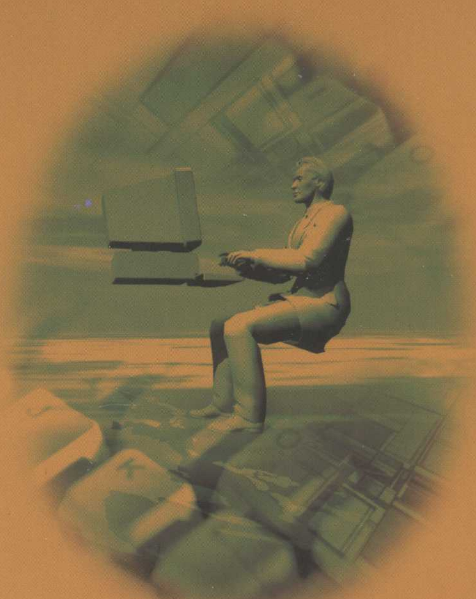
高等院校规划教材

GongChengJingJi GaiLun

工程经济概论

白 越 韩国波 主编



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工程经济概论

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内 容 提 要

本教材分四章内容详细讲述，第 1 章是工程经济学介绍，包括概念、起源与原理；第 2 章是成本概念和设计经济学，主要介绍各类成本概念、易损平衡概念与计算，产品寿命周期等内容；第 3 章是货币—时间关系和等价原理，包括等值的概念、常用计算式与应用、常用复利计算形式的求解方法等；第 4 章工程经济学的其他命题及应用。为方便师生教学，书后附有部分疑难单词、词组和短语的解释，课后问题的答案，离散型复利计算表三项内容。

本书主要供普通高等院校工程管理专业、土木工程专业、水利水电工程专业、建筑与环境工程以及其他类工程专业的本科和专科双语教学之用，也可供广大热爱工程经济学的读者参阅。

前　言

工程经济学是高等学校工程管理专业的主干技术基础课程，也是土木工程专业、水利水电工程专业、建筑与环境工程以及其他类工程专业的重要专业基础课。但随着世界经济一体化的趋势和中国加入WTO，我国对精通外语的专业人才的需求在不断增加。为迅速缩短与世界先进国家的差距，更好地了解发达国家的教育模式与教材的使用情况，按照教育部的统一部署，我国普通高等院校有针对地开展了双语教学的教学模式，目的是使高等院校学生通过对外文原版专业课教材的学习，双语教学的教授方式，了解国际上发达国家同类课程的设置内容以及与之接轨的切入点。在高校中开展双语教学，采用外文原版教材，直接学习、了解工程经济学（尤其是经济发达国家）的主要内容、掌握工程经济学的基本原理、分析方法，对解决工程中的事前可行性研究和决策方案的确定、事中的信息反馈和方案的调整、事后的效果评价和社会影响，都是非常重要的。

本教材是编者通过多年双语教学实践经验，参考 WilliamG(美)《Engineering Economy》一书以及有关资料而编写的，教材以工程经济学的基本概念为主要出发点，旨在对工科类应用型本科教育培养复合外向型人才，使他们在掌握比较完善的工程技术知识的同时，又具备对工程项目进行经济分析、多方案的设计以及在可选方案中进行决策的基本理念和方法。为应用型本科教育走向世界提供必要的技术保障。教材主要内容包括：工程经济学的基础，包括概念和起源；基本原理与方法；工程经济学理论的应用范畴等。旨在为高等院校工科专业学生提供双语专业课外文原版教材，从而掌握工程经济学的基本概念和方法。

本书由白越、韩国波主编。其中，第一章由韩国波编写，第二、三章由白越编写，第四章由卫赵斌编写。

由于编者水平有限，教材中难免存在一些错误和不妥之处，恳请读者给予批评指正。

编　者

2009年6月

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Contests

Chapter 1 Introduction to Engineering Economy

The objectives of chapter 1 are to (1) introduce the subject of engineering economy, (2) discuss its critical role in engineering design and analysis, (3) discuss the basic principles of the subject, and (4) provide and overview of the book.

The following topics are discussed in this chapter.

(1) The importance of this subject in engineering practice.

(2) Origins of engineering economy.

(3) Engineering economy and the design process.

(4) Accounting and engineering economy studies.

(5) Overview of the book.

1.1 Introduction

The technological and social environments in which we live continue to change at a rapid rate. In recent decades, advances in science and engineering have made space travel possible, transformed our transportation systems, revolutionized the practice of medicine, and miniaturized electronic circuits so that a computer can be placed on a semiconductor chip. The list of such achievements seems almost endless. In your science and engineering courses, you will learn about some of the physical laws that underlie these accomplishments.

The utilization of scientific and engineering knowledge for our benefit is achieved through the design of things we use, such as machines, structures, products, and services. However, these achievements don't occur without a price, monetary or otherwise. Therefore, the purpose of this book is to develop and illustrate the principles and methodology required to answer the basic economic question of any design: Do its benefits exceed its costs?

The Accreditation Board for Engineering and Technology states that 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."* In this definition, the economic aspects of engineering are emphasized, as well as the physical aspects. Clearly, it is essential that the economic part of engineering practice be accomplished well.

Engineering Economy involves the systematic evaluation of the economic merits of proposed solution to engineering problem. To be economically acceptable (i. e., affordable),

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* Accreditation Board of Engineering and Technology, Criteria for Accrediting Programs in Engineering the United States (New York: 1998, ABET, Baltimore, MD).

solutions to engineering problems must demonstrate a positive balance of long-term benefits over long-term costs, and they must also

- **promote the well-being and survival of an organization.**
- **embody creative and innovative technology and ideas.**
- **permit identification and scrutiny of their estimated outcomes. and**
- **translate profitability to the "bottom line" through a valid and acceptable measure of merit.**

Therefore, engineering economy is the dollars-and-cents side of the decisions that engineers make or recommend as they work to position a firm to be profitable in a highly competitive marketplace. Inherent to these decisions are trade-offs among different types of costs and the performance (response time, safety, weight, reliability, etc.) provided by the proposed design or problem solution. The mission of engineering economy is to balance these trade-offs in the most economical manner.

For instance, if an engineer at Ford Motor Company invents a new transmission lubricant that increases fuel mileage by 10% and extends the life of the transmission by 30,000 miles, how much can the company afford to spend to implement this invention? Engineering economy can provide an answer.

A few more of the myriad situations in which engineering economy plays a crucial role come to mind:

(1) Choosing the best design for a high-efficiency gas furnace.

(2) Selecting the most suitable robot for a welding operation on an automotive assembly line.

(3) Making a recommendation about whether jet airplanes for an overnight delivery service should be purchased or leased.

(4) Determining the optimal staffing plan for a computer help desk.

From these illustrations, it should be obvious that engineering economy includes significant technical considerations. Thus, engineering economy involves technical analysis, with emphasis on the economic aspects, and has the objective of assisting decisions. This is true whether the decision maker is an engineer interactively analyzing alternatives at a computer-aided design workstation or the Chief Executive Officer (CEO) considering a new project. An engineer who is unprepared to excel at engineering economy is not properly equipped for his or her job.

1.2 Origins of Engineering Economy

Cost considerations and comparisons are fundamental aspects of engineering practice. This basic point was emphasized in Section 1.1. However, the development of engineering economy methodology, which is now used in nearly all engineering work, is relatively recent. This does not mean that, historically, costs were usually overlooked in engineering decisions. However, the perspective that ultimate economy is a primary concern to the engineer and the availability of sound techniques to address this concern differentiate this aspect of modern engineering practice from that of the past.

A pioneer in the field was Arthur M. Wellington,* a civil engineer, who in the latter part of the nineteenth century specifically addressed the role of economic analysis in engineering projects. His particular area of interest was railroad building in the United States. This early work was followed by other contributions in which the emphasis was on techniques that depended primarily on financial and actuarial mathematics. In 1930, Eugene Grant published the first edition of his textbook.** This was a milestone in the development of engineering economy as we know it today. He placed emphasis on developing an economic point of view in engineering, and (as he stated in the preface) "this point of view involves a realization that quite as definite a body of principles governs the economic aspects of an engineering decision as governs its physical aspects." In 1942, Woods and DeGarmo wrote the first edition of this book, later titled Engineering Economy.

1.3 The Principles of Engineering Economy

The development, study, and application of any discipline must begin with a basic foundation. We define the foundation for engineering economy to be a set of principles, or fundamental concepts, that provide a comprehensive doctrine for developing the methodology. These principles will be mastered by students as they progress through this book. However, in engineering economic analysis, experience has shown that most errors can be traced to some violation of or lack of adherence to the basic principles can be discussed in terms of seven principles.

PRINCIPLE 1—DEVELOP THE ALTERNATIVES:

The choice(decision) is among alternatives. The alternatives need to be identified and then defined for subsequent analysis.

A decision situation involves making a choice among two or more alternatives. Developing and defining the alternatives for detailed evaluation is important because of the resulting impact on the quality of the decision. Engineers and managers should place a high priority on this responsibility. Creativity and innovation are essential to the process.

One alternative that may be feasible in a decision situation is making no change to the current operation or set of conditions (i.e., doing nothing). If you judge this option feasible, make sure it is considered in the analysis. However, do not focus on the status quo to the detriment of

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* A. M. Wellington, The Economic Theory of Railway Location, 2nd ed. (New York: John Wiley & Sons, 1887).

** E. L. Grant, Principles of Engineering Economy (New York: The Ronald Press Company, 1930), The definition of the principles of engineering economy varies somewhat with different authors.

Examples of other definitions may be found in the following works:

(1) E.L. Grant, W. G. Ireson, and R. S. Leavenworth, Principles of Engineering Economy, 8th ed. (New York: John Wiley & Sons, 1990).

(2) Report titled "Research Planning Conference for Developing a Research Framework for Engineering Economics," Gerald j. Thuesen (editor), Georgia Institute of Technology, March1986.

The report was the result of National Science Foundation Grant WEA-8501237.

innovative or necessary change.

PRINCIPLE 2—FOCUS ON THE DIFFERENCES:

Only the differences in expected future outcomes among the alternatives are Relevant to their comparison and should be considered in the decision.

If all prospective outcomes of the feasible alternatives were exactly the same, there would be no basis or need for comparison. We would be indifferent among the alternatives and could make a decision using a random selection.

Obviously, only the differences in the future outcomes of the alternatives are important . Outcomes that are common to all alternatives can be disregarded in the comparison and decision. For example, if your feasible housing alternatives were two residences with the same purchase (or rental) price, price would be inconsequential to your final choice. Instead, the decision would depend on other factors, such as location and annual operating and maintenance expenses. This example illustrates, in a simple way, Principle 2, which emphasizes the basic purpose of an engineering economic analysis: to recommend a future course of action based on the differences among feasible alternatives.

PRINCIPLE 3—USE A CONSISTENT VIEWPOINT:

The prospective outcomes of the alternatives, economic and other, should be consistently development from a defined viewpoint(perspective).

The perspective of the decision maker, which is often that of the owners of the firm, would normally be used. However, it is important that the viewpoint for the particular decision be first defined and then used consistently in the description, analysis, and comparison of the alternatives.

As an example, consider a public organization operating for the purpose of developing a river basin, including the generation and wholesale distribution of electricity from dams on the river system. A program is being planned to upgrade and increase the capacity of the power generators at two sites. What perspective should be used in defining the technical alternatives for the program? The "owners of the firm" in this example means the segment of the public that will pay the cost of the program and their viewpoint should be adopted in this situation.

Now let us look at an example where the viewpoint may not be that of the owners of the firm. Suppose that the company in this example is a private firm and that the problem deals with providing a flexible benefits package for the employees. Also, assume that the feasible alternatives for operating the plan all have the same future costs to the company. The alternatives, however, have differences from the perspective of the employees, and their satisfaction is an important decision criterion. The viewpoint for this analysis and decision should be that of the employees of the company as a group, and the feasible alternatives should be defined from their perspective.

PRINCIPLE 4—USE A COMMON UNIT OF MEASURE:

Using a common unit of measurement to enumerate as many of the prospective outcomes as possible will simplify the analysis and comparison of the alternative.

It is desirable to make as many prospective outcomes as possible commensurable(directly comparable). For economic consequences, a monetary unit such as dollars is the common measure. You should also try to translate other outcomes (which do not initially appear to be economic) into the monetary unit. This translation, of course, will not be feasible with some of the outcomes, but the additional effort toward this goal will enhance commensurability and make the subsequent analysis and comparison of alternatives easier.

What should you do with the outcomes that are not economic (i.e., the expected consequences that cannot be translated (and estimated) using the monetary unit)?

First, if possible, quantify the expected future results using an appropriate unit of measurement for each outcome. If this is not feasible for one or more outcomes, describe these consequences explicitly so that the information is useful to the decision maker in the comparison of the alternatives.

PRINCIPLE 5—CONSIDER ALL RELEVANT CRITERIA:

Selection of a preferred alternative (decision making) requires the use of a criterion (or several criteria). The decision process should consider both the outcomes enumerated in the monetary unit and those expressed in some other unit of measurement or made explicit in a descriptive manner.

The decision maker will normally select the alternative that will best serve the long-term interests of the owners of the organization. In engineering economic analysis, the primary criterion relates to the long-term financial interests of the owners. This is based on the assumption that available capital will be allocated to provide maximum monetary return to the owners. Often, though, there are other organizational objectives you would like to achieve with your decision, and these should be considered and given weight in the selection of an alternative. These nonmonetary attributes and multiple objectives become the basis for additional criteria in the decision-making process.

PRINCIPLE 6—MAKE UNCERTAINTY EXPLICIT:

Uncertainly is inherent in projecting (or estimating) the future outcomes of the alternatives and should be recognized in their analysis and comparison.

The analysis of the alternatives involves projecting or estimating the future consequences associated with each of them. The magnitude and the impact of future outcomes of any course of action are uncertain. Even if the alternative involves no change from current operations, the probability is high that today's estimates of, for example, future cash receipts and expenses will not be what eventually occurs. Thus, dealing with uncertainty is an important aspect of engineering economic analysis and is the subject of further studies.

PRINCIPLE 7—REVISIT YOUR DECISIONS:

Improved decision making results from an adaptive process, to the extent Practicable, the initial projected outcomes of the selected alternative should be subsequently compare with actual result achieved.

A good decision-making process can result in a decision that has an undesirable outcome. Other decisions, even though relatively successful, will have results significantly different from the initial estimates of the consequences. Learning from and adapting based on our experience are essential and are indicators of a good organization.

The evaluation of results versus the initial estimate of outcomes for the selected alternative is often considered impracticable or not worth the effort. Too often, no feedback to the decision-making process occurs. Organizational discipline is needed to ensure that implemented decisions are routinely postevaluated and that the results used to improve future analyses of alternatives and the quality of decision making. The percentage of important decisions in an organization that are not postevaluated should be small. For example, a common mistake made in the comparison of alternatives is the failure to examine adequately the impact of uncertainty in the estimates for selected factors on the decision. Only postevaluations will highlight this type of weakness in the engineering economy studies being done in an organization.

1.4 Engineering Economy and the Design Process

An engineering economy study is accomplished using a structured procedure and mathematical modeling techniques. The economic results are then used in a decision situation that involves two or more alternatives and normally includes other engineering knowledge and input.

A sound engineering economic analysis procedure incorporates the basic principles discussed in Section 1.3 and involves several steps. We represent the procedure, and will discuss it later in this section, in terms of the seven steps listed in the left hand column of Table 1-1. There are several feedback loops (not shown) within the procedure. For example, within Step 1, information developed in evaluating the problem will be used as feedback to refine the problem definition. As another example, information from the analysis of alternatives (Step 5) may indicate the need to change one or more of them or to develop additional alternatives.

The seven-step procedure is also used to assist decision making within the engineering design process, shown as the right-hand column in Table 1-1. In this case, activities in the design process contribute information to related steps in the economic analysis procedure. The general relationship between the activities in the design process and the steps of the economic analysis procedure is indicated in Table 1-1.

Table 1-1 The General Relation between the Engineering Economic Analysis Procedure and the Engineering Design Process

Engineering Economic Analysis Procedure	Engineering Design Process
Step	Activity
Problem recognition, definition, and evaluation	Problem/need definition
Development of the feasible alternatives	Problem/need formulation and evaluation
Development of the outcomes and cash flows for each alternative	Synthesis of possible solutions (alternatives)
Selection of a criterion (or criteria)	Analysis, optimization, and evaluation
Analysis and comparison of the alternatives	Specification of preferred alternative
Selection of the preferred alternative	Communication
Performance monitoring and post-evaluation of results	

Middendorf* states that "engineering design is an iterative, decision making activity whereby scientific and technological information is used to produce a system, device, or process which is different, in some degree, from what the designer knows to have been done before and which is meant to meet human needs." Also, we want to meet the human needs economically as emphasized in the definition of engineering in Section 1.1.

The engineering design process may be repeated in phases to accomplish a total design effort. For example, in the first phase, a full cycle of the process may be undertaken to select a conceptual or preliminary design alternative. Then, in the second phase, the activities are repeated to develop the preferred detailed design based on the selected preliminary design. The seven-step economic analysis procedure would be repeated as required to assist decision making in each phase of the total design effort. This procedure is discussed next.

1.4.1 Problem Definition

It is not adequate simply to think about a perplexing question or situation. Rather, a problem must be well understood and stated in an explicit form before the project team proceeds with the rest of the analysis. The first step of the engineering economic analysis procedure (problem definition) is particularly important, since it provides the basis for the rest of the analysis.

The term problem is used here generically. It includes all decision situations for which an engineering economy analysis is required. Recognition of the problem is normally Stimulated by internal or external organizational needs or requirements. An operating problem within a company (internal need) or a customer expectation about a product or service (external requirement) are examples.

Once the problem is recognized, its formulation should be viewed from a systems perspective. That is, the boundary or extent of the situation needs to be carefully defined, thus establishing the elements of the problem and what constitutes its environment.

Evaluation of the problem includes refinement of needs and requirements, and information from the evaluation phase may change the original formulation of the problem. In fact, redefining the problem until a consensus is reached may be the most important part of the problem-solving process!

1.4.2 Development of Alternatives**

The two primary actions in Step 2 of the procedure are (1) searching for potential alternatives and (2) screening them to select a smaller group of feasible alternatives for detailed analysis and comparison in Step 5. The term feasible here means that each alternative selected for

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* W. H. Middendorf, Design of Devices and Systems (New York: Marcel Dekker, Inc., 1986).

** This is sometimes called option development. This important step is described in detail in A. B. VanGundy, Techniques of Structured Problem Solving, 2nd ed. (New York: Van Nostrand Reinhold Co.,1988). For additional reading, see E. Lumsdaine and M. Lumsdaine, Creative Problem Solving An Introductory Course for Engineering Students (New York: McGraw-Hill Book Co., 1990), and J. L. Adams, Conceptual Blockbusting A Guide to Better Ideas (Reading, MA: Addison-Wesley Publishing Co.,1986).

further analysis is judged, based on preliminary evaluation, to meet or exceed the requirements established for the situation.

1.4.2.1 Searching for Superior Alternatives

In the discussion of Principle 1 (Section 1.3), creativity and resourcefulness were emphasized as being absolutely essential to the development of potential alternatives. The difference between good alternatives and great alternatives depends largely on an individual's or group's problem-solving efficiency. Such efficiency can be increased in the following ways:

(1) Concentrate on redefining one problem at a time in Step 1.

(2) Develop many redefinitions for the problem.

(3) Avoid making judgments as new problem definitions are created.

(4) Attempt to redefine a problem in terms that are dramatically different from the original Step 1 problem definition.

(5) Make sure that the true problem is well researched and understood.

In searching for superior alternatives or identifying the true problem, several limitations invariably exist, including (1) lack of time and money, (2) preconceptions engineer or project team will be working with less-than-perfect problem solutions in the practice of engineering.

EXAMPLE 1-1

The management team of a small furniture-manufacturing company is under pressure to increase profitability in order to get a much-needed loan from the bank to purchase a more modern pattern-cutting machine. One proposed solution is to sell waste wood chips and shavings to a local charcoal manufacturer instead of using them to fuel space heaters for the company's office and factory areas.

(1) Define the company's problem. Next, reformulated problems in creative ways.

(2) Develop at least one potential alternative for your reformulated problems in part (1). (Don't concern yourself with feasibility at this point.)

SOLUTION

(1) The company's problem appears to be that revenues are not sufficiently covering costs. Several reformulations can be posed:

a. The problem is to increase revenues while reducing costs.

b. The problem is to maintain revenues while reducing costs.

c.The problem is an accounting system that provides distorted cost information.

d. The problem is that the new machine is really not needed (and hence there is no need for a bank loan).

(2) Based only on reformulation 1, an alternative is to sell wood chips and shavings as long as increased revenue exceeds extra expenses that may be require to heat the buildings. Another alternative is to discontinue the manufacture of specialty items and concentrate on standardized, high-volume products. Yet another alternative is to pool purchasing, accounting, engineering, and other white-collar support services with other small firms in the area by contracting with a local company involved in providing these services.