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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 an overview of the book. The following topics are discussed in this chapter:

- The importance of this subject in engineering practice
- Origins of engineering economy
- The principles of engineering economy
- Engineering economy and the design process
- Accounting and engineering economy studies
- Overview of the book

I

Background and Tools of Engineering Economy

[Engineering] Is the Art of Doing That Well with One Dollar Which any Bungler Can Do with Two . . .

— A. M. Wellington, *The Economic Theory of the Location of Railways*, John Wiley & Sons, New York, 1887

1.1 Introduction

The changes occurring in the technological and social environments in which we live are continuing 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 judgement 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 as well as the physical aspects are emphasized. Therefore, it is essential that the economic part of engineering practice be accomplished effectively.

> *Engineering economy* is the discipline concerned with the economic aspects of engineering, and involves the systematic evaluation of the costs and benefits of proposed technical and business projects and ventures. The principles and methodology of engineering economy are an integral part of the daily management and operation of private sector companies and corporations, regulated public utilities, government units or agencies, and nonprofit organizations. They are utilized to analyze alternative uses of financial resources, particularly in relation to the physical assets and the operation of an organization. Last, but certainly not least, engineering economy will prove to be invaluable to you in assessing the economic merits of alternative uses of your personal funds.

*Accreditation Board of Engineering and Technology, "Criteria for Accrediting Programs in Engineering in the United States," New York, 1990.

In the operation of an organization, engineers and managers use engineering economy to assist with decision making in situations such as the following:

1. Selecting among alternative preliminary designs, or alternative detailed designs, as part of the engineering design process.
2. Estimating and analyzing the economic consequences of alternative automation improvements in a factory operation.
3. Selecting among proposed projects within the annual capital budget limits established in a corporation.
4. Analyzing whether the transportation equipment in the service fleet should be replaced, and at what rate.
5. Choosing between asset lease and purchase options to support a new product line within a company.

This list could go on. However, the importance of the subject to engineers and managers employed in either the private or public sector of the economy is obvious from these examples.

Engineering economic analysis, which is used interchangeably with *engineering economy*, usually includes significant technical considerations. Conceptually, engineering economic analysis is the same as that used in most other types of technical analysis. Thus, engineering economy involves technical analysis, with emphasis on the economic aspects, and has a decision-assisting objective. 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.

Engineers and other personnel engaged in management will find this subject vital to the accomplishment of their assigned responsibilities and to the achievement of their career goals. The experience of the authors and the corroborative experience of others clearly indicate the high use and utility of engineering economy in today's workplace. An engineer who is unprepared to excel at engineering economic analysis 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 of relatively recent origin. This does not mean that, historically, costs have usually been 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 past practices.

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. Even though Grant relied on the mathematics of finance as a basic part of the methodology, he definitively established that engineering economy was not just the use of these techniques in engineering problems. 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."

The development of engineering economy over more than a century, similar to the development of most fields of knowledge, has incorporated concepts from a number of other disciplines. This development and assimilation process has occurred rather rapidly in the past 50 years. Accounting, finance, microeconomics, and engineering—combined with modeling and analysis—have provided an initial core of knowledge from which the evolutionary development proceeded.

1.3 What Are the Principles of Engineering Economy?

The development, study, and application of any discipline must begin with a basic foundation. The foundation for engineering economy is a set of principles, or fundamental concepts, that provide a sound basis for development of the methodology.‡ These principles must be adhered to. However, in engineering economic analysis experience has shown that most errors can be traced to some violation or lack of adherence to the basic principles. We will define and discuss the foundation of the discipline in terms of seven principles.

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

†Eugene 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. Eugene L. Grant, W. Grant Ireson, and Richard S. Leavenworth, *Principles of Engineering Economy*, 8th ed. (New York: John Wiley and Sons, 1989).
2. G. A. Fleischer, *Engineering Economy: Capital Allocation Theory* (Monterey, Calif: Brooks/Cole Engineering Division, 1984).
3. Report titled "Research Planning Conference for Developing a Research Framework for Engineering Economics," Gerald J. Thuesen (editor), Georgia Institute of Technology, March 1986. The report was the result of National Science Foundation Grant MEA-8501237.

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 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, it is only differences in the future outcomes of the alternatives that are important. Those outcomes 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, this consideration would be inconsequential to your final choice. Instead, the decision would depend on other factors such as location and annual operating and maintenance costs. This 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 developed from a defined viewpoint (perspective).

The perspective of the decision maker, which often is that of the owners of the firm, would normally be used. However, it is important that the viewpoint for the particular decision is 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 river basin development, 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 dam sites. What perspective should be used in defining the technical alternatives for the program? The "owners of the firm," in this example, is the segment of the public that will pay the cost of the program as well as benefit from it, and that perspective should be used.

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 the problem deals with providing a flexible benefit 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, comparison, 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 make easier the analysis and comparison of the alternatives.

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

What should you do with the outcomes that are not economic, that is, the expected consequences that cannot be translated (and estimated) using the monetary unit? First, if possible, enumerate 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 criteria). The decision process should consider 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: Uncertainty 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. Estimating the magnitude and the impact of future outcomes of any course of action is uncertain. Even if the alternative involves no change from current operations, the probability is high that today's estimates of future cash receipts and disbursements, for example, will not be what eventually occurs. Thus, dealing with uncertainty is an important aspect of engineering economic analysis and is the subject of Chapters 10 and 15.

PRINCIPLE 7—REVISIT YOUR DECISIONS: Improved decision making results from an adaptive process; to the extent practicable, initial projected outcomes of the selected alternative and actual results achieved should be subsequently compared.

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 whether in the private or public sector of our economy, they 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 postevaluations of implemented decisions are routinely accomplished and 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 on the decision of uncertainty in the estimates for selected factors. Only postevaluations will highlight this of weakness in the engineering economy studies being done in an organi tion.

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 p ciples discussed in Section 1.3 and involves several steps. We represent procedure, and will discuss it later in this section, in terms of the *seven* s listed in the first column of Figure 1-1. There are several feedback loops (shown) within the procedure. For example, within Step 1, information de

Engineering Economic Analysis Procedure	*Engineering Design Process*
Step	*Activity*
1. Problem recognition, formulation, and evaluation.	1. Problem/need definition.
	2. Problem/need formulation an evaluation.
2. Development of the feasible alternatives.	3. Synthesis of possible solution (alternatives).
3. Development of the net cash flow for each alternative. 4. Selection of a criterion (or criteria). 5. Analysis and comparison of the alternatives.	4. Analysis, optimization, and evaluation.
6. Selection of the preferred alternative.	5. Specification of preferred alternative. 6. Communication.
7. Performance monitoring and post-evaluation of results.	

FIGURE 1-1 The General Relationship Between the Economic Analysis Procedure and the Engineering Design Process

oped in evaluating the problem will be used as feedback to refine the problem definition. As another example, information from the analysis of alternatives may indicate the need to change one or more of them or to develop additional alternatives.

An engineering economic analysis is often used to address a specific problem or decision situation. For example, the study may involve the replacement of a piece of equipment, the manufacture of a component versus purchase from a vendor, and so on. In these separate applications, all steps in the procedure are done for the study. However, the seven-step procedure is also used to assist decision making within the engineering design process. In this case, activities in the design process (second column of Figure 1-1) contribute information to related steps in the economic analysis procedure and reduce the total effort required. The general relationship between the activities in the design process and the steps of the procedure is indicated by their listings in Figure 1-1.

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.

4.1 Problem Definition

It is not adequate to simply think about a perplexing question or situation. Rather, a problem must be well understood and stated in an explicit form before proceeding 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 economic 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.

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*W. H. Middendorf, *Design of Devices and Systems* (New York: Marcel Dekker, Inc., 1986), p. 2.

Once recognized, formulation of the problem should be viewed from a *syst perspective*. That is, the boundary or extent of the situation needs to be caref defined, thus establishing the elements of the problem and what constitute environment.

Evaluation of the problem includes refinement of needs and requireme and information from the evaluation phase may change the original formula of the problem. In fact, redefining the problem may be the most important of the problem-solving process!

1.4.2 Search for Alternatives*

The two primary actions in Step 2 of the procedure are (1) developing the of potential alternatives and (2) evaluating (screening) them to select a sma group of feasible alternatives for detailed analysis and comparison in Step The term *feasible* here means that each alternative selected for further analy is judged, based on preliminary evaluation, to meet or exceed the specificati established for the situation.

In the discussion of Principle 1 (Section 1.3), creativity and resourcefuln were emphasized as being absolutely essential to the development of feasi alternatives. The difference between good alternatives and great alternati depends largely on an individual's or group's *problem-solving efficiency*. Such ficiency can be increased in the following ways: (1) develop many redefinitio for the problem in Step 1, (2) concentrate on redefining one problem at a tim (3) avoid making judgments as new problem definitions are created, (4) tempt to redefine a problem in terms that are dramatically different from t original Step 1 problem statement, and (5) make sure that the true problem well researched and understood. In Step 2 a systems approach, as shown Figure 1-2, is essential to an efficient search for problem solutions (i.e., feasib alternatives).

This approach uses a systems perspective to identify potential alternati solutions. Then, based on consideration of the related external and intern factors, several feasible alternatives are identified which merit detailed analysi When implemented, each of these alternatives is judged capable of achievin the desired results.

When searching for alternatives, several limitations invariably exist, includin (1) lack of time and money, (2) preconceptions of what will and what will n work, and (3) lack of knowledge. Consequently, the analyst will be workin with less than perfect problem solutions in the practice of engineering.

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

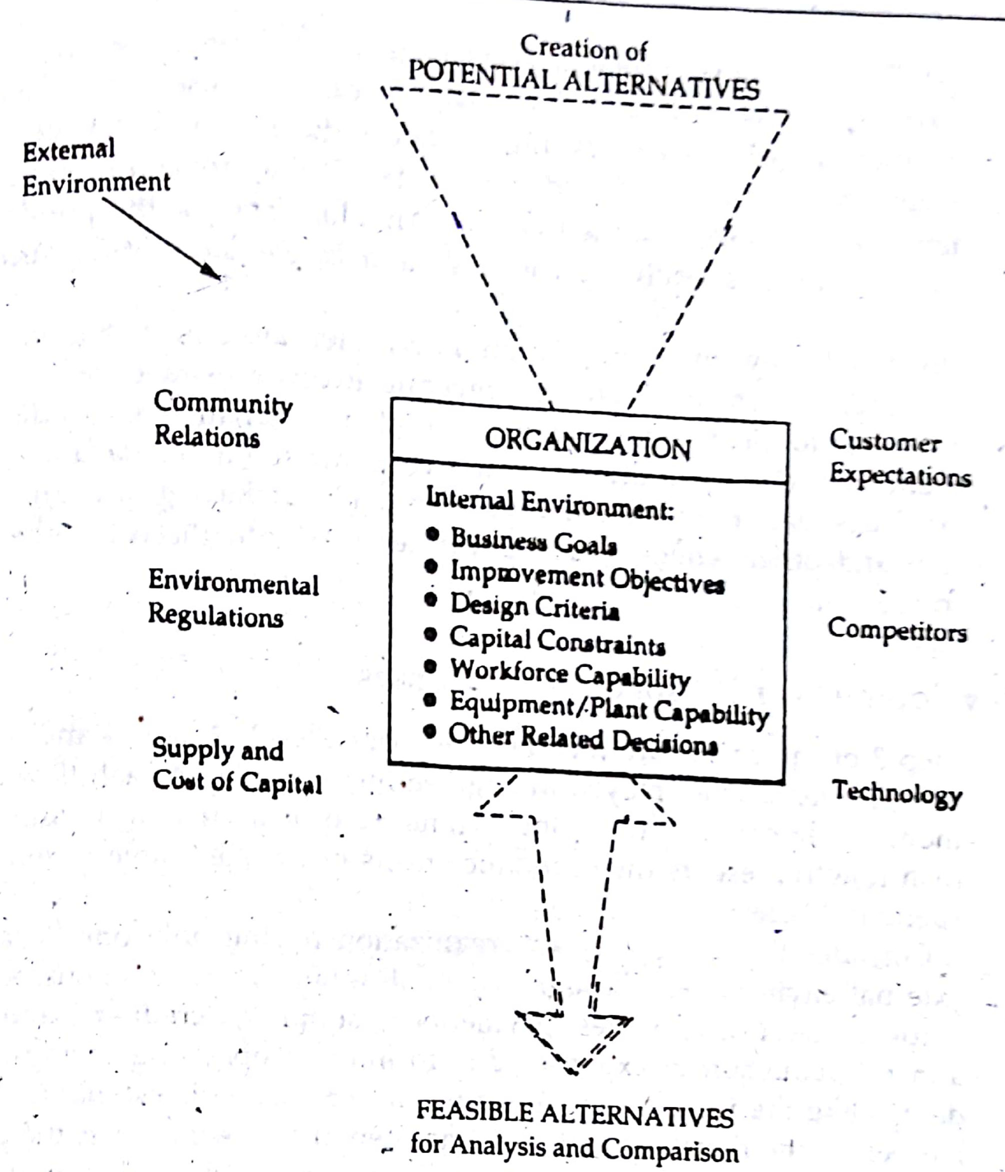

FIGURE 1-2 Systems Approach to Select the Feasible Alternatives

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.

(a) Formulate the company's problem. Next, reformulate the problem in a variety of creative ways.

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

Solution

(a) The company's problem appears to be that revenues are not sufficiently covering costs. Several reformulations can be posed; for example, (1) the problem is to increase revenues while reducing costs, (2) the problem is to maintain revenues while reducing costs, (3) the problem is an accounting system that provides distorted cost information, and (4) the problem is that the new machine is really not needed (and hence there is no need for a bank loan).

(b) 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 required 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 those of other small firms in the area. ∎

1.4.3 Development of Prospective Outcomes

Step 3 of the procedure incorporates Principles 2, 3, and 4 and uses the basic *cash flow approach* employed in engineering economy. A cash flow occurs when money is transferred from one organization or individual to another. Thus, a cash flow represents the economic effects of an alternative in terms of money spent and received.

Consider the concept of an organization having only one "window" to its external environment through which all monetary transactions occur—for example, receipt of revenues; payments to suppliers, creditors, and employees; and the reduction in expenses due to internal operating savings. The key to developing the related cash flows for an alternative is estimating what would happen to the revenues and costs, as seen at this window, if the particular alternative were implemented. The *cash flow* for an alternative is the difference between all cash inflows (receipts or savings) and cash outflows (costs or expenses) during each time period.

In addition to the economic aspects of decision making, *nonmonetary factors (attributes)* often play a significant role in the final recommendation. Examples of objectives other than profit maximization or cost minimization that can be important to an organization include the following:

1. Meeting or exceeding customer expectations.
2. Safety.
3. Improving employee satisfaction..
4. Maintaining production flexibility to meet changing demands.
5. Meeting or exceeding all environmental requirements.
6. Achieving good public relations; being an exemplary member of the community.
7. Leveling cyclic fluctuations in production.

1.4.4 Selection of Decision Criteria and Analysis of Alternatives

The selection of decision criteria (Step 4 of the analysis procedure) incorporates Principle 5. The decision maker will normally select the alternative that will best serve the long-term interests of the owners of the organization. Analysis of the economic aspects of an engineering decision situation (Step 5) is largely based on the cash flows developed for the feasible alternatives. The consideration of uncertainty in the estimates (Principle 6) may also be required, as well as a focus on the differences in cash flows between each pair of alternatives (Principle 2).

1.4.5 Selection of the Preferred Alternative

When the first five steps of the engineering economic analysis procedure have been done properly, the preferred alternative (Step 6) is simply a result of the total effort. Thus, the soundness of the technical-economic modeling and analysis techniques dictates the quality of the results obtained and the recommended course of action.

Step 6 is included in Activity 5 of the engineering design process (specification of the preferred alternative) when done as part of a design effort.

1.4.6 Performance Monitoring and Postevaluation of Results

This final step implements Principle 7 and is accomplished during and after the results achieved from the selected alternative have been collected. Monitoring project performance during its operational phase improves the achievement of related goals and objectives, as well as reducing the variability in desired results. Step 7 is also the follow-up step to a previous analysis that compares actual results achieved with the previously estimated outcomes. The aim is to learn how to do better analyses, and the feedback from postimplementation evaluation is important to the continuing improvement of operations in any organization. Unfortunately, like Step 1, this final step is often not done consistently or well in engineering practice; therefore it needs particular attention to ensure feedback for use in ongoing and subsequent studies.

EXAMPLE 1-2

An engineering project team has been organized in your corporation to reanalyze the size of a new office and service support building being designed and to review the use of other space. The problem under review concerns the projected increase in requirements for laboratory space (26%) and personnel space (11%). Due to the status of the detailed design effort, it is important that the team present a recommendation to management within 7 weeks on the best way to meet these additional space requirements. Discuss representative activities of the team in terms of the previous discussion of engineering economy and the design process.

Solution The team began its effort with a detailed examination of the additional space requirements and a review of the design results to date. The following information was obtained from the design process and other sources as part of problem definition:

1. The foundation and structural design will permit the addition of two floors to the six presently planned for the building. Each floor has 22,000 gross square feet of space.
2. The heating, ventilation, and air conditioning (HVAC) system is planned for six floors. The detailed design of the system has not started, but the cost of a larger HVAC system would have to be included if additional floors were added.
3. The additional laboratory space (26%) and personnel space (11%) will require 31,500 gross square feet.
4. There is a time constraint. The need for the new building space is urgent.
5. Additional money for the new building, beyond that already allocated, is limited.

The team, in the search for alternatives, worked as a group to develop a list of potential alternatives to meet future space needs. Then, the team (1) developed in more detail the constraints, the internal and external requirements, and the desired outcomes related to space needs and (2) screened the potential alternatives using this information and a systems approach. The result was the identification of three feasible alternatives:

1. Add two floors to the design of the new building.
2. Rehabilitate some existing storage space for laboratory space and rent the additional space needed for personnel and storage.
3. Rent the additional space required for laboratories and personnel.

The team, in accomplishing the analysis and comparison of the feasible alternatives, decided that an appropriate period for the study was 15 years, and the primary decision criterion was minimizing costs. However, other criteria such as meeting the time constraint and causing minimum disruption to present operations would be considered. Then the relevant cost data and other information needed for the analysis were developed and organized. The team leader at this point divided the team into three working groups. Each group was assigned to estimate the economic consequences in cash flow form and to organize other information relevant to the decision for one alternative. After the groups finished, the whole team reviewed the cash flow and other information for each alternative. They found, when all costs were considered, that Alternative 2 was slightly better. However, Alternatives 2 and 3 were equal regarding schedule (time constraint), and Alternative 3 was preferred regarding minimizing the disruption of current operations. Alternative 1 was considered infeasible (after the detailed analysis) due to the additional funds required immediately for the new building if two floors were added to the design and due to the longer schedule that would result.

Based on these results, the team, in selecting the preferred alternative, decided to recommend Alternative 2. They completed the documentation of their analysis and submitted the report and final recommendation to senior management. Included in the report was an implementation plan for Alternative 2. In addition, as part of communicating the results, the team prepared and gave to management personnel a comprehensive briefing on their analysis and recommended course of action. After meeting with the engineering team early in the seventh week, management approved Alternative 2 for implementation. ▪

.5 Accounting and Engineering Economy Studies

In Section 1.1, we emphasized that engineers and managers use the principles and methodology of engineering economy to assist decision making. Thus, engineering economy studies provide information upon which current decisions pertaining to the *future* operation of an organization can be based.

After a decision to invest capital in a project has been made and the money has been invested, those who supply and manage the capital want to know the financial results. Therefore, accounting procedures are established so that financial events relating to the investment can be recorded and summarized and *financial performance* determined. At the same time, through the use of proper financial information, controls can be established and utilized to aid in guiding the operation toward the desired financial goals. *General accounting* and *cost accounting* are the procedures that provide these necessary services in a business organization. Thus, accounting data are primarily concerned with *past* and *current* financial events even though such data are often used to make projections about the future.

Accounting procedures are similar to recording data in a scientific experiment. A recorder reads the pertinent gauges and meters and records all the essential data during the course of an experiment. From these data it is possible to determine the results of the experiment and to prepare a report. Similarly, an accountant records all significant financial events connected with an investment and the operation of an organization, and from these data he or she can determine what the results have been and can prepare financial reports. Just as an engineer, by understanding what is happening during the course of an experiment and making suitable corrections, can gain more information and better results from the experiment, managers must also rely on accounting reports to make corrective decisions in order to improve the current and future financial performance of the business.

General accounting is a source of much of the past financial data needed in making estimates of future financial conditions. Accounting is also a source of data for analyses that might be made regarding how well the results of a capital investment turned out compared to the results that were predicted in the engineering economic analysis.

Cost accounting, or management accounting, is a phase of accounting that is of particular importance because it is concerned principally with decision making and control in a firm. Consequently, it is the source of some of the data that are needed in engineering economy studies. Modern cost accou may satisfy any or all of the following objectives:

1. Determination of the cost of products or services.
2. Provision of a rational basis for pricing goods or services.
3. Provision of a means for controlling expenditures.
4. Provision of information on which operating decisions may be based and results evaluated.

Although the basic objectives of cost accounting are simple, the exact de mination of costs usually is not. As a result, some of the procedures used arbitrary conventions that make it possible to obtain reasonably accurate c in some situations, but in many others the information is too aggregated a distorted to be relevant in managerial planning and control decisions.

Some of the inaccuracies of traditional cost accounting techniques have b remedied by a relatively recent methodology known as *activity-based accounti* This methodology is aimed at producing more accurate and timely cost inf mation primarily by (1) carefully tracing overhead to its causal activities a (2) assigning technology costs equitably over the entire product life cycle. cause overhead and technology account for as much as 60% of total prod cost in many industries, improved cost reporting and control is made po ble by being able to trace these two major cost components to activities, a subsequently products, that truly create them.

An adequate understanding of the origins and meaning of accounting data necessary to be able to interpret that data for use in engineering economy stu ies. Thus, a brief discussion of accounting, including activity-based accountin is provided in Appendix A.

1.6 Overview of the Book

The contents of this book have been organized in three parts, with the chapte in a logical sequence for both teaching and applying the principles and metho ology of engineering economy. The three parts of the book, and the chapters i each part, are:

1. Part I: Background and Tools of Engineering Economy (Chapters 1–3).
2. Part II: Applications of Engineering Economy (Chapters 4–12).
3. Part III: Special Topics in Engineering Economy (Chapters 13–17).

In this first chapter, after a general discussion of the subject and its impor tance to the engineer, we presented the fundamental concepts of engineerin economy in terms of seven basic principles; discussed the steps involved in a engineering economic analysis as well as their relationships to the principles and then related the analysis procedure to the engineering design process. Th interface between accounting and engineering economy was also discussed Thus, in Chapter 1, the basic foundation of the subject has been established.

In Chapter 2, selected cost terms and other cost concepts important in engineering economy studies are presented. Particular emphasis is placed on the life cycle and its relative costs. The application of selected cost concepts is also discussed, including breakeven analysis, the average unit cost function, and present economy studies. Thus, in Chapter 2 the foundation of the subject is further extended to support the subsequent development and application of the methodology.

Chapter 3 concentrates on the concepts of money–time relationships, specifically the development of proper techniques to consider the time value of money in manipulating the future revenues and costs associated with an alternative (course of action). Then in Chapter 4 the methods commonly used in practice to analyze the economic consequences of an alternative are developed and demonstrated. These methods, and their proper use in the analysis and comparison of alternatives, are primary subjects of Chapter 5. Included in Chapter 5 is a discussion of the appropriate time period for an analysis, as well as other topics related to the comparison of alternatives on a before-tax basis. Thus, Chapters 3, 4, and 5 together develop and discuss an essential part of the methodolgy needed for understanding the remainder of the book and for performing engineering economy studies on a before-tax basis.

In Chapter 6 and Chapter 7 , the additional techniques required to accomplish engineering economy studies on an after-tax basis are developed and discussed. In the private sector, most engineering economy studies are done on an after-tax basis. Therefore, these two chapters add to the basic part of the methodology developed in Chapters 3, 4, and 5. A major portion of Chapter 6 is concerned with depreciation under the modified accelerated cost recovery system authorized by the Tax Reform Act of 1986. However, techniques applicable to assets acquired prior to the effective date of the act are also included. Similarly, the emphasis in Chapter 7 is on performing after-tax analysis under the Tax Reform Act of 1986.

Chapter 8 considers the critical question of how to develop estimates of the future economic consequences associated with an alternative. The process associated with this step in an engineering economic analysis constitutes a crucial part of application and practice. This topic is placed in Chapter 8, instead of earlier in the book, so that the basic methodology of analyzing and comparing the estimated revenues and costs associated with alternatives on both a before-tax and an after-tax basis can be discussed in an integrated manner. Consequently, the development of these estimates of economic impact for an alternative is given concentrated attention in a chapter dedicated to this subject.

The consideration of inflation (or deflation) and price changes is the topic of Chapter 9. This important subject needs to be understood by engineers in current practice. The concepts for handling price changes in an engineering economic analysis are discussed both comprehensively and pragmatically from an application viewpoint.

The concern over uncertainty is a reality in engineering practice. Chapter 10 considers the impact of potential variation between the estimated economic outcomes of an alternative and the results that may occur are considered; that is, nonprobabilistic techniques for analyzing the consequences of uncertainty in future estimates of revenues and costs are developed and discussed.

The analysis of whether existing assets should be continued in service or replaced with new assets to meet current and future operating needs is a frequent question within an organization. In Chapter 11, techniques for addressing this question are developed and discussed. Since the replacement of assets results in a significant demand for capital, decisions made in this area are important and require particular attention.

Replacement of assets is one source of demand for capital in an organization. In Chapter 12 the proper identification and analysis of all projects and other needs for capital within an organization, and the capital financing and capital allocation process to meet these needs, are addressed. This process is crucial to the welfare of an organization since it affects most operating outcomes, whether in terms of current product quality and service effectiveness or long-term capability to compete in the world marketplace.

Privately owned, regulated public utilities are an important part of the U.S. economy. In Chapter 13, the unique characteristics of these firms, and the revenue requirements method of accomplishing engineering economy studies related to their operations, are discussed.

Numerous public works projects are authorized, financed, and operated by local, state, and federal agencies. The subject of Chapter 14 is how to conduct engineering economy studies for such public projects by using the benefit-cost ratio technique.

In Chapter 15, probabilistic techniques for analyzing the consequences of uncertainty in future cash flow estimates are discussed. Discrete and continuous probability concepts, as well as Monte Carlo simulation techniques, are included.

Chapter 16 presents techniques for simultaneously dealing with economic (monetary) and nonmonetary factors (attributes) when multiple objectives are involved in the decision. More and more decisions involve the explicit consideration of nonmonetary factors in choosing a course of action.

Computer spreadsheet programs are used extensively in engineering economic analysis to organize and process data. In Chapter 17, a practical discussion of spreadsheet programs with engineering economy examples is provided to facilitate this important area of study and practice.

1.7 Summary

In this first chapter, we have provided an introduction to the discipline of engineering economy, including a brief summary of its background and continuing development. The importance to an engineer of having a good working knowledge of the principles and methodology of the subject in today's workplace was emphasized. The engineer who is unprepared to handle the economic aspects of an engineering decision just as competently as its physical aspects is not properly equipped to perform his or her total job.

The application of the principles and methodology of engineering economy normally occurs in a decision-making situation with two or more alternatives, and involves other engineering knowledge and input. This is true whether the decision maker is an engineer involved in an alternative design question or a senior manager considering a new project. Thus, as business continues to become more technical, the engineering and management functions are increasingly interconnected and the importance of engineering economy to the operation of an organization increases.

The foundation for engineering economy is a set of fundamental concepts that provide a sound basis for the development and application of the methodology. We have delineated and discussed these fundamental concepts in terms of seven principles. These principles are incorporated in the steps for accomplishing engineering economic analysis, and this affects the economic aspects of engineering design. Therefore, your understanding of them is critical in engineering practice. In summary, here are the seven principles:

1. Develop the alternatives.
2. Focus on the differences (among alternatives).
3. Use a consistent viewpoint (in estimating outcomes).
4. Use a common unit of measure (the monetary unit to the maximum extent).
5. Consider all relevant criteria.
6. Make uncertainty explicit.
7. Revisit your decisions.

8 Problems

1. List 10 typical situations in the operation f an organization where an engineering eco- iomic analysis would significantly assist deci- ion making. You may assume a specific type of rganization (e.g., manufacturing firm, medical ealth center and hospital, transportation com- any, government agency, etc.) if it will assist i the development of your answer (state any ssumptions). (1.1)*

. Explain why the subject of engineering onomy is important to the practicing engineer. .1–1.4)

. Assume that your employer is a manu- cturing firm that produces several different ectronic consumer products. What are five onmonetary factors (attributes) that may be important when a significant change is considered in the design of the current best-selling product? (1.3, 1.4)

1-4. Will the increased use of automation increase the importance of engineering economy studies? Why or why not?

1-5. Explain the meaning of the statement "the choice (decision) is among alternatives." (1.3)

1-6. Describe the outcomes that should be expected from a feasible alternative. What are the differences between potential alternatives and feasible alternatives? (1.4)

1-7. Define uncertainty. What are some of the basic causes of uncertainty in engineering economy studies? (1.3)

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number(s) in parentheses at the end of a problem refer to the section(s) in that chapter most closely related to e problem.