packages to broaden understanding of this material.

Those familiar with earlier editions of this text will note that we have retained the basic conceptual approach with considerable emphasis on examples. Also retained is the scheme, originated by H. G. Thuesen, for application of the functional factor designation system facilitating time value calculations. The symbols in this book are based on those published by the American National Standards Institute Terminology Standards ANSI Z.94. Retained from the previous edition is the numbering of important equations while key equations are displayed. Principles are highlighted for easy reference. The reader will also find key points listed at the end of each chapter.

It is our pleasure to acknowledge the significant contribution in the preparation of new problems and the revisions of previous problems by Dyan Thuesen Jacobus and Dr. James Kurt Jacobus. We thank Joseph Hartman, Lehigh University; Brian Thorn, Rochester Institute of Technology; and Fred A. DeWinter, Boston University for their careful review of this book. Actual preparation of the solutions manual was handled professionally by Dagoberto Garza N.

G. J. Thuesen
W. J. Fabrycky

Contents

Preface ix

PART I INTRODUCTION TO ENGINEERING ECONOMY 1

Chapter 1
Engineering and Engineering Economy

1.1. Engineering and Science 2
1.2. The Bi-Environmental Nature of Engineering 3
1.3. Physical and Economic Efficiency 5
1.4. The Engineering Process 6
1.5. Engineering for Economic Competitiveness 10
1.6. Engineering Economy and the Engineer 11
Key Points 13
Questions 13

Chapter 2
Some Economic and Cost Concepts

2.1. Concepts of Value and Utility 15
2.2. Consumer and Producer Goods 16
2.3. Economic Aspects of Exchange 18
2.4. Classifications of Cost 21

2.5. Life-Cycle Cost 25
2.6. Interest and Interest Rate 28
2.7. The Time Value of Money 30
2.8. The Earning Power of Money 31
2.9. The Purchasing Power of Money 32
Key Points 33
Questions 33

PART II INTEREST FORMULAS AND EQUIVALENCE 35

Chapter 3
Interest Formulas

3.1. Simple and Compound Interest 36
3.2. Describing Cash Flows Over Time 38
3.3. Interest Formulas (Discrete Compounding, Discrete Payments) 40
3.4. Interest-Formula Relationships 53
3.5. Compounding Frequency Considerations 55
3.6. Interest Formulas (Continuous Compounding, Discrete Payments) 59
3.7. Summary of Interest Formulas 63
Problems 65

Chapter 4
Calculations of Economic Equivalence

4.1. The Meaning of Equivalence 72
4.2. Equivalence Calculations Involving a Single Factor 74
4.3. Equivalence Calculations Involving Cash Flows 81
4.4. Principles of Equivalence 85
4.5. Equivalence Calculations with More Frequent Compounding 89
4.6. Equivalence Calculations Involving Bonds 93
4.7. Equivalence Calculations Involving Loans 97
4.8. Equivalence Calculations Involving Working Capital 101
Key Points 102
Problems 103

Chapter 5
Equivalence Involving Inflation

5.1. Measures of Inflation and Deflation 115
5.2. The Inflation Rate 117
5.3. Considering the Effects of Inflation 123
5.4. Analyzing Inflation in Investments 128
Key Points 139
Problems 140

PART III ECONOMIC ANALYSIS OF ALTERNATIVES 151

Chapter 6
Bases for Comparison of Alternatives

6.1. Present Worth 152
6.2. Annual Equivalent 154
6.3. Future Worth 156
6.4. Internal Rate of Return 157
6.5. Payback Period 166
6.6. Capitalized Equivalent Amount 170
6.7. Capital Recovery with Return 171
6.8. Project Balance 173
Key Points 179
Problems 180

Chapter 7
Decision Making Among Alternatives

7.1. Types of Investment Proposals 190
7.2. Forming Mutually Exclusive Alternatives 192
7.3. Elements of Decision Criteria 197
7.4. Present Worth on Incremental Investment 202
7.5. IRR on Incremental Investment 205
7.6. Comparisons Based on Total Investment 209
7.7. Comparing Alternatives with Unequal Lives 215
Key Points 225
Problems 225

Chapter 8
Evaluating Production Operations

8.1. Characteristics of Production Operations 244
8.2. Break-Even Analysis 248
8.3. Operation and Production Decisions 261
8.4. Economic Operation of Equipment 271
8.5. Models for Procurement Operations 276
Key Points 283
Problems 284

Chapter 9
Evaluating Replacement Alternatives

9.1. The General Nature of Replacement Analysis 297
9.2. Describing Replacement Alternatives 299

9.3. Replacement Analysis for Unequal Lives 304
9.4. The Economic Life of an Asset 307
9.5. Replacement Assumptions and Decisions 311
9.6. Retirement or Abandonment Decisions 323
9.7. Examples of Replacement Problems 324
Key Points 330
Problems 331

Chapter 10
Evaluating Public Activities

10.1. General Welfare Aim of Government 348
10.2. The Nature of Public Activities 350
10.3. Financing Public Activities 352
10.4. Public Activities and Engineering Economy 355
10.5. Benefit-Cost Analysis 355
10.6. Identifying Benefits, Disbenefits, and Costs 367
10.7. Cost-Effectiveness Analysis 370
Key Points 374
Questions and Problems 374

PART IV ACCOUNTING, DEPRECIATION, AND INCOME TAXES 387

Chapter 11
Accounting and Depreciation Accounting

11.1. General Accounting 388
11.2. Cost Accounting 391
11.3. Depreciation 397
11.4. Accounting for the Depreciation of Capital Assets 399
11.5. Basic Depreciation Methods 401
11.6. Modified Accelerated Cost Recovery System (MACRS) 406
11.7. Units-of-Production Depreciation 411
11.8. Depletion 412
Key Points 414
Questions and Problems 414

Chapter 12
Income Taxes in Economic Analysis

12.1. Relation of Income Taxes to Profit 420
12.2. Federal Income Tax for Corporations 421
12.3. Effective Income-Tax Rates 425
12.4. Interest and Income Taxes 426
12.5. Depreciation and Income Taxes 428
12.6. Gain or Loss on Disposition of Depreciable Assets 433

12.7. Tax Credits 434
12.8. Depletion and Income Taxes 434
12.9. Calculating After-Tax Cash Flows 436
12.10. Evaluation of Financing Methods Using After-Tax Cash Flows 440
12.11. Capital Gains in After-Tax Cash Flows 447
12.12. Inflation and its Effects on After-Tax Flows 449
12.13. After-Tax Analysis of Replacements 450
Key Points 455
Problems 456

PART V ESTIMATES, RISK, AND UNCERTAINTY 467

Chapter 13
Estimating Economic Elements

13.1. The Elements to Be Estimated 468
13.2. Cost Estimating Methods 472
13.3. Adjustment of Cost Data 475
13.4. Cost-Estimating Relationships 483
13.5. Estimating and Allocating Indirect Costs 490
13.6. Accounting Data in Estimating 496
13.7. Judgment in Estimating 498
Key Points 499
Questions and Problems 500

Chapter 14
Estimates and Decision Making

14.1. An Example Decision Based upon Estimates 502
14.2. Allowances for Uncertainty in Estimates 504
14.3. Considering a Range of Estimates 506
14.4. Sensitivity Analysis 508
Key Points 518
Questions and Problems 518

Chapter 15
Decisions Under Risk and Uncertainty

15.1. Criteria for Decisions Under Risk 521
15.2. Expected-Value Decision Making 525
15.3. Expectation Variance Decision Making 528
15.4. Monte Carlo Analysis 533
15.5. Decision Trees in Decision Making 536
15.6. Decisions Under Uncertainty 546
Key Points 552
Problems 552

Chapter 16
Decisions Involving Multiple Criteria

16.1. Multiple Criteria Considerations 565
16.2. Direct Ranking Methods 567
16.3. Systematic Elimination Methods 569
16.4. Weighting Methods of Evaluation 572
16.5. Decision Evaluation Display 574
16.6. Decision Evaluation Display Examples 576
16.7. Summary: Making the Decision 580
Key Points 582
Questions and Problems 583

Appendices

Appendix A Interest Factors for Discrete Compounding 587
Appendix B Effective Interest Rates Corresponding to Nominal Rate r 617

Selected References 619

Index 623

Part One

INTRODUCTION TO ENGINEERING ECONOMY

The first part of this text introduces engineering economy—its relationship to engineering and to the engineering process. The focus is on technical concepts to facilitate the process for performing engineering economy studies. Selected economic concepts and cost classifications are then provided as a foundation for quantitative methods that will appear in subsequent chapters. Next, interest and inflation rates are introduced as the basis for time value analysis. Finally, Part One presents the concept of the earning power of money as the primary justification for borrowing to increase productivity.

1

Engineering and Engineering Economy

Engineering activities of analysis and design are not an end in themselves. They are a means for satisfying human wants. Thus, engineering has two concerns: the materials and forces of nature, and the needs of people. Because of resource constraints, engineering must be closely associated with economics. It is essential that engineering proposals be evaluated in terms of worth and cost before they are undertaken. In this chapter and throughout the text, we emphasize that an essential prerequisite of successful engineering application is economic feasibility.

1.1 ENGINEERING AND SCIENCE

Engineering is not a science, but an application of science. It is an art composed of skill and ingenuity in adapting knowledge to the uses of humanity. The Accreditation Board for Engineering and Technology has adopted the following definition:

> **Engineering** is the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize economically the materials and forces of nature for the benefit of mankind.

This, like most other accepted definitions, emphasizes the applied nature of engineering.

The role of the scientist is to add to humankind's accumulated body of systematic knowledge and to discover universal laws of behavior. The role of the engineer is to apply this knowledge to particular situations to produce products and services. To the engineer, knowledge is not an end in itself but is the raw material from which he or she fashions structures, systems, products, and services. Thus, engineering involves the determination of the combination of materials, forces, information, and human factors that will yield a desired result. Engineering activities are rarely carried out for the satisfaction that may be derived from them directly. With few exceptions, their use is confined to satisfying human wants.

Modern civilization depends to a large degree upon engineering. Most products and services used to facilitate work, communication, transportation, and national defense and to furnish sustenance, shelter, and health are directly or indirectly a result of engineering activity. Engineering has also been instrumental in providing leisure time for pursuing and enjoying culture. Through the development of instant communication and rapid transportation, engineering has provided the means for both cultural and economic improvement of humanity.

Science is the foundation upon which the engineer builds toward the advancement of humankind. With the continued development of science and the worldwide application of engineering, the general standard of living may be expected to improve and further increase the demand for those things that contribute to people's love for the comfortable and beautiful. The fact that these human wants may be expected increasingly to engage the attention of engineers is, in part, the basis for the incorporation of humanistic and social considerations in engineering curricula. An understanding of these fields is essential as engineers seek solutions to the complex sociotechnological problems of today.

1.2 THE BI-ENVIRONMENTAL NATURE OF ENGINEERING

Engineers are confronted with two important interconnected environments, the *physical* and the *economic*. Their success in altering the physical environment to produce products and services depends upon a knowledge of physical laws. However, the worth of these products and services lies in their utility measured in economic terms. There are numerous examples of structures, machines, processes, and systems that exhibit excellent physical design but have little economic merit.

Want satisfaction in the economic environment and engineering proposals in the physical environment are linked by the production or the construction process. Figure 1.1 illustrates the relationship among engineering proposals, production or construction, and want satisfaction.

In dealing with the physical environment engineers have a body of physical laws upon which to base their reasoning. Such laws as Boyle's law, Ohm's law, and Newton's laws of motion were developed primarily by collecting and comparing numerous similar instances and by the use of an inductive process. These laws may

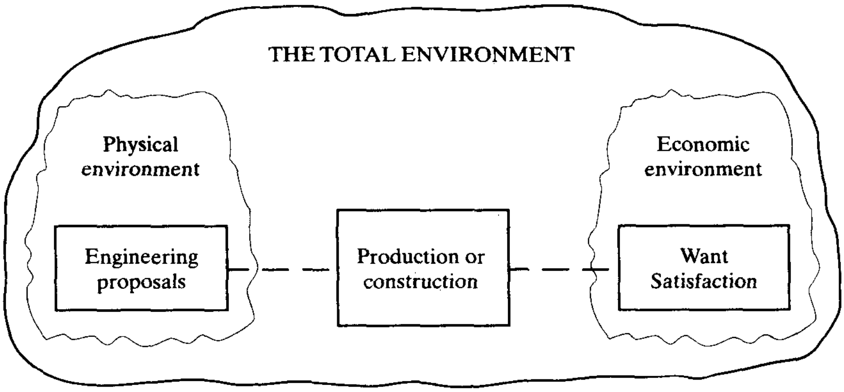

FIGURE 1.1. The physical and economic environments.

then be applied by deduction to specific instances. They are supplemented by many formulas and known facts, all of which enable the engineer to come to conclusions that match the facts of the physical environment within narrow limits. Much is known with certainty about the physical environment.

Much less, particularly of a quantitative nature, is known about the economic environment. Since economics is involved with the actions of people, it is apparent that economic laws must be based upon their behavior. Economic laws can be no more exact than the description of the behavior of people acting singly and collectively.

The usual function of engineering is to manipulate the elements of one environment, the physical, to create value in a second environment, the economic. However, engineers sometimes have a tendency to disregard economic feasibility and are often appalled in practice by the necessity for meeting situations in which action must be based on estimates and judgment. Yet today's engineering graduates are increasingly finding themselves in positions in which their responsibility is extended to include economic considerations.

There are those, and some are engineers, who feel that engineers should restrict themselves to the consideration of physical factors and leave the economic and humanistic aspects of engineering to others; some would not even consider these aspects as coming under engineering. The reason may be that those who take pleasure in discovering and applying the well-ordered certainties of the physical environment find it difficult to adjust their thinking to consider the complexities of the economic environment.

Engineers can readily extend their inherent ability of analysis to become proficient in the analysis of the economic aspects of engineering application. Furthermore, the engineer who aspires to a creative position in engineering will find proficiency in economic analysis helpful. The large percentage of engineers who will eventually be engaged in managerial activities will find such proficiency a necessity.

Initiative for the use of engineering rests, for the most part, upon those who will concern themselves with social and economic consequences. To maintain the initiative, engineers must operate successfully in both the physical and economic sectors of the total environment. It is the objective of *engineering economy* to prepare engineers to cope effectively with the bi-environmental nature of engineering application.

1.3 PHYSICAL AND ECONOMIC EFFICIENCY

Both individuals and organizations possess limited resources. This makes it necessary to produce the greatest output for a given input—that is, to operate at high efficiency. Thus, the search is not merely for a *good* opportunity for the employment of limited resources, but for the *best* opportunity.

People are continually seeking to satisfy their wants. They give up certain utilities in order to gain others that they value more. This is essentially an economic process, in which the objective is the maximization of economic efficiency.

Engineering is primarily a producer activity that comes into being to satisfy human wants. Its objective is to get the greatest end result per unit of resource expenditure. This is essentially a physical process in which the objective is the maximization of physical efficiency, which may be stated as

$$\boxed{\text{efficiency (physical)} = \frac{\text{output}}{\text{input}}.} \tag{1.1}$$

If interpreted broadly enough, physical efficiency is a measure of the success of engineering activity in the physical environment. However, the engineer must be concerned with two levels of efficiency. On the first level is physical efficiency expressed as outputs divided by inputs of such physical units as Btu's, kilowatts, and foot-pounds. When such physical units are involved, efficiency will always be less than unity, or less than 100%.

On the second level are economic efficiencies. These are expressed in terms of economic units of output divided by economic units of input, each expressed in terms of a medium of exchange such as money. Economic efficiency may be stated as

$$\boxed{\text{efficiency (economic)} = \frac{\text{worth}}{\text{cost}}.} \tag{1.2}$$

It is well known that physical efficiencies over 100% are not possible. However, economic efficiencies can exceed 100% and must do so for economic ventures to be successful.

Physical efficiency is related to economic efficiency. For example, a power plant may be profitable in economic terms even though its physical efficiency in converting units of energy in coal to electrical energy may be relatively low. As an example, in the conversion of energy in a certain plant, assume that the physical efficiency is only 36%. Assuming that output Btu's in the form of electrical energy have an economic worth of $14.65 per million and that input Btu's in the form of coal have an economic cost of $1.80 per million, then

$$\text{efficiency (economic)} = \frac{\text{Btu output} \times \text{worth of electricity}}{\text{Btu input} \times \text{cost of coal}}$$

$$= 0.36 \times \frac{\$14.65}{\$1.80} = 293\%.$$

Since physical processes are of necessity carried out at efficiencies less than 100% and economic ventures are feasible only if they attain efficiencies greater than 100%, it is clear that in feasible economic ventures the economic worth per unit of physical output must always be greater than the economic cost per unit of physical input. Consequently, economic efficiency must depend more upon the worth and cost per unit of physical outputs and inputs than upon physical efficiency. Physical efficiency is always significant, but only to the extent that it contributes to economic efficiency.

In the final evaluation of most ventures, even those in which engineering plays a leading role, economic efficiencies must take precedence over physical efficiencies. This is because the function of engineering is to create utility in the economic environment by altering elements of the physical environment.

1.4 THE ENGINEERING PROCESS

Engineering activities dealing with elements of the physical environment take place to meet human needs that arise in an economic setting, as was illustrated by Figure 1.1. The engineering process employed from the time a particular need is recognized until it is satisfied may be divided into a number of phases. These phases are discussed in this section.

1.4.1 Determination of Objectives

One important phase of the engineering process involves the search for new objectives for engineering application—to find out what people need and want that can be supplied by engineering. In the field of invention, success is not a direct result of the fabrication of a new device; rather, it depends upon the capability of the invention to satisfy human wants. Thus, market studies seek to learn what the desires of people are. Automobile manufacturers make surveys to learn what me-