Chapter 6

Economic Considerations

The objectives of this chapter are:

- to explain the basic economic concepts,
- to present the discounting techniques that are commonly used,
- to discuss optimal allocation of water from the point of view of economics, and
- to describe the procedure of allocation of cost in a multipurpose project.

Water is a renewable resource whose supply is uncertain in nature and depends on space and time. Water is a mobile resource whose availability at one place is affected by the use at other places. For this reason, the problems related to water supply are site-specific. When its availability is less, droughts occur, which adversely affect agriculture, municipal life, and cattle. An excess availability of water leads to flooding which also has high damage potential. Water is also a very good solvent and this property makes it vulnerable to pollution by a number of pollutants which adversely affects its economic value. Highly polluted water is a liability rather than an asset.

Rarely, water is completely consumed while being used to meet the requisite demands. A fraction of the water withdrawn (although of degraded quality) comes back to the system as return flow. Affected by this phenomenon are the users in the downstream reaches of an area because the quantity, quality and timing of water available to them are affected by the upstream usage. These interdependencies are known as externalities.

Due to the site-specific nature of water supply and demand, the problems of water resources management are also site-specific. The projects which are constructed to utilize raw water resources are huge and have important impacts on regional economy and environment. These projects provide significant employment opportunities and also support ancillary activities. Another feature of water management is that the projects display *economy of scale*, i.e., the cost per unit of water decrease as the project size increases.

Water is a unique economic commodity. It has a high economic value, yet it is available freely. In an extensive study in USA, Federick et al. (1996) found that the value of water is the highest in the drier, water scarce regions (USA $ 191 per acre foot) and is the lowest in humid regions ($ 7 for Great Lakes region). Regarding use, the water value is the highest for industrial processing ($ 282) and domestic uses ($ 194), and the lowest for recreation and waste disposal ($ 3).

Water was also the central subject of an interesting enigma in economics that came to be known as water-diamond paradox. This paradox can be stated as follows. Although water is necessary for human survival and consequently has higher value in terms of use, its price is very low. In contrast, diamonds are not at all essential for human survival but their value is very high. This paradox could be explained when the marginal and total values of these two commodities are considered. It is well known that the total utility of water exceeds the utility of diamonds. But the marginal utility of diamonds exceeds the marginal utility of water because diamonds are scarce and water is much more easily available. This scarcity-based higher marginal utility of diamonds is the root cause of much greater price of diamonds than that of water.

After a water resources development project is made operational, it produces a time-pattern of economical consequences. Since large sums of money and other resources are involved, it is necessary that the consequences must be carefully predicted, evaluated and compared before the project is taken up for execution. For example, consider that a dam is to be constructed in a basin to provide water for irrigation, municipal and industrial use, generate hydropower, and control flood. The reservoir may also submerge villages, and agricultural and forest areas, and people may have to be rehabilitated and resettled. Different locations and different heights of the dam will produce different patterns of desirable and undesirable effects. All the benefits and costs must be suitably considered to determine the best project configuration.

An improvement in the quality of life and enhancement of public welfare through accelerated economic development is the most common goal of national governments. The impact of a project on economic welfare can be evaluated in terms of the relative values of associated benefits and costs. If benefits are more than costs, it implies that the nation would be better off by taking up the project. On the other hand, an excess of costs over benefits indicates wastage of money. In this case, compensating the affected people by providing relief measures or rehabilitating them might be a better policy. Of course, it is also necessary to consider factors like environmental sustainability, employment generation, and national security. Logic would guide that usually a project should be taken up only if its benefits exceeded costs.

6.1 BASIC PRINCIPLES OF PROJECT ECONOMICS

Engineering economics is concerned with applying economic criteria to select the best alternative from a group of feasible engineering designs, or to evolve the best economic policy for planning, operation or management of an engineering project. The principles of engineering economics guide the ranking of alternatives so that they may be compared to determine which alternative should be selected. The project evaluation process requires prediction of consequences expected to result from picking an alternative, estimation of the magnitude of each consequence, and converting the consequences into commensurable units to facilitate comparison.

An important economic concept is that of opportunity costs. It refers to the benefits foregone when a resource is used for one purpose instead of its next best alternative use. Another concept is the marginalism. This emphasizes the importance of considering incremental gains related to incremental costs. The law of diminishing returns implies that from the producers' point of view, an increase in the use of a given input, when all other inputs are held constant, leads to decreasing increments of products. The responsiveness of demand to change in prices is measured in terms of the elasticity of demand. This term is defined as the percentage by which the quantity taken changes in response to a 1% change in the variable. The 'price elasticity of demand' for water is a measure of the willingness of the consumers to reduce water use due to rise in price or the tendency to use more if the price reduces.

Some important frequently used concepts of economic analysis are discussed below.

6.1.1 Cash Flow Diagram

After the physical consequences of each alternative are identified, only the relevant and important consequences are considered for further analysis. The consequences which do not influence the decision-making process are eliminated. Each consequence is assigned a monetary value. After assigning the monetary values to all the relevant consequences, the cash flow diagram is drawn to convert the time stream of monetary value into an equivalent single number. The intangible values are properly treated and quantified.

The graphic representation of each monetary value with time is called a *cash flow diagram*. In a cash flow diagram, the horizontal axis denotes time. The benefits are represented by arrows pointing upward, while costs are represented by arrows pointing downward. The length of the arrow need not be scaled although attempts are made to make them proportional to the cost or benefit. For convenience of analysis and with little loss in accuracy for long-lived projects, all cash flows during a year are by convention combined into lump sums occurring at the end of the year. Fig. 6.1 shows a cash flow diagram for a hypothetical irrigation project. A large sum of expenditure is made in the beginning and, thereafter, benefits are received every year. The diagram also shows expenditures that are made for maintenance every few years. In a strict sense, annual benefits and costs will not be constant every year, but will vary depending on crop production, and market price of inputs and produce. However, only expected average values are normally predicted in advance, even though the random component could also be introduced.

6.1.2 Discount Rate

A discount rate is the expression of the time value of the capital that is used in equivalence

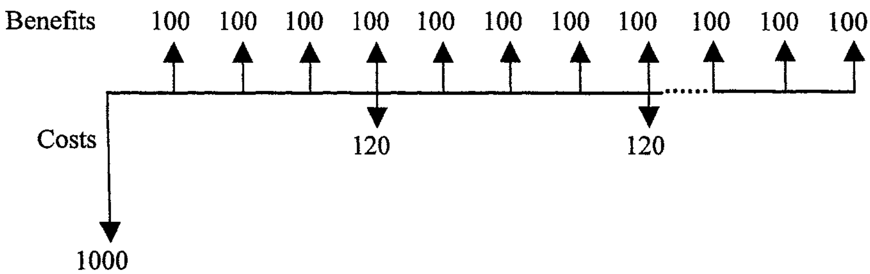

Fig. 6.1 Cashflow diagram for a hypothetical project.

calculations to compare alternatives. The rate is essentially a value judgment based on a compromise between the present consumption and capital formation from the viewpoint of the decision maker. For public works planning, this means the viewpoint of the society as a whole. The ideal discount rate would achieve a rate of capital formation maximizing the total social welfare. Many viewpoints are encountered in the selection of the best discount rate. Depending on the viewpoint, the choice of a discount rate also changes. The economic feasibility of a project greatly depends on the discount rate. Discount rate differs from the interest rate if they are defined precisely. The interest rate expresses the time value of the capital; Interest is the fee paid by an entity to use the capital of another, e.g., the rate at which banks make payment to depositors. In some way, it is rent paid to use someone else's money just like the rent paid to use a car or an apartment. The interest rate is determined by the capital market. An enterprise seeking to improve its own economic health will try to earn money by investing it in projects that give returns exceeding the borrowing rate of capital.

A low discount rate is favorable to the construction of public works projects and the groups which are benefited by project construction. Sometimes, allocation for current needs may have to be sacrificed for the future benefit. However, excessive diversion of resources to the public sector is detrimental in the long-run. Generally, a lower value may be chosen for justifying projects of greater national importance, and a higher value may be chosen for projects in private sectors. But too low a rate has serious adverse consequences to national economic growth. Since in many countries, all water resources projects are owned by government or public undertakings and there is hardly any involvement of private sector, a smaller rate of interest may be chosen by the decision maker. Finally, the discount rate changes with time and from one public body to another.

While choosing a discount rate, the lower bound should be at least as big as the available risk-free interest rate. Thus, no investment is worth undertaking unless it is just as productive as any of the comparable investments which are commonly available, such as long-term government bonds (de Neufville and Stafford, 1971). It will be better for any rational government to payback its debts rather than invest in any project whose returns are less than the interest rate of its bonds. Most large-scale water projects are taken up by governments and for such projects, social discount rates should apply.

6.1.3 Discount Factors

Before a comparison can be made, all components or consequences of a project under consideration are to be expressed in a common unit. The most convenient unit in the present era is a money unit. But the value of money changes with time and therefore, even though the consequences are expressed in monetary units, amounts at different times cannot be compared or combined. To make them comparable, all monetary values are converted to equivalent amounts at some definite time. This conversion is made by using *discount factors*.

The major obstacles in comparison of alternatives are the differences in kind and in time. The two basic principles: equivalence of kind and equivalence of time are employed to facilitate the comparison. The following example will help in clarifying these concepts.

Example 6.1: Consider two irrigation projects having the same construction costs. The first project provides water for rice and will yield 40 tons of rice and the second for sugarcane to produce 50 tons of sugarcane. If one has to invest money for only one project, which one should be selected?

Solution: This question cannot be answered with the given information because the outputs from the two irrigation projects are not in commensurable units. To answer this question, some additional information is needed - whether 40 tons of rice is more valuable than 50 tons of sugarcane or vice versa. If both crops are converted into monetary values, the comparison will be easy. The project whose output has more monetary value will evidently be selected.

Example 6.2: Assume that there are two options A and B for production of rice in Example 6.1. Option A will provide water immediately and will cost X. Under option B, the cost will be Y and water supply will start after 5 years from now. Which option should be selected ?

Solution: It is easy to see that 40 tons of rice this year will not have the same value compared to the value 5 years from now. If X = Y, people would be more inclined to invest money to produce 40 tons of rice now (option A) than 5 years from now (option B). But the two options cannot be compared with the available data because of differences in time and costs. To compare, the information about the price of rice and discount rate is needed.

We begin with the simplest case. Assume that some principal amount *P* units (say Indian rupees) are invested at an annual interest rate of *i* percent. After one year, the amount will grow to become $P(1+i)$. After one more year, it will be $P(1+i)^2$. In this way, after *n* years, the final amount will be $P(1+i)^n$. If this final amount is denoted by F then

$$F = P(1+i)^n \tag{6.1}$$

In this case, the principal amount is paid just once and it gets compounded to become *F* after *n* years. The final amount is obtained by multiplying *P* by the factor $(1+i)^n$. This factor is termed as single-payment compound amount factor. The *rule of 72* has emerged from the tables of this factor. It states: *the value of a sum doubles when the product of i (in %) and n is about 72.* Thus, a certain amount invested at 12% interest rate will double in 6 years (12x6 = 72). Also, at $i = 8\%$, the present worth of an amount that will be received 9 years later is half.

Depending upon the payment of principal and compounding interest, many discount factors are used in economic analysis. A summary of these is given in Table 6.1.

Table 6.1 Summary of discounting factors.

Type of Discount Factor	Description	Formula
	Single-Payment Factors	
Compound–amount factor	An amount P invested at the beginning of first year grows to F after end of n years.	$F = P(1+i)^n$
Present worth factor	It gives the present value of a future amount F that might be available after n years (inverse of above).	$P = F/(1+i)^n$
	Uniform Annual Series Factors	
Sinking-fund factor	The amount A that should be invested at the end of each year, for n years, to yield F at the end of n years.	$A = Fi/[(1+i)^n - 1]$
Capital-recovery factor	The amount A that will be received at the end of each year, for n years, if amount P is invested at the beginning of first year.	$A = Pi(1+i)^n / [(1+i)^n - 1]$
Series-compound amount factor	The amount F that will be obtained at the end of n years if an amount A is invested at the end of each year, for n years.	$F = A[(1+i)^n - 1]/i$
Series present worth factor	The present value of P if an amount A is invested at the end of each year, for n years.	$P = A[(1+i)^n - 1] / i(1+i)^n$

Example 6.3: A bank launches a new scheme in which an investor has to deposit Rs. 1000 each year for 10 years and he will get Rs. 14500 at the end of 10 years. What is the rate of interest that an investor will be getting upon joining this scheme?

Solution: Applying the equation for the series compound amount factor (Table 6.1)

$$F = A[(1+i)^n - 1]/i$$
$$14500 = 1000*[(1+i)^n - 1]/i$$

Solving by trial and error, i is about 0.08. So, the investor will get return at 8% per annum.

Example 6.4: A friend of Mr. B offers him a bond for Rs. 6000. This bond will yield him Rs. 150 per month for the next 50 months. Mr. B has the money and it can otherwise give him a return @ 1% per month. Should he accept the offer?

Solution: To make a decision, the present worth of a payment of Rs. 150 for 50 months @ 1% is to be determined. Using the formula for the series present worth factor,

$$P = A\,[(1+i)^n - 1] / [i(1+i)^n]$$
$$= 150\,[(1+0.01)^{50} - 1] / [0.01(1+0.01)^{50}]$$
$$= 5879$$

Since the present worth of the bond is less than the asking price, the offer should be rejected.

6.1.4 Sunk Cost

While comparing projects, or analyzing the justification for alterations or expansions in a project, it is necessary to see how much money has already been spent. Obviously, the money already spent cannot be made available for investment now nor can it be recovered. Therefore, such an investment is not taken into consideration for an economic study. Past expenditure, which has no economic relevance in deciding future alternatives, is termed as *sunk cost*. Sunk costs may be disregarded while comparing alternatives except for their influence on future cash flows. However, sunk costs may influence decisions for two main reasons. The decision maker may have some prior commitment to continue a policy so that the past efforts are not wasted. Also, an un-depreciated book value for assets which have no economic worth may restrict freedom to make a new investment. In any case, past mistakes are not legitimate and plausible reasons to continue with an unjustifiable policy.

6.1.5 Intangible Values

An economic study seeks to evaluate all consequences in commensurable monetary units. But there are many items which cannot be quantified in terms of monetary units. An old temple, for instance, which will be submerged in the reservoir or a valley with natural beauty cannot be assigned a money value. Each such matter which cannot be expressed in monetary terms is called an *intangible*. Such matters do not have direct effects on human beings physically through the loss of health or life, emotionally through the loss of national prestige or personal integrity, or psychologically through environmental changes. Moreover, monetary values cannot measure the achievement of many extra economic goals, such as income redistribution, increased economic stability, or improved environmental quality.

The inability to express a value in economic units does not necessarily preclude its evaluation in other units. All intangible values should be quantified as precisely as possible because these do influence decisions. While weighing whether a given sacrifice in economic value is worthwhile to achieve a goal, the decision maker should have access to the best possible data on the nature of the intangible consequences in addition to the economic consequences.

5.1.6 Salvage Value

Some project elements may have economic or physical lives shorter than the period of analysis. Such elements need periodic replacement. However, all alternative projects must be evaluated over the same period of analysis. If the period of analysis is not an even multiple of life of elements, the service life of some replaced elements will extend beyond this period. In this case, an adjustment must be made through a negative cash flow equal to the value of the element at the end of the period of analysis. The value of the unused life of an element at the end of the period of analysis is its salvage value. The straight-line depreciation may be used to estimate the salvage value (S) of an element by the following formula:

$$S = I\,(1 - U/L) \qquad (6.2)$$

where U is the years of unused life, L is the years of total life, and I is the initial value.

Example 6.5: A pump requires replacement every 20 years and is to be used in a project where the economic study is based on a period of analysis of 70 years. What salvage value should be used if the initial cost is Rs. 25000? Also, determine the total number of pumps which will be required during the economic life of the project which is also 70 years.

Solution: Since a new pump will be installed at the interval of 20 years, the fourth pump will be required to be installed in the year 60. This pump will have 20 - (70 - 60) = 10 years of useful life remaining at the end of the period of analysis. Therefore, U = 10 years, L = 20 years, and I = Rs. 25000. From eq. (6.2)

Salvage value, S = 25000 (1 - 10/20) = Rs. 12500

Total number of pumps required = 70/20 = 3.5 = 4 (rounded to next higher integer).

6.1.7 Marginal Returns

The rate of change of output of a process with respect to change in individual resources is known as marginal product with respect to that resource:

$$MP_i = \Delta P / \Delta x_i \qquad (6.3)$$

where ΔP is the change in the product, and Δx_i is the change in input x_i. As more and more quantity of a resource is used, its marginal product eventually decreases, leading to the law of diminishing marginal return. At the optimum solution, the marginal product per unit cost of resource must be the same for all resources.

6.1.8 Planning Horizons

The planning horizon is the most distant future time considered in an engineering economic study. The uncertainty inherent in predicting the more distant future favors short planning periods. But the water resources projects have long life necessitating an analysis of long-term effects of projects even though they might be constructed to meet immediate requirements. Actually, three different time horizons must be considered in any economic analysis: (1) the economic life, (2) the physical life, and (3) the period of analysis. These are explained below.

Economic life: The time span after which the benefits from the operation of a project are less than the cost of operation is called the economic life. After the economic life is over, the project no longer gives benefits which exceed the operation and maintenance cost. The economic life of different project components may be different, e.g., the spillway gates and turbines in a hydropower plant will have different life spans.

Physical life: This is the length of time beyond which the project can no longer physically perform its intended functions. The economic life can be greater or equal to the physical life, because of obsolescence and changing demands for services. Many factors cause economic life to be shorter than the physical life. As an example, due to rapid developments in electronics, it may be economical to get a defective computer replaced rather than repaired.

Period of analysis: This is the length of time over which the project consequences are considered in the analysis. The project economic life is the upper limit of this period. For water resources projects, the period of analysis may be in the range of 50 to100 years.

6.2 DEMAND AND UTILITY OF WATER

Consider that a consumer has to purchase some commodity to meet his needs and a number of alternatives are available to him. These alternatives mainly differ in terms of price and the consumer is aware of this. The behavior of a consumer with and his decision making process can be explained using some concepts that are explained in this section.

6.2.1 Water Demand and Cost

A user gets many types of benefits from water which are (Young 1996): 1) Commodity benefits, 2) Waste assimilation benefits, 3) Public and private aesthetic and recreational benefits, 4) Species and ecosystem preservation, and 5) Social and cultural values. The first three can be treated as economic considerations, because they are characterized by increasing scarcity and the associated problems of allocation among completing uses to maximize economic benefits.

The demand for water can be for in-situ or withdrawal uses. For in-situ or in-stream uses, such as hydropower generation, recreation, and waste assimilation, water need not be removed from its source. The withdrawal uses, such as municipal and industrial uses, and irrigation, water needs to be removed from its source. The willingness of consumers to pay for water varies inversely with the amount being procured. The following functional relationship relates the demand to the cause variables

$$D_w = f(P_w, P_a, I, P, Z) \tag{6.4}$$

where D_w is the demand of water over a given time; P_w is the price of water; P_a is the price of an alternative source of water; I is the income of the consumer; P refers to overall price index such as the consumer price index; and Z represents the effect of other relevant factors.

The demand function of a consumer is used to determine the quantity of a commodity that he is willing to buy as a function of price and income. A typical demand function is plotted in Fig. 6.2. Since the quantity of a commodity that is demanded increases as the price is reduced, the graph of demand function slopes towards right. The consumption decreases as the price increases and this is known as substitution effect.

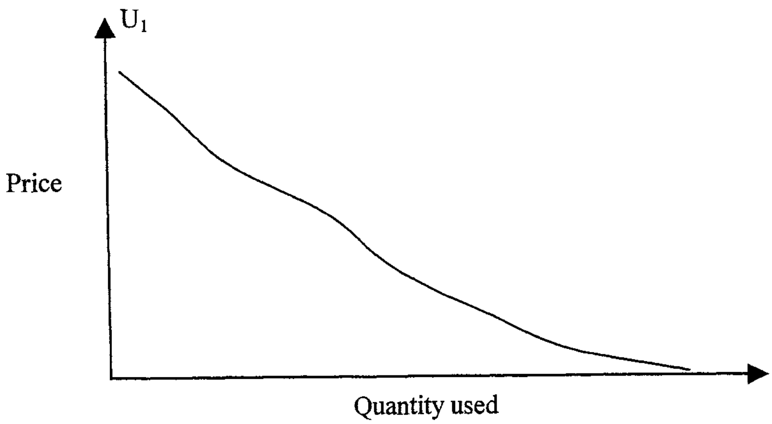

Fig. 6.2 A typical demand curve for water.

Three components that add up to make the cost of water were mentioned by Rogers et al. (1998). These are: the full supply cost, the full economic cost, and the full cost. Each of these is composed of separate elements. Fig. 6.3 schematically shows the components. The full supply cost includes the costs associated with the supply of water to a consumer without consideration of either the externalities imposed upon others or of the alternate uses of water. For a water supply system, full supply costs are composed of operation and maintenance (O&M) cost, and capital charges. O&M costs include price of raw water, electricity for pumping, expenditure for treatment plants, wages, and expenditure for maintenance of the components. Capital charges should include depreciation charges and interest costs. The sum of the full supply cost, the opportunity cost associated with the alternate use of the same water resource, and the economic externalities imposed upon others due to the consumption of water by a specific sector gives the full economic cost of water. The opportunity cost arises because by consuming water, another user of water is being deprived of water. If there is no shortage of water, the opportunity cost is zero.

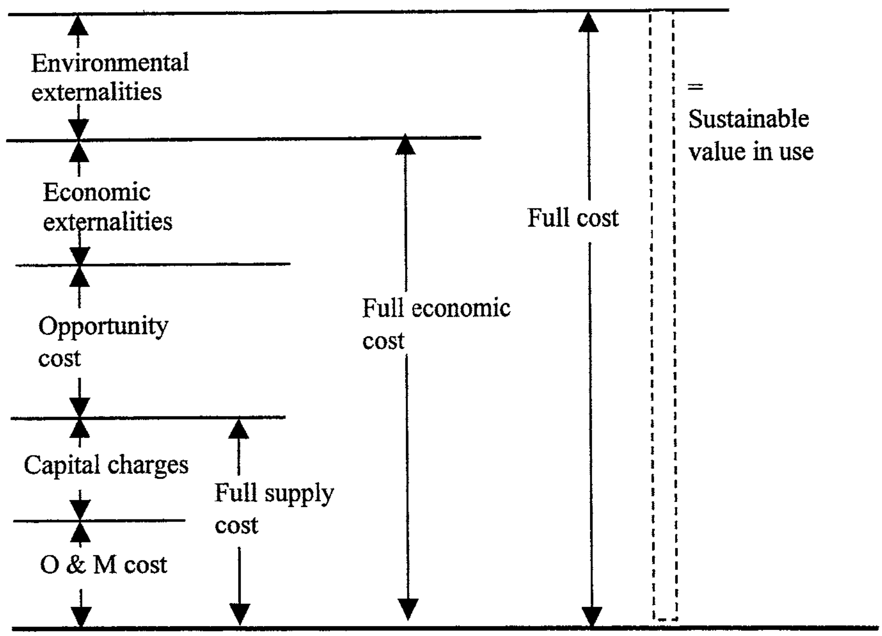

Fig. 6.3 General principles for cost of water [Source: Rogers et al. (1998). Copyright © Global Water Partnership. Used by permission].

6.2.2 Elasticity of Water Demand

The elasticity of demand is a measure of responsiveness of consumers' purchases to variation in price. It is defined as the percentage by which the quantity used changes in response to a 1% change in price. The price elasticity of demand for water is a measure of willingness of a consumer to reduce the use of water in response to the rise in price or use more water if price falls. If the quantity demanded does not change much with price, then the demand is said to be inelastic and it is elastic when there are large changes in demand with price. A change in price of water does not produce immediate reactions but the effects are felt in the long-run. The uses of water for outdoor activities, such as lawns and gardens, show an elastic response, while the use in homes is inelastic.

Since the elasticity of a commodity is determined from the demand curve, it is influenced by all those factors which influence demand. Typically, the more elastic a commodity is and more substitutes are available, the wider is the range of uses and the larger is the proportion of consumer's income that is spent on the commodity

6.2.3 Utility Theory

An intelligent consumer always chooses that particular alternative which gives him the maximum level of satisfaction. Utility functions provide information about satisfaction that a consumer gets by consuming a certain quantity of given commodities during a specified span of time. Let the quantity of n commodities that a consumer uses be $c_1, c_2, \ldots c_n$. His utility function can be expressed as

$$U = f(c_1, c_2, \ldots, c_n) \tag{6.5}$$

A utility function is a continuous function. Suppose that the consumer chooses a number of consumption combinations of these commodities such that the level of satisfaction remains the same. A locus of these points is known as an *indifference curve.* Note that the indifference curves do not intersect because a given combination of commodities will yield a unique level of satisfaction. Such a curve when there are only two commodities is shown in Fig. 6.4. In this figure, different curves represent different values of utility, viz., U_1, U_2, U_3 ...

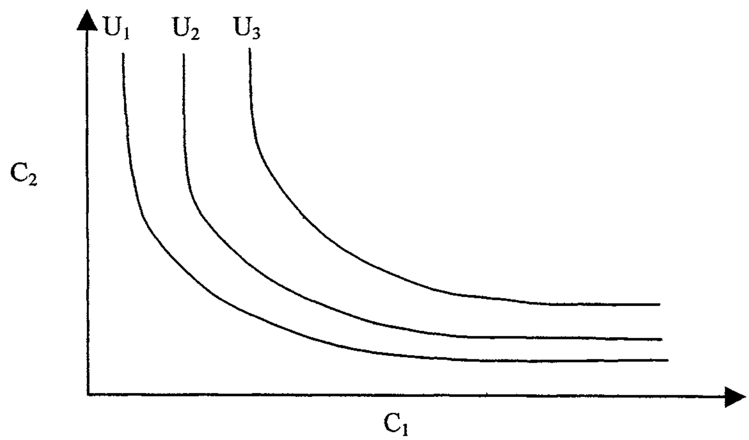

Fig. 6.4 Indifference curves for two commodity case.

It can also be seen from Fig. 6.4 that the end segments of the indifference curves are asymptotic to the axes because as less and less of one commodity is consumed, more and more of the other commodity must be used to derive the same level of satisfaction. The change in utility function with respect to a change in consumption of a commodity at a point on indifference curve is its marginal utility. The differential of utility function eq. (6.5) can be written as

$$dU = (\partial U/\partial C_1)dC_1 + (\partial U/\partial C_2)dC_2 + \ldots + (\partial U/\partial C_1)dC_1 \tag{6.6}$$

Here, quantity $(\partial U/\partial C_1)$ is the marginal utility of commodity C_1, and so on.

The utility theory has not found wide applications in water resources systems engineering. The main reason behind this (Loucks et al. 1981) is the requirement that the decision maker quantifies his attitudes toward risk. This is usually problematic because it is difficult for someone to articulate how he values an investment whose return is a random variable.

6.3 PROJECT ECONOMICS AND EVALUATION

Project economics involves the identification and quantification of all kinds of costs and benefits associated with a project and economic analysis of the proposed plans. Project evaluation involves testing the project for all types of feasibilities, its evaluation, and assessment of implications of changes in inputs. These studies are important before adopting a project plan or policy because water resources projects directly affect the development of a state, or region and the living standard of the people therein.

6.3.1 Project Cost

The initial cost of a project includes construction cost, engineering and administration cost, right-of-way cost, the cost of relocating facilities, and other minor costs. Construction cost is the amount spent on physical works outlined in the plans and specifications. The engineering cost is the amount spent on preparing the plans; structural and hydrologic design, and specifications; inspecting construction work; conducting special investigations, such as structural and hydraulic model studies, geologic explorations; technical review of engineering details, etc. The administration costs include salary and perks of staff, office expenses (paper work, audit), and legal costs. The right-of-way cost is the payment to use the land required for project purposes. The land cost, which may still be used by the original owner but is secured against possible threat due to project is termed as easement cost. Relocation cost is the expense to move or modify the existing facilities, such as bridges, roads, railroads, and powerlines located on the project right-of-way. Other costs include payments for water-rights acquisition (if any), publicity through media, etc.

After installation, the project requires continuous expenditure for operation, maintenance and replacement. Operation costs include those costs which are associated with the control of outlets/gates, supervision of hydroelectric plants, purchasing power for pumping, and other activities required to produce project output on a continuing basis. Maintenance costs are those associated with the preventive measures to reduce breakdowns, repair of works, etc. Major repairs of civil works are usually needed after large floods. Replacement includes periodic changing of parts, such as pumps, well casings, or machinery whose useful life is less than that of the project as a whole, and normal wear and tear. The capital cost of a project is compiled by adding costs for items, such as investigation and planning, land, building, works, tools and plants, work-charged staff, maintenance during construction, contingency, etc.

6.3.2 Project Installation Cost

The construction cost can be estimated by determining the quantity of each input required to complete the project and multiplying the quantity by a unit cost. The unit cost can be based on contract bid prices for that item in similar recent construction projects. A contingency estimate of about 15% of the sum of the item costs is normally added to the total to allow for unforeseen developments during construction. The contingency allowance should be larger for preliminary planning estimates where the analysis has been less detailed. Note that the norms will vary with country and region.

Engineering and administration costs are estimated as a fixed percentage of the construction cost. Extra costs may be added when unusual design or construction problems are likely to be encountered or when the project is located in a difficult terrain.

The price for right-of-way is estimated based on the judgment of professional appraisers from their experience with real-estate market. Adjustments to this estimate are needed because the market value of the property is based on an implicit capitalization of the expected future income at a discount rate well in excess of that used in project planning. An unwilling seller places a value on a property in excess of the market price since he wants to derive a value from his property, based on sentimental attachment, effect on his way of life and established relationships with others in his community. In some cases, the resistance to sell depends on the degree of threatened change in his life and the seller would like to be compensated for this.

The adjustment for the right-of-way cost due to the first kind is made by expressing the market value, M_v, in terms of the economic value, E_v, as:

$$E_v = i\, M_v / d \tag{6.7}$$

where d is the planning discount rate, and i is the implicit market discount rate. If this adjustment is not made, the use of two discount rates will severely distort the project evaluation. The above expression assumes that the property has an indefinitely long life. A typical value for i is about 7 to 8%. The economic value for the second type of adjustment is difficult to quantify.

Easement costs are taken as a percentage of the purchase cost determined by the degree the easement restricts private land use. However, easement costs are not too popular because their cost is usually close to the full land value. Severance damages must be paid when the right-of-way separates parcels under common ownership or interferes with land use or access. The acquisition cost, legal fees, and administrative expenses can be estimated as a fixed sum for each parcel which must be purchased.

6.3.3 Rehabilitation and Resettlement Costs

Rehabilitation and Resettlement (R&R) of the population displaced or affected due to a project has been a hotly debated issue in recent years. In countries with high population density, a large number of people may be affected by a project. Therefore, this is a very important issue and in the absence of a satisfactory resolution, the progress of a project may be completely halted. The packages for rehabilitation at the new site consist of infrastructure facilities, compensation for the land submerged and plots for building houses at the new site at nominal costs. Free facilities for transport of personal effects and loans, etc. are provided to the population displaced. In many projects, the R&R packages offered by the project authorities have been rejected by the beneficiaries as being inadequate. This topic is dealt with in detail in Chapter 7.

Recent experience shows that the R&R expenses are a significant part of the total project budget. But there is a tendency on the part of planners to earmark a small amount for this purpose so that the benefit-cost (BC) ratio, and thereby the justification of the project is not adversely affected. However, such projects usually face funding problems when the work is at advanced stage. It is, therefore, important that a realistic estimate of R&R costs is made by considering the current market (or even slightly higher) prices. A reasonable amount may be set aside to provide soft loans to the affected people to start new business or vocation.

6.3.4 Operation, Maintenance and Replacement Costs

The operation costs are estimated from expected salaries, fringe benefits, and overhead costs of hiring the required operating personnel, providing them with the required equipment and supplies, and the market cost of electricity or fuel consumed in operation. The number and type of operational personnel, supplies and equipment required can be estimated from experience in operating similar projects. The annual cost of project administration should also be included.

The annual maintenance cost may be estimated as a percentage of the construction cost for each group of items. Typical percentages are 3.0 for earth channels, 0.5 for earth dams, and 0.1 for concrete structures. An alternative method is to estimate these costs from a maintenance program in which the required quantity of personnel, equipment, and supplies is estimated, and its cost is determined from prevailing prices.

Replacement costs are developed from the estimated dates and costs of replacing assets whose lives are shorter than those of the project. Annual replacement cost, A_c, over the project life is determined as:

$$A_c = (P - L)[\,(A/P, i\%, L_a) - (A/P, i\%, L_p)] \tag{6.8}$$

where P, L, L_p and L_a are the costs of new asset, the salvage value of the old, the project life, and the asset life, respectively. The notation (A/P, i%,L) denotes capital recovery factor (see Table 6.1).

6.3.5 Total Annual Cost

The total annual cost of a project is the sum of the annual recovery cost and annual expenditure on operation, maintenance and replacement. The annual recovery cost is obtained by multiplying the capital investment with the capital recovery factor. The Capital Recovery Factor (CRF) indicates the number of rupees one can withdraw in equal amounts at the end of each of N years if Rs. 1 is initially deposited at i% interest per annum. It is a factor by which the capital investment or the present value at the beginning of a project's life should be multiplied to get an equivalent annual recovery cost or fixed annual figure sufficient to repay exactly the present sum in N years with interest rate i. The CRF is explained in Table 6.1. If a fixed initial cost (capital investment) of a project is C_o, and a constant annual operation, maintenance and repair cost is OMR, then the total annual cost (TAC) is given by:

$$TAC = (CRF)C_o + OMR \qquad (6.9)$$

Example 6.6: The construction of a hydroelectric project would cost Rs. 70 million. The project has an annual operation and maintenance cost of Rs. 4 million and a 50-year life. What is the annual cost of the project if a planning discount rate of 3% is to be used?

Solution: The CRF is computed by

$$CRF = [0.03(1 + 0.03)^{50} \} / [(1 + 0.03)^{50} - 1]= 0.0388654$$

$$TAC = (0.0388654)*70 + 0.40 = 3.1205846 = \text{Rs. } 3.12 \text{ million/year.}$$

6.3.6 Project Benefits

Benefits from a water resources project can be classified into two categories: direct and indirect. Direct benefits refer to those that are produced on account of direct physical effects of projects, such as increased agricultural production, hydro-power generation, reduction of flood damage and benefits from municipal and industrial water supply, etc. Benefits arising out of technological and economic linkages of the effects of a project are regarded as indirect, e.g., increased benefits due to better quality of life (because of the availability of sufficient water) or increase in agricultural productivity on account of flood control measures. These benefits may stem from or be induced by direct benefits.

Normally the benefits that are taken into account for project formulation belong to the category of direct benefits only. Indirect benefits are not included because there is no well-accepted way of quantifying them. Project promoters are often eager and include these benefits so as to improve the benefit-cost ratio. Since indirect costs also enter into the estimates along with benefits, they tend to reduce the overall benefits. But whatever that may be, there is no justification in neglecting the indirect effects altogether. These benefits and costs constitute an important aspect of project impact and must be appropriately included in the benefit-cost analysis.

The procedures for estimating annual benefits are different for flood control, drainage and anti-erosion works. In the case of flood control works, say, embankments, an estimate of annual benefits is made by finding out the average monetary value of annual flood damages of a few years before the construction of the project. In some cases, benefit is estimated by multiplying the area affected by some assumed value of the damage per hectare for unirrigated and irrigated lands. From this, an estimate of the average annual damage after the construction of the project is deducted. There is also provision for appropriate adjustments for the beneficial value of silt deposition, if any. But there are no standard guidelines to estimate these and the practice varies from country to country and may be even within the same country too.

6.4 DISCOUNTING TECHNIQUES

Water resources planning and management involves choices amongst physically feasible alternatives which are governed by many factors, such as technical, economic, social, financial, environmental, and political. An engineering alternative is a course of action which is physically capable of achieving the design objectives. The alternatives are called mutually exclusive if only one from a set can be selected, may be due to conflicting site requirements, limited financial resources, or inputs. Sometimes, it may be practical to implement two or more alternatives to arrive at the solution. A properly defined alternative must be specified with sufficient clarity so that its economic and intangible consequences can be evaluated.

An economic analysis is performed in a series of steps as given below:

1. Each promising alternative is identified and explicitly defined in physical terms.
2. The physical consequences of each alternative are expressed in terms of monetary estimates, including the dates as well as the magnitudes of the receipts and disbursements.
3. A period of analysis is decided.
4. The estimates of the lives and salvage values, if any, of the structures and other assets are prepared.
5. A discount rate is selected and applied to convert the predicted time stream of monetary values into an equivalent single number.
6. The alternatives are compared on the basis of equivalent monetary values.

The procedures in which discounting factors are systematically applied to compare alternatives are known as discounting techniques. The alternatives may be either different projects or different sizes of the same project. Discounting factors are applied to convert cash flows to an equivalent single number at some definite time. The present value of either benefit or cost is obtained by applying suitable discounting factors to cash flow. It can also be estimated as:

$$PV = \sum_{t=1}^{T} (1+ i)^{-t} A_t \qquad (6.10)$$

where PV, T, t, i, and A_t denote the present value (of benefit or cost), the planning horizon, the index for time, the discount rate, and the amount (benefit or cost) at time t, respectively. The discounted amounts for costs and benefits, or net benefits are analyzed by one of the discounting techniques to arrive at the best alternative.

The commonly used discounting techniques are: a) The benefit-cost ratio method, b) The present worth method, c) The rate-of-return method, and d) The annual-cost method. If properly applied, each method should lead to more or less the same conclusion. These methods are discussed in what follows.

6.5 BENEFIT-COST RATIO METHOD

The principles of welfare economics are based on the assumption that each individual is the best judge of his or her own welfare, and the welfare of the society is based on that of its citizens. The gross welfare of the society increases if the welfare of one individual increases without corresponding reduction for individuals. This is called a *Pareto improvement.*

A fundamental concept of the benefit-cost (BC) analysis is the principle of Pareto superiority which was defined by Vilfredo Pareto (an Italian social scientist) as: *Economic state 1 is to be judged socially superior to economic state 2 if at least one person individually judges 1 superior to 2, and no one judges 2 superior to 1.* In other words, a Pareto improvement is a change in economic situation that makes one or more members of society better off without making any one worse off. Although this concept sounds good, is difficult to realize because in practice, a policy aimed at making some one better might make some others worse. Therefore, a modification in terms of a majority rule is desirable. This leads to what has been termed as *Potential Pareto Superiority* rule which states: "Economic state 1 is socially superior to economic state 2 if those who gain by the choice of 1 over 2 could compensate those who lose so that if compensation were paid, the final result would be that no one would be worse off than he would be in state 2". A Pareto optimum is a solution in which it is not possible to increase welfare of any individual without decreasing the welfare of some other person.

The BC ratio is defined as the ratio of the present worth of benefits and the present worth of costs. The benefits are positive effects of a project for which the beneficiaries are willing to pay. The costs are the value of opportunities forgone because of commitment of resources to the project or the willingness to pay to avoid detrimental effects. The present worths of costs and benefits are computed separately, and then the ratio is determined. The annual values can be used as an alternate without affecting the ratio. The term *opportunity costs* refer to the benefits that are foregone when a scarce resource is used for a purpose instead of its next best alternative use.

Note that the BC criterion requires that those who gain are able to compensate losers and still be better off. This is the rational of the BC analysis. However the criterion does not demand that the compensation actually be paid, only that it is possible that suitable compensation exists to leave no one worse off.

Although it does not reflect the real productivity, the BC ratio has a lot of relevance under certain conditions. This is when several independent projects are to be chosen, given some capital constraint. Then, it is appropriate to rank the projects by their respective BC ratios, implementing successively lower projects until the BC ratio of the marginal project reaches unity.

6.5.1 Steps of BC Analysis

As stated, the BC ratio (R) is the ratio of the present value of all benefits to the present value of all costs. It can be calculated as

$$R = \frac{B}{C} = \sum_{t=0}^{n} \frac{B_t}{(1+i)^t} \Big/ \sum_{t=0}^{n} \frac{C_t}{(1+i)^t} \tag{6.11}$$

where B_t and C_t are the monetary values of benefits and costs incurred at time t respectively,

i is the discount rate, and n is the life of the project. In some cases, the sum of the discounted net benefits in those years when gross benefits exceed the total cost (discounted positive net benefits) divided by the sum of discounted net benefits in those years when total costs exceed gross benefits (discounted negative benefits) is computed. This discounting method is also termed as the *net benefit-investment ratio.*

While computing BC ratios, it is important to use uniform computational methods to achieve comparable results. A different and lower value of the BC ratio is obtained using gross benefits and gross costs. In other words, moving a cost from the denominator and subtracting it from the numerator (as by omitting the production cost from the gross cost stream and instead deducting it from the gross benefit stream) will change the ratio value. Clearly, any manipulation that reduces the size of the denominator will increase the ratio. It is common not to compute the BC ratio using gross costs and gross benefits but to compare the present worth of net benefits with the present worth of investment cost plus operation and maintenance costs.

The following steps are followed to choose the best alternative by this method:

1. Calculate the BC ratio for each alternative.
2. Choose all alternatives having a BC ratio exceeding unity. Reject the rest. If the sets of mutually exclusive alternatives are involved, proceed to steps 3, 4 and 5.
3. Rank the alternatives in the set of mutually exclusive alternatives in order of increasing cost. Calculate the BC ratio by using the incremental cost and the incremental benefit of the next alternative above the least costly alternatives.
4. Choose the more costly alternative if the incremental BC ratio exceeds unity. Otherwise, choose the less costly alternative.
5. Continue the analysis by considering the alternatives in order of rank.

While performing the above steps, all BC ratios should be computed by using the same discount rate and the same period of analysis. The BC ratio does not distinguish between a big project and a small project. Being a ratio, it does not reflect the actual productivity. This ratio is particularly favourable to projects where most of the cost is initial investment and the year-to-year expenses are minimal. It is important to recognize that the best project has the greatest net benefits, not the largest benefit-cost ratio. Sometimes, the BC ratio method leads to different decisions than do other techniques. However, this conflict occurs when the incremental-cost principle of steps 3-5 is neglected.

The BC ratio can also be obtained by dividing the net annual benefits estimated as the difference between the 'with' and 'without' scenarios by the annual cost. In India, for example, the latter includes annualized interest on capital cost at 10%, depreciation at 2%, and operation and maintenance expenses. The discount rate used is usually the opportunity cost of capital.

The decision on whether particular cash flows should be considered costs or negative benefits is sometimes arbitrary and affects the BC ratio. There is considerable variation among agencies in the definition of cost in the BC ratio. Most agencies include the entire government cost on the cost side, but there are differences in the treatment of associated cost by individuals, which in some instances are considered among costs, in others as negative benefits. Since these costs are rarely a high percentage of all project costs, the error is relatively small. The practice understates BC ratios, since the subtraction of a negative constant from the numerator plus its addition to the denominator of a ratio greater than one always acts to reduce the result. Thus, if benefits are 12, government costs 7, and associated costs 2, the BC ratio according to economists is (12-2)/7 or 1.43, while engineers may calculate it as 12/(7+2) or 1.33.

The BC ratio method is the conventional technique that is widely used to analyze public works proposals. After eliminating technically unsound alternatives, some other criteria are applied for further screening of projects. This has led to the use of the BC ratio as the major deciding criterion. Generally, only those schemes that show a favorable BC ratio are taken up for further examination or execution. In special cases, strong justification, other than economic criterion based on the basic needs of the specific area, are taken into account. For example, a project may be taken up in a drought-prone area, even though it might not have a favorable BC ratio.

Some economists have advanced the concept of a social BC ratio. In this approach, the benefits and costs are social benefits and social costs and social discount rate is used. These are different than the actual benefits and costs. The reason is that the value of a unit output generated by a project in a poor or backward region is more than the same output in a prosperous region. How much more this value will be depends on socio-political conditions of the country.

6.5.2 Incremental Benefit and Cost

Any change in the proposed project plan results in changes in associated benefits and costs. The terms *incremental benefit* and *incremental cost* indicate the changes that occur in the benefit and the cost, respectively, due to alterations in the project plan. According to the incremental cost principle, the change in benefits and costs resulting from a given decision determine the merit of that decision. Each project segment should be judged on its own merit. The decision to increase the size of a project should be justified by extra benefits and the incremental benefit should be more than the incremental cost. Analysis based on the total cost and total benefit may give different solutions to those obtained from the incremental cost principal.

Example 6.7: Two alternative projects are under consideration. The estimated cost of the first proposal is Rs. 40 million, whereas that for the second is Rs. 45 million. If the benefits from these proposals are Rs. 45 and 48 million, respectively, which proposal should be adopted?

Solution: The BC ratio for proposal 1 = 45/40 = 1.125. The BC ratio for proposal 2 = 48/45 = 1.067. Since both proposals have BC ratios greater than 1, both will be analyzed using the incremental principle as per step 3 described earlier. The first proposal will have rank 1, and the second one will have rank 2. Thus, incremental cost (second proposal over first proposal) = 45 - 40 = Rs. 5 million. Incremental benefit (second proposal over first proposal) = 48 - 45 = Rs. 3 million. Incremental BC ratio = 3/5 = 0.6. Since incremental benefit-cost ratio is less than 1, the less costly alternative will be selected. Therefore, proposal 1 will be selected.

Example 6.8: A project costing Rs. 2.0 million is expected to produce the benefits of Rs. 3.0 million. Before starting the project, it is observed that the adoption of some advanced technology can increase the benefits to Rs. 3.2 million. If the consultation charge for the advanced technology is Rs. 0.5 million, state whether the adoption of advanced technology is justified?

Solution: BC ratio without advanced technology= 3.0/2.0 = 1.5.
Incremental cost of advanced technology = 0.5 million rupees.
Incremental benefit from advanced technology= 3.2 – 3.0 = 0.2 million rupees.
B/C Ratio with advanced technology= 3.2/(2 + 0.5) = 3.2/2.5= 1.28.

Since the incremental cost of the advanced technology is more than the incremental benefit, the adoption of advanced technology is not justified. Further, the BC ratio without the advanced technology is higher than with advanced technology. Hence, it is advisable to continue with the original plan.

Example 6.9: An amount of Rs. 1000 is invested each in projects A and B. Project A returns Rs. 200 at the end of year for 10 years while Project B returns Rs. 130 at the end of the year for 20 years. Rank the projects using the BC ratio method if the discount rate is 4%. Also, rank them if the discount rate is 11%. This example illustrates the role of the discount rate in project ranking.

Solution: The computations are shown in the table below. The present value of benefits can be obtained using the series present worth factor (see Table 6.1).

Project	Initial cost	Benefits	For r = 4%		For r = 11%	
			Present value of benefits	BC ratio	Present value of benefits	BC ratio
A	Rs. 1000	Rs. 200 per year for 10 years	Rs. 1622	1622/1000 = 1.622	Rs. 1177	1177/1000 = 1.177
B	Rs. 1000	Rs. 130 per year for 20 years	Rs. 1766	1766/1000 = 1.766	Rs. 1035	1035/1000 = 1.035

Evidently, at r = 4%, project B scores over A due to higher BC ratio. But when r = 11%, project A has higher ranking than B.

5.5.3 Economic Rationale of Benefit-Cost Analysis

The rationale for BC analysis is based on two fundamental economic concepts: scarcity and substitution. The first of these implies that the resources, e.g., water, housing, food, education or good environment, are limited and should be used efficiently. The concept of substitution indicates that individuals, social groups and institutions are generally willing to trade-off a certain amount of one objective for more of another. It implies that the limited resources could be put to alternate uses to obtain the maximum benefit. The general economic problem is how to use available scarce resources to maximize the resulting human welfare. The scarcity is registered in the market place by price. In regard to water resources development, the maximization of the net benefit objective requires the efficient allocation of water to various uses (for example, hydropower, irrigation, water supply, flood control, navigation) over time and space.

The water resources projects take considerable time in realizing the maximum possible benefits and this must be reflected in their ranking. To clearly bring out the advantages of quicker implementation, the discounted cash flow method may be used. This method better reflects the time value of money.

Different types of benefits and costs are generated by a given pattern of resource use. For a BC analysis, the benefits and costs are to be expressed in monetary units. For that, it is required to estimate the monetary value of irrigation water, hydropower production, navigation, flood control, etc. An important source of prices used is the current market trend.

Some benefits and costs are correctly registered in market prices, some are registered in no markets, although simulated market values (i.e., what users would pay if a market existed) can be computed, and for others it may be nearly impossible to have an adequate market valuation. The market prices are assumed to be an accurate reflection of marginal social values. But if the markets are not competitive, the prices are not appropriate indicators of costs and benefits and should be adjusted appropriately. In some cases, the market prices are not registered, as for example, for the use of water for environmental preservation or recreation and the analyst has to estimate these prices.

Even when benefits and costs are registered in market prices which could be measured as the aggregate net willingness-to-pay of those affected, it may still not be possible that the beneficiaries could compensate the loser in all cases and that everyone would benefit from the project. While the owners of many resources required for the project, such as land, are compensated, those people who lose favorite scenic sites or suffer a decrease in the value of their property because of the project are seldom compensated. Likewise, the host population (those that receive the resettlers) do not generally receive any compensation. The compensation criterion also ignores the resultant income redistribution which should be considered during the plan selection process. The compensation criterion implies that the marginal social value of income to all affected parties is the same. Although the analysis will determine the amount of income stream generated over and above the costs of labor and other inputs, it does not specify who actually receives it.

A real-world economic system, even when operating under fairly competitive conditions, seldom generates a socially acceptable distribution. As things stand, the common feeling is that the poor become poorer while the rich, richer possibly because the poor do not have resources to exploit the new opportunities. May be the distribution of income is not socially considered as adequate but is the outcome of the lack of knowledge of how to correct it because of the ability of the economically powerful groups to prevent corrective measures. In such a case, market prices cannot be taken as an acceptable measure of the value for the evaluation of projects or policies which affect the economically disadvantaged segments of population. This is particularly true for developing countries.

The market prices reflect economic values when these are fair and competitive or they will be shadow prices. The term *shadow price* denotes the value assigned by public to goods and services that are not marketed. Market prices do not always reflect the relative scarcity of different resources because these may be modified to differing degrees by taxes, subsidies, and exchange rates (if imported products are involved). For some final goods and services, however, the concept of the opportunity cost is not applicable because it is the consumption value that sets the economic value, not the value in some alternative use. In such instances, the "willingness to pay" criterion will need to be applied. This is because the ultimate objective of all economic activity is to satisfy the consumption wants, all opportunity costs are derived from consumption values, and thus from the willingness to pay. The topic is covered in detail by Howe (1971) and Griffin (1998).

The economic efficiency in resource allocation is obtained when no individual could be made better off without making someone else worse off. This condition is termed as Pareto optimality. The beneficial effects of a project increase positive utility or remove existing negative utility. A drawback of the benefit-cost analysis approach is that a potential Pareto improvement treats all users equally. In other words, efficient allocations are not necessarily fair or just. Another criticism is that the conventional measures of benefits and costs are dependent on the existing distribution of wealth, and may serve to enshrine the status quo (Young, 1996).

6.6 OTHER DISCOUNTING METHODS

The other important discounting methods are discussed in this section.

6.6.1 Present Worth Method

While selecting a project, an intuitive approach can be to choose the project which has the largest present worth of the discounted algebraic sum of benefits minus costs over its life. It is the present worth method. This technique is also called the net present worth or the net present value because this method reduces a stream of costs and benefits to a single number. The net worth (benefit – cost) for each year is computed and discounted to the present. A sum of these gives the net present value (NPV):

$$NPV = \frac{B_0 - C_0}{(1+i)^0} + \frac{B_1 - C_1}{(1+i)^1} + \dots + \frac{B_t - C_t}{(1+i)^t} + \dots + \frac{B_n - C_n}{(1+i)^n} \tag{6.12}$$

where, C_t is the monetary value of costs and B_t is the monetary value of benefits, both at time t, i is the discount rate, and n is the life of the project. The determination of the appropriate discount rate is important in this method. Sensitivity analysis of this value (i) will, to some extent, reduce the arbitrariness in selecting this value.

The steps involved in this method are enumerated below:

1. Calculate the present worth of each alternative using appropriate discounting factors.
2. Choose all the alternatives having a positive present worth. Reject the rest. If no sets of mutually exclusive alternatives remain, stop. Otherwise, step 3 or 4, as appropriate, is adopted to choose the best alternative.
3. In a set of mutually exclusive alternatives, choose the one that has the greatest present worth.
4. If in a set of mutually exclusive alternatives, some have benefits that cannot be quantified but are approximately equal, choose the alternative having the least cost.

The following rules are followed while calculating the present worth of a project:

Rule 1. Compute all present worths to the same time base, irrespective of the initial time of different alternatives.
Rule 2. Compute all present worths by using the same discount rate, even if the alternatives are being financed from different sources.
Rule 3. Base all present worths on the same period of analysis, irrespective of differences in economic life.

The discounting rate used for the analysis is either the social rate of discount or the opportunity cost of capital. The social rate of discount is the rate at which society's weight on increments to consumption declines over time. This rate of discount depends on many factors, including (a) society's present level of consumption, (b) the expected growth of consumption, (c) the expected growth of population, (d) the rate at which marginal utility of consumption diminishes, and (e) society's time preference. The opportunity cost of capital refers to the *marginal productivity of capital* (MPC), which, in turn, is the same as the internal rate of return of the marginal project. The internal rate of return will be discussed in a later section.

Example 6.10: There are three mutually exclusive alternatives for a water supply project. The present worth of costs and benefits associated with these alternatives is given below:

Item	Present worth (Million Rs.)		
	Alternative A	Alternative B	Alternative C
Construction cost	42	38	40
Operation & maintenance cost	10	12	11
Benefit	60	59	56

Compare the alternatives and suggest the best. Assume that all present worth figures have been obtained using the same discount rate and period of analysis.

Solution: Net present worth for alternative A = 60 - (42 + 10) = Rs. 8 million.
Net present worth for alternative B = 59 - (38 + 12) = Rs. 9 million.
Net present worth for alternative C = 56 - (40 + 11) = Rs. 5 million.

Thus, alternative B should be chosen, since its net present worth is the maximum.

6.6.2 Rate-of-Return Method

The rate-of-return is the discount rate at which the present worth of the discounted algebraic sum of benefits minus costs over the project life equals zero. This rate, which is found by trial and error, is the rate-of-return that equates the initial cost and the sum of discounted future net benefits. At this rate, the benefit-cost ratio is close to one. This rate represents the average rate of interest at which a project pays back the investment over its life time. It, therefore, is a criterion for comparing alternative investment opportunities. Some writers call this technique as the *internal rate-of-return* (IRR) method.

Mathematically, IRR is some discount rate r such that the initial cost C_0 is equal to the present worth of benefits:

$$C_0 = \frac{B_1 - C_1}{(1+r)^1} + \frac{B_2 - C_2}{(1+r)^2} + ... + \frac{B_n - C_n}{(1+r)^n} \quad (6.13)$$

Alternatively, it is the discount rate r which would make NPV of the project equal to zero. Newnan (1983) has defined rate of return as the interest rate earned on the unrecovered investment such that the payment schedule makes the unrecovered investment equal to zero at the end of the life of the investment. Higher the rate, more attractive is the project. A project with an IRR exceeding some predetermined level (e.g., the social discount rate) is deemed acceptable. For a given stream of benefit and cost, the determination of IRR is by trial and error. For assumed values of discount rate, one can calculate net benefit which is equal to present value of benefits minus the present value of costs. The Fig. 6.5 illustrates the concept of IRR.

Example 6.11: The initial cost of a project is Rs. 1000 and it gives benefits @ Rs. 250/- per year for 5 years. Find the IRR. What will be the IRR if benefits are obtained at the same rate for 6 years?

Solution: Application of eq. (6.13) yields

$$1000 = \frac{250}{(1+r)^1} + \frac{250}{(1+r)^2} + \frac{250}{(1+r)^3} + \frac{250}{(1+r)^4} + \frac{250}{(1+r)^5}$$

This equation can be solved by trial and error to yield r = 7.9%. Note that IRR should not be construed that one will get an annual return @ 7.9% of Rs. 1000. Each payment of Rs. 250 implies a return @ 7.9% on the unrecovered investment plus the partial return of the investment. For the first year, out of Rs. 250, 79 is return on Rs. 1000 (at 7.9%

per annum) and balance 250 – 79 = 171 is repayment of the investment. This leaves unrecovered investment of Rs. 829 at the beginning of 2nd year. The uncovered investment reduces each year and at the end of 5th year, it will be nil.

If the benefits are obtained for 6 years, there will be one more term in the equation:

$$1000 = \frac{250}{(1+r)^1} + \frac{250}{(1+r)^2} + \frac{250}{(1+r)^3} + \frac{250}{(1+r)^4} + \frac{250}{(1+r)^5} + \frac{250}{(1+r)^6}$$

The solution gives $r = 13\%$. This shows that IRR of the venture has increased considerably.

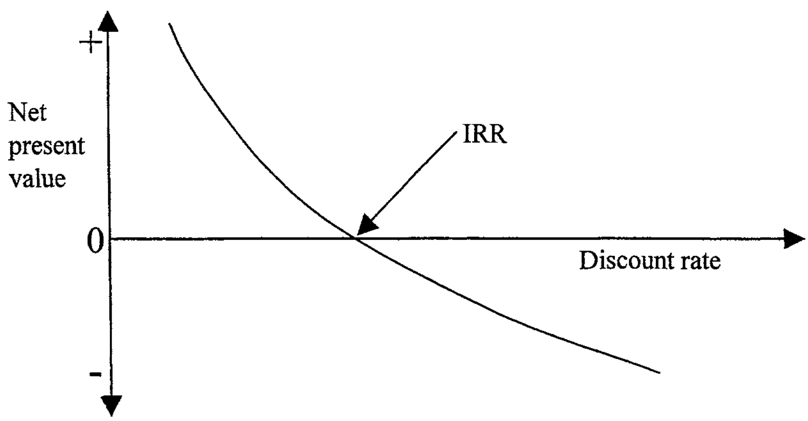

Fig. 6.5 Illustration of internal rate of return.

The following steps are involved in comparing alternatives by this method:

1. Calculate the rate of return for each alternative.
2. Choose all alternatives having a rate of return exceeding the minimum acceptable value, known as minimum attractive rate of return (MARR). Reject the rest. If sets of mutually exclusive alternatives are involved, proceed to steps 3, 4 and 5.
3. Rank the alternatives in the set of mutually exclusive alternatives in order of increasing cost. Calculate the rate of return on the incremental cost and incremental benefits of the next alternative above the least costly alternative.
4. Choose the more costly alternative if IRR exceeds the minimum acceptable discount rate. Otherwise choose the less costly alternative.
5. Continue the analysis by considering the alternatives in order of rank.

Other decision rules are also used in this method. All alternatives are compared over the same period of analysis. The rate-of-return method will not lead to the same decision as the present worth method unless the incremental analysis of steps 3-5 is used in place of selecting the mutually exclusive alternative with the highest rate-of-return. This method must be applied with caution because more than one rate-of-return exists when annual costs exceed annual benefits in years after annual benefits first exceed annual costs. However, this method, using steps 3-5, still gives consistent answers even when dual solutions exist. The water resources planner needs to be alert to this problem when comparing alternatives by the rate-of-return method.

While using this method, it is necessary to select an MARR be desirable to work out a minimum cut-off rate. This rate varies with the country and depends on the economic conditions, inflation, etc. For a large country with wide disparities, it will not be advisable to follow a uniform rate throughout. Somewhat lower values have been recommended for drought-prone regions, chronically flood-prone areas, and hilly regions. A lower rate-of-return would also be appropriate in a water scarce basin most of whose flow has already been utilized. According to Newnan (1983), MARR should be equal to the highest of the three: the cost of borrowing money, the cost of capital, and opportunity cost. The cost of borrowed money is the interest rate at which money can be borrowed. The cost of capital depends on many factors. Basically, the money a firm uses for investment is drawn from the various components of the overall capitalization and their rate of return determines it. Further, in the event of limited money, a person or a firm may not be able to use all the investment opportunities. After choosing better opportunities, the rate of return of the best rejected alternative is the opportunity cost.

The main advantage of this method is that it gives a measure of the strength of a project in terms of a single, well-understood number. Also, the discount rate need not be assumed as in other criteria. Two problems may be encountered in this method:

(i) The rate r that is the solution of the eq. (6.13) is not necessarily unique. Newnan (1983) explains how to resolve this situation.
(ii) The criterion implicitly assumes a single discount rate over the life of the project.

Example 6.12: A person has Rs. 10 million to invest. The available alternatives with required investment and returns are as follows. 1: Rs. 3 million; 15%; 2: Rs. 4 million, 20%; 3: Rs. 1 million; 18.5%; 4: Rs. 2 million, 19%; 5: Rs. 3 million, 18%; 6: Rs. 4.5 million, 16%; 7: Rs. 2 million, 17%. Find the opportunity cost of money for him?

Solution: If the alternatives are ranked according to the rate of return, the following ordering is obtained: 1: Rs. 4 million, 20%; 2: Rs. 2 million, 19%; 3: Rs. 1 million, 18.5%; 4: Rs. 3 million, 18%; 5: Rs. 2 million, 17%; 6: Rs. 4.5 million, 16%; 7: Rs. 3 million, 15%. Clearly, the person would invest in first four alternatives. Among the rejected ones, the best alternative can give a return @17% and this is the opportunity cost for him.

6.6.3 Comparison of BC Ratio and IRR Method

Let O be the annual operation, maintenance, and replacement (OMR) costs which are assumed uniform for the sake of simplicity. If K denotes the fixed investment at the beginning, i the discount rate, and T the life of the project in years, the present value of the total cost will be

$$PV_C = \sum_{t=1}^{T} \frac{O}{(1+i)^t} + K \qquad (6.14)$$

Let B be benefits received annually. The present value of total benefits is

$$PV_B = \sum_{t=1}^{T} \frac{B}{(1+i)^t} \qquad (6.15)$$

and the BC ratio (R) is

$$R = \frac{PV_B}{PV_C} = \sum_{t=1}^{T} \frac{B}{(1+i)^t} \left[\sum_{t=1}^{T} \frac{O}{(1+i)^t} + K \right]^{-1} \qquad (6.16)$$

Dividing the numerator and denominator by $\sum_{t=1}^{T} \frac{1}{(1+i)^t}$, the ratio becomes

$$R = \frac{B}{O + K \left[\sum_{t=1}^{T} \frac{1}{(1+i)^t} \right]^{-1}} \qquad (6.17)$$

Define

$$a_{iT} = \left[\sum_{t=1}^{T} \frac{1}{(1+i)^t} \right]^{-1} \qquad (6.18)$$

Actually, a_{iT} is the annual capital charge per unit investment, representing both interest and amortization. It can be calculated, given i and T. Now, eq. (6.17) becomes

$$R = B / [O + a_{iT} K] \qquad (6.19)$$

Eq. (6.19) expresses R, i.e., the BC ratio, in terms of annual costs and annual benefits. Referring to eq. (6.13), the rate-of-return r is given by:

$$K = \sum_{t=1}^{T} \frac{B-O}{(1+r)^t} \qquad (6.20)$$

On the pattern of a_{iT}, we define a_{rT} as

$$a_{rT} = \left[\sum_{t=1}^{T} \frac{1}{(1+r)^t} \right]^{-1} \qquad (6.21)$$

Hence, eq. (6.20) becomes

$$K = (B - O)/a_{rT} \qquad (6.22)$$

or $$B = a_{rT} K + O \qquad (6.23)$$

and the BC ratio R is

$$R = (a_{rT} K + O)/(a_{iT} K + O) \qquad (6.24)$$

Solving for a_{rT},

$$a_{rT} = [R\,(a_{iT}\,K + O) - O]/K = (a_{iT} + O/K)R - O/K \qquad (6.25)$$

or

$$a_{rT} = a_{iT}\,R + (O/K)\,(R - 1) \qquad (6.26)$$

This enables computation of a_{rT}, knowing *R, O, K*, and *i*. Given a_{rT}, *r* can be readily found. If there are no current costs (*O* is zero), the two criteria coincide and eq. (6.26) becomes

$$a_{rT} = a_{iT}\,R$$

Here, whatever the interest rate is, a higher *R* will result in a higher value for a_{rT} and hence higher *r*. If *R* is 1, the two criteria become identical as the second term in eq. (6.26) becomes zero.

The degree to which the use of *R* affects the ranking of projects as compared to the rate-of-return method depends on the range of values of O/K. Projects of similar type, such as hydroelectric or irrigation projects, will obviously have similar values of O/K. But there will be much larger differences in projects of different purposes.

6.6.4 Annual Cost Method

In this method, all benefits and costs are converted into equivalent uniform annual figures. Decision rules resemble those for the present worth method because each annual cost is present worth times a constant capital recovery factor. The steps involved are:

1. Calculate the net annual benefit of each alternative.
2. Choose all alternatives having a positive net annual benefit. Reject the rest. If sets of mutually exclusive alternatives are involved, proceed to step 3 or 4, as appropriate.
3. Choose the alternative in a set of mutually exclusive alternatives having the greatest net annual benefit.
4. If the alternatives in the set of mutually exclusive alternatives have benefits which cannot be quantified but are approximately equal, choose the alternative having the least annual cost.

Example 6.13: The annual benefits from projects A and B are Rs. 4.2 and 4.1 million, respectively, and the annual costs of these projects are Rs. 3.95 and 3.6 million, respectively. State which project is more beneficial? Also find the net annual worth in percentage by which the chosen project is more favorable over the other.

Solution: Net annual worth of project A = 4.2 - 3.95 = Rs. 0.55 million.
Net annual worth of project B = 4.1 - 3.60 = Rs. 0.50 million.
Since project A is has more net annual worth, it will be more beneficial.
Difference in the net annual worths (A over B) = 0.55 - 0.50 = 0.05.
Percentage difference by which project A is more favorable over B = 0.05 * 100/0.50 = 10%.

6.6.5 Comparison of Discounting Techniques

Each of the four discounting techniques will yield the same solution if used correctly. However, each technique has advantages and disadvantages associated with ease of calculation, presentation, and understanding of the results. These are important considerations while selecting a method. The present worth method is simpler, safer, easier and more direct. It does not require an additional set of computations to apply the incremental-cost principle. The direct expression of the net present worth is conceptually straightforward and easily presented. The weak point is that the method involves working with large numbers which may be hard to visualize. Besides, the present worth method cannot be used to rank projects in order of economic desirability unless all of them require equal investment. Being an absolute measure, the present worth is not effective to compare the profitability of alternative investment. It is an important complement to IRR particularly to compare projects that are mutually exclusive or that have a high rate of return.

The rate-of-return technique is a valuable analytical tool because it does not require a preselected discount rate. The rates-of-return are intuitively meaningful to many investors and the resulting rates can be compared with those for many other types of investment. This method is criticized because:

(1) ambiguous answer may occur due to dual solutions,
(2) it necessitates the calculation of incremental rate-of-return for interdependent projects,
(3) there is a danger of people's accepting the overall return in contrast with incremental rates of return as indicators of rank, and
(4) the solutions via trial-and-error are a bit difficult to obtain.

The rate-of-return technique has distinct advantages over other discounted measures of projects worth in a sense that the calculation does not depend on assumptions about the opportunity cost of capital. Unlike the net present worth, a relative measure can be used to compare the profitability of projects.

The benefit-cost ratio method is widely used by water resources planners. However, this method, without applying the required incremental BC analysis, can lead to serious errors. Interdependent projects cannot be ranked according to their BC ratios, because each enlargement must pass the incremental BC ratio test.

Since the annual cost technique uses constant multiplies of the present worth method, it has the same advantages and disadvantages, except for the use of smaller numbers. The annual cost method is sometimes preferred because more people are accustomed to thinking in terms of annual costs than of present worths. As far as the selection of a method is concerned, it depends primarily on the purpose of analysis. It is not possible to use the benefit-cost and rate-of-return techniques when benefits cannot be evaluated. Costs alone must be compared by using the present worth or annual cost method. More calculations are involved in the rate-of-return and BC ratio methods. A comparison of three measures of present value is given in Table 6.2.

Table 6.2 Comparison of three measures of present value.

	Net present value	Internal rate of return	Benefit-cost ratio
Selecting or ranking rule for independent projects			
No constraint on costs	Select all projects with NPV > 0; project ranking not required	Select all projects with IRR greater than cut –off rate of return; project ranking not required	Select all projects with B/C > 1; project ranking not required
Constraint on costs	Not suitable for ranking projects	Ranking all projects by IRR may give incorrect results	Ranking all projects by B/C where C is defined as constrained cost will always give correct ranking
Mutually exclusive projects (no constraint on costs)	Select alternative with largest NPV	Selection of alternative with highest IRR may give incorrect results	Selection of alternative with highest IRR may give incorrect results
Discount rate	Appropriate discount rate must be adopted	No discount rate required, but cut-off rate of return must be adopted	Appropriate discount rate must be adopted

Source: Adapted from Gittinger (1982).

6.7 PROJECT FEASIBILITY AND OPTIMALITY

The development, utilization, preservation, and management of most water resources projects involve political and social objectives in addition to the specific objectives of the project. All decisions are concerned with the quality of life and its distribution to society now and in the future. Before adopting a project or going for economic analysis, it must be ensured that all projects pass feasibility criteria. Each project must pass six feasibility tests: Engineering, Economic, Financial, Political, Social and Environmental (or EEFPSE).

Engineering Feasibility

If the proposed project is physically capable of performing its intended objective(s), it is called technically feasible. The engineering design must be confined within the technologically feasible region. Engineering analysis will show the combination of outputs which can be physically produced and those which cannot be produced by a project. All other feasibility tests are carried out only for the alternatives that pass engineering feasibility tests.

Economic feasibility

The project is said to be economically feasible when the benefits from the project exceed the costs. It is important to note that the comparison should be between *with* and *without* rather than *before* and *after* because many of the after-effects may occur even without the project. Thus, the use of before and after concept is not proper in project justification.

Financial feasibility

Even though a project may clear all other feasibility tests, it may remain un-implemented if funds are not available. The test of financial feasibility is determined by examining potential sources of available funds and is passed if sufficient funds can be raised to pay for project construction and operation. A project may be economically feasible but financially infeasible because the benefits are insufficiently concrete for the beneficiaries to appreciate their true value or are thinly distributed among too many beneficiaries or a large area. A project may be economically infeasible but financially feasible (although rare) because someone is willing to pay for the fulfillment of non-economic goals. Financial feasibility also depends on local interests who want the likely economic benefits to the degree that they are willing to arrange their portion of the required funds.

Political feasibility

The political feasibility of a project is achieved when the required political approval can be secured. Political feasibility is determined by an analysis of how key decision makers assess the favorable and adverse effects of the project, the direction of popular feelings, and the project potential for obtaining widespread public support. Ordinarily, political support follows economic and engineering feasibility. Sometimes, despite economic infeasibility, political pressure for a project is sufficiently strong to eventually pave the way for its construction. Conversely, strong groups who feel that they may be adversely affected, are at times able to stop a project in spite of all other favorable indicators.

Social feasibility

If the target beneficiaries respond favorably to project construction, it is said that the project is socially feasible. This feasibility is determined by assessing the change that the project is expected to impart to the lives of the beneficiaries and evaluating the willingness of those affected to adopt. The opinion of the people, who will be beneficiaries or affected by the project, must be positive regarding the project launching. Otherwise, successful completion of a project within the scheduled time may not be possible and this will change the time stream of costs and benefits. Land acquisition, rehabilitation and resettlement, employment, income redistribution, project output distribution and environmental deterioration are some of the issues on which different groups in the project region may have diametrically opposite view points. This is not a good omen and is likely to put hurdles in project completion.

The success of a project depends on the willingness of the users to realize project benefits. The more drastic are the changes that a project requires in the lives of the beneficiaries, the greater is the likely resistance to change. The infusion of productive capital does not automatically transform a society.

Environmental feasibility

All project proposals considered for evaluation must pass environmental feasibility. The project should not generate adverse environmental consequences. The issues related to ecological disturbances may raise a number of constraints during execution. The growing awareness of ecological considerations over the last few decades has led to the involvement of many diverse decision makers and a number of additional institutional and social constraints. It will ultimately affect the cash flow pattern and delay the completion.

The water resources development projects are viewed by some as having a destructive influence on the environmental quality as they often lead to the submergence of forests and displacement of people. The conflict can be mitigated by introducing a design which is in consonance with the environment, is aesthetically pleasing, and by choosing a plan which leads to minimum deforestation and resettlements of people.

The environmental aspects have been discussed at length in Chapter 7.

6.7.1 Cost and Benefit Curves

Economic evaluation of production alternatives is based on the variation in total production cost with the level of production output, and the variation in the resulting benefit with the level of production output. The total cost curve is developed by summing the required input costs for a series of outputs. Similarly, the total benefit curve is developed by summing values received by output users. The total cost includes fixed costs and variable costs. The fixed costs remain constant regardless of the output, while the variable costs vary with the level of the output. The average cost or average benefit curves are developed from total cost or total benefit curves by dividing the total value by the level of output. Average cost curves are usually U-shaped. The marginal cost or marginal benefit curves represent the slope of the total cost or total benefit curves. The slope represents the change in the total cost or the total benefit associated with a one-unit change in the output. Like average curves, marginal curves are generally U-shaped but justified more to the left.

The common approach to estimate benefits from flood management is the 'property damage avoided' approach. This approach measures the present value of the expected property damages which are avoided by a project or policy. The replacement and maintenance costs to the affected structures are estimated for a number of water levels with and without the project. The estimated annual benefit for a given flow level is the difference between these costs.

6.7.2 Optimal Allocation of Water to Individual Users

In the problem of optimal water allocation to individual users, the usual assumption is that water is supplied to each individual user by an existing supplier. Naturally, the private supplier would like to allocate the water among the users so that his benefits are the maximum. However, from the point of view of the society, it is important to achieve economic efficiency and equity (recall the concept of Pareto superiority). The requirement to provide services much beyond the design limits is the root cause of degradation of services in many cases.

The problem of optimal allocation can be easily understood with the help of demand and cost curves. In Fig. 6.6, the horizontal axis represents the quantity of water used per unit time while the vertical axis shows prices. The curve labeled MW depicts the users' marginal willingness to pay for an additional unit of water per unit time. This curve slopes downwards to the right as the marginal willingness goes on decreasing as additional units are made available. The curve MC shows the incremental or marginal cost of providing one unit of water per unit time. Clearly, the marginal cost increases as additional quantities are made available. The two curves intersect at point O^* where the marginal cost and marginal benefit are equal. Therefore, this is the optimal point where the marginal willingness to pay for each additional unit of water is equal to the marginal cost of supplying that unit. Note that if supply is more than this amount, then the marginal benefit will be less than the marginal cost of supply. Conversely, when a lesser quantity is supplied then the marginal benefits will exceed the marginal costs.

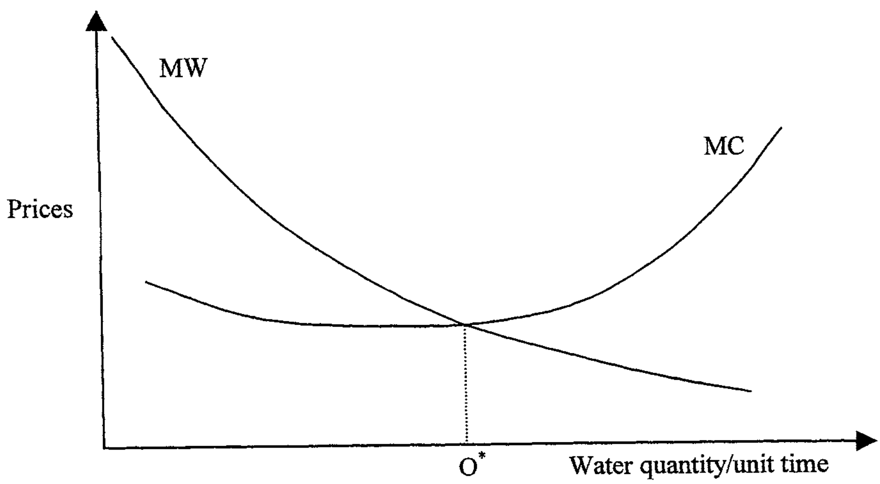

Fig. 6.6 Optimal allocation of water to individual users.

6.7.3 Optimal Allocation of Water among Different Uses

In the case where limited water is to be allocated among different sectors in a region, the optimal solution from economic point of view would be the one that maximizes the benefit. According to the *equimarginal principle* (Young, 1996), the net benefit function is maximized when the net marginal benefits per unit of water used are equal in all use sectors. Consider Fig. 6.7 for the case of two uses, agriculture and urban. The curve MB_1 represents the marginal net benefit for supplies to use-1 and slopes downwards to the right indicating diminishing returns as more quantity is supplied. The curve MB_2 shows marginal benefits for use-2 and here it is drawn in reverse form from the right-hand axis just to illustrate the underlying concept. The intersection of these two curves at O^* represents the optimal balance between the two uses.

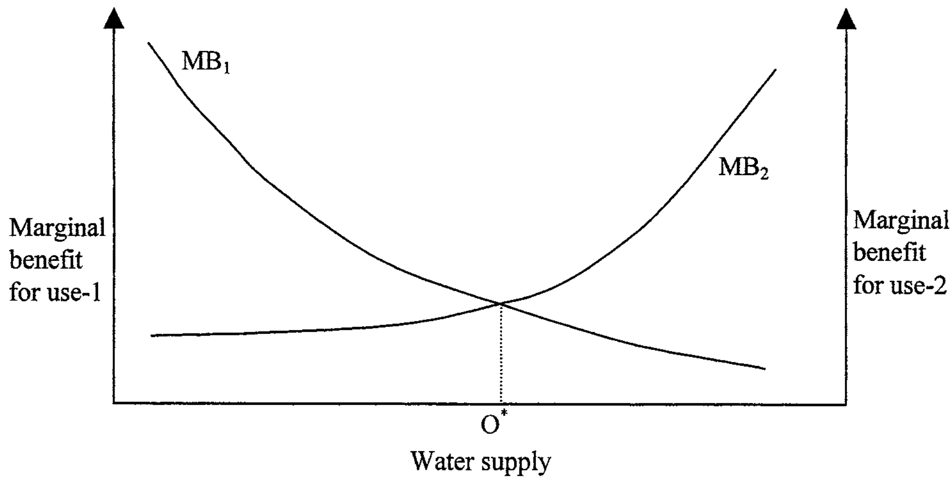

Fig. 6.7 Optimal allocation of water to two different uses.

6.7.4 Allocation of Ground Water

The problem of ground water allocation is quite different from that of surface water allocation. The major difference is that the velocity of ground water flow is much slower than that of the surface water. Also, the aquifers are not very extensively measured and sub-surface investigations are fairly expensive. Usually, the optimal allocation is ascertained by balancing the diminishing returns to the present period use to the increased pumping cost and the discounted future benefits. The enforcement of ground water allocation is difficult, although very much necessary. In the absence of such enforcement, many regions in the world are witnessing rapid declines of the ground water table, which is also responsible for a number of environmental problems and water quality problems.

6.7.5 Project Optimality

Water resources planning, development, or management can be thought of as a production process. In planning a production process for the public sector, many valuable insights can be gained from analyzing how economic forces would act to order production under ideal conditions. The basic purpose of production is to convert resource (input) into more useful form (output). A water resources project is constructed to produce such desired outputs as irrigation water, reduced flood damage, a navigable channel, or electric power from a set of such inputs as earth, concrete, steel, pumping energy, and natural streamflow, etc.

After obtaining an optimal solution, it is necessary to examine how sensitive the project's net present worth, rate of return, the BC ratio, etc. are to likely changes, such as increased construction cost, extension of the construction period, and changes in output prices. An analysis to find what happens under these changed circumstances is called sensitivity analysis. Since the outputs of the projects are subject to uncertainty, sensitivity analysis should form an integral part of economic analyses of all projects.

In general, project outputs are sensitive to changes in four principal areas, namely prices, delay in implementation, cost overrun, and yield. As regards prices, every project should be examined to see what happens if the assumptions about the sale prices of the project's product prove wrong. The delay in implementation affects many projects. The cause could be the administrative delay in ordering or receiving equipment and stores, delay due to agitation against the project, nonavailability of funds, etc. Determination of the effects of delay on the net present worth, the financial and economic rates of return and the net benefit-investment ratio of a proposed agricultural investment is an important part of the sensitivity analysis. Every project should be tested for sensitivity to cost overrun, especially for construction because so often the costs are incurred early in the project when they weigh heavily in the discounting process, and also for facilities that must be complete before any benefit can be realized. It may also be necessary to test a proposed project for sensitivity to errors in the estimated yield. There is a tendency in many agricultural projects to be optimistic about potential yields based mainly on data from experimental fields, especially when new cropping patterns are proposed. It has also been found in many projects that the cropping patterns being followed by the farmers were quite different than what was assumed, resulting in serious deviations in water demands as well as returns.

6.8 ALLOCATION OF PROJECT COST

In multipurpose water resources projects, it is necessary to divide the project cost among several uses and/or different groups of beneficiaries to examine the viability of uses and fix charges for services. For instance, a dam might be serving for irrigation and hydropower and the cost of providing each service will be needed to levy fair charges for each. Similarly, the share of flood control in the cost of a multipurpose project must be distinguished from that for irrigation to properly assess net benefits. The problem assumes significance when the costs and benefits of a project are spread over more than one administrative unit which is quite often the case. For example, two nearby cities may decide to jointly build a facility for water supply. An objective basis of cost allocation is needed to avoid inter-state or inter-group disputes. The procedure for dividing the total cost among responsible heads is called cost allocation. Once a formula to allocate costs is established, it may have to be incorporated into a legally binding cost-sharing agreement. Cost allocation falls under financial analysis.

If there are many user groups, cost allocation requires division of costs among these groups. Each entity that is assigned a cost is called a cost center. The methods that are commonly used in practice are: 1) allocation of costs in proportion to some numerical criterion, such as population, water use, or 2) allocation of costs like marginal costs directly and dividing the remaining cost based on some criterion.

A project element is a distinct physical part of the project. Some project elements serve only one cost center and their costs are termed as direct costs. If an element serves more than one cost center, the difference in its cost with and without serving a cost center is the *separable cost* of that element with respect to that cost center. This cost can be is determined from project designs with the two scenarios. *Nonseparable cost* is the difference between the total project cost and the sum of separable costs. Thus, in a project serving irrigation and hydropower demands, the separable cost of hydropower is the cost of the project less the cost of an equivalent pure irrigation project. Normally, the sum of separable costs for all the purposes will be less than the total project cost due to economies of scale. Nonseparable costs include joint costs and common costs. If a project element contributes to the production of more than one output, its cost is joint cost. Common costs are those indirect or other fixed costs which must be incurred but cannot be associated with any specific purpose such as the wages of common-pool administrative staff.

In a fair system, the allocation of cost to any cost center should neither be less than the additional cost of including that center in the plan nor more than the total benefits of the center. The allocation should not burden any objective with a greater investment than the fair capitalized value of the annual benefit of that objective. It should not result in charging any objective with a greater investment than would be necessary for its development at an alternate single purpose site. Mathematically, this can be represented as (Heaney and Dickinson, 1982):

$$x(i) \leq \min\,[b(i), c(i)] \qquad \forall\ i \in N \tag{6.27}$$

where $x(i)$ is cost allocated to group i, $b(i)$ is benefit of group i, $c(i)$ is alternative cost if group i acts independently, and N is set of all groups, $\{1, 2, \ldots\ i, \ldots\ n\}$. Further

$$\sum_{i \in S} x(i) \leq c(S) \quad \forall S \subset N \tag{6.28}$$

where $c(S)$ is the alternative cost if the subset S acts independently and S is any subset of the master set N.

The allocation of costs by following the methods in the first category is simple. The commonly used methods in the second category are the separable costs, remaining benefits (SCRB) method, alternative justifiable-expenditure method, and use-of-facilities method. In the SCRB method (James and Lee, 1971), the joint costs of a project are apportioned among the purposes using the ratio of remaining benefits to the total benefits. The remaining benefits are the lesser of benefits of costs of least-cost alternative minus separable cost. The total remaining benefits are the benefits of independent action less separable cost. Following Heaney and Dickinson (1982), separable costs are

$$sc(i) = c(N) - c[(N) - \{i\}] \qquad \forall\ i \in N \tag{6.29}$$

where $sc(i)$ is the separable cost to group i, $c(N)$ is total cost for the grand coalition of n groups, and $c[(N) - \{i\}]$ is total cost for the grand coalition with group i excluded. After separable costs are assigned to each group, the remaining cost are nonseparable costs (nsc)

$$nsc = c(N) - \sum_{i \in N} sc(i) \tag{6.30}$$

$$\beta(i) = [\min\{b(i), c(i)\}] - sc(i) * \left\{ \sum_{i \in N} \{[\min(b(i), c(i))] - sc(i)\} \right\}^{-1} \qquad (6.31)$$

The sum of the prorating factors will be unity. Thus, in the SCRB method, the total charge to the i^{th} cost center is

$$x(i) = sc(i) + \beta(i)*nsc \qquad (6.32)$$

The following points are important while allocating costs:

1) The allocation process should be straightforward and simple enough to be easily understood. Conflicting interests are resolved on the basis of their best understanding.
2) The sum of the allocations to all the cost centers normally equals the total project cost. Most of the methods require this condition to be fulfilled but this has not been followed in many instances. Heaney and Dickinson (1982) quote cost allocation for TVA projects where it was concluded that it is not possible to meaningfully assign joint costs; these were viewed as sunk costs which need not be recovered.
3) Joint facilities should be operated in accordance with cost allocation. It is not equitable to allocate most of the cost to a center having a low service priority in facility operation.
4) Costs nonseparable to any single or group of cost centers must be allocated among all centers; and costs separable to a group but not to a single cost center must be allocated among the centers composing that group.
5) Since cost allocation directly affects economic and social efficiency, that allocation method should be used which does the most to promote the desired social goals.

The essence of cost allocation is a successful resolution of conflicting interests among parties in a fair manner. Strictly speaking, there is no unique method of cost allocation in conflicting situations, because each party tends to influence the allocation by shifting the largest share of joint costs to others. The SCRB method has a flaw in that it is not monotonic in total costs, i.e., increase in total costs may result in some participants having to pay less than before due to the way the marginal costs are introduced. Allocation of joint costs is complex and some authors believe that there is no economically justifiable way for this. Besides, most allocation schemes use information about demands and the optimal scale of development that in practice may be unreliable or nonexistent. Young et al. (1982) cite a case from Sweden in which the cost of water supply system was to be allocated among 6 groups of municipalities. Of all techniques, the scheme based on the size of population was actually adopted.

According to Votruba et al. (1988), the practice in Chechoslovakia was to allocate costs in proportion to benefits and side effects expressed in monetary units. If there are significant side effects among inputs and outputs of the multi-purpose water engineering project, which can not be evaluated by shadow prices, these effects may be evaluated by the initial and OMR costs of the substitute or they may be determined by agreement among the users.

6.8.1 Cost Allocation Practices in India

According to the Damodar Valley Corporation act of 1948, the joint costs are allocated to different purposes in proportion to the expenditure which would have been incurred in constructing a separate structure solely for that purpose, less any amount which is solely attributable to the object. In the case of the Hirakud Project, the same principle of alternative justifiable-expenditure method was originally followed and accordingly the allocation of the costs of storage capacities between flood control, irrigation and power was in the ratio of 38:20:42. In 1952, this approach was replaced by a new method based on the ultimate utility of water for various purposes. Flood control as a separate purpose was eliminated. Subsequently, at a seminar organized by the Government of India in 1961, it was decided that joint costs be allocated to various purposes in proportion to the reservoir capacity or quantity of water utilized for each purpose. In light of this, flood control was to share 25 per cent of the reservoir cost on account of the consideration that the reservoir operates for flood control for three months in a year.

For the Kosi project in Bihar, the cost of barrage is deemed to be a common facility for flood control and irrigation and its cost is divided equally between them. In the case of Rengali Project in Orissa, the cost of Stage I of works was allocated equally between flood control and irrigation, since the same storage capacity could be used equally for both functions. In April 1967, the Government of India recommended the adoption of the facilities used method for allocation of joint costs of multi-purpose river valley projects. The alternative justifiable-expenditure approach was recommended by the Rashtriya Barh Ayog in 1976 to allocate costs in multi-purpose projects. A discussion on economic aspects of irrigation projects in India was given by Navalawala (1993).

6.8.2 Funding Needs in Water Sector

The water sector projects are highly capitalistic. The construction of large infrastructure to manage river basins, inter-basin transfers, canal networks, water supply and wastewater collection and treatment plants, all require significant funding. The amortization of this large amount is only possible over a very long period, may be extending to several decades. It is a fact that many governments are not in a position to bear all costs and that public funding has reached its limits. Except in a few, the funding requirements greatly exceed the abilities of national or regional public budgets to sustain services.

Every year various users pay large sums for water consumption and treatment. According to estimates, the amount is about 1 % of the World Gross Product or about US$ 300 billion per year (1990s estimate). In terms of the volume of water consumed, the urban consumers use about 10 to 15 % of the total but pay most of the above amount while agricultural users consume about 70 % of the total quantity but are highly subsidized. Paradoxically, many of the poor living in arid regions pay a huge price for water, typically 5-10 times that which would be necessary to pay the full costs of a well-designed water supply system. It is instructive to note that:

- In many developing countries, poor people often have to purchase water in small quantities (often of dubious quality) to meet their basic needs by paying very high price for it. Alternately, some of these people have resorted to costly individual means to pump water.
- The time and efforts of the women who have to walk over long distances everyday to fetch water are rarely taken into account.
- If the individual expenses to get water for domestic use (cisterns or roof-top tanks, bore holes and pumping) are summed up for a sizeable society, the totals may reach very high amounts that could be better used by the community.

In some countries, water for agriculture is provided free of cost or the prices are so low that these do not even cover the amount spent on operation and maintenance of infrastructure. This is an important reason behind degradation of infrastructure in many places. Unwillingness of private investment in this sector also largely stems from this. A private supplier will charge not only for water as such, but also the expenses that he has to incur to make it available where the user needs it, with the required reliability in terms of quantity and quality. However, reliable services can be provided at affordable cost. For instance, the price of treatment and supply of a cubic meter of drinking water (including taxes) is nearly the same as that of a "soft drink" in a bar !

The role of governments in water resources development is crucial. The governments' primary responsibilities are: a) create and implement a legislative and regulatory framework that governs water, b) create national and basin level authorities, c) plan, construct, or operate water resources development projects alone or in association with private parties or create conditions that are conducive for participation of private parties in these activities, and d) provide the enabling framework for community action that empowers the poor, women and the minorities. Unfortunately, traditional public subsidies, mainly sourced from general budgets, have reached their limit and it is becoming increasingly difficult almost everywhere to meet the needs of the water sector with traditional public budgetary means.

The money from the private sector will flow to this sector only if investors are sure of getting competitive returns and there is an efficient, strong, and transparent regulatory framework which protects the interests of both investors and consumers. Undoubtedly, private sector can considerably improve the dismal technical and financial performance that characterizes most public utilities in developing countries. It is, however, pertinent to note that participation of private sector is not a panacea for all problems and the experiences so far have been mixed.

6.8.3 Case Study of Dharoi Project

In this section, the main heads of expenditure that were used to estimate the project cost and the apportionment of cost among purposes will be explained. As per the project report (Govt. of Gujarat, 1976), the revised estimates of the cost of works related to the Dharoi project pegged the total expenditure at Rs. 500.184 million. While preparing the estimates, the expenditures were grouped under three heads: Dam and appurtenant works, Fatewadi barrage (near Ahmedabad city) and canal system, and main canal and branches.

The total cost of the dam and the appurtenant works was Rs. 325.951 million. The main heads under this expenditure was sub-divided were preliminary survey and investigations, acquisition of lands (submergence, for offices and residential colonies), structures likely to be submerged, and rehabilitation. The key construction activities for which funds were needed were masonry dam and spillway, earthen dam, dykes, head regulator for canal, and instrumentation for earth dam and dykes. The expenditure on residential and non-residential buildings which were required for housing of staff and offices of the project, their maintenance, and construction of approach roads, etc. were also grouped under this head.

As water supply for irrigation was one of the main purposes of the Dharoi project, construction of canals and water distribution system was an important activity. The heads of expenses under this broad heading included preliminary investigations and tests, land acquisition for canals and branches, and construction cost of regulators, earthwork, lining of the canals, falls, cross-drainage works, bridges, and escapes. It was also necessary to construct some buildings for office purposes for the canal division, service roads, etc. The total cost under this head was estimated at Rs. 94.049 million. As part of this project, a barrage known as Fatewadi barrage was also constructed downstream of the city of Ahmedabad to divert water for agriculture. The expenditure on barrage and canal system was estimated at Rs. 80.184 million. It may be noted that these estimates were prepared in the mid 1970's.

While allocating the cost of the project among various purposes, the following benefits were identified:

a. Drinking water supply to the city of Ahmedabad and Gandhinagar.
b. Irrigation in the command area.
c. Partial flood control, and
d. Improvement of road communication due to dam and additional roads constructed for the project purposes.

It was argued that the flood control benefit is a result of build up of storage in the reservoir above FRL and hence it is an incidental benefit for this project. Similarly, the improvement in road communication was also considered to be incidental in nature. Therefore, the apportionment of the project cost was made for irrigation and water supply purposes. The committee constituted to identify the method for this apportionment recommended the following two methods:

1. Reservoir storage space used by each purpose, and
2. Quantity of water utilised for each purpose.

In the reservoir space method, the idea is that each purpose should be charged on the basis of the reservoir storage space that is used to hold water for that purpose. The space required for municipal water supply needs in post-monsoon season as well as storage reserved for water supply (to ensure 90% reliability) were entirely charged for water supply use. Likewise, the storage space to meet irrigation requirements in the command in post-monsoon period was charged to irrigation. The carryover space was allocated between water supply and irrigation as per expected use. The evaporation loss was divided between these two purposes in the ratio of storage space occupied for each purpose. The space allocated for sediment accumulation was equally divided between two purposes. When all these requirements for two purposes were summed up and percentages were determined, these turned out to be 59.5% for water supply and 40.5% for irrigation. Therefore, of the total project cost, 59.5% was charged to the water supply purpose and 40.5% to irrigation. The expenditure for water supply was charged to Ahmedabad and Gandhinagar city in proportion to the projected requirements. Accordingly, 92.6% of the cost was allocated to the city of Ahmedabad and 7.4% to the city of Gandhinagar.

6.9 CLOSURE

The economic analysis of water resources projects is an evaluation of various alternatives, plans, or policies. It can be used to identify the best and feasible alternative as per economic criterion to logically resolve the conflicts and to assess the sensitivity of the project outputs to changes in project configuration and economic conditions. Economic analysis is intended to guide decisions on the use of scarce water resources and economical conditions and to provide criteria for ranking different water development and management policies.

In any scheme of water resources development, it is necessary to prepare a number of technically feasible alternatives to meet particular objectives and estimate costs and benefits, both tangible and intangible, for each alternative. Each of the technically feasible alternatives will produce a unique time pattern of consequences. To compare alternative plans, or policies, all consequences are expressed in monetary values, and cash flows representing the variation of costs and benefits with time stream are discounted to find out their net present worth.

Sensitivity analysis and multiobjective planning further expand the scope of analysis and involve broader social goals that water resources development might help attain, like a larger national income, a more equitable distribution of income between people and region, and environmental protection. Fundamental to all development planning is the availability of reliable and adequate data about water and related-land resources of a region meant to serve. The socio-economic factors play a vital role in planning, evaluating, and implementing the water resources development plans. The economic analysis involves the decision makers while testing the projects for its feasibility and allocating the cost in multipurpose projects.

6.10 REFERENCES

Frederick, K., VandenBerg, T., and Hanson, J. (1996). Economic values of freshwater in the United States. Resources for the Future, Washington, 1996.

Gittinger, J.P. (1982). Economic Analysis of Agricultural Projects. Johns Hopkins University Press, Baltimore.

Govt. of Gujarat (1976). Sabaramati Reservoir Project at Dharoi (Revised). Volume - I. Public Works Department, Govt. of Gujarat, Gandhinagar.

Griffin, C.G. (1998). The fundamental principles of cost-benefit analysis. Water resources research, 34(8), 2063-2071.

Heaney, J.P., and Dickinson, R.E. (1982). Methods for apportioning the cost of a water resources project. Water Resources Research, 18(3), 476-482.

Howe, C.W. (1983). Benefit-cost Analysis for Water Systems Planning. AGU Water Resources Monograph 2, Washington, D.C.

Howe, C.W. (1983). Impact of Price on Residential Water Demand: New Insights. Water Resources Research, 18(5), 713-716.

James, L. D. and Lee, R. R. (1971). Economics of Water Resources Planning. McGraw-Hill Book Co., New York.

Loucks, D.P., Stedinger, J.R. and Haith, D.A. (1981). Water Resources Systems Planning and Analysis, Prentice Hall Inc., New Jersey.

Lund, J.R. (1992). Benefit-cost ratios: failures and alternatives. Journal of Water Resources Planning and Management, ASCE, 118(1), 94-100.

Navalawala, B.N. (1993). Economic aspects of irrigation and pricing of water, Irrigation Water Management, Water Management Forum, Institution of Engineers (India), Ahmedabad.

Neufville, R. de, and Stafford, J.H. (1971). Systems Analysis for Engineers and Managers. McGraw-Hill Book Company, New York.

Newnan, D.G. (1983). Engineering Economic Analysis. Engineering Press Inc., San Jose, California.

ReVelle, C., Whitlatch, E.E., and Wright, J.R. (1997). Civil and Environmental Systems Engineering. Prentice Hall, New Jersey.

Rogers, P., Bhatia, R., and Huber, A. (1998). Water as a Social and Economic Good: How to Put the Principle into Practice. Global Water Partnership/Swedish International Development Cooperation Agency, Stockholm, Sweden.

Votruba,L., Kos, Z., Nachazel, K., Patera, A., and Zeman, V. (1988). Analysis of Water Resources Systems. Elsevier, Amsterdam.

Young, H.P., Okada, N., and Hashimoto, T. (1982). Cost Allocation in Water Resources Development. Water Resources Research, 18(3), 463-475.

Young, R.A. (1986). Water Economics. Chapter 3 in Water Resources Handbook, Edited by L.W. Mays. McGraw-Hill, New York.