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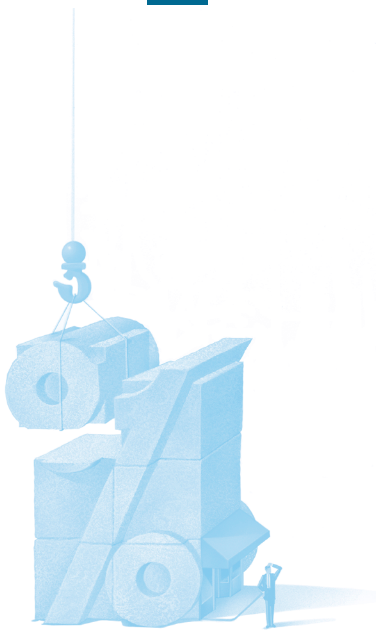


Basics of Financial Decisions

CHAPTER ONE

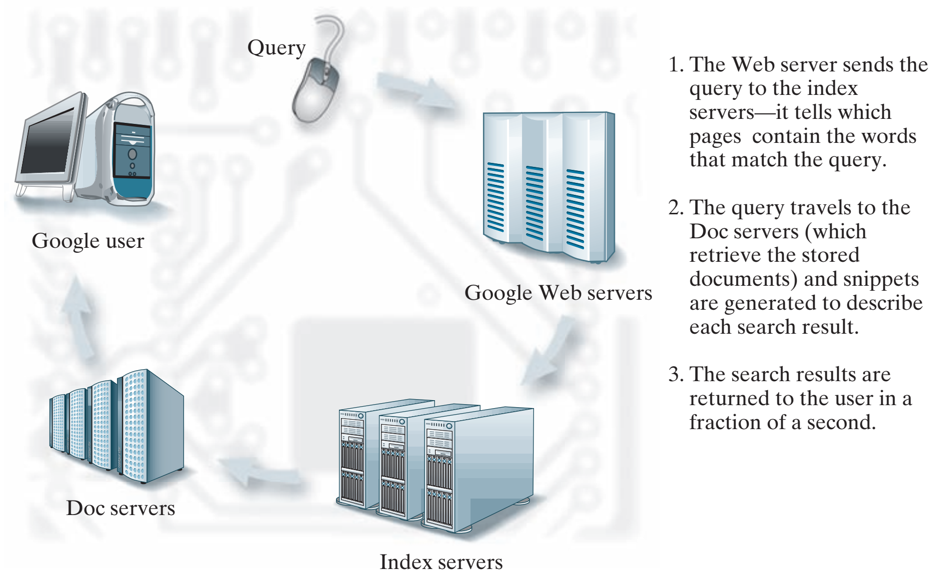
Engineering Economic Decisions

Google Cofounder Sergey Brin Comes to Class at Berkeley[1] Sergey Brin, cofounder of Google, showed up for class as a guest speaker at Berkeley on October 3, 2005. Casual and relaxed, Brin talked about how Google came to be, answered students' questions, and showed that someone worth $11 billion (give or take a billion) still can be comfortable in an old pair of blue jeans. Indistinguishable in dress, age, and demeanor from many of the students in the class, Brin covered a lot of ground in his remarks, but ultimately it was his unspoken message that was most powerful: To those with focus and passion, all things are possible. In his remarks to the class, Brin stressed simplicity. Simple ideas sometimes can change the world, he said. Likewise, Google started out with the simplest of ideas, with a global audience in mind. In the mid-1990s, Brin and Larry Page were Stanford students pursuing doctorates in computer science. Brin recalled that at that time there were some five major Internet search engines, the importance of searching was being de-emphasized, and the owners of these major search sites were focusing on creating portals with increased content offerings. "We believed we could build a better search. We had a simple idea—that not all pages are created equal. Some are more important," related Brin. Eventually, they developed a unique approach to solving one of computing's biggest challenges: retrieving relevant information from a massive set of data.

According to Google lore,[1] by January of 1996 Larry and Sergey had begun collaboration on a search engine called BackRub, named for its unique ability to analyze the "back links" pointing to a given website.

[1]*UC Berkeley News*, Oct. 4, 2005, UC Regents and Google Corporate Information: http://www.google.com/corporate/history.html.

How Google Works



Larry, who had always enjoyed tinkering with machinery and had gained some "notoriety" for building a working printer out of Lego® bricks, took on the task of creating a new kind of server environment that used low-end PCs instead of big expensive machines. Afflicted by the perennial shortage of cash common to graduate students everywhere, the pair took to haunting the department's loading docks in hopes of tracking down newly arrived computers that they could borrow for their network. A year later, their unique approach to link analysis was earning BackRub a growing reputation among those who had seen it. Buzz about the new search technology began to build as word spread around campus. Eventually, in 1998 they decided to create a company named "Google" by raising $25 million from venture capital firms Kleiner Perkins Caufield & Byers and Sequoia Capital. Since taking their Internet search engine public in August 2004, the dynamic duo behind Google has seen their combined fortune soar to $22 billion. At a recent $400, Google trades at 90 times trailing earnings, after starting out at $85. The success has vaulted both Larry and Sergey into *Forbes* magazine's list of the 400 wealthiest Americans. The net worth of the pair is estimated at $11 billion each.

A Little Google History

- 1995
  - Developed in dorm room of Larry Page and Sergey Brin, graduate students at Stanford University
  - Nicknamed BackRub
- 1998
  - Raised $25 million to set up Google, Inc.
  - Ran 100,000 queries a day out of a garage in Menlo Park
- 2005
  - Over 4,000 employees worldwide
  - Over 8 billion pages indexed

The story of how the Google founders got motivated to invent a search engine and eventually transformed their invention to a multibillion-dollar business is a typical one. Companies such as Dell, Microsoft, and Yahoo all produce computer-related products and have market values of several billion dollars. These companies were all started by highly motivated young college students just like Brin. One thing that is also common to all these successful businesses is that they have capable and imaginative engineers who constantly generate good ideas for capital investment, execute them well, and obtain good results. You might wonder about what kind of role these engineers play in making such business decisions. In other words, what specific tasks are assigned to these engineers, and what tools and techniques are available to them for making such capital investment decisions? We answer these questions and explore related issues throughout this book.

CHAPTER LEARNING OBJECTIVES

After completing this chapter, you should understand the following concepts:

- The role of engineers in business.
- Types of business organization.
- The nature and types of engineering economic decisions.
- What makes the engineering economic decisions difficult.
- How a typical engineering project idea evolves in business.
- Fundamental principles of engineering economics.

1.1 Role of Engineers in Business

Yahoo, Apple Computer, Microsoft Corporation, and Sun Microsystems produce computer products and have a market value of several billion dollars each. These companies were all started by young college students with technical backgrounds. When they went into the computer business, these students initially organized their companies as proprietorships. As the businesses grew, they became partnerships and were eventually converted to corporations. This chapter begins by introducing the three primary forms of business organization and briefly discusses the role of engineers in business.

1.1.1 Types of Business Organization

As an engineer, you should understand the nature of the business organization with which you are associated. This section will present some basic information about the type of organization you should choose should you decide to go into business for yourself.

The three legal forms of business, each having certain advantages and disadvantages, are proprietorships, partnerships, and corporations.

Proprietorships

A **proprietorship** is a business owned by one individual. This person is responsible for the firm's policies, owns all its assets, and is personally liable for its debts. A proprietorship has two major advantages. First, it can be formed easily and inexpensively. No legal and organizational requirements are associated with setting up a proprietorship, and organizational costs are therefore virtually nil. Second, the earnings of a proprietorship are taxed at the owner's personal tax rate, which may be lower than the rate at which corporate income is taxed. Apart from personal liability considerations, the major disadvantage of a proprietorship is that it cannot issue stocks and bonds, making it difficult to raise capital for any business expansion.

Partnerships

A **partnership** is similar to a proprietorship, except that it has more than one owner. Most partnerships are established by a written contract between the partners. The contract normally specifies salaries, contributions to capital, and the distribution of profits and losses. A partnership has many advantages, among which are its low cost and ease of formation. Because more than one person makes contributions, a partnership typically has a larger amount of capital available for business use. Since the personal assets of all the partners stand behind the business, a partnership can borrow money more easily from a bank. Each partner pays only personal income tax on his or her share of a partnership's taxable income.

On the negative side, under partnership law each partner is liable for a business's debts. This means that the partners must risk all their personal assets—even those not invested in the business. And while each partner is responsible for his or her portion of the debts in the event of bankruptcy, if any partners cannot meet their pro rata claims, the remaining partners must take over the unresolved claims. Finally, a partnership has a limited life, insofar as it must be dissolved and reorganized if one of the partners quits.

Corporations

A **corporation** is a legal entity created under provincial or federal law. It is separate from its owners and managers. This separation gives the corporation four major advantages: (1) It can raise capital from a large number of investors by issuing stocks and bonds; (2) it permits easy transfer of ownership interest by trading shares of stock; (3) it allows limited liability—personal liability is limited to the amount of the individual's investment in the business; and (4) it is taxed differently than proprietorships and partnerships, and under certain conditions, the tax laws favor corporations. On the negative side, it is expensive to establish a corporation. Furthermore, a corporation is subject to numerous governmental requirements and regulations.

As a firm grows, it may need to change its legal form because the form of a business affects the extent to which it has control of its own operations and its ability to acquire funds. The legal form of an organization also affects the risk borne by its owners in case of bankruptcy and the manner in which the firm is taxed. Apple Computer, for example, started out as a two-man garage operation. As the business grew, the owners felt constricted by this form of organization: It was difficult to raise capital for business expansion; they felt that the risk of bankruptcy was too high to bear; and as their business income grew, their tax burden grew as well. Eventually, they found it necessary to convert the partnership into a corporation.

In the United States, the overwhelming majority of business firms are proprietorships, followed by corporations and partnerships. However, in terms of total business volume (dollars of sales), the quantity of business transacted by proprietorships and partnerships is several times less than that of corporations. Since most business is conducted by corporations, this text will generally address economic decisions encountered in that form of ownership.

1.1.2 Engineering Economic Decisions

What role do engineers play within a firm? What specific tasks are assigned to the engineering staff, and what tools and techniques are available to it to improve a firm's profits? Engineers are called upon to participate in a variety of decisions, ranging from manufacturing, through marketing, to financing decisions. We will restrict our focus, however, to various economic decisions related to engineering projects. We refer to these decisions as **engineering economic decisions**.

In manufacturing, engineering is involved in every detail of a product's production, from conceptual design to shipping. In fact, engineering decisions account for the majority (some say 85%) of product costs. Engineers must consider the effective use of capital assets such as buildings and machinery. One of the engineer's primary tasks is to plan for the acquisition of equipment **(capital expenditure)** that will enable the firm to design and produce products economically.

With the purchase of any fixed asset—equipment, for instance—we need to estimate the profits (more precisely, cash flows) that the asset will generate during its period of service. In other words, we have to make capital expenditure decisions based on predictions about the future. Suppose, for example, you are considering the purchase of a deburring machine to meet the anticipated demand for hubs and sleeves used in the production of gear couplings. You expect the machine to last 10 years. This decision thus involves an implicit 10-year sales forecast for the gear couplings, which means that a long waiting period will be required before you will know whether the purchase was justified.

An inaccurate estimate of the need for assets can have serious consequences. If you invest too much in assets, you incur unnecessarily heavy expenses. Spending too little on fixed assets, however, is also harmful, for then the firm's equipment may be too obsolete to produce products competitively, and without an adequate capacity, you may lose a portion of your market share to rival firms. Regaining lost customers involves heavy marketing expenses and may even require price reductions or product improvements, both of which are costly.

1.1.3 Personal Economic Decisions

In the same way that an engineer can play a role in the effective utilization of corporate financial assets, each of us is responsible for managing our personal financial affairs. After we have paid for nondiscretionary or essential needs, such as housing, food, clothing, and transportation, any remaining money is available for discretionary expenditures on items such as entertainment, travel, and investment. For money we choose to invest, we want to maximize the economic benefit at some acceptable risk. The investment choices are unlimited and include savings accounts, guaranteed investment certificates, stocks, bonds, mutual funds, registered retirement savings plans, rental properties, land, business ownership, and more.

How do you choose? The analysis of one's personal investment opportunities utilizes the same techniques that are used for engineering economic decisions. Again, the challenge is predicting the performance of an investment into the future. Choosing wisely can be very rewarding, while choosing poorly can be disastrous. Some investors in the energy stock Enron who sold prior to the fraud investigation became millionaires. Others, who did not sell, lost everything.

A wise investment strategy is a strategy that manages risk by diversifying investments. With such an approach, you have a number of different investments ranging from very low to very high risk and are in a number of business sectors. Since you do not have all your money in one place, the risk of losing everything is significantly reduced. (We discuss some of these important issues in Chapters 12 and 13.)

1.2 What Makes the Engineering Economic Decision Difficult?

The economic decisions that engineers make in business differ very little from the financial decisions made by individuals, except for the scale of the concern. Suppose, for example, that a firm is using a lathe that was purchased 12 years ago to produce pump shafts. As the production engineer in charge of this product, you expect demand to continue into the foreseeable future. However, the lathe has begun to show its age: It has broken frequently during the last 2 years and has finally stopped operating altogether. Now you have to decide whether to replace or repair it. If you expect a more efficient lathe to be available in the next 1 or 2 years, you might repair the old lathe instead of replacing it. The major issue is whether you should make the considerable investment in a new lathe now or later. As an added complication, if demand for your product begins to decline, you may have to conduct an economic analysis to determine whether declining profits from the project offset the cost of a new lathe.

Let us consider a real-world engineering decision problem on a much larger scale, as taken from an article from *The Washington Post*.[2] Ever since Hurricane Katrina hit the city of New Orleans in August 2005, the U.S. federal government has been under pressure to show strong support for rebuilding levees in order to encourage homeowners and businesses to return to neighborhoods that were flooded when the city's levees crumbled under Katrina's storm surge. Many evacuees have expressed reluctance to rebuild without assurances that New Orleans will be made safe from future hurricanes, including Category 5 storms, the most severe. Some U.S. Army Corps of Engineers officers estimated that it would cost more than $1.6 billion to restore the levee system merely to its design strength—that is, to withstand a Category 3 storm. New design features would include floodgates on several key canals, as well as stone-and-concrete fortification of some of

[2] Joby Warrick and Peter Baker, "Bush Pledges $1.5 Billion for New Orleans—Proposal Would Double Aid From U.S. for Flood Protection," *The Washington Post*, Dec. 16, 2005, p. A03.

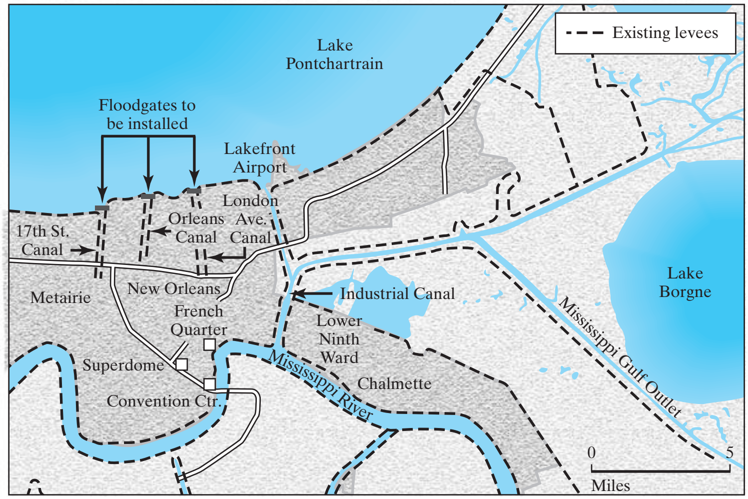


Figure 1.1 The White House pledged $1.5 billion to armor existing New Orleans levees with concrete and stone, build floodgates on three canals, and upgrade the city's pumping system.

the city's earthen levees, as illustrated in Figure 1.1. Donald E. Powell, the administration's coordinator of post-Katrina recovery, insisted that the improvements would make the levee system much stronger than it had been in the past. But he declined to say whether the administration would support further upgrades of the system to Category 5 protection, which would require substantial reengineering of existing levees at a cost that could, by many estimates, exceed $30 billion.

Obviously, this level of engineering decision is far more complex and more significant than a business decision about when to introduce a new product. Projects of this nature involve large sums of money over long periods of time, and it is difficult to justify the cost of the system purely on the basis of economic reasoning, since we do not know when another Katrina-strength storm will be on the horizon. Even if we decide to rebuild the levee systems, should we build just enough to withstand a Category 3 storm, or should we build to withstand a Category 5 storm? Any engineering economic decision pertaining to this type of extreme event will be extremely difficult to make.

In this book, we will consider many types of investments—personal investments as well as business investments. The focus, however, will be on evaluating engineering projects on the basis of their economic desirability and on dealing with investment situations that a typical firm faces.

1.3 Economic Decisions versus Design Decisions

Economic decisions differ in a fundamental way from the types of decisions typically encountered in engineering design. In a design situation, the engineer utilizes known physical properties, the principles of chemistry and physics, engineering design correlations, and engineering judgment to arrive at a workable and optimal design. If the judgment is sound, the calculations are done correctly, and we ignore technological advances, the design is time invariant. In other words, if the engineering design to meet a particular need is done today, next year, or in five years' time, the final design would not change significantly.

In considering economic decisions, the measurement of investment attractiveness, which is the subject of this book, is relatively straightforward. However, the information required in such evaluations always involves predicting or forecasting product sales, product selling prices, and various costs over some future time frame—5 years, 10 years, 25 years, etc.

All such forecasts have two things in common. First, they are never completely accurate compared with the actual values realized at future times. Second, a prediction or forecast made today is likely to be different from one made at some point in the future. It is this ever-changing view of the future that can make it necessary to revisit and even change previous economic decisions. Thus, unlike engineering design, the conclusions reached through economic evaluation are not necessarily time invariant. Economic decisions have to be based on the best information available at the time of the decision and a thorough understanding of the uncertainties in the forecasted data.

1.4 Large-Scale Engineering Projects

In the development of any product, a company's engineers are called upon to translate an idea into reality. A firm's growth and development depend largely upon a constant flow of ideas for new products, and for the firm to remain competitive, it has to make existing products better or produce them at a lower cost. In the next section, we present an example of how a design engineer's idea eventually turned into an innovative automotive product.

1.4.1 How a Typical Project Idea Evolves

The Toyota Motor Corporation introduced the world's first mass-produced car powered by a combination of gasoline and electricity. Known as the Prius, this vehicle is the first of a new generation of Toyota cars whose engines cut air pollution dramatically and boost fuel efficiency to significant levels. Toyota, in short, wants to launch and dominate a new "green" era for automobiles—and is spending $1.5 billion to do it. Developed for the Japanese market initially, the Prius uses both a gasoline engine and an electric motor as its motive power source. The Prius emits less pollution than ordinary cars, and it gets more mileage, which means less output of carbon dioxide. Moreover, the Prius gives a highly responsive performance and smooth acceleration. The following information from *BusinessWeek*[3] illustrates how a typical strategic business decision is made by the engineering staff of a larger company. Additional information has been provided by Toyota Motor Corporation.

Why Go for a Greener Car?

Toyota first started to develop the Prius in 1995. Four engineers were assigned to figure out what types of cars people would drive in the 21st century. After a year of research, a

[3] Emily Thornton (Tokyo), Keith Naughton (Detroit), and David Woodruff, "Japan's Hybrid Cars—Toyota and rivals are betting on pollution fighters—Will they succeed?" *BusinessWeek*, Dec. 4, 1997.

chief engineer concluded that Toyota would have to sell cars better suited to a world with scarce natural resources. He considered electric motors. But an electric car can travel only 215 km before it must be recharged. Another option was fuel-cell cars that run on hydrogen. But he suspected that mass production of this type of car might not be possible for another 15 years. So the engineer finally settled on a hybrid system powered by an electric motor, a nickel–metal hydride battery, and a gasoline engine. From Toyota's perspective, it is a big bet, as oil and gasoline prices are bumping along at record lows at that time. Many green cars remain expensive and require trade-offs in terms of performance. No carmaker has ever succeeded in selling consumers en masse something they have never wanted to buy: *cleaner air*. Even in Japan, where a liter of regular gas can cost as much as $1, carmakers have trouble pushing higher fuel economy and lower carbon emissions. Toyota has several reasons for going green. In the next century, as millions of new car owners in China, India, and elsewhere take to the road, Toyota predicts that gasoline prices will rise worldwide. At the same time, Japan's carmakers expect pollution and global warming to become such threats that governments will enact tough measures to clean the air.

What Is So Unique in Design?

It took Toyota engineers two years to develop the current power system in the Prius. The car comes with a dual engine powered by both an electric motor and a newly developed 1.5-liter gasoline engine. When the engine is in use, a special "power split device" sends some of the power to the driveshaft to move the car's wheels. The device also sends some of the power to a generator, which in turn creates electricity, to either drive the motor or recharge the battery. Thanks to this variable transmission, the Prius can switch back and forth between motor and engine, or employ both, without creating any jerking motion. The battery and electric motor propel the car at slow speeds. At normal speeds, the electric motor and gasoline engine work together to power the wheels. At higher speeds, the battery kicks in extra power if the driver must pass another car or zoom up a hill.

When the car decelerates and brakes, the motor converts the vehicle's kinetic energy into electricity and sends it through an inverter to be stored in the battery. (See Figure 1.2.)

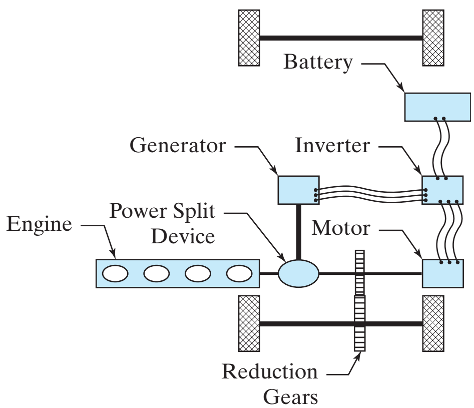


Figure 1.2 Arrangement of components of the Toyota Hybrid System II.
(*Source: Evaluation of 2004 Toyota Prius Hybrid Electric Drive System*, Oak Ridge National Laboratory, ONR/TM2004/247, U.S. Department of Energy.)

- When engine efficiency is low, such as during start-up and with midrange speeds, motive power is provided by the motor alone, using energy stored in the battery.
- Under normal driving conditions, overall efficiency is optimized by controlling the power allocation so that some of the engine power is used for turning the generator to supply electricity for the motor while the remaining power is used for turning the wheels.
- During periods of acceleration, when extra power is needed, the generator supplements the electricity being drawn from the battery, so the motor is supplied with the required level of electrical energy.
- While decelerating and braking, the motor acts as a generator that is driven by the wheels, thus allowing the recovery of kinetic energy. The recovered kinetic energy is converted to electrical energy that is stored in the battery.
- When necessary, the generator recharges the battery to maintain sufficient reserves.
- When the vehicle is not moving and when the engine moves outside of certain speed and load conditions, the engine stops automatically.

So the car's own movement, as well as the power from the gasoline engine, provides the electricity needed. The energy created and stored by deceleration boosts the car's efficiency. So does the automatic shutdown of the engine when the car stops at a light. At higher speeds and during acceleration, the companion electric motor works harder, allowing the gas engine to run at peak efficiency. Toyota claims that, in tests, its hybrid car has boosted fuel economy by 100% and engine efficiency by 80%. The Prius emits about half as much carbon dioxide, and about one-tenth as much carbon monoxide, hydrocarbons, and nitrous oxide, as conventional cars.

Is It Safe to Drive on a Rainy Day?

Yet, major hurdles remain to be overcome in creating a mass market for green vehicles. Car buyers are not anxious enough about global warming to justify a "sea-level change" in automakers' marketing. Many of Japan's innovations run the risk of becoming impressive technologies meant for the masses, but bought only by the elite. The unfamiliarity of green technology can also frighten consumers. The Japanese government sponsors festivals at which people can test drive alternative-fuel vehicles. But some turned down that chance on a rainy weekend in May because they feared that riding in an electric car might electrocute them. An engineer points out, "It took 20 years for the automatic transmission to become popular in Japan." It certainly would take that long for many of these technologies to catch on.

How Much Would It Cost?

The biggest question remaining about the mass production of the vehicle concerns its production cost. Costs will need to come down for Toyota's hybrid to be competitive around the world, where gasoline prices are lower than in Japan. Economies of scale will help as production volumes increase, but further advances in engineering also will be essential. With its current design, Prius's monthly operating cost would be roughly twice that of a conventional automobile. Still, Toyota believes that it will sell more than 12,000 Prius models to Japanese drivers during the first year. To do that, it is charging just $17,000 a car. The company insists that it will not lose any money on the Prius, but rivals and analysts estimate that, at current production levels, the cost of building a Prius could be as much as $32,000. If so, Toyota's low-price strategy will generate annual losses of more than $100 million on the new compact.

Will There Be Enough Demand?

Why buy a $17,000 Prius when a $13,000 Corolla is more affordable? It does not help Toyota that it is launching the Prius in the middle of a sagging domestic car market. Nobody really knows how big the final market for hybrids will be. Toyota forecasts that hybrids will account for a third of the world's auto market as early as 2005, but Japan's Ministry of International Trade and Industry expects 2.4 million alternative-fuel vehicles, including hybrids, to roam Japan's backstreets by 2010. Nonetheless, the Prius has set a new standard for Toyota's competitors. There seems to be no turning back for the Japanese. The government may soon tell carmakers to slash carbon dioxide emissions by 20% by 2010. And it wants them to cut nitrous oxide, hydrocarbon, and carbon monoxide emissions by 80%. The government may also soon give tax breaks to consumers who buy green cars.

Prospects for the Prius started looking good: Total sales for Prius reached over 7,700 units as of June 1998. With this encouraging sales trend, Toyota finally announced that the Prius would be introduced in the North American and European markets by the year 2000. The total sales volume will be approximately 20,000 units per year in the North American and European market combined. As with the 2000 North American and European introduction, Toyota is planning to use the next two years to develop a hybrid vehicle optimized to the usage conditions of each market.

What Is the Business Risk in Marketing the Prius?

Engineers at Toyota Motors have stated that California would be the primary market for the Prius outside Japan, but they added that an annual demand of 50,000 cars would be necessary to justify production. Despite Toyota management's decision to introduce the hybrid electric car into the U.S. market, the Toyota engineers were still uncertain whether there would be enough demand. Furthermore, competitors, including U.S. automakers, just do not see how Toyota can achieve the economies of scale needed to produce green cars at a profit. The primary advantage of the design, however, is that the Prius can cut auto pollution in half. This is a feature that could be very appealing at a time when government air-quality standards are becoming more rigorous and consumer interest in the environment is strong. However, in the case of the Prius, if a significant reduction in production cost never materializes, demand may remain insufficient to justify the investment in the green car.

1.4.2 Impact of Engineering Projects on Financial Statements

Engineers must understand the business environment in which a company's major business decisions are made. It is important for an engineering project to generate profits, but it also must strengthen the firm's overall financial position. How do we measure Toyota's success in the Prius project? Will enough Prius models be sold, for example, to keep the green-engineering business as Toyota's major source of profits? While the Prius project will provide comfortable, reliable, low-cost driving for the company's customers, the bottom line is its financial performance over the long run.

Regardless of a business's form, each company has to produce basic financial statements at the end of each operating cycle (typically a year). These financial statements provide the basis for future investment analysis. In practice, we seldom make investment decisions solely on the basis of an estimate of a project's profitability, because we must also consider the overall impact of the investment on the financial strength and position of the company.

Suppose that you were the president of the Toyota Corporation. Suppose further that you even hold some shares in the company, making you one of the company's many owners. What objectives would you set for the company? While all firms are in business in hopes of making a profit, what determines the market value of a company are not profits per se, but cash flow. It is, after all, available cash that determines the future investments and growth of the firm. Therefore, one of your objectives should be to increase the company's value to its owners (including yourself) as much as possible. To some extent, the market price of your company's stock represents the value of your company. Many factors affect your company's market value: present and expected future earnings, the timing and duration of those earnings, and the risks associated with them. Certainly, any successful investment decision will increase a company's market value. Stock price can be a good indicator of your company's financial health and may also reflect the market's attitude about how well your company is managed for the benefit of its owners.

1.4.3 A Look Back in 2005: Did Toyota Make the Right Decision?

Clearly, there were many doubts and uncertainties about the market for hybrids in 1998. Even Toyota engineers were not sure that there would be enough demand in the U.S. market to justify the production of the vehicle. Seven years after the Prius was introduced, it turns out that Toyota's decision to go ahead was the right decision. The continued success of the vehicle led to the launching of a second-generation Prius at the New York Motor Show in 2003. This car delivered higher power and better fuel economy than its predecessor. Indeed, the new Prius proved that Toyota has achieved its goal: to create an eco-car with high-level environmental performance, but with the conventional draw of a modern car. These features, combined with its efficient handling and attractive design, are making the Prius a popular choice of individuals and companies alike. In fact, Toyota has already announced that it will double Prius production for the U.S. market, from 50,000 to 100,000 units annually, but even that may fall short of demand if oil prices continue to increase in the future.

Toyota made its investors happy, as the public liked the new hybrid car, resulting in an increased demand for the product. This, in turn, caused stock prices, and hence shareholder wealth, to increase. In fact, the new, heavily promoted, green car turned out to be a market leader in its class and contributed to sending Toyota's stock to an all-time high in late 2005.[4] Toyota's market value continued to increase well into 2006. Any successful investment decision on Prius's scale will tend to increase a firm's stock prices in the marketplace and promote long-term success. Thus, in making a large-scale engineering project decision, we must consider its possible effect on the firm's market value. (In Chapter 2, we discuss the financial statements in detail and show how to use them in our investment decision making.)

1.5 Common Types of Strategic Engineering Economic Decisions

The story of how the Toyota Corporation successfully introduced a new product and became the market leader in the hybrid electric car market is typical: Someone had a good idea, executed it well, and obtained good results. Project ideas such as the Prius can originate from many different levels in an organization. Since some ideas will be good, while others

[4] Toyota Motor Corporation, *Annual Report, 2005*.

will not, we need to establish procedures for screening projects. Many large companies have a specialized project analysis division that actively searches for new ideas, projects, and ventures. Once project ideas are identified, they are typically classified as (1) equipment or process selection, (2) equipment replacement, (3) new product or product expansion, (4) cost reduction, or (5) improvement in service or quality. This classification scheme allows management to address key questions: Can the existing plant, for example, be used to attain the new production levels? Does the firm have the knowledge and skill to undertake the new investment? Does the new proposal warrant the recruitment of new technical personnel? The answers to these questions help firms screen out proposals that are not feasible, given a company's resources.

The Prius project represents a fairly complex engineering decision that required the approval of top executives and the board of directors. Virtually all big businesses face investment decisions of this magnitude at some time. In general, the larger the investment, the more detailed is the analysis required to support the expenditure. For example, expenditures aimed at increasing the output of existing products or at manufacturing a new product would invariably require a very detailed economic justification. Final decisions on new products, as well as marketing decisions, are generally made at a high level within the company. By contrast, a decision to repair damaged equipment can be made at a lower level. The five classifications of project ideas are as follows:

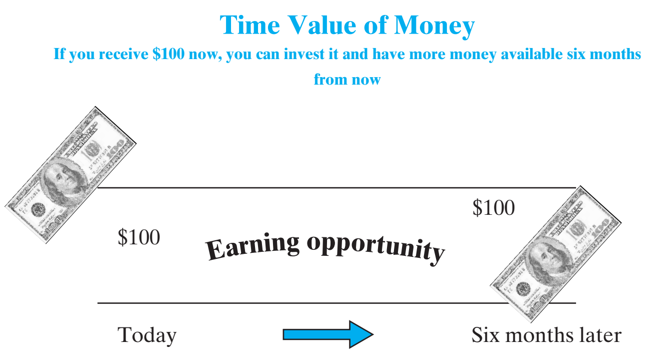
- **Equipment or Process Selection.** This class of engineering decision problems involves selecting the best course of action out of several that meet a project's requirements. For example, which of several proposed items of equipment shall we purchase for a given purpose? The choice often hinges on which item is expected to generate the largest savings (or the largest return on the investment). For example, the choice of material will dictate the manufacturing process for the body panels in the automobile. Many factors will affect the ultimate choice of the material, and engineers should consider all major cost elements, such as the cost of machinery and equipment, tooling, labor, and material. Other factors may include press and assembly, production and engineered scrap, the number of dies and tools, and the cycle times for various processes.
- **Equipment Replacement.** This category of investment decisions involves considering the expenditure necessary to replace worn-out or obsolete equipment. For example, a company may purchase 10 large presses, expecting them to produce stamped metal parts for 10 years. After 5 years, however, it may become necessary to produce the parts in plastic, which would require retiring the presses early and purchasing plastic molding machines. Similarly, a company may find that, for competitive reasons, larger and more accurate parts are required, making the purchased machines become obsolete earlier than expected.
- **New Product or Product Expansion.** Investments in this category increase company revenues if output is increased. One common type of expansion decision includes decisions about expenditures aimed at increasing the output of existing production or distribution facilities. In these situations, we are basically asking, "Shall we build or otherwise acquire a new facility?" The expected future cash inflows in this investment category are the profits from the goods and services produced in the new facility. A second type of expenditure decision includes considering expenditures necessary to produce a new product or to expand into a new geographic area. These projects normally require large sums of money over long periods.

- **Cost Reduction.** A cost-reduction project is a project that attempts to lower a firm's operating costs. Typically, we need to consider whether a company should buy equipment to perform an operation currently done manually or spend money now in order to save more money later. The expected future cash inflows on this investment are savings resulting from lower operating costs.
- **Improvement in Service or Quality.** Most of the examples in the previous sections were related to economic decisions in the manufacturing sector. The decision techniques we develop in this book are also applicable to various economic decisions related to improving services or quality of product.

1.6 Fundamental Principles of Engineering Economics

This book is focused on the principles and procedures engineers use to make sound economic decisions. To the first-time student of engineering economics, anything related to money matters may seem quite strange when compared to other engineering subjects. However, the decision logic involved in solving problems in this domain is quite similar to that employed in any other engineering subject. There are fundamental principles to follow in engineering economics that unite the concepts and techniques presented in this text, thereby allowing us to focus on the logic underlying the practice of engineering economics.

- **Principle 1: A nearby penny is worth a distant dollar.** A fundamental concept in engineering economics is that money has a time value associated with it. Because we can earn interest on money received today, it is better to receive money earlier than later. This concept will be the basic foundation for all engineering project evaluation.



- **Principle 2: All that counts are the differences among alternatives.** An economic decision should be based on the *differences* among the alternatives considered. All that is common is irrelevant to the decision. Certainly, any economic decision is no better than the alternatives being considered. Thus, an economic decision should be based on the objective of making the best use of limited resources. Whenever a choice is made, something is given up. The opportunity cost of a choice is the value of the best alternative given up.

Comparing Buy versus Lease

Whatever you decide, you need to spend the same amount of money on fuel and maintenance

Option	Monthly Fuel Cost	Monthly Maintenance	Cash Outlay at Signing	Monthly Payment	Salvage Value at End of Year 3
Buy	$960	$550	$6,500	$350	$9,000
Lease	$960	$550	$2,400	$550	0

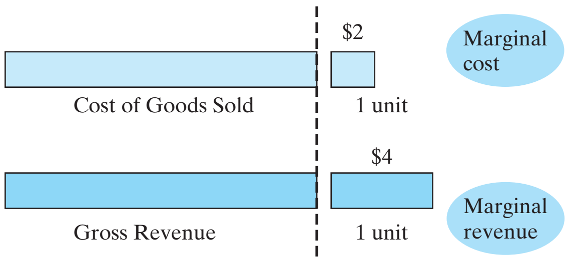
Irrelevant items in decision making

- **Principle 3: Marginal revenue must exceed marginal cost.** Effective decision making requires comparing the additional costs of alternatives with the additional benefits. Each decision alternative must be justified on its own economic merits before being compared with other alternatives. Any increased economic activity must be justified on the basis of the fundamental economic principle that marginal revenue must exceed marginal cost. Here, *marginal revenue* means the additional revenue made possible by increasing the activity by one unit (or small unit). *Marginal cost* has an analogous definition. Productive resources—the natural resources, human resources, and capital goods available to make goods and services—are limited. Therefore, people cannot have all the goods and services they want; as a result, they must choose some things and give up others.

Marginal cost: The cost associated with one additional unit of production, also called the incremental cost.

Marginal Analysis

To justify your action, marginal revenue must exceed marginal cost



- **Principle 4: Additional risk is not taken without the expected additional return.** For delaying consumption, investors demand a minimum return that must be greater than the anticipated rate of inflation or any perceived risk. If they didn't receive enough to compensate for anticipated inflation and the perceived investment risk, investors would purchase whatever goods they desired ahead of time or invest in assets that would provide a sufficient return to compensate for any loss from inflation or potential risk.

Risk-return tradeoff: Invested money can render higher profits only if it is subject to the possibility of being lost.

Risk and Return Trade-Off

Expected returns from bonds and stocks are normally higher than the expected return from a savings account

Investment Class	Potential Risk	Expected Return
Savings account (cash)	Low/None	1.5%
Bond (debt)	Moderate	4.8%
Stock (equity)	High	11.5%

The preceding four principles are as much statements of common sense as they are theoretical precepts. These principles provide the logic behind what is to follow. We build on them and attempt to draw out their implications for decision making. As we continue, keep in mind that, while the topics being treated may change from chapter to chapter, the logic driving our treatment of them is constant and rooted in the four fundamental principles.

SUMMARY

- This chapter has given us an overview of a variety of engineering economic problems that commonly are found in the business world. We examined the role, and the increasing importance, of engineers in the firm, as evidenced by the development at Toyota of the Prius, a hybrid vehicle. Commonly, engineers are called upon to participate in a variety of strategic business decisions ranging from product design to marketing.
- The term **engineering economic decision** refers to any investment decision related to an engineering project. The facet of an economic decision that is of most interest from an engineer's point of view is the evaluation of costs and benefits associated with making a capital investment.
- The five main types of engineering economic decisions are (1) equipment or process selection, (2) equipment replacement, (3) new product or product expansion, (4) cost reduction, and (5) improvement in service or quality.
- The factors of **time** and **uncertainty** are the defining aspects of any investment project.
- The four fundamental principles that must be applied in all engineering economic decisions are (1) the time value of money, (2) differential (incremental) cost and revenue, (3) marginal cost and revenue, and (4) the trade-off between risk and reward.