

## **Chapter 2**

# **The Theory and Practice of Decision-making Concerning Capital Projects**

### **2.1 Introduction**

The purpose of the assessment of projects is to determine if the project justifies investment. There are usually many projects that the organization assesses and approves each year. The available money, or capital resources, must be divided between the different projects. In other words, the capital resources must be allocated to the projects. The activities for the assessment of projects and the allocation of capital are known variously as cost-benefit analysis, engineering economics, and capital budgeting, terms that arise from the different professions of economics, engineering and finance. They are all concerned with the allocation of resources to projects in a company in the most cost effective and profitable manner. The success of all enterprises, both private and public, depends on how well the enterprise chooses projects and allocates resources to its projects. As a result, these are critically important activities for an enterprise.

The objective of this chapter is to present the context within a company for decision-making concerning capital projects. This context concerns the history of these activities, the organization of the finance function within a company, the framework for decision-making in general, and the practice of decision-making for capital projects. An important part of this context is the understanding of the aims and objectives of the professions that impact on the investment in capital projects. The classification of projects and the practice of promoting a project are also discussed. The history of cost-benefit analysis, engineering economics and capital budgeting is described in the next section.

### **2.2 Cost-benefit Analysis, Engineering Economics and Capital Budgeting**

#### **(i) Cost-benefit analysis**

Cost-benefit analysis is the practice of assessing the desirability of projects from the perspective of an economist. It takes both a long-term and a wide view. It is long-

term in the sense of examining the effects, implications and repercussions both in the short and long-term. It takes a wide view in the sense of examining the effects of the project on different peoples, industries and regions. It is a broad treatment, and has more in common with economics than with business and commerce. It draws on a range of subdisciplines within economics, such as resource economics and public finance, to create a coherent view of the project.

Cost-benefit analysis has a long history, particularly in France, where the engineer Dupuit published a paper in 1844 on the utility of public works, a groundbreaking contribution to the field of economics. In the US, the early practice of cost-benefit analysis was closely associated with control of navigation. It came about as an administrative function, little related to economics. The River and Harbor Act of 1902 required the Army Corps of Engineers to report on the desirability of their river and harbour projects by accounting for their benefits to commerce and their associated cost. The terms of reference were broadened in the 1930s. The Flood Control Act of 1936 authorised projects by the Army Corps of Engineers “if the benefits to whomsoever they may accrue are in excess of the estimated costs.” It should be pointed out that the practice of cost-benefit analysis in these cases was not only to justify projects, but also to determine who should pay for them. This practice spread to other US government agencies, and in the 1950s, the general principles of cost-benefit analysis, including the considerations of welfare economics, were codified. As a result of this developmental history, the application of cost-benefit analysis was and still is clearly situated in the domain of public works.

Cost-benefit analysis is primarily an economic analysis. Although market prices are a starting point for the determination of the benefits and the costs, they imperfectly represent the interests of various parties and stakeholders in the project. Market prices may be distorted by political intervention, taxes, subsidies, incentives, lack of competition, price control and other factors. In an economic cost-benefit analysis, prices are adjusted towards their efficiency prices, those that would be achieved in a perfect market as a result of the best allocation of resources due to supply and demand. This is in contrast with financial or commercial analysis, which considers the flow of cash at market price.

While the engineers of the Corps des Ingenieurs des Ponts et Chaussées in France, most notably Dupuit, contributed significantly to the early development of economics itself, endeavours in the US focused on the combination of engineering design with economic choice.

## (ii) Engineering economics

The involvement of engineers in the evaluation of the benefits and costs of projects led to the development of the field of *engineering economics*. Arthur M. Wellington, the pioneer of the field, published “The Economic Theory of the Location of Railways” in 1877 that included the notion of “the judicious use of capital” in the engineering design process. Wellington was concerned with the most cost effective location of railways, and the application of economic choices to other engineering design questions, such as the grade and the gauge of the railway. For example, he demonstrated that light rail was false economy using his analysis techniques.

Wellington was the first to describe the application of present value techniques for the allocation of capital within a company. Present value techniques, also called discounted cash flow techniques, account for the time value of money. The concept of the time value of money has been known since the early 1800s. Today it is regarded as necessary to account for the time value of money in the evaluation of projects that last for more than a few years. Wellington wrote for engineers. Early adopters of the discounted cash flow techniques that incorporated Wellington's ideas of the time value of money were the engineers of mining companies and public utility industries. Beginning in the 1920s, the new field of engineering economics influenced the way in which AT&T made capital allocations to possible projects. These ideas of the use of time value of money in the assessment of the economics of a project slowly diffused through engineers, reaching the petroleum industry by the 1950s.

Engineering economics is more restricted than cost-benefit analysis, limiting itself to the application of a number of techniques for economic choice rather than engaging in a full economic analysis as would be expected in cost-benefit analysis. The analysis is performed from one point of view, rather than representing the views of all the stakeholders. Engineering economics has more in common with investment analysis than with economics.

The relatively slow rate of adoption of techniques incorporating the time value of money between the 1920s and the 1960s is due, in part, to Du Pont's development of the concept of return on investment, which was a development of equal importance to the time value of money for the analysis of the performance of capital investments, and their development of a system for the allocation of capital resources to projects. This system is known as capital budgeting, and is discussed next.

### (iii) Capital budgeting

In contrast with cost-benefit analysis, which takes a broad view, the assessment of projects within a company takes a narrower view. The view is narrowed by mainly considering the benefits or costs to the company, not to society. This is not to say that the companies do or should act irresponsibly; it is merely that the company's viewpoint is that the main beneficiary of its investments should be itself. The activities within a company of assessing long-term opportunities and allocating capital to them are known as *capital budgeting* within the field of financial management. It addresses essentially the same questions as engineering economics. Examples of capital budgeting decisions are the acquisition of land, buildings, equipment, and vehicles, amongst others, for productive use by the company.

The history of capital budgeting runs parallel to that of engineering economics. In 1903 the E.I. du Pont de Nemours Powder Company merged the functions of scores of smaller, specialized firms, and centralized the manufacturing and distribution process. Pierre du Pont wished to measure both the profitability of the current operations and the attractiveness of future investments in terms of the capital invested in each venture or department. He and his accounting staff developed the concept of return on investment accompanied by a system for allocating capital resources to projects. The return on investment combined the profit margin with the

asset turnover. This concept, and the system of reporting that it created, significantly decreased the cost of managing a complex company like Du Pont.

Du Pont owned 23% of General Motors, a company also created from the merger of many smaller firms. When faced with financial and administration problems in 1920, General Motors consulted Pierre du Pont. The capital-budgeting system GM constructed allowed operational managers to decide how best to employ their division's resources, while at the same time maintaining central control by senior executives.

Although the techniques used at Du Pont and General Motors, and subsequently adopted by other industries, were highly effective, they were designed for the projection of the next year's performance. At the time, they did not forecast performance or evaluate projects on a long-term basis; as a result, they did not need to incorporate Wellington's ideas of the time value of money into their assessment of the project or capital investment. However, these concepts were gradually incorporated into the capital-budgeting framework. Indeed, today they are the dominant measures of economic viability used by companies to assess capital projects.

Investment in projects is extremely important to a company. Such investment represents a fairly large commitment of the company's resources; they are invested for a long time, and the operating needs of the company will be driven by these investment choices. Since the company may be viewed as the sum of its investments, the future development of the company depends on the efficient choice of these investments. Capital budgeting is a strategic activity, central to the business objectives and business plan of the company.

Cost-benefit analysis, engineering economics and capital budgeting offer methods and techniques for the choice of investments in both the government and private sectors. The analysis of government projects is closer to economic cost-benefit analysis than it is to capital budgeting, because government has a broader remit than does a company. Many of the infrastructure projects that government invests in, such as dams, power schemes, and highways, are typically very long lived. However, both government and company decisions are championed and made by people, not necessarily in the best interests of the public or the company, and are subject to the politics of the organization. In a company, it is the duty of the executive management to set the direction and the strategy of the company clearly, so that the most efficient choices can be made. The understanding of different viewpoints and the organization and the business context in which investment decisions are made is important, and is discussed in the following few sections.

## 2.3 Perspectives for the Assessment of Projects

Various views of investment decisions other than those of engineers and economists are important in both the public and private sectors. Within the private sector, there are two divergent viewpoints that are important to bear in mind when the results of

any analysis are communicated. These viewpoints are those of financial accounting and financial management.

Financial accounting has a particular perspective. For these professionals, the measure of financial success is based on liquidity in the short-term and on profitability in the long-term. Liquidity means that sufficient cash is available for the business and that it is not bound in assets that are difficult to sell, that is, are illiquid. A profitable business is one in which the revenues exceed the costs. The liquidity requirement translates into measures of success based on how quickly the investment can recoup its costs, as encapsulated in the payback period discussed in Chapter 1. The profitability measure translates to how productive the investment is at generating cash flows or profit. This notion is encapsulated in the return on investment as a measure and decision criterion. These are both accounting measures made with accounting data.

Financial management has a worldview different to that of financial accounting. The aim, and hence the measure of financial success, of financial management is to create and maximize shareholder wealth. Shareholder wealth is not seen as being driven by profitability; rather it is seen as a function of returns of cash to the investor in the medium and long-term. The goal of maximizing shareholder value leads to measures for the evaluation of investments and projects that maximize the future cash flows for the allocated capital. These notions are encapsulated in a number of decision criteria such as net present value and internal rate of return, that account for both the cost of the funds required to pursue the opportunity and the time value of money. The details of these criteria are discussed in Chapter 6.

Both of these perspectives are of value. Generally, the perspective that is required by engineers, scientists and managers is one that is closer to financial management than it is to either economics or accounting, and this theme dominates the treatment followed in this text. However, it is essential to understand the accounting view, since the engineers, scientists and managers must be able to communicate effectively with other professions. Since the perspective required of engineers is closer to financial management, it is instructive to examine the components of value for a shareholder or an investor.

## 2.4 Enhancing Value for Investors

Investors will choose to invest in a business based on what they expect the business to return to them. In evaluating an investment opportunity, investors will compare the expected returns with those from the many other choices that they have for the investment of their money. Once the investors have placed their money in the business, the onus is on the management to ensure that the expected returns materialize. The overall aim of the company's management, including the company's engineers and scientists, is therefore to maximize the value of the investment made by investor for the benefit of investors and other stakeholders in the company.

There are three main drivers for enhancing the value of a company. These are (i) through the superior use of *finance*; (ii) through superior *organization*; and (iii) through superior *strategy*. The first driver has three elements: the control of costs, the use of capital, and the raising of capital. The second driver refers to the management of processes, people, performance and talent. The third driver refers to the superior anticipation of the future, of trends and events that may affect the business, and the superior deals that place the company in a better position than competitors. These factors, and the company's performance in managing them, influence the value of the company.

Engineers and other technical professionals contribute significantly to all of the main drivers of value. The focus of most engineers and scientists is on enhancing value through the optimum use of resources, the control of costs and the management of processes. Some may find themselves working in research and development on strategic projects that anticipate, or take a leading role in shaping, future trends. Others have personal leadership qualities, and rise to become part of the leadership of the organisation.

The value of a company is most easily measured by the generation of cash by the company. Value is measured by cash flows. More particularly, value depends on the amounts of cash flow, the anticipated timing of future cash flow, and the risk of these anticipated cash flows not materializing. If the company is listed on a public exchange, the value of the company is reflected directly in the share price. The same factors that affect value for an investor in a public company, that is, the amount, timing and risk of the expected cash flows, affect the value for investors in a private company.

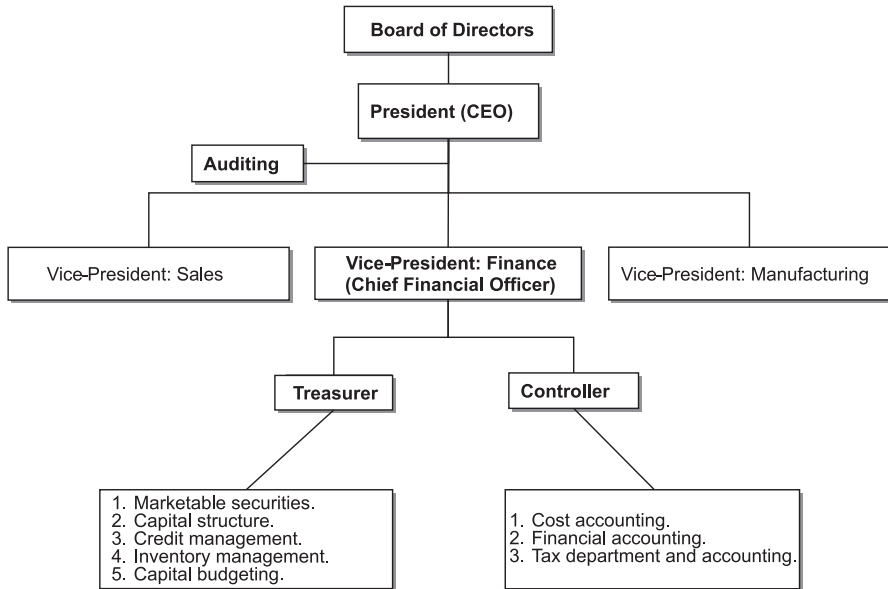
Clearly, a major task of the engineers and scientists employed in any organization is to ensure that capital resources are allocated optimally to the benefit of all the organization's stakeholders. The business context in which these decisions take place is sketched in the next section.

## 2.5 Business Context

In order to pursue a project or an investment opportunity, the organization needs funds. The sources of the funds, the stewardship of the funds within the organization and the interaction between financing and investment constitute the context that impacts on the evaluation of capital projects, the decisions concerning which projects are pursued and those which are not. These topics are discussed next.

### 2.5.1 *Financial Stewardship Within a Business*

The two major functions of the finance department in a company or corporation are the treasury and the controller. This is illustrated schematically in Figure 2.1. The treasury is responsible for managing the cash and investments of cash in the financial



**Figure 2.1** Functional roles of the finance in a corporation

markets (marketable securities) and managing the company's debt. The controller is responsible for functions like cost accounting, financial accounting, and tax. The chief financial officer (CFO) is responsible for both of these functions.

Another function within the domain of the CFO is broadly called the financial management of a company. Financial management aims to maximize value for the shareholders while managing the risk profile of the company. The opportunities for the financial manager to create value for the company are in arranging the company's financing efficiently and in using these finances effectively. As a result, the type of decisions required of financial managers can be classified as either financing decisions or investment decisions. The raising and allocating of funds is discussed next.

### 2.5.2 Sources and Use of Funds

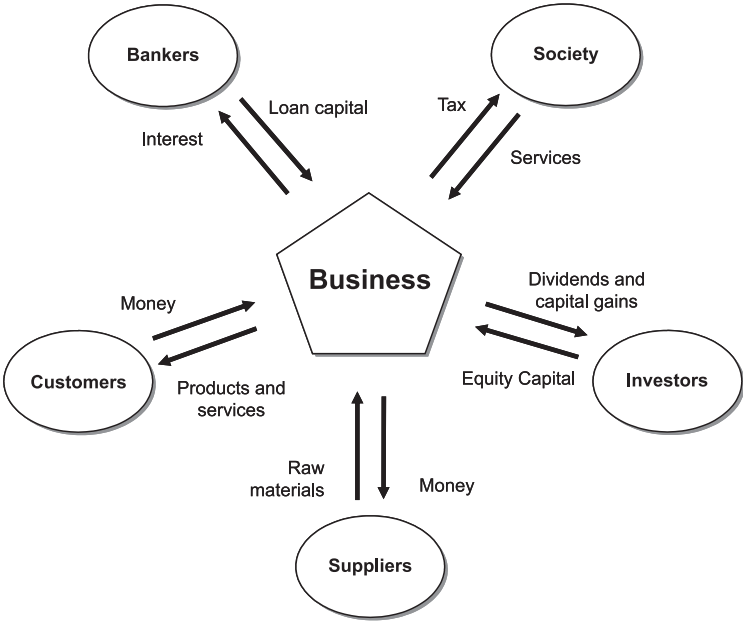
The aim of a company is to meet a market need. Purchasing the company's products will satisfy the customer's needs. In order to provide this product or service, the company embarks on a project that requires a production facility to manufacture the product and a distribution network to bring the product or service to market. The company requires capital for the acquisition of the assets to do this.

The company raises the capital it requires from two main sources: shareholders and debt-holders. Shareholders are part owners of the company. They are rewarded

for the risk they take in investing in the company through the increased value of the company (the capital gain), and through regular cash payments made by the company (the dividends). The company’s lenders loan money to the company. A loan is also called debt, and the lenders are also called debt-holders. The debt-holders require the loan to be repaid in full, and are rewarded for the risk that they take by earning interest at regular intervals on the loan.

In addition to raising capital from shareholders and debt-holders, the company can obtain short-term finance from creditors in the form of the credit terms offered by suppliers. The source and use of these funds are illustrated in the business interactions shown in Figure 2.2.

The capital that is raised from investors is used to meet the market need by building the production facility, making the product, and selling the product to customers for more than it costs to make the product. The business does this so that it can pay taxes, repay the interest and principal on loans to the debt-holders, retain some earnings for the future, and pay the shareholders a return in the form of a dividend. The activities of the company and the profit from these activities benefit society through the meeting of the customer’s need and the employment of people, benefit the government through the paying of taxes, benefit the banks and other debt providers through the paying of interest, and benefit the shareholders through the paying of dividends and the increased value of the company.



**Figure 2.2** Interactions between a business, its markets (suppliers and customers), funders (investors and bankers) and society represented by the government



The source and use of funds is clearly seen in the balance sheet of a company. The balance sheet will be discussed more comprehensively in Chapter 3. It is a statement of the assets, liabilities and owners' equity of a company. The assets are the items that the company owns, the liabilities are the amounts of money that company owes to others, and the owner's equity is the contribution by the shareholders to the value of the company. The source of funds is represented by the liabilities and the owner's equity, and the use of funds is represented by the assets. Thus, the balance sheet reflects the interactions between the investment and financing activities of the company.

### ***2.5.3 Investment and Financing Decisions Within the Business***

Another way of viewing the balance sheet of a company is as a representation of the investment and financing decisions made by the company.

Investment decisions concern the acquisition of operating assets or financial assets. Operating assets are items such as machinery, vehicles, property, inventory and buildings. A distinction is usually drawn between fixed assets, such as production equipment, and working capital, which is the net amount of money required for stock, inventory, debtors and creditors. The company may own shares in other companies, or it may loan money to other companies. These investments are in financial assets. In other words, the company may acquire financial assets by investing in other businesses or by investing in financial instruments sold in the financial markets.

Financing, or the financing decision in a company, is the function of determining the most suitable financing arrangement or structure to fund the company's opportunities. The financing decisions are mostly concerned with the following three issues: (i) how much debt can the company afford to have (called the capital structure); (ii) how much credit the company can afford to provide to its clients (called the credit policy); and (iii) how much of the company's profits should be retained by the company (by not paying all the profits to the shareholders) to have sufficient resources for all anticipated needs and future investments (called the dividend policy). In later chapters, it will be shown that it is advantageous to have as much debt as possible, because the returns to shareholders increase with increasing debt. However, increasing debt also increases the risk for the company. In structuring the finances for the company, the financial manager makes a trade-off between return and risk. Similar trade-offs are involved in considering the other two issues.

From a strategic viewpoint, the financial manager must ensure that the company has sufficient resources to meet its goals. The financial manager must forecast what the resource requirements are, and determine if additional resources are required. If insufficient, the financial manager must raise the additional capital that matches the requirement from either shareholders or debt-holders. The funding requirements for the company are pooled or lumped together; finance is not generally arranged for a particular project. The financial manager determines the total requirements for

the company, and determines the best method for meeting these requirements. The sources of funds are discussed in more detail in Chapter 16.

The investment and financing decisions represent the core of what a company does. It raises the funds to invest in projects. It raises capital, which are the financing activities, and it allocates that capital, which are the investment activities. The analysis, planning and evaluation of these opportunities are intimately tied to the company's strategic objectives.

The functions of the investment and financing activities are usually separated in corporations. The functional teams working on investment proposals are usually not those working on financing structure. In other words, they occur in different departments. This separation is also in timing. As mentioned in Chapter 1, the first decision is whether it is a good opportunity for the company in the context of all the other opportunities available to the company, and the second decision is how best to access the funds to implement the investment proposal. The separation of these decisions is useful for a number of reasons: (i) it clarifies what decision is required; (ii) it allows opportunities to be evaluated on a common basis; and (iii) it clarifies the roles and responsibilities of different functional units within the organization or company.

#### ***2.5.4 Evaluation of Investment Opportunities***

The decision to make an investment in an asset (operating or financial) is taken on the basis of a business evaluation. The evaluation has the objective of building a business case for the investment proposal. It requires an overall perspective of the business, of the company's positioning on strategy, marketing, and production. It requires an understanding of the company's risks and returns and it must integrate aspects of tax, commercial agreements, and possible liabilities. It requires knowledge of the project, through the construction, commissioning ramp-up and production stages. In addition to analytical skills, business evaluation involves judgement, experience and wisdom.

There are essentially four parts to the evaluation of an investment opportunity. These are the strategic evaluation, the economic evaluation, the technical evaluation and the financial evaluation. Not all of these are relevant to all organizations or to all investments.

##### **(i) Strategic evaluation**

The strategic evaluation considers key factors for the success of the project, such as the company's ability to penetrate the market and the structure of competition in the industry. The markets that most companies operate in are competitive, resulting in a drive for efficiency and effectiveness. The company must be able to understand the dynamics of the industry and harness this knowledge profitably. Strategic evaluation encompasses an overall knowledge of the company's current and future activities, including the company's anticipated projects.

The company does not only exist in the context of its market. Beyond its markets, the company exists within a system of law, society and politics. Knowledge of, and an anticipation of the changes in, the external factors, such as public opinion and the regulatory environment, that may impact on the business's ability to execute its business plan, is essential for the strategy of a business to be successful.

(ii) Financial evaluation

The financial evaluation is the function within the business evaluation that examines all the available information from a financial viewpoint. The merits of the investment are examined on the basis of the investment costs and the cash flows that will be generated from the investment. It includes the synthesis and financial quantification of the company's knowledge of the key factors for success, and an assessment of the risks to the company.

(iii) Technical evaluation

The technical evaluation is usually a staged process that occurs with the design of the equipment for the operation. Within the various engineering disciplines and industries there are differing names for the stages, but generally they consist of concept, pre-feasibility, feasibility and final design. The staged approach to project design and evaluation is discussed further in Chapter 4.

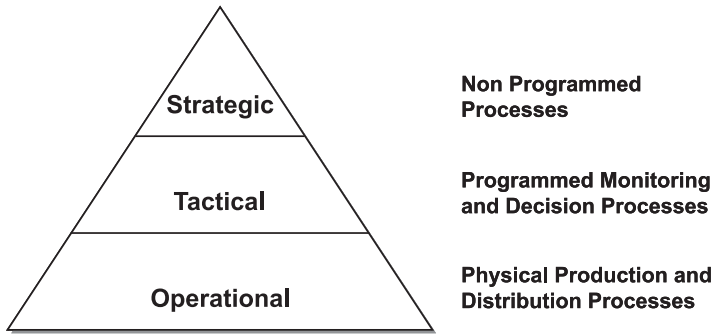
(iv) Economic evaluation

The aim of an economic evaluation is to assess the costs and benefits of the project to all stakeholders in the project. This is a much broader view than the financial evaluation mentioned earlier. Another important difference is that in the opinion of the economists performing the analysis, market values and prices may not be a true reflection of the costs and benefits to all the stakeholders. In this case, the economic analysis may include adjustments to account for these anomalies.

Once the project has been assessed, a decision needs to be taken on whether to invest in it or not. Prior to discussing the practice of investment decisions for capital projects, it is worth discussing the theory and practice of decision-making in general within a business.

## 2.6 Business Decision-making

The process of arriving at a decision in an organization is a complex interaction of factors such as personal psychology, group dynamics, context, access to information and self-interest. These decisions are either programmed or not programmed. Programmed decisions are those in which a policy, a standard operating procedure, a rule or some precedence exists. Creativity and analytical thought is not required. Most decisions, even at executive level, are of this kind. In contrast, non-programmed decisions are ill structured and elusive – there is no standard way to



**Figure 2.3** Three layers of decision processes found within organisations and corporations

answer them. Very few decisions within an organization are of the non-programmed variety.

Within any organization or corporation, there is a hierarchy of decisions that is taken, illustrated in Figure 2.3. At the bottom of the hierarchy is the mass of production-related decisions that are largely programmed, the middle layer is concerned with monitoring first layer processes and making largely programmed decisions, and at the top of the hierarchy is a layer of non-programmed decisions relating to redesigning or changing parameters for first layer processes.

The investment and financing decisions are at the top of the hierarchy, and contain significant strategic content. They are long-term, have significant cost and risk, and set the course for the business for some years to come. Programmed, operational decisions have less strategic content. They are the day-to-day decisions that have impact in the shorter-term, are largely based on past experience, and generally do not clearly or directly impact on the direction of the company.

Decisions can be reversible or irreversible. If the money invested can be easily recovered without cost, the decision is reversible. For example, consider an investor who purchases an item in a market. If, after a short time, a better opportunity arises and she decides to sell the item and receives almost the price paid originally, then the decision is reversible. If, on the other hand, the investor cannot sell the item, or can only dispose of it for a small fraction of its cost, then the decision is irreversible. Irreversible decisions consume resources and reduce flexibility. If all an investor's resources are invested in assets that cannot be easily sold, then the investor does not have the flexibility to engage in more profitable ventures that might arise, or to liquidate their assets to meet expenses if economic conditions deteriorate. The decision to invest in a capital project is usually an irreversible decision. The costs of buildings, facilities and plants that are constructed for a company cannot be easily recovered.

The function of the financial and strategic evaluation of business opportunities by engineers and scientists is to maximize value for shareholders. Tactics that may be adopted in the short-term, such as increasing sales, decreasing costs or maintaining market position, are subordinate to the long-term goal of maximizing the value of

the company. However, in practice, it is often easier to implement short-term tactics and the results are seen more quickly. Since managers are largely focused on their individual career paths, not necessarily on creating shareholder wealth, programmed decisions with mostly short-term, tactical contact are favoured. Thus, it is often easier to get a decision to replace ageing equipment than to get one to increase production capacity by de-bottlenecking, and easier to get a decision to increase production capacity by de-bottlenecking than to get one to build a new production facility.

In evaluating a decision, a distinction should be made between the decision process, and the outcome of the decision. It was not a good decision because the outcome was good, or vice versa. It was a good decision because it was considered, transparent, inclusive and rational. It was a good decision if the assumptions in both the problem formulation and the solution process were interrogated and found to be valid. It was a good decision if information was collected thoroughly, and was presented in an unfiltered and unbiased fashion.

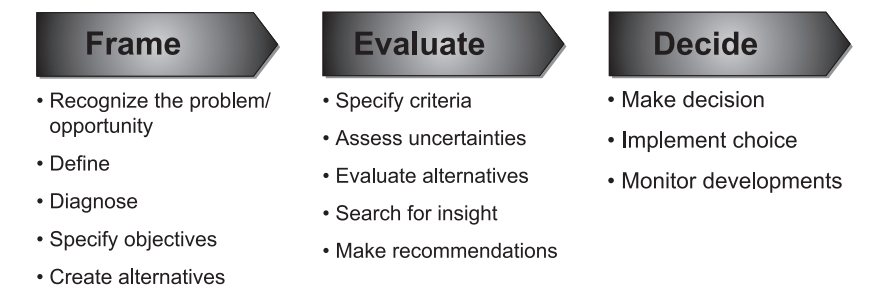
## **2.7 A Framework for Decision-making**

Decision-making can be examined from two different viewpoints: the *normative* view and the *descriptive* view. The normative view suggests what ought to take place, that is, how the ideal decision maker would set about the task. The descriptive view is how it actually happens. A prime criticism of the normative process is that there isn't time to make a full analysis of the alternatives to arrive at the best option. Besides, people usually aren't interested in the best option, they will settle for the first option that meets the minimum requirements, a process known as "satisficing," meaning both to satisfy and to sacrifice.

The focus of our attention is on providing the methods and the means to make successful capital investment decisions. These decisions are not made on the spur of the moment. They usually involve the outlay of significant resources and consequently they more closely represent the normative process. For this reason, the discussion of the decision-making process that follows is based on the normative view.

### ***2.7.1 Steps in the Decision-making Process***

The decision-making process can be broken down into different steps. One formulation that might be useful is shown in Figure 2.4. In this formulation, the decision-making process occurs in three stages: frame, evaluate and decide. Each of these stages is discussed below.



**Figure 2.4** The decision-making process

**2.7.2 *Frame: the Decision Context and Possible Alternatives***

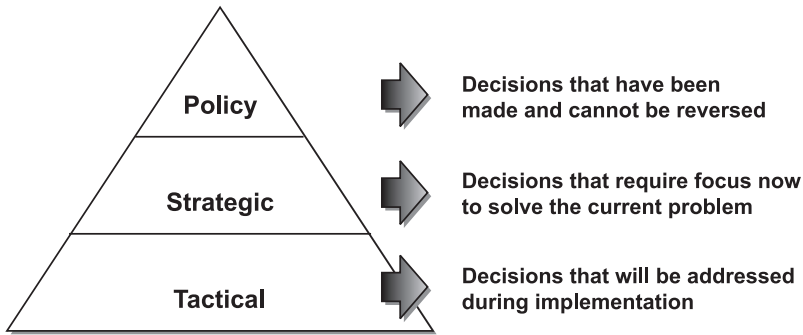
Management has to solve problems of a wide-ranging nature. For example, the pump station of a major water supply utility is not performing to specification, requiring maintenance or replacement. Should management repair or replace the equipment? Another example is the following. The capacity of the manufacturing facility will be exceeded in three years at the current rate of increase in production. Since it takes at least that long to authorize the approvals and to build a new facility, should management expand the current operations or should they build a new factory?

The decision frame is the context of the decision. The particular problem or opportunity usually comes with an “in-built” context. However, simply accepting this context limits the possibilities for a creative and better solution.

The object of the framing stage is to define thoroughly the problem or opportunity, and to specify criteria and objectives for the decision that is required. A technique that can assist in clarifying the decision frame is to ask simple questions, such as the following: (i) what is the problem? (ii) what question are we trying to address? (iii) what decisions might we have to make? (iv) what are the uncertainties? (v) what is the important background information? and (vi) what questions are we not trying to answer?

Another technique that is useful in framing a decision is to ask stakeholders what the top issues are with regards to the opportunity. These issues and their associated information can be categorized into facts, uncertainties and decisions. In this context, a fact is known information, an uncertainty is a quantity or variable about which the decision maker or the company has no control, and a decision is a choice that the decision maker can control. The category of uncertainties is used in building a model of the possible outcomes. A decision hierarchy of three different groups can be used to segregate the decisions group: the policy decisions are those that have already been made; the strategic decisions are those that are needed to solve the problem; and the tactical decisions are those that will be made later. The decision hierarchy is useful in determining and maintaining focus during the decision steps (Figure 2.5). The decision hierarchy is discussed in Chapters 9 and 14.

Other well-known management techniques may also be useful in this regard. SWOT analysis, in which the strengths, weaknesses, opportunities and threats are examined, and PEST analysis, in which the political, environmental, social and



**Figure 2.5** The decision hierarchy

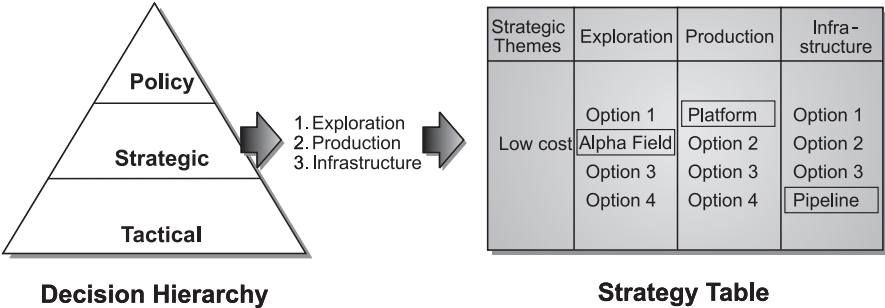
technical factors are discussed, can both be useful. Scenario descriptions, in which a number of different “states of the world” are envisaged, can be useful to indicate some of the issues at hand.

Some alternative solutions to the problem will generally emerge during a “framing session,” in which decision makers, project sponsors and other stakeholders meet to determine the problem, the boundaries of the problems and other elements of the decision frame. Additional alternatives can be generated using creative techniques, such as brainstorming and blockbusting. Brainstorming is the creation of ideas and alternatives, while blockbusting is used to remove mental “road-blocks.”

One method for seeking out viable alternatives is to generate a strategy table. The strategic decisions from the decision hierarchy are used to generate alternatives using the strategy table. For example, consider the situation in which an opportunity existed to lease a new oil property. Should the company go ahead? Decisions that are required now concern the exploration, the development and the infrastructure alternatives. Tactical decisions are those that are required later, such as, the choice of engineering contractor. The strategic decisions become the column headings for the strategy table, and the various options for each strategic decision are listed under each heading. These options are then linked together in a coherent set of choices, called a theme. The theme should have an objective and a rationale that links the various choices together in an identifiable solution strategy. These themes are viable alternatives for the solution of the problem as a whole.

An example of a strategy table is shown in Figure 2.6. There are three elements to the strategic decisions for this problem, which are the headings for columns of the strategy table. Options for each of these strategic decisions are listed in each of the columns. A strategy is the set of choices from each column that is coherent and coordinated, and is linked by a theme or rationale that drives that particular set of choices. The strategic theme shown in Figure 2.6 is the “low cost” strategy, which links the choice of the Alpha Field as the exploration target with the Platform as the means of production and the Pipeline option for the infrastructure choice. The use of the strategy table to create alternative solutions is illustrated in Chapters 9 and 14.

The framing stage of the decision process determines the problem and the boundaries of the problem, that is, what has already been decided, what needs to be decided and what is permissible in moving forward. The framing stage should deliver



**Figure 2.6** Constructing a strategy table from the decision hierarchy

a clear understanding of the problem, its limits, the decision objectives and several themed strategies that are viable possible solutions. The next step of the decision process is the analysis of these alternatives to determine the most attractive alternative.

**2.7.3 Evaluate: the Assessment of Alternatives Based on Criteria**

The second step is the evaluation of alternatives against a set of requirements or criteria. Three things are required to perform this step: (i) alternatives, which have been generated in the decision framing step; (ii) a set of criteria; and (iii) a method of evaluation. The set of criteria in general decision-making can be broad. However, in investment decisions, the main criterion is usually that the company should create wealth for its shareholders, that is, the project seeking approval must be economically viable or profitable. The senior management of a company usually specify a measure of profitability that must be used, like the payback period and return on investment discussed in Chapter 1. The method of evaluation involves both the methods for the calculation of the decision criteria and a method for assessing the most attractive alternative. A number of methods are discussed in Chapter 6.

A number of tools can assist in the evaluation stage. Influence diagrams are one these. They link the uncertainties and choices that were delineated in the framing step to the decision criteria. The influence diagrams are used to determine that all the factors that influence the decision have been included in the evaluation, and they are used to build a model of the decision criteria. They create a visual understanding of the interactions between the factors that influence the decision criteria. Influence diagrams and their application to capital project decisions are discussed in detail in Chapter 9.

Decision trees link the outcomes of events and decisions to the value of the decision criteria. Choices and events create different outcomes and these are represented as different paths on the decision tree. The values of the final outcomes are used to determine the optimal choice or set of choices. Decision tree analysis is presented in further detail in Chapter 14.







Other useful techniques in the evaluation stage are sensitivity analysis and scenario analysis. Sensitivity analysis is the determination of how much the decision criterion changes in response to variations in input values. For example, say profit was the decision measure, and two of the uncertainties are the level of market penetration and the production cost per unit. The sensitivity of the first uncertainty is the amount of change of the profit to a change in market share, and the sensitivity of the second uncertainty is the amount of change of the profit to a change in production cost. Scenario analysis is the description of several scenarios, and the examination of the impact of the outcomes expressed in the different scenarios on the decision criteria. The application of scenario and sensitivity analysis to the assessment of capital projects is discussed in further detail in Chapter 9.

### 2.7.4 Decide: the Act of Decision-making

The final step is the act of choosing the preferred alternative and implementing the decision. This may take a variety of forms depending on the stage of development of the project and the decision that has been made. For example, there are a number of decision stages in the approval of a capital project, each one of which will require the three decision-making steps discussed. The engineering and approval processes are generally aligned, as shown in Figure 2.7. Once approval has been granted for the next stage, the engineering, projects and business teams implement that next phase.

The project moves through the stages outlined in Figure 2.7. Finally, the engineering and projects team enter the stage of detailed engineering. Detailed engineering is followed by the implementation phase, which involves procurement, construction and commissioning. Once the project has been implemented, a post audit is usually conducted to assess the effectiveness of the decision-making.

Role	Stage of Project			
Business Development	Opportunity Assessment	Business Case	Business Plan	Final Business Plan
Engineering Study	Concept	Pre-Feasibility	Feasibility	Detailed Engineering
Approval	 → Y • Accept next phase plan	 → Y • Accept next phase plan	 → Y • Accept next phase plan	 → Y • Accept implementation plan

**Figure 2.7** An overview of the business development, engineering design and approval phases for a project

## **2.8 The Practice of Decision-making for Capital Projects**

Capital projects involve significant capital resources, the benefits of which will be experienced over many years. As such, there is a sense in which the present is sacrificed for the future. In the practice of making decisions about whether to invest in a project, companies will classify projects and determine the relationship between projects. These topics are discussed before discussing the decision authority for capital projects.

### ***2.8.1 Classification of Capital Projects***

Most organizations specify guidelines that assist managers in their motivation of a particular proposal. The guidelines may include a classification system for investment proposals that is appropriate to the company. The decisions concerning capital investment may be classified according to a variety of different measures depending on what is considered important about the project and the decision to invest in it. For example, the relationship between projects under consideration may be important. Projects may be independent of one another, or, they may be mutually exclusive, which means that only one of those under consideration can be chosen. They may also be classified on basis of the method of evaluation. For example, they may be classified into projects in which little or no detailed analysis is required, such as projects that are required by law, and those where detailed analysis is both possible and necessary, such as new equipment. A further classification might be made based on project risk. Low risk projects might be those such as equipment replacement decisions, normal risk projects may be those such as the expansion of the production capacity of the manufacturing operations, while high risk projects may be those such as the development of a new line of business.

The most practical distinction between projects is made based on whether the project is mandatory or discretionary. Mandatory projects are those that are required by law or contractual obligations, those that are required in order to maintain product quality or the process reliability, and those that are required to replace equipment. Discretionary projects are those that expand production, that create new business lines or that cut costs.

### ***2.8.2 Relationship Between Projects***

The relationship or dependency between proposed projects is an important consideration in making decisions concerning projects. The possible relationships between projects are the following:

- (i) Mutually exclusive. Only one of the proposals may be accepted, so that the acceptance of one proposal precludes the other possibilities.
- (ii) Independent. More than one proposal can be accepted, and each proposal has no influence on the others.
- (iii) Complementary. The acceptance of one proposal enhances the prospects of another proposal.
- (iv) Contingent. The acceptance of one proposal is dependent on the prior acceptance of another project.

These relationships between the projects influence the decisions concerning them, and should be acknowledged clearly in the decision process.

**2.8.3 Decision Authority for Capital Projects**

It has been argued that investment decisions are a critical part of a company’s success. However, in contrast to other strategic decisions, decisions on capital projects are decentralized, from corporate to divisions, divisions to operations, from operations to departments. Central control is exercised by setting budget limits for capital expenditure, hence the name capital budgeting. The board of directors sets approval limits on capital expenditure for the chief executive officer and the senior executives. The senior management then cascades these limits down to middle management positions along with other objectives, roles and responsibilities. Thus, the site of the decision-making authority depends on the size of the proposal. An example of the decision-making authority for different sized projects within a company is illustrated in Table 2.1. As shown in Figure 2.7, most projects are executed in stages. The early stages are exploratory, and even though it may eventually be a large proposal requiring the approval of the board of directors, it starts off as a divisional project requiring divisional approval for an initial engineering study.

The aims of the company and the purpose and role of the management of the company have been examined in broad terms in previous sections of this chapter. Two case studies of the practice of decision-making for the allocation of capital are described next. These examples are typical, generic descriptions of actual practice in a company. The first concerns a small project, and the other, a large project.

**Table 2.1** An illustration of the investment authority for projects of different sizes

	Project size	Authority
Very small	Less than \$100,000	Plant
Small	\$100,000 to \$1 million	Division
Medium	\$1 million to \$10 million	Corporate Investment Committee
Large	Over \$10 million	CEO and Board of Directors

### ***2.8.4 Case Study: Small Project***

Rob Sinclair is the member of the company's divisional development team. The development team's primary responsibility is to investigate improvements to the operations. These can consist of a variety of projects, from those for improved efficiency through to those for cost cutting. One of Rob's projects concerns the processing of the raw material to improve the overall cost position of the division. In discussion with the plant engineer, Rob has identified that the mill, a major consumer of energy in the plant, could benefit from advanced control techniques. Rob estimates that advanced control techniques might make savings in the electricity costs and might improve product quality. Rob obtains quotations from the two vendors who supply advanced controls systems for mills, and estimates the benefits.

Armed with a rough "business case," Rob needs to get the approval of the operations manager. The operations manager is the king of the plant; he can veto or block any initiative on the plant. Reasons for his decisions are not for questioning. If other managers seek to challenge him, he replies that their proposals are a risk to "his" operation. The operations manager views technological change with suspicion; however, competitors have implemented the same control system at their operations without disruption. Much to Rob's surprise, both the operations manager and Rob's superior give approval to prepare the engineering design and the investment proposal.

Rob contacts the two vendors, each of whom provide an engineering design and an estimate of the capital and operating costs. Rob determines the benefits to the operations, estimating the electricity savings based on the savings achieved by the competitors that they reported at the local branch meeting of the engineering professional institute. Rob decides that although the improved quality from the mill is important, it is not possible for him to quantify this, so he excludes it from his estimate of cost savings.

The capital cost is higher than Rob originally anticipated. He was hoping that he could keep the project decision at plant level, but this is not possible. As a result, the decision will be made at divisional level. He believes that it is more difficult to get projects approved at plant and divisional level than at corporate level. However, significantly more work is required to prepare a proposal for approval at corporate level, so he does not want it to be large enough that it needs the approval from the corporate investment committee. He has observed that higher-level managers in the company are more interested in projects that improve chances for the growth of the business, while the lower level managers are interested in projects that improve the efficiency of the manufacturing process. Cost-cutting measures have the best chance of approval at plant level.

Rob's calculations indicate that the payback period is 2 years, which is longer than those approved by the division in the previous year. Part of the cost of the project is the lost production while the new system is being installed and commissioned. Rob gets the vendors to redesign an implementation programme that results in minimal disruption to the production from the plant in an attempt to decrease

the payback period. The vendors' work results in reduced disruption, so that the payback period is reduced to 1.6 years.

Rob also computes several measures of economic viability based on discounted cash flow (DCF) techniques, which account for the time value of money. The company has several defined procedures for doing this. For this type of project, he must assume that the project has a ten-year life, that all prices are escalated at 6% for inflation, and that the calculations are based on after-tax cash flows. Rob assumes that the reduction in electricity consumption will be constant over the period. Rob does not perform an assessment of the financial risk. Although he calculated the more sophisticated DCF measures required by the company, the project is discussed solely in terms of its payback period at plant level.

Rob prepares a request for funds. It is a two-page document with a technical description and comments on the benefits, including the possible effect the control system may have on product quality. Rob sends it to the plant manager, who has an overview of all the requests for capital funds sent from the plant to the division. The plant manager is not particularly impressed with the project, but he has respect for Rob because of his success in previous projects. The plant manager sends it to the plant engineer for comment, before submitting it, along with other requests, to the divisional headquarters. The company has an annual capital budgeting and planning cycle during which the budgets for capital equipment are set for the year ahead. The plant manager knows that he has not exceeded the budgeted amount for the plant.

The person at the divisional headquarters who has the most influence on the decision is a vice president in charge of operations. He has prior knowledge of all of the requests for capital from the scheduled meetings with the plant manager. The company policy is to decide on capital expenditure based on the internal rate of return (IRR), one of the DCF measures that Rob has calculated. He notes that the IRR for this project is above the rate required by the company for acceptance, called the "hurdle rate." He trusts that Rob has calculated these values according to the company's procedures, and he trusts the review process undertaken at the plant.

The division has a fixed budget for capital expenses, which is split between mandatory and discretionary projects. The funding for mandatory projects across all the division's plants has increased, so that there is a significant shortfall of funds available for the discretionary projects. The division could make a request for additional funds from corporate, but the divisional president views this unfavourably, because he believes it will create a perception at corporate that he cannot control his budget or his operations.

If all the projects were ranked according to IRR, and only those with the highest IRR selected, Rob's project would not be selected. However, the vice president believes that Rob has been conservative in his estimates so he personally backs it at the meeting to review capital projects. He also argues that it is necessary to begin to examine advanced control systems for all their plants, and that this is an excellent way to do that with minimal cost and disruption to production. The project is approved.

### ***2.8.5 Case Study: Large Project***

Sarah Charlton is the divisional technology manager responsible for three of the division's nine operations. The other six operations are upstream of the three plants for which she is responsible. Demand for the division's products has increased over a number of years. Sarah believes that one of the plants within her remit will become capacity constrained within the next three years. The plant is not core to the division's primary business; however, it produces commodity products, and because most of the production costs are assigned to the core products, the plant ranks as one of the producers with the lowest costs in the industry.

She is concerned; no one in the divisional planning department or strategy department has mentioned the impending capacity constraint. In her opinion, this is a major oversight, because it takes about three years to approve a large project and begin construction. She raises this concern with the vice president in charge of operations. He asks her to prepare a proposal with a budget to perform an initial estimate of the capital costs, called an order-of-magnitude estimate. This proposal is to be submitted to the divisional steering committee, which is a subcommittee of the divisional executive committee.

Although there are few similar operations in the world, and none that have been constructed in the last twenty years, Sarah estimates that the capital cost will be in the region of \$500 million if a new operation is built, and \$350 million if a significant amount of the current equipment can be used. She obtains this estimate by escalating the capital costs of the current plant in order to account for inflation from the date when it was built. Generally, the cost of obtaining an initial capital estimate (order of magnitude estimate) costs between 0.1 and 0.5% of the estimate itself. Sarah's budget request for an engineering firm to perform the order-of-magnitude estimate is about \$2.5 million. Her proposal to the steering committee is based on two factors: firstly, the strategic need for an entirely new plant, and, secondly, an analysis of the project financials and economics.

There has been talk in the past to sell this operation because it is non-core business, so the economics must be attractive and the business case compelling to justify the construction of an entirely new operation. The methods for the analysis of the project financials are specified by corporate: all decisions are based on net present value, a discounted cash flow technique, using a discount rate derived from the weighted average cost of capital plus two percent for country risk. She has to value the operations based on a twenty-year life for the plant. She estimates three different scenarios based on different capital requirements. While all three scenarios are positive, they are only just positive.

At the next monthly meeting of the steering committee, she gets approval for the initial phase of the order-of-magnitude cost study.

Sarah and her technology manager at the facility recognize the opportunity to install modern systems and possibly new process technology. Her choice of the engineering contractor for this initial cost estimate is based on her assessment of their technical ability at the conceptual level of design. She is acutely aware of the need

to keep the capital as low as possible, and instructs the engineering company to use as much of the existing equipment as possible.

While the capital budget for the division is larger than \$100 million a year, proposals such as this do not occur often, perhaps once every four years across the entire division. As a result, they are studied in more detail and more departments are involved than for the smaller projects where the economic analysis is standardized and the decision-making is decentralized throughout the division. Two other departments at divisional headquarters will have input into the decisions as the project moves forward. These are the Projects Department and the Strategic Planning Department.

Sarah assesses that she needs to build alliances within the Strategic Planning Department and the Projects Department, both of whom will assess the project as it moves through the early engineering approval stages. The Projects Department is primarily a project management department, responsible for managing engineering projects. The Projects Department usually prepares the investment proposals for major capital expenditure for approval by the Corporate Investment Committee. The Strategic Planning Department is responsible for production forecasting and the overall scheduling of these production plans within the division. Any planned capital expenditure must also fit into their forecasts of the division's activities. At a later stage, Sarah's project will also be assessed by the division's Corporate Finance Department.

Due to some superb engineering by Sarah's technology team and the engineering company, the estimate for the capital cost of the new operation is \$250 million. The error limits on this estimate are +/- 30%. Sarah reports the findings to the steering committee. The project is assigned to the Projects Department, which is responsible for guiding it through the engineering design and capital approval process. A project manager is assigned to the project. Sarah's role now is as technical leader on the project. In addition, Sarah has secured for herself the role of producing the project financials and the financial evaluation of the project.

The Projects Department convene a framing meeting. A wide range of departments within the division is represented at the meeting, which is held to clarify the decision frame for the project. Following the framing meeting, the project moves through two further stages of engineering design: the pre-feasibility and feasibility stages. At the end of each stage, approval is sought from the steering committee for the funds to engage in the next stage. At the end of the feasibility stage, before the basic engineering work is approved, the project is assessed and examined from both technical and economic viewpoints. The project financials that Sarah has produced and refined throughout the various stages of design are scrutinised by the division's corporate finance department. The design is reviewed by a team of experts chosen from within the division and from external consultants.

A project of this size needs corporate approval. The project is placed on the agenda for the Corporate Investment Committee and onto the agenda for the meeting of the corporate Board of Directors. This establishes a deadline for the completion of the feasibility stage of the engineering and the financial evaluation of the project. Prior to the meeting of the Corporate Investment Committee, the corporate



Technical Department, the corporate Finance Department and the Strategic Planning Department need to assess and approve the project.

An investment proposal is prepared in accordance with the prescribed format and topics required by the Corporate Investment Committee. Because Sarah has maintained close contact with the Projects Department, she and the project manager are the prime authors of the proposal. She does this work in addition to her regular duties as technology manager. Sarah's project eventually is approved by all the departments, the Corporate Investment Committee and, finally, by the Board of Directors.

## 2.9 Summary

An overview of an investment in a capital project by an organization was given in Chapter 1. This chapter has provided an overview of the business context of the decision to invest in projects. The history of the field has roots in economics, engineering, financial management and accounting. As such, it is a truly interdisciplinary activity.

The financial evaluation of projects within a company is known more commonly within the fields of financial management and corporate finance as capital budgeting and within the engineering community as engineering economy. Since the process of allocating funds to the investment in capital projects is a managerial function that is at the heart of the company's future, it is often assumed that the decision-making process is a financial function that lies with the chief financial officer (CFO). In reality, many of the decisions are evaluated and made by technical and engineering staff several layers deeper in the hierarchy than the CFO. Capital budgeting is a decentralized function, governed managerially by setting approval limits. Capital budgeting is also part of long range planning and it must be integrated into the company's business plan and strategy.

The goal of the financial management of a company is to increase the value of the company for the owners of the company. The owners have tasked the management, through the Board of Directors, to run the company so that the owner's value increases. The company must be run profitably on both a year-by-year basis, and in the longer-term. The benefits of a profitable company flow to society as a whole through the payment of tax, and to other stakeholders such as the suppliers and customers, employees and owners. For the company to run a profitable operation in the longer-term, the management must continuously approve projects that they anticipate will create value for the shareholders. Management must make the right decisions about which projects to approve for a profitable future.

A decision is a good decision if process for making it is transparent, inclusive, rational and unbiased. There are a number of descriptions of the decision-making process, and all of them have similar elements. The three-step process is described. The first step, called "frame," is the framing of the decision. It consists of the recognition for the need for a decision, the definition of the decision required, its boundaries



and permitted solutions, the definition of the decision objectives, and the creation of alternatives. The second step, called “evaluate,” is the assessment of the alternatives. It consists of the specification of the decision criteria, the assessment of the alternatives, the generation of further insight into the decision problem, and the recommendation of the preferred choice. The third step, called “decide,” is the actual decision. It consists of making the decision, implementing the preferred choice, monitoring developments and evaluating the performance.

The project proposals for the investment in fixed capital are usually prepared in accordance with procedures specified by the company. There are no globally accepted procedures, and each company has different requirements for the preparation of proposals. A practical distinction between projects that is often useful can be on the basis of whether the project is mandatory or discretionary. Mandatory projects are those that must be implemented. Reasons for these projects may be that they are required because of contracts or regulations, or, more commonly, they are required to maintain product quality and process reliability. Discretionary projects are those that are not mandatory. Examples are process improvements, expansions, new products or cost-cutting exercises.

The decision authority for the approval of projects is cascaded down through an organization. The site of the decision depends on the size of the project and the levels of authority within the organization. The approval process for a larger project is usually staged. The engineering design and approval stages are coordinated so that the correct approvals are obtained with the correct engineering information.

The engineers and scientists in an organization must be able to communicate effectively with one another about financial issues and with the personnel from the accounting and finance departments. This requirement to communicate effectively becomes a prime skill as the career of the engineer or scientist develops.

## 2.10 Looking Ahead

The key concepts of accounting are discussed in the next chapter. These concepts are formulated as the three financial statements: the balance sheet, the income statement and the cash flow statement. The construction of these financial statements from business transactions is discussed. The relationship between the financial statements and with project financials is explained. Finally, the measures of the performance of a business are presented.

## 2.11 Review Questions

1. What is the difference between cost-benefit analysis, engineering economics, and capital budgeting?

2. What does financial success mean for financial accounting and financial management?
3. Why is it important for engineers and scientists to understand the viewpoints of financial accountants and financial managements?
4. What are the main drivers of value in a company?
5. What is the aim of the company's management?
6. What affects the value of a company?
7. What are the sources of funds for a company?
8. How do the activities of a company benefit society?
9. What are the roles of financial management within a company?
10. What are the main types of decisions made by the financial managers of a company?
11. Outline the types of evaluation that a project decision can be based on.
12. What are the basic stages of a decision?
13. What are programmed decisions?
14. How are projects classified?
15. Describe the decision-making process for a small and a large project in a company.

## 2.12 Exercises

1. In the description of both small and large projects, there seemed to be a shortage of capital for investment in projects. In fact, the name "capital budgeting," for the approval process and techniques for assessment of projects used in the field of financial management suggests a shortage of funds that must be budgeted. Surely if a project is a winner, the company should raise the extra financing to fund it, and thereby grow the company. This limitation of funds is called capital rationing. Discuss reasons why there might be a rationing of funds within a company.



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