

An Overview of Engineering Economic Analysis

LEARNING OBJECTIVES

When you have finished studying this chapter, you should be able to:

- 1.1** Apply the four discounted cash flow (DCF) rules to simple time value of money (TVOM) situations. (Section 1.1)
- 1.2** Identify the 10 principles of engineering economic analysis that can be used by all engineers in analyzing the economic performance of the products, processes, and systems they design. (Section 1.2)
- 1.3** Identify the seven steps of the systematic economic analysis technique (SEAT) used to perform engineering economic analyses. (Section 1.3)

Engineering Economics in Practice

Walmart

In fiscal year (FY) 2018, Walmart (WMT) employed more than 2.2 million people worldwide, including 1.5 million in the United States. Its revenue surpassed \$500 billion for the first time and it returned \$14.4 billion to shareholders. As of January 31, 2018, Walmart had a total of 11,700 stores serving nearly 270 million customers a week operating in 28 countries including Walmart U.S., Sam's Club U.S., and Walmart International. Walmart eCommerce sales grew 44% to \$11.5 billion.

A major factor in Walmart's success has been the efficiency of its supply chain. Walmart was among the first to adopt electronic data interchange (EDI), allowing it to pay vendors for products purchased by customers in its stores. The real-time management of money across its thousands of stores has contributed significantly to Walmart's economic performance.

Walmart is an international leader in logistics, and its distribution network includes approximately 150 distribution centers and 50 transportation offices. It has one of the largest

distribution operations in the world, servicing stores, clubs, and direct delivery to customers. Walmart transportation has a fleet of 6,100 tractors, 61,000 trailers, and more than 7,800 drivers. It has 6 disaster distribution centers, strategically located across the United States and stocked to provide rapid response in the event of a natural disaster. In FY 2018 alone Walmart responded to the devastating damage caused by hurricanes impacting Puerto Rico, Texas, and Florida, and an earthquake in Mexico with relief supplies to assist communities in distress.

Walmart was a pioneer in the use of radio frequency identification (RFID) to do real-time tracking of products throughout the supply chain. In recent years, Walmart has targeted sustainability and worked with its vendor community to dramatically reduce the amount of waste arriving at and leaving from its stores in the form of packing and packaging materials. Its engineers work with vendors' engineers to significantly reduce energy consumption in distributing the products it sells and to increase energy efficiency in its stores.

Walmart continues to be innovative via digitizing experiences to make it easier and faster for customers to shop and more efficient for associates to manage inventory and serve customers. Its eCommerce business continues to expand. In FY 2018, it nearly doubled the number of stores offering online grocery pickup to more than 1,100 locations in the United States with plans to add another 1,000 in FY 2019. Online grocery shopping will expand also in Canada, Mexico and China. In FY 2018, Walmart has shifted its spending from opening new stores to remodels, eCommerce, supply chain, and technology to position itself for the future.

Robert Thompson's Financial Planning

Robert Thompson is a recent engineering graduate who desires to invest a portion of his annual income each year. He is unsure about the kind of investments he should make—stocks, bonds, mutual funds, U.S. Treasury notes, certificates of deposit, rental property, land, and so on. Also, he is undecided

about how much of his annual income he should set aside for investment. Further, he does not know what annual return he should expect to earn on his investments. Finally, he wonders how long it will take for him to achieve his financial goals.

Discussion Questions

1. What do the preceding two examples have in common?
2. What role does engineering economic analysis play in these scenarios?
3. Is an engineering economic analysis just as relevant for the complicated business transactions at Walmart as for Robert Thompson's much simpler transactions?
4. Compare the length of the financial planning horizon that each investor (Walmart and Robert) is considering. Are they the same or different?

Introduction

The subject matter of this text is variously referred to as *economic analysis*, *engineering economy*, *economic justification*, *capital investment analysis*, or *economic decision analysis*. Traditionally, the application of economic analysis techniques in the comparison of engineering design alternatives has been referred to as *engineering economy*. The emergence of a widespread interest in economic analysis in public-sector decision making, however, has brought about greater use of the more general term *economic analysis*. We define *engineering economic analysis* as using a combination of quantitative and qualitative techniques to analyze *economic differences* among engineering design alternatives in selecting the preferred design.

In this text we use a *cash flow approach* to the subject. A cash flow occurs when money actually changes hands from one individual to another or from one organization to another. Thus, money received and money dispersed (spent or paid) constitutes a cash flow.

It is always tempting to skip the first chapter of an engineering textbook. It would be a big mistake to do so here, however. You will build on the foundation concepts introduced in this chapter throughout the rest of your study of engineering economics.

1.1 Time Value of Money

LEARNING OBJECTIVE

Apply the four discounted cash flow (DCF) rules to simple time value of money (TVOM) situations.



Video Lesson:
Time Value of Money

Time Value of Money (TVOM) The value of a given sum of money depends on both the amount of money and the point in time when the money is received or paid.

A fundamental concept underlies much of the material covered in the text: Money has a time value. This means that the value of a given sum of money depends on both the amount of money and the point in time when the money is received or paid. Just as in construction the placement of forces along a beam matters in designing structures, so the placement in time of money received or paid matters when evaluating the economic worth of an investment.

EXAMPLE 1.1 | The Time Value of Money Illustrated

To illustrate the time value of money (TVOM) concept, suppose a wealthy individual approaches you and says, “Because of your outstanding ability to manage money, I am prepared to present you with a tax-free gift of \$1,000. If you prefer, however, I will postpone the presentation for a year, at which time I will guarantee that you will receive a tax-free gift of \$ X .” (For purposes of this example, assume that the guarantee is risk-free.) In other words, you can choose to receive \$1,000 today or receive \$ X 1 year from today. Which would you choose if X equals (1) \$1,000, (2) \$1,050, (3) \$1,100, (4) \$1,500, (5) \$2,000, (6) \$5,000, (7) \$10,000, (8) \$100,000?

Solution In presenting this situation to students in our classes, none preferred to receive \$1,000 a year from now instead of receiving \$1,000 today. Also, none preferred to receive \$1,050 a year from now instead of \$1,000 today. Gradually, as the value of X increased, more and more students switched from preferring \$1,000 today to preferring \$ X a year from now. Not surprisingly, every student preferred to receive \$100,000 a year from now to receiving \$1,000 today. Also, it was no surprise that all students preferred to receive \$10,000 a year from now to receiving \$1,000 today. The greatest debate and uncertainty among the students concerning which amount to choose occurred when X was between \$1,100 and \$2,000.

For each student, some value (or range of values) of \$ X exists for which the student is indifferent—that is, has no preference—about receiving \$1,000 today versus receiving \$ X a year from today. If a student is indifferent when X equals \$1,200, then we would conclude that \$1,200 received 1 year from now has a *present value* or *present worth* of \$1,000 for that particular student in his or her current circumstances. We would conclude that this student’s TVOM is 20%.

From students’ responses to the questions posed in the preceding example, patterns have been noted in the choices they make. Several indicate a very strong need for money now, not later. Their personal circumstances are such that they do not believe they can wait a year to receive the money, even if they will receive significantly more at that time. Others are skeptical regarding the guarantee of the money being available a year later—they resort to the “bird in the hand, versus many birds in the bush” philosophy.

Such responses occur in industry as well. Corporate executives exhibit similar tendencies when faced with current versus deferred choices.

1.1.1 Earning Power Versus Inflation

Occasionally, students claim that inflation will make the future amount of money worth less to them. While it is certainly true that inflation, which represents a decrease in the purchasing power of money, will diminish the present worth of a future sum of money, money has time value even in the absence of inflation. (Chapter 10 will examine the effects of inflation on engineering economic decisions.)

Why do we claim that money has time value in the absence of inflation? Because money has “earning power.” If you own money and someone else temporarily needs it, you can loan it to them and charge them interest. The interest rate you charge should be based on your TVOM. After all, if you loan it to someone, then you can no longer invest it; hence, you forego the opportunity to earn a return on your money. The lost opportunity should factor into how much you charge someone for using your money. Because of this, the TVOM is sometimes referred to as the opportunity cost of money.

Other terms used to express the TVOM are *interest rate*, *discount rate*, *hurdle rate*, *minimum attractive rate of return*, and *cost of capital*. These terms will be used somewhat interchangeably throughout the text. In the first few chapters, however, interest rate and discount rate are used most frequently.

1.1.2 Discounted Cash Flows

Discounted Cash Flow (DCF) The movement of money forward or backward in time.

Another term used in financial circles and throughout the text is **discounted cash flows**, often referred to as DCF. Originally, DCF referred to the process of using the TVOM or discount rate to convert all future cash flows to a present single sum equivalent.¹ Today, DCF tends to refer to any movement of money backward or forward in time.

The fact that money has a time value changes how mathematical operations involving money should be performed. Simply stated, because money has a time value, one should not add or subtract money unless it occurs at the same point in time.

Having introduced the notion of new rules for dealing with money, we can now summarize the four DCF rules:

1. Money has a time value.
2. Quantities of money cannot be added or subtracted unless they occur at the same point in time.
3. To move money forward one time unit, multiply by 1 plus the discount or interest rate.
4. To move money backward one time unit, divide by 1 plus the discount or interest rate.

EXAMPLE 1.2 | Applying the Four DCF Rules

Recall the previous example, where the student's TVOM was 20%. Suppose the student is guaranteed to receive \$1,100 one year from today, and nothing thereafter, if \$1,000 is invested today in a particular venture. What is the return on the student's investment?

Solution It would be a mistake for the student to subtract the \$1,000 investment from the \$1,100 return and conclude that the investment yielded a net positive return of \$100. Why? Rule 1 establishes that money has a time value; for this student, it can be represented by a 20% annual rate. Rule 2 establishes that the \$1,000 investment cannot be subtracted from the \$1,100 return, because they occur at different points in time.

So, what should the student do? Apply either Rule 3 or Rule 4. Using Rule 3, the student would conclude that the *future value* or *future worth* of the \$1,000 investment, based on a 20% TVOM, equals $\$1,000(1.20)$ or \$1,200 one year later. Because the \$1,000 was an expenditure or investment, it is a negative cash flow, whereas the \$1,100 return on the investment was a positive cash flow. Hence, the net future worth of the investment is $-\$1,200 + \$1,100$, or $-\$100$. Because the future worth is negative, the investment would not be considered a good one by the student.

Using Rule 4, the student would conclude that the *present value* or *present worth* of \$1,100 a year from now equals $\$1,100/1.20$, or \$916.67. Therefore, the \$1,000 investment yields a negative net present value of \$83.33. Again, the student should conclude that the investment was not a good one. Note that different conclusions would have occurred if the student's TVOM had been 8% instead of 20%.

By the way, if you did not understand the mathematics used here, don't worry. The mathematics of TVOM operations are covered in Chapters 2 and 3.

¹Strictly speaking, *compounded cash flow* means moving money forward in time and *discounted cash flow* means moving money backward in time; that is, using the TVOM to calculate a future value. This text, however, follows the generally accepted practice of using the term *discounted cash flow* or DCF to refer to the movement of money forward or backward in time.

Concept Check 01.01-CC001

Positive and negative cash flows occurring at varying points in time can simply be summed to determine a total cash flow. True or False?

[Answers may be found in all digital versions of the text.]

Concept Check 01.01-CC002

Money has time value:

- a. Because it has “earning power”
- b. Because of inflation
- c. Because it earns interest
- d. All of the above

[Answers may be found in all digital versions of the text.]

Concept Check 01.01-CC003

To move money forward one time unit:

- a. Divide by 1 plus the discount or interest rate
- b. Divide by the discount or interest rate
- c. Multiply by 1 plus the discount or interest rate
- d. Multiply by the discount or interest rate

[Answers may be found in all digital versions of the text.]

1.2

Engineering Economy Principles

LEARNING OBJECTIVE

Identify the 10 principles of engineering economic analysis that can be used by all engineers in analyzing the economic performance of the products, processes, and systems they design.

Throughout this text, basic principles are presented that all engineers can use in analyzing the economic performance of the products, processes, and systems they design. No matter how impressive or how sophisticated an engineering design might be, if it fails to “measure up” economically, it usually is doomed to failure.

The following 10 principles of engineering economic analysis provide a foundation for this text:

1. **Money has a time value.** This principle underlies almost everything we cover in the text. Due to the TVOM, we prefer to receive a fixed sum of money sooner rather than later; likewise, we prefer to pay a fixed sum of money later, rather than sooner. (Notice how many of the following principles are corollaries of the TVOM principle.)
2. **Make investments that are economically justified.** The second principle is captured in a succinct statement attributed to Henry Ford in the early 1900s: “If you need a new machine and don’t buy it, you pay for it without ever getting it.” The key to his quote is the word need; need indicates justification. The need can manifest itself in terms of cost reductions that will occur if a new machine is purchased, or the need can reflect the added business that will result from adding new manufacturing capacity or capability. Hence, if savings or revenues that will easily offset the purchase price of a new machine are foregone, then the new machine’s price is paid by continuing to incur higher costs than will occur with the new machine or by passing up the profits that will result from increased capacity or added capability.
3. **Choose the mutually exclusive investment alternative that maximizes economic worth.** This is a corollary of the first and second principles. The third principle addresses the situation when multiple investment alternatives exist and only one can be chosen. We refer to such investments as mutually exclusive. Note that the third principle considers only monetary aspects of the alternatives. Nonmonetary considerations may cause an alternative to be chosen that does not maximize economic worth. (The third principle is incorporated in Chapters 4, 5, and 6.)
4. **Two investment alternatives are equivalent if they have the same economic worth.** The fourth principle is an extension of the third, which states that for well-behaved cash flow profiles, the equivalence holds only for the TVOM that equates their economic worths. (Chapters 2 and 6 examine this principle more closely.)
5. **Marginal revenue must exceed marginal cost.** The fifth principle comes from a first course in economics. Based on this principle, one should not make an investment unless the added revenues are greater than the added costs. Based on the first principle, the TVOM must be used in comparing marginal revenues and marginal costs if they occur at different points in time.
6. **Continue to invest as long as each additional increment of investment yields a return that is greater than the investor’s TVOM.** The sixth principle, a corollary of the fifth principle, was verbalized in a statement made in 1924 by General Motors’ chief financial officer, Donald Brown: “The object of management is not necessarily the highest rate of return on capital, but . . . to assure profit with each increment of volume that will at least equal the economic cost of additional capital required.” The sixth principle can also be stated as follows: Use someone else’s money if you can earn more by investing it than you have to pay to obtain it. Of course, one must consider the risks involved in borrowing money in order to make good investments. (More will be devoted to this principle in Chapters 6, 9, 10, and 12.)
7. **Consider only differences in cash flows among investment alternatives.** In performing engineering economic analyses, decisions are made between alternatives; hence, costs and revenues common to all investment alternatives can be

ignored in choosing the preferred investment. (The seventh principle, which is also a corollary of the fifth principle, is at the heart of Chapters 4 through 11.)

- 8. Compare investment alternatives over a common period of time.** The eighth principle is often violated. When alternatives have useful lives that differ in duration, there is a temptation to compare the life cycle of one investment with the unequal life cycle of another. As you will learn, it is important to compare the alternatives over the same length of time. (We address this principle in this chapter, Chapters 4 through 6, and in Chapter 12.)
- 9. Risks and returns tend to be positively correlated.** The higher the risks associated with an investment, the greater the anticipated returns must be to justify the investment.
- 10. Past costs are irrelevant in engineering economic analyses, unless they impact future costs.** The tenth principle relates to past costs or investments made previously. Past costs that have no carryover effect in the future, also called *sunk costs*, must be ignored when performing an engineering economic analysis. (Applications of this principle will occur throughout the text.)

This text emphasizes the use of these 10 principles in choosing the best investment to make and addresses specific kinds of engineering investments. What kind of investments do we consider? When an existing production machine or process must be replaced, many alternatives are usually available as replacement candidates; but which one is best? Alternative candidates for replacement also exist when faced with replacing bridges, transformers, telecommunications base stations, computers, road surfaces, sewers, chemical mixers, furnaces, and so forth. Likewise, investments in existing equipment—such as overhauling the equipment or adding new features to extend its useful life or to add new production capability—are included in the text.

In designing a new product, many design decisions involve choosing from among alternatives. Some examples of choices include whether to use standardized parts that can be purchased or specially designed parts that must be produced; whether to enclose the product in a molded plastic case or a formed metal case; whether to use standard, replaceable batteries or a specially designed rechargeable battery; and whether to perform the manufacturing and assembly in-house versus outsourcing the manufacturing and assembly. Decisions must also be made regarding materials to use in construction and repair activities, as well as transportation alternatives for moving people and materials. Discounted cash flow methods also play a critical role in decisions regarding mergers, acquisitions, and disposition of manufacturing plants. Regardless of which branch of engineering is involved, numerous choices occur in designing and improving products, processes, and systems.

Finally, while this text emphasizes engineering applications, the material it presents can be of great personal value. The principles provided can be used to identify the best engineering design, product, process, or system, and to assist in personal investing. This is particularly true for the material presented in Chapters 2 and 3.

Concept Check 01.02-CC001

Investment alternatives should be compared over the same length of time. True or False?

[Answers may be found in all digital versions of the text.]

Concept Check 01.02-CC002

When choosing among mutually exclusive investments, multiple options may be selected. True or False?

[Answers may be found in all digital versions of the text.]

Concept Check 01.02-CC003

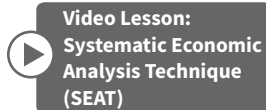
Past costs (or sunk costs) are irrelevant in engineering economic analysis, unless they impact future costs. True or False?

[Answers may be found in all digital versions of the text.]

1.3 Economic Justification of Capital Investments

LEARNING OBJECTIVE

Identify the seven steps of the systematic economic analysis technique (SEAT) used to perform engineering economic analyses.



In performing engineering economic analyses, it is helpful to follow a consistent methodology. The following 7-step systematic economic analysis technique (SEAT) is recommended:

1. Identify the investment alternatives.
2. Define the planning horizon.
3. Specify the discount rate.
4. Estimate the cash flows.
5. Compare the alternatives.
6. Perform supplementary analyses.
7. Select the preferred investment.

This text focuses particularly on step 5—comparing alternative investments in order to identify the best one—although several of the others also will be mentioned. Although typically not every step of this method is explicitly performed in the examples and problems in this text, you will need to understand the important concepts behind the steps. With this end in mind, the following sections take a closer look at each step.

1.3.1 SEAT Step 1 of 7: Identify the Investment Alternatives

Generally, the aim is to select the best investment from a feasible set of mutually exclusive and collectively exhaustive investment alternatives. “Mutually exclusive” as used here means “either/or but not both.” “Collectively exhaustive” means that no other investment alternatives are available—all possible investments are considered.

The collectively exhaustive assumption is critical. Care must be taken when forming the alternatives to ensure that all available alternatives are being considered.

A “do-nothing” alternative frequently is included in the set of feasible investment alternatives to be compared. Such an alternative is intended to represent “business as usual” or “maintaining the status quo.” Business conditions rarely stand still, however. Doing nothing does not mean that nothing will be done; rather, it could mean that management has opted to forego the opportunity to influence future events. The “do nothing” alternative often is used as a baseline against which other investment alternatives are compared.

In this text, as a matter of convenience, zero incremental costs often are associated with doing nothing. In practice, when the “do nothing” alternative is feasible, extreme care must be taken not to underestimate the cost of doing nothing. For many firms, business as usual is the most expensive alternative; “standing pat” for too long can be a disastrous course, because while the firm is doing nothing, its competitors are generally doing something.

1.3.2 SEAT Step 2 of 7: Defining the Planning Horizon

As noted in the eighth principle of engineering economic analysis, it is important to compare investment alternatives over a common period of time. In this text, this period of time is referred to as the **planning horizon**. For investments in, say, equipment to perform a required service, the period of time over which the service is required might be used as the planning horizon. Likewise, with one-shot investment alternatives, the period of time over which receipts continue to occur might define the planning horizon.

In a sense, the planning horizon defines the width of the “window” through which the economic performance of each investment alternative will be viewed. Using too short a planning horizon could preclude an investment that would yield very sizeable returns in the long run. Conversely, too long a planning horizon can result in the firm going out of business before realizing the promised long-term benefits.

When the lives of investment alternatives differ, five general approaches are used to determine the planning horizon’s length:

1. Set the planning horizon equal to the shortest life among the alternatives.
2. Set the planning horizon equal to the longest life among the alternatives.
3. Set the planning horizon equal to the least common multiple of the lives of the various alternatives.
4. Use a standard length horizon equal to the period of time that best fits the organization’s need, such as 10 years.
5. Use an infinitely long planning horizon.

Planning Horizon The period of time or width of the “window” over which the economic performance of each investment alternative will be viewed.

Approach #3, the least common multiple of lives, is a popular choice. When it is used, each alternative's cash flow profile is assumed to repeat in the future until all investment alternatives under consideration conclude at the same time. Such an assumption might be practical for some applications, but it can prove untenable for others. For example, assume Alternative A has a useful life of 4 years, Alternative B has a useful life of 5 years, and Alternative C has a useful life of 6 years. What is the least common multiple of 4, 5, and 6? The answer is 60. It does not seem realistic to assume that identical cash flow profiles will repeat over a period of 60 years.

Using the shortest life approach (#1) would establish the planning horizon's length for Alternatives A, B, and C as 4 years. With a 4-year planning horizon, one must estimate the value of the one remaining year of useful service for Alternative B. Similarly, one must estimate the value of the 2 years of useful service available with Alternative C.

The longest life approach (#2) would establish 6 years as the planning horizon for Alternatives A, B, and C. In this case, decisions must be made about the 2-year gap for Alternative A and the 1-year gap for Alternative B. Will identical replacements be made? If so, what will be their monetary values at the end of the planning horizon?

Next, we consider the impact of a standard planning horizon of, say, 10 years (approach #4). As before, it is assumed that identical replacements will occur. For Alternative A, 10 years represents two complete life cycles and one-half a life cycle. For the latter, a salvage value would have to be estimated. For Alternative B, 10 years represents two complete life cycles. For Alternative C, 10 years represents one full life cycle and one partial life cycle; thus, requiring another salvage value estimate.

Finally, we consider the infinitely long planning horizon (#5). Obviously, for many investments, it makes no sense to assume an indefinite planning horizon. When the least common multiple of lives is quite long, however, an infinitely long planning horizon will yield a reasonably good approximation.

1.3.3 SEAT Step 3 of 7: Specifying the Minimum Attractive Rate of Return

The chapters that follow will examine many investment opportunities, always using an interest rate to compound (move forward in time) or discount (move backward in time) cash flows. This interest rate is commonly referred to as the **minimum attractive rate of return** or MARR. The value used for the minimum attractive rate of return matters—a lot!

Because any investment will consume some portion of a firm's scarce resources, it is important for the investment to earn more than it costs to obtain the investment capital. In addition, the MARR should reflect the opportunity cost associated with investing in the candidate alternative as opposed to investing in other available alternatives. In fact, it is assumed that investment capital not committed to the candidate alternative is earning a return at least equal to the MARR. Generally, a company has multiple sources of capital: loans, bonds, stocks, and so on. Each has a different cost associated with it.

Because firms have multiple sources of capital, they typically calculate the **weighted average cost of capital (WACC)** and use it to establish a lower bound on the MARR. It is only a lower bound because certain unprofitable investments often are required. For example, investments made to ensure compliance with governmental regulations, to enhance employee morale, to protect lives, and to prevent injuries have positive returns, particularly if social costs and social returns are included. It is difficult to quantify such returns, however. Even though the returns are less than the WACC, these investments still

Minimum Attractive Rate of Return (MARR)

Also referred to as the *hurdle rate* or *discount rate*, the MARR is the minimum rate of return on an investment that a decision maker is willing to accept given the associated risk and the opportunity cost of other forgone investments.

Weighted Average Cost of Capital (WACC)

The WACC is a value calculated to establish the lower bound on the MARR and to take into account that most firms have multiple sources of capital.

will be made. For this reason, optional investments must earn more than enough to cover the WACC.

Capital available to a corporation can be categorized as either debt capital or equity capital. Examples of debt capital are bonds, loans, mortgages, and accounts payable; examples of equity capital are preferred stock, common stock, and retained earnings. Typically, capital for a particular investment consists of a mixture of debt and equity capital.

Although many variations are available, a widely accepted WACC formula is

$$\text{WACC} = (E/V) i_e + (D/V) i_d (1 - itr) \quad (1.1)$$

where E = a firm's total equity, expressed in dollars

D = a firm's total debt and leases, expressed in dollars

$V = E + D$, a firm's total invested capital

i_e = cost of equity or expected rate of return on equity, expressed in percent

i_d = cost of debt or expected rate of return on borrowing, expressed in percent

itr = corporate tax rate

The costs associated with debt capital are deductible from taxable income; however, the costs associated with equity capital are not deductible. As a result, $(1 - itr)$ is associated with debt capital but not equity capital.

1.3.4 SEAT Step 4 of 7: Estimate the Cash Flows

Once the planning horizon is determined, cash flow estimates are needed for each investment alternative for each year of the planning horizon. The Association for the Advancement of Cost Engineering International (www.aacei.org) defines cost estimating as

a predictive process used to quantify, cost, and price the resources required by the scope of an asset investment option, activity or project. As a predictive process, estimating must address risks and uncertainties. The outputs of estimating are used primarily as inputs for budgeting, cost or value analysis, decision making in business, asset and project planning, or for project cost and schedule control processes.

Cost estimating is not an exact science. Rather, it is an approximation that involves the availability and relevancy of appropriate historical data, personal judgments based on the estimator's experience, and the time frame available for completing the estimating activity.

1.3.5 SEAT Step 5 of 7: Comparing Alternatives

After the investment alternatives are identified, the planning horizon is defined, the discount rate is specified, and the cash flows are estimated, it is time to evaluate the alternatives in terms of their economic performance. When doing the comparison, it is necessary to select a criterion to use. Many options exist. In fact, two already have been presented. In Example 1.2, the investment was evaluated on the basis of its present value or present worth, as well as its future value or future worth. Later chapters will consider present worth analysis in more detail, as well as benefit-cost, payback period, discounted payback period, capitalized worth, future worth, annual worth, and rate of return analyses.

Depending on the particular type of investment as well as the country in which the investment is made, depreciation, income taxes, replacement, and inflation may need to be considered in comparing the alternatives. These topics also are covered in more detail in later chapters.

1.3.6 SEAT Step 6 of 7: Performing Supplementary Analyses

The sixth step in comparing investment alternatives is performing supplementary analyses. The intent of this step is to answer as many “what if” questions as possible. Up to this point, it has been assumed that the cash flow estimates, the length of the planning horizon, and the TVOM used were error free. Obviously, that will not always be the case. Conditions change, errors are made, and risks and uncertainties exist. In this step, risk and uncertainty are explicitly considered.

1.3.7 SEAT Step 7 of 7: Select the Preferred Investment

Selecting the preferred investment is the final step in a systematic engineering analysis. Because many factors must be considered in making the selection, the preferred investment may not be the one that performs best when considered using only the economic criteria.

Typically, multiple criteria exist rather than a single criterion of maximizing, say, present worth. The presence of multiple criteria coupled with the risks and uncertainties associated with estimating future outcomes makes the selection process quite complicated. To make this process easier, the engineer is encouraged to address as many of management’s concerns as possible in comparing the investment alternatives. If management’s concerns are adequately addressed, the selection decision will agree with the engineer’s recommendations.

The text concentrates on economic factors throughout. Keep in mind, however, that management’s ultimate choice may be based on a host of criteria rather than a single monetary criterion. Despite attempts to quantify all benefits in economic terms, some intangible factors or attributes probably will not be reduced to dollars. Consider, for example, such factors as improved safety, reduced cycle times, improved quality, increased flexibility, increased customer service, improved employee morale, being the first in the industry to use a particular technology, and increased market visibility. Clearly, some of these factors are more readily measured in economic terms than are others.

Concept Check 01.03-CC001

When identifying the investment alternatives:

- a. Identify mutually exclusive alternatives
- b. Identify collectively exhaustive alternatives
- c. Frequently include the “do nothing” alternative
- d. All of the above

[Answers may be found in all digital versions of the text.]

Concept Check 01.03-CC002

The period of time, or width of the “window,” over which alternatives will be compared is also known as the:

- a. Planning horizon
- b. Shortest life
- c. Minimum Attractive Rate of Return
- d. Do-nothing alternative

[Answers may be found in all digital versions of the text.]

Concept Check 01.03-CC003

When specifying the minimum attractive rate of return (MARR):

- a. Use the value 10%, as it is an easy multiple to work with
- b. Exercise caution in calculating it, as once it is defined, you can use it indefinitely for all future investments
- c. Ensure that it reflects the opportunity cost associated with investing in the candidate alternative as opposed to investing in other available alternatives
- d. Calculate the weighted average cost of capital (WACC) to establish the upper bound on the MARR

[Answers may be found in all digital versions of the text.]

Key Concepts

LEARNING OBJECTIVE 1.1: Apply the four discounted cash flow (DCF) rules to simple time value of money (TVOM) situations. (Section 1.1)

The four DCF rules state that

1. Money has a time value.
2. Quantities of money cannot be added or subtracted unless they occur at the same point in time.
3. To move money forward one time unit, multiply by 1 plus the discount or interest rate.
4. To move money backward one time unit, divide by 1 plus the discount or interest rate.

LEARNING OBJECTIVE 1.2: Identify the 10 principles of engineering economic analysis that can be used by all engineers in analyzing the economic performance of the products, processes, and systems they design. (Section 1.2)

The 10 principles of engineering economic analysis can be summarized as follows:

1. Money has a time value.
2. Make investments that are economically justified.

3. Choose the mutually exclusive investment alternative that maximizes economic worth.
4. Two investment alternatives are equivalent if they have the same economic worth.
5. Marginal revenue must exceed marginal cost.
6. Continue to invest as long as each additional increment of investment yields a return that is greater than the investor's TVOM.
7. Consider only differences in cash flows among investment alternatives.
8. Compare investment alternatives over a common period of time.
9. Risks and returns tend to be positively correlated.
10. Past costs are irrelevant in engineering economic analyses, unless they impact future costs.

LEARNING OBJECTIVE 1.3: Identify the seven steps of the systematic economic analysis technique (SEAT) used to perform engineering economic analyses. (Section 1.3)

The 7-step systematic economic analysis technique (SEAT) used to perform engineering economic analysis can be summarized as follows:

1. Identify the investment alternatives.
2. Define the planning horizon.
3. Specify the minimum attractive rate of return (MARR), also known as the *discount rate*.
4. Estimate the cash flows.
5. Compare the alternatives.
6. Perform supplementary analyses.
7. Select the preferred investment.