TRAINING COURSE

ON

RESERVOIR OPERATION

(UNDER WORLD BANK AIDED HYDROLOGY PROJECT)

Module 11

Economic Aspects

of

Water Resources Systems

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ECONOMIC ASPECTS OF WATER RESOURCES SYSTEMS

1.0 INTRODUCTION

An increase in people's welfare through the process of economic development has been the most important objective that the nation has set before itself ever since independence. Effect of a project on economic welfare can be evaluated in terms of the relative values of benefits and costs associated with it. An excess of benefits over costs implies that people would be better off by undertaking the project. On the other hand, an excess of costs over benefits would indicate diminution in welfare. Thus, for a project to be taken up, it must provide more benefits than its costs.

A project or a policy, if implemented, produces a time pattern of consequences. These consequences must be predicted, evaluated and compared. For example, let us consider a case in which a dam is to be constructed. Depending upon the intended purposes, once this dam is operational, it will help in irrigating some agricultural area, supplying water for municipal supply, generating hydropower and controlling flood. Besides this, the reservoir will also submerge some agriculture and forest area, thus, people will have to be rehabilitated. The different locations and different heights of the dam will produce different patterns of desirable and undesirable effects. These must be suitably considered to arrive at the best project configuration. The arriving at the best project configuration or the best project proposal is a decision making process, and involves many aspects in addition to the technical and economic.

The objective of this training course material is to introduce the basic economic principles, their applications to the various problems related to water sector, and their worth for the public and national welfare. The various economic aspects have been covered which will provide a basis for the decision making process, and thus to lead a more viable, feasible and productive project configuration. Besides the basic principles, the economic evaluation of water resources projects has been covered in detail. The project feasibility, project optimality, cost allocation in multipurpose projects and methods to analyse the projects having conflicting goals are also addressed to give the necessary feedbacks to the readers. Since the topic encompasses a very wide area, it is difficult to make the course material exhaustive because of the nature of the training course. However, it is compact, easily understandable and sufficient in itself. Illustrative examples are given wherever necessary. For more on the economic aspects and the economic analysis related to water resources planning, development and management, readers may refer James and Lee (1971), Hall and Dracup (1979) and Linsley et al. (1992).

2.0 PRINCIPLES OF ENGINEERING ECONOMICS

Engineering economics is the science of applying economic criteria to select the best alternative from a group of 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 structuring of alternatives, so that they may be compared to determine which one should be selected. The evaluation process requires prediction of the consequences expected to result from picking the alternative, estimation of the magnitude of each consequence, and converting the consequences into commensurable units to facilitate the comparison. The economic analysis is performed not only for the newer project alternatives, but also for the ongoing projects for its better monitoring, utilization and scheduling.

All items, components, or consequences of the projects under consideration are expressed in a common unit before the choice is made. The most convenient unit in the present era to express the consequences or items involved in the analysis is a money unit. Amounts at different times or differing in kinds can not be compared or combined. To make them comparable, the amounts are expressed in money units, and all monetary values are converted in equivalent amounts at some definite time. Therefore, to make a realistic decision, each monetary value must be identified by both amount and time. Amounts in different time periods are converted in equivalent amounts at some definite time by multiplying future amounts by a factor becoming progressively smaller into the more distant future. The time rate of decrease in this factor expressed in percent is called the *discount rate*.

The monetary value depends on the viewpoint taken in the evaluation. Basically, three viewpoints are considered in an engineering economic study. These viewpoints are:

- Viewpoint of a small group who is sponsoring or financing the project.
- Viewpoint of all the people in a specific area such as a district or a state.
- Viewpoint of the entire nation.

The viewpoint 1 considers only consequences affecting the sponsoring group. It is based on the premise that this group should promote its own welfare, and thus the personal welfare is given more weight than the public welfare. Viewpoint 2 considers only consequences affecting those living in the area where the project is located. The adjoining or other areas may have different opinions due to the adverse or undesirable consequences affecting their areas or national welfare. Viewpoint 3 considers all consequences to whomsoever may accrue. In principle, this viewpoint should be taken by every level of government to maximize aggregate national welfare in the long run. Regional interests may try to influence federal agencies to select projects producing regional benefit, where they must repay only a fraction of project costs.

The major obstacles in comparison of alternatives are the differences in kind and in time. In real life situations, such situations often occur because many alternatives differ in kind, time and also in both. The two basic principles: (i) Equivalence of kind, and (ii) Equivalence of time are employed to facilitate the comparison.

Some important terms which are frequently used in economic analysis and are very useful for the economic evaluation of the project are defined below:

2.1 Sunk Cost

While comparing the project proposals, or analysing the justification for alterations or expansions in a project, we first investigate how much money has been already spent for each project proposals. The spent money cannot be made available for investment as per the modified policies, nor it will be retracted. Thus, such invested money in past are not taken into consideration for economic study. Past expenditure having no economic relevance for deciding among alternatives are referred as *sunk cost*. Sunk costs are disregarded for the comparison of alternatives because they do not affect future cash flows. However, sunk costs are often allowed to influence decisions. The main reasons which are instrumental in influencing the decisions are:

- The decision makers may have a psychological, political or even a legal commitment to continue a past policy so that past efforts are not wasted.
- Accounting records indicating an underpriced book value for assets having no economic worth may restrict freedom to make new investment.

However, in no case, past mistakes are a legitimate excuse for continuing a policy which cannot be justified by future benefits.

2.2 Incremental Benefit and Cost

Any change in the proposed project plan results in changes in the benefits and the costs associated with the project. We generally call incremental benefit and incremental cost for the changes occurred 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 the change in costs resulting from a given decision determine the merit of that decision. Each project segment should be judged on its own merits. The decision to enlarge a project should be justified by the enlargement's increasing benefits. The incremental benefit should be more than the incremental cost. Analysis based on the total cost and total benefit may give different solution to those obtained from the incremental cost principle.

2.3 Intangible Values

We have seen in earlier sections that an economic study seeks to evaluate all consequences in commensurable monetary units, but there are many values which cannot be quantified in terms of monetary units. Unique or extremely rare items such as species of plant or animal life or sights of unusual beauty have no acknowledged money value. Such matters do not have direct effects on human being physically through loss of health or life, emotionally through loss of national prestige or personal integrity, or psychologically through environmental changes. In addition, monetary values do not serve to measure the achievement of such extra economic goals as income redistribution, increased economic stability, or improved environmental quality. Each value which cannot be expressed in monetary terms is called an *intangible or irreducible.*

Inability to express a value in economic units does not necessarily preclude evaluation in other units. All intangible values should be quantified as precisely as possible, because these factors will influence the decisions makers. In weighing whether a given sacrifice in economic value is worthwhile to achieve a goal, the decision maker should have access to the best possible information on the nature of the intangible consequences as well as the magnitude of the economic consequences.

2.4 Risk and Uncertainty

Since hydrologic processes and the variables/parameters involved in the economic analysis are stochastic in nature, many uncertainties or risks are encountered while dealing with various kinds of water resources projects. The values of inputs and outputs may differ from expectations because of the probabilistic nature of the hydrology involved and the social and economic factors on which the real success or failure of the project depends. The major uncertainties lie in the economic and demographic parameters that are critical to planning. These uncertainties are associated with the population of the area to be served, the exact location, the economic prosperity of the area, the growth path of demand that results from these features, changes in taste, changes in world markets affecting demand for project output, and so on. Any change whether hydrological, social, environmental, economical, or others may influence the decisions severely. It may be also observed that changes in the parameters might not affect the physical performance of the projects, but they may greatly affect the appropriate design for the project and the project's value to society. Therefore, information regarding the fluctuation in the values of parameter is important in the economic analysis.

It is necessary to convert all future events to a risk basis and to decide about the risk reduction to be undertaken. Risk situations are usually defined as the cases in which a range of future events is possible, and each of these events can be associated to a probability of occurrence. Economically, this is usually defined as an insurable situation. Risk in water development involves frequency of droughts and floods. Uncertain situations are defined as cases in which future events cannot be associated to a probability of occurrence, and are therefore termed as uninsurable. Uncertainty is an inherent element in the planning process. It arises because the value of many factors, that affect the performance of water resource system, is not known with certainty when the system is planned and constructed. Whereas the classical economic investigations are not adapted to deal with risk and uncertain situations, systems techniques are employed to deal with such cases.

The reliability of each decision in economic analysis depends on the ability to predict future events. It is because, comparison is done on the basis of future consequences of engineering alternatives. No matter how much data or experience one has, predicting the future is inherently uncertain. Especially, all the processes, assessments and evaluations in water resources are uncertain in strict sense. For example, predicting precipitation, runoff, flood, flood levels, damages, estimating reservoir capacity or cost of a water resources project, predicting groundwater levels, its potential etc. all involve uncertainty. Basically, uncertainty associated with water resources systems can be classified in the following groups:

- Uncertainty associated with the objectives.
- Uncertainty associated with the constraints on the system.
- Uncertainty associated with the public response.
- Uncertainty associated with the technological change.

- Uncertainty associated with the chance element in recurring events.

Many methodologies are being developed to deal with the associated uncertainties. This area is still in active research. Widely used approaches to treat the uncertainties of a project are:

- Applying preselected percentages to increase costs or reduce benefits.
- Adding a risk increment to the discount rate.
- Applying probabilistic approach.

2.5 Planning Horizon

The planning horizon is the most distant future time considered in an engineering economy study. The inherent uncertainty of predicting the more distant future favours short planning periods, but the need for analysis of the long-run effects of plans to meet immediate requirements favours a longer period. Generally, four different periods of time are considered in any economic analysis. These periods are: (1) the economic life, (2) the physical life, (3) the period of analysis, and (4) the construction horizon.

The period of analysis is the length of time over which the project consequences are included in a particular study. The period of analysis for comparing alternative project designs has the project economic life as its upper limit, but may be shortened arbitrarily to exclude the highly uncertain events of the very distant future. Regular maintenance and periodic replacement of worn parts may extend the life of water resources project almost indefinitely. In water resources project study, 50 or 100 years is generally used as a period of analysis. The period of analysis may be longer than the construction horizon. The longer period of analysis helps in integrating the present action into the long-run solution. The shorter construction horizon adds flexibility to deal with unforeseen changes.

2.6 Salvage Value

We observe that some project elements may have economic or physical lives shorter than the period of analysis. Such project elements need periodic replacement. However, when alternative schemes of water resources development are being compared, all must be evaluated over the same period of analysis. Therefore, if the period of analysis is not an even multiple of element lives, service life of some replaced elements may extend beyond the period of analysis. 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 element at the end of the period of analysis is basically an amount equivalent for the unused life of the element, and this amount is termed as *salvage value* of the element. Straight-line depreciation may be used to estimate the value of unused life of an element. The straight-line depreciation formula can be expressed as:

$$S = K\left(1 - \frac{X}{L}\right) \qquad \ldots(1)$$

where X is the years of unused life, L is the years of total life, K is the initial value, and S is the estimate of unused life of an element.

3. DATA BASE AND FRAMEWORK OF ECONOMIC ANALYSIS

Data collection represents a major effort in most large scale economic investigations. It is therefore essential to determine the directions in which the effort should be carried out. The traditional approach is to collect all the data available for a particular area and then to scan them in order to get a picture of the problems of a river basin or area under investigation. The systems approach in this respect is more selective, and involves several stages. A limited amount of synthetic data will be initially required for a general assessment. However, the entire set of analytical data will be collected exclusively if they are required for a particular analysis, model or decision. The entire data collecting process has to be goal oriented.

It can be basically assumed that if any data have been collected having no bearing in the decision process, the effort of obtaining these data was completely wasted. It is not relevant here that the unused data may be utilized for other kinds of analysis. A correctly carried out exercise would have to be able to show where in the subsequent studies any particular data has been used, even if this use would have been only an investigation to show that in that particular case its influence was negligible. The following analysis on data collection should be considered in this context. It actually represents a list of data which might be required for systems analysis studies and which should be collected only after an assessment of their use and necessity.

3.1 Compilation of Data

We always put the effort in compilation of data in two conditions; "with" and "without" project conditions. Fundamental to all development planning is the availability of reliable and adequate data about the water and related land resources of a region, and the community of people to be served. The comparison of future conditions with and without the selected plans is of fundamental assumption which established the structure of the economic analysis. It is improper to base the analysis on a comparison of conditions before and after project construction, because prospective decline or improvement of present conditions might occur even in the absence of the prospective project and should be so recognized in determining the effects properly attributable to the project. Consistent assumptions should be applied to future conditions with and without the project so that comparability is assured. This is important to arriving at the net incremental benefit stream which will be an accurate reflection of the project's income generating capacity, that is, its net contribution to real national income. The basic requirement for planning and utilization of water potential is an appraisal of available water resources. It is very essential to emphasize both quality and quantity aspects of water available for future use. It is equally important to note not only the total quantity of water, but also its distribution from season to season, and its location basinwise and regionwise alongwith its quality.

3.2 Survey for Data Collection

The data to be collected for an economic analysis depend upon the nature of the project being handled. The nature of the project gives an insight to the problem and provides an intuition to list the data items which will be required for the economic study. For an agricultural irrigation project, the survey should cover the following aspects:

- Demographic and social characteristics
- Employment and income (farm and non-farm)
- Land use, ownership and farm size distributions
- Existing cropping pattern and yields
- Farm budgets and net farm income
- Agricultural production and marketable surplus
- Use of agricultural inputs under rainfed and irrigated conditions
- Prevailing wage rates by season and by major agricultural operations
- Marketing channels and prices
- Agricultural supporting services

3.3 Socio-Economic Survey

In view of the importance of socio-economic factors in the execution of water resources development plans, a Socio-Economic Bench Mark Survey is recommended by many international institutions to provide background for an agricultural development plans and to provide a bench mark against which future improvements in the economic welfare of the population resulting from water resource development project can be measured. This survey also helps in assessing the improvement in the socio-economic conditions of the people due to water resources development projects. Regions requiring priority for development can be identified. These data can also help in determining and sequencing and scheduling of the different projects over the time horizon. One of the aims of socio-economic survey is to determine the size of active and potential labour force for agriculture, together with that for tertiary sector contributing to agricultural development. The survey will also help in ascertaining the aspirations of the population so as to gauge its ability to adapt to radical changes in agriculture, and it will also help in forecasting with some accuracy how long the period of adaptation will last and how it will progress. Water projects yield benefits and generate costs. However, these benefits and costs accrue to particular persons of groups, and society has an interest in who, these persons or groups are. The socio-economic survey will be able to help to a certain extent in identifying the strata of society to whom the benefit should accrue.

4.0 EVALUATION OF TIME STREAMS OF BENEFITS AND COSTS

Alternative plans may involve construction of different projects with different economic lives, and hence they result in different time streams of future benefits and costs. All amounts, costs and benefits, are expressed in money units, and are converted into an equivalent amounts at some definite time. The equivalent amount is termed as present value or present worth. To obtain the present worth, all monetary values are represented as a cash flow diagram, and then discounted by appropriate discounting factor.

4.1 Cash Flow Diagram

The graphic representation of each monetary value with time is called a *cash flow diagram* (Fig. 1). In a standard representation of a cash flow diagram, the benefits are represented by arrows pointing upward, while costs are represented by arrows pointing downward. In a general diagram, direction of arrow may be taken either way. The length of the arrow is made proportional to the cost or benefit. The horizontal axis denotes time. For convenience in 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. Drawing of the cash flow diagram can be greatly simplified by use of envelope curves as a substitute for the many arrows.

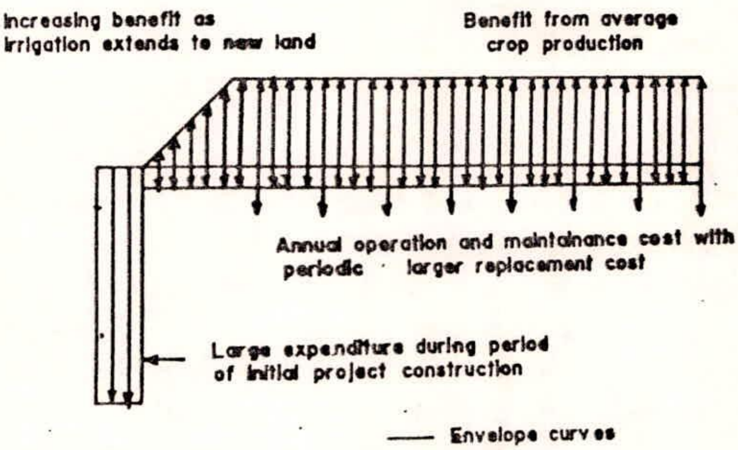

Fig. 1 Cash Flow Diagram for a Hypothetical Irrigation Project

Fig. 1 shows a cash flow diagram for a hypothetical irrigation project. In strict sense, annual benefits and costs (Fig. 1) will not be constant every year, but will vary around average values in an almost random fashion with crop production and maintenance needs. However, only expected average values are normally predicted in advance, even though the random component could conceivably be introduced through simulation.

4.2 Present Worth

The total present values of the benefits and costs generated by plan p, denoted by PVB_p and PVC_p, respectively, are the sum of the present values of the benefits and costs accrued at the end of each time period, respectively. These quantities can be expressed as:

$$PVB_p = \sum_{t=1}^{T_p} (1 + i)^{-t} B_t \qquad ...(2)$$

and

$$PVC_p = \sum_{t=1}^{T_p} (1 + i)^{-t} C_t \qquad ...(3)$$

where B_t , C_t , t, i, and T_p denote benefit at time t, cost at time t, time, discount rate, and planning horizon, respectively.

4.3 Average Annual Amount

The average annual amounts for benefit and cost corresponding to their present values are obtained by multiplying the corresponding present values to 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. The capital recovery factor is basically a factor by which the capital investment or 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 expressed as:

$$CRF = \frac{i(1+i)^N}{(1+i)^N - 1} \qquad ...(4)$$

Thus, average annual benefit, AAB, and average annual cost, AAC, can be obtained by:

$$AAB = (CRF)PVB_p \qquad ...(5)$$

$$AAC = (CRF)PVC_p \qquad ...(6)$$

If a fixed initial construction cost (capital investment) of a water resources project is C_o , and a constant annual operation, maintenance, and repair cost (recurring annual expenditure) is OMR, then the total annual cost, TAC, is given by:

$$TAC = (CRF)C_o + OMR \qquad ...(7)$$

5.0 COST-BENEFIT ANALYSIS

Water resources planning involves choices among physically feasible alternatives which are governed by many factors like economic, social, financial, environmental, and political in addition to the technical considerations. Before picking an alternative or implementing a project, it is necessary to perform cost-benefit analysis, because the ultimate aim of the water resources development is to increase the economic and social welfare as much as possible. Any project in which costs are more than the benefits can not be implemented because it will not be judicious in the interest of nation. The worth of the project will be clear only when the cost-benefit analysis is performed. The cost-benefit analysis basically comes under the purview of an economic analysis. The economic analysis is performed in a series of steps. The steps are listed below:

1. Each promising alternative should be identified and explicitly defined in physical terms.
2. The resulting physical consequences of each alternative must be predicted.
3. These physical consequences must be expressed in terms of money estimates. Estimates should be made of the dates as well as the magnitudes of the receipts and disbursements. The estimates of the lives and salvage values, if any, of the structures and other assets will be also required.
4. A period of analysis for the economy study should be carefully decided.
5. A discount rate must be selected and applied to convert the predicted time stream of monetary values into an equivalent single number.
6. Alternatives are compared on the basis of equivalent monetary values.

There are many methods for the economic analysis. The most commonly used methods are: (1) the present-worth method, (2) the rate-of-return method, (3) the benefit-cost ratio method, and (4) the annual-cost method. These methods are also termed as discounting techniques, because in these methods, discounting factors are systematically applied to compare the alternatives for arriving at the best alternative or proposal. Each method may, if used correctly, lead to the same evaluation of the relative merit. However, each technique has advantages and disadvantages associated with ease of calculation, presentation and understanding of the results. These aspects are generally considered while selecting a method for the economic analysis. In fact, the selection of a particular method depends primarily on the purpose of the analysis and available information.

The most widely used method for the cost-benefit analysis in our country is the Benefit-Cost Ratio (BCR) method. Adoption of this method was realized when the question of laying down suitable criteria in the case of flood control projects was raised first at the time of selecting projects for inclusion in the Second Five Year Plan. It was felt that apart from technical soundness, some basic criteria must be satisfied before a project was approved for inclusion in the Plan. This led to the adoption of benefit-cost ratio as the major deciding criterion. It was laid down that the schemes *should generally show a favourable benefit-cost ratio. In special cases, adequate justification other than economic based on the basic needs of the specific area would have to be made out*. In deciding priorities, preference should be given to those schemes where land required for flood protection works was offered free by beneficiaries as also those where it would be possible to realize from beneficiaries a betterment levy or cess in respect of land and property protected.

5.1 Benefit-Cost Ratio Method

The benefit-cost ratio is defined as the ratio of the present worth of the benefits and the present worth of the costs. The present worths of costs and benefits are computed separately, and then ratio is determined. The annual values can be used as an alternate without affecting the ratio. The following steps are adopted to choose the best alternative by this method:

1. Calculate the benefit-cost ratio for each alternative.

2. Choose all alternatives having a benefit-cost ratio exceeding unity. 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 benefit-cost 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 benefit-cost 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 benefit-cost ratios should be computed by using the same discount rate and the same period of analysis. It is important to recognize that the best project has the greatest net benefits, not the largest benefit-cost ratio. Sometimes, it is observed that the benefit-cost ratio method leads to different decisions than the other techniques do. However, this conflict only occurs when the incremental-cost principle of steps 3-5 is neglected. The benefit-cost ratio method is the conventional technique being used to analyse the public works proposals, and is almost universally used by water resources planners.

In the case of multi-purpose projects, benefit-cost ratios are worked out separately for each purpose on the basis of apportioned costs and benefits from each use in order to ensure that every particular purpose of the project fulfils the criterion laid down for it.

5.2 Illustrative Example 1

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

Solution:

Benefit-Cost ratio for proposal 1 = 45/40 = 1.125

Benefit-Cost ratio for proposal 2 = 48/45 = 1.067

Here both proposals are having Benefit-Cost ratio greater than 1, hence both proposals now will be analysed using incremental principle as per step 3 as 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 crore

and incremental benefit (second proposal over first proposal)

= 48 - 45 = Rs. 3 crore

Therefore, Incremental Benefit-Cost ratio = 3/5 = 0.6

Since incremental benefit-cost ratio is less than 1, less costly alternative will be selected. Therefore, proposal 1 will be selected.

6.0 ECONOMIC RATIONALE OF BENEFIT COST ANALYSIS

The rationale for benefit-cost 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 that these resources 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 to use available scarce resources to maximize resultant human welfare. The scarcity is registered in the market place by price. In regard to water resources development, maximization of the net benefit objective requires the efficient allocation of water to various uses such as hydro-power, irrigation, water supply, flood control, navigation, etc. over time and space.

Economic analysis will state the cost and benefit of the proposed investment to the society either in opportunity cost or in values determined in part by both the resource constraints and the policy constraints faced by project. The difference between benefit and cost - the incremental net benefit stream - will be an accurate reflection of the projects' income generating capacity or its net contribution to real national income.

7.0 PROJECT ECONOMICS AND EVALUATION

Project economics involve the identification and quantification of all kinds of costs and benefits associated with the project, economic analysis of proposed plans, or policies. Project evaluation involves the testing of the project for all types of feasibility requirements, its optimal evaluation and assessment of implications of changes in input parameters comprising the project configuration. These studies are important before adopting a project plan or policy, because water resources projects are tool for controlling the diseconomics inherent in the excessive congestion associated with large metropolitan cities as well as accelerating economic growth in lagging areas. In fact, water resources projects directly affect the development of the nation, state, or region and the living standard of the people, and thus welfare of the whole nation.

7.1 Project Feasibility

The development, utilization, preservation and management of most water resources projects involve political-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 today and in future. Before adopting a project or going for economic analysis, it must be assured that all projects considered for analysis fulfil the requirements posed by feasibility criteria. Each proposal must pass six feasibility tests. These tests can be abbreviated by EEFPSE for easy to remember. It stands for Engineering, Economic, Financial, Political, Social and Environmental. These tests are essential for implementing any decision regarding a water resources project. These aspects should not be overlooked or misunderstood, as it may exert an adverse effect on the decisions made on the basis of only technical requirements.

Engineering Feasibility:

If the proposed project is physically capable of performing its intended objective, the project is called technically feasible. Engineering design must be confined within the technologically feasible region. Engineering analysis may show the combination of outputs which could be produced physically, and the combination of outputs which would not be physically possible to produce. Continued analysis of alternative production possibilities will show which output vectors can and which output vectors can not be produced. All those that can be produced are said to fall in the technologically feasible region. Thus, an engineering feasibility is ascertained through design analysis as described in standard engineering texts for different components of various water resources projects.

Economic feasibility:

The project is said to be economically feasible when the additional benefits from the project exceed the project cost. It is important to note that the comparison should be with and without rather than before and after. It is because many of the after effects may even occur without the project, and thus, it cannot be properly used in project justification. Economic feasibility is contingent on engineering feasibility because a project incapable of producing the desired output is not going to produce the benefits needed for its justification.

Financial feasibility:

It is very important criteria. Even though the project may clear all other feasibility tests, it may not be implemented because of nonavailability of funds. The test of financial feasibility is passed if sufficient funds can be raised to pay for project installation 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 people. A project may be economically infeasible, but financially feasible because someone is willing to pay for the fulfilment of noneconomic goals. Financial feasibility also depends on local interests believing estimated economic benefit to the degree that they are willing to raise their portion of the required funds. Thus, financial feasibility is determined by examining potential sources of available funds.

Political feasibility:

The political feasibility of a project is achieved when the required political approval can be secured. Ordinarily political support follows proof of economic and engineering feasibility. Political pressure for project construction may even be quite strong despite proof of economic infeasibility. On the other hand, groups which feel they are adversely affected, often oppose project installation. Political feasibility is determined by analysis of how key decision makers assess the favourable and adverse effects of the project, the intensity of popular feelings, and the project potential for obtaining widespread public support.

Social feasibility:

If the potential users respond favourably to project construction, it is said that the project is socially feasible. 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 cannot be hoped within a scheduled time, and thus will change the time stream pattern of costs and benefits cash flows. Land acquisition, employment, income redistribution, project output distribution, environmental deterioration, adverse implications after project construction or due to any failure during the project life, etc. are the specific points on which the people of the region, in which the project is located, may have different view points, and this will impose a number of constraints on the project launching.

The success of a project depends upon the willingness of the users to do whatever is needed to realize potential project benefits, to shift to irrigated agriculture, to utilize electrical equipment etc. The more drastic changes a project requires in the lives of the beneficiaries, the greater is the likely inertia from the beneficiaries to change their way of living. The infusion of productive capital does not automatically transform a tradition bound society. Social 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.

Environmental feasibility:

All project proposals considered for the evaluation must pass environmental feasibility. The possible consequences of project installation should not give a viable threat to environment. The ecological disturbances issues may raise a number of constraints and obstacles during the execution of the projects. The growing awareness of ecological disbalance may change the opinion of the people, and thus may involve many diverse decision makers which will impose a large number of unintentional institutional and social constraints. It will ultimately affect the cash flow pattern and will create hindrance for the successful completion of the project.

Unless explicit safeguards are introduced, planning based on economic and technical criteria may inadvertently destroy the quality of environment required to preserve man's psychological and even long run physical well being. Even though individuals differ widely in environmental preference, common consensus is often reached to support unique natural areas and save open countryside, and oppose destructive pollution or excessive congestion and resultant blight. Structural measures for water resources development are widely viewed as having a destructive influence on environmental quality. The conflict can be mitigated by introducing an aesthetically more pleasing design or by achieving project objectives through nonstructural measures. Explicit analysis requires both precise definition of what aspect of environmental quality is to be preserved or promoted, and development of an index proportional to the quality achieved.

7.2 Project Optimality

Water resources planning, development, or management can be thought of a production process. In planning a production process for the public sector, many valuable insights can be gained from analysing 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, and natural streamflow, etc.. The optimum combination of construction items in building a given intermediate product is best found by minimizing the total cost or maximizing the net benefits. This is an economic criteria for the evaluation of the optimum solution. By the optimum solution, we mean the best solution of the problem as per prescribed criterion. In broad sense, the criterion for obtaining an optimum solution may be different from the economic one. The criterion based on which the optimal solution is sought is termed as the objective function. In this course material, we will confine ourselves to an economic criterion only.

Whenever, a water resources project is decided to be implemented, it is often desired that the proposed proposal is the best and any other possible alternative will not be better than the proposed one. Thus, the selected project should be optimally planned. The project, which gives the maximum net benefits or the project which gives maximum return or investment, may be approved depending upon the need of the project, the availability of funds, etc., as optimally planned project. In all public utility projects, such as dams, flood walls, irrigation projects, etc., the general objective is to maximize the net benefits rather than achieving the maximum return or investments.

Conceptually, both benefits and costs may be either measured in monetary units or defined with respect to some broader based social welfare function without affecting the optimality criteria. For a water resources project in which a number of alternatives are to be analyzed for choosing the best one, the goal is to find an alternative having maximum value of the objective function under the imposed constraints. There are several ways for evaluating the optimal point. It depends upon the formulation and nature of the problem. The techniques available for determining the optimal point encompasses a very wide range from the simple graphical and analytical approaches to complex and highly sophisticated optimization techniques. Optimization techniques include linear programming, nonlinear programming, geometric programming, integer programming, dynamic programming, multiobjective optimization, parametric programming, genetic algorithms etc. Selection of a particular method depends upon the nature of the problem, applicability, suitability, computing feasibility of the method, and available computing power.

8.0 ECONOMIC EFFECTIVENESS OF RESERVOIRS

Reservoirs are a part of the economic potential of any country. Since their construction require capital investments, they must be evaluated carefully. An objective measure is to determine how they help to raise national economy, which is done with the help of quantitative economic indices. Some capital investment consequences can only be estimated qualitatively and not quantitatively. However, the qualitative evaluation is of great importance for reservoirs. Intangible effects can lead to a choice of an alternative, which is less effective economically, but more advantageous socially. Different alternate plans may often satisfy same needs. The most effective option is determined by a comparison of technical and economical indices of all implementable and interchangeable options. The needs can be met by various resources or by a different exploitation of the same source. All losses and benefits must be taken into account.

How the water demand from a certain source is met, depends on the natural conditions and on the parameters of a reservoir, i.e., its dimensions and methods of operation. These are derived from a synthesis of technical and economical calculations, including quantitative indices and qualitative characteristics. The effectiveness of capital investments is determined by a complex comparative analysis of all decisive factors which influence the demands and effect of the capital investments. The characteristics for reservoirs and dams which influence the evaluation of their effectiveness are:

- long service life
- relationship with other branches of the economy and with the human environment
- functions in large and complicated systems
- multi-purpose use
- possibility of construction in stages

9.0 MULTIOBJECTIVE APPROACH TO WATER RESOURCES DEVELOPMENT

We have seen that the important considerations in water resources planning are the technical, financial, and political feasibilities of alternatives. Other aspects to be considered are the income redistribution aspects, regional development, creation of employment, environment protection etc. Thus, the decision maker has to satisfy more than one objective, and hence the problem is multiobjective. In fact, most decisions related to water resources projects are multiobjective. The traditional benefit-cost analysis may not be suitable in all such cases. Multiobjective planning is, however, not the same as 'multi-purpose' nature of the project. The expression multi-purpose denotes that project produces various outputs; for example, a dam may cater for water supply, hydropower and flood control. In multiobjective, basically we deal with a number of conflicting objectives associated with the project. This subject is getting more attention now-a-days because of complex man's interaction with the project and growing awareness of the people regarding environment.

Under situations of commensurate objectives, a number of alternative plans can be suggested, and these plans can be ranked easily based on the net benefit or other utility criteria. When the objectives are in conflict with each other, for instance, between the construction of a reservoir for irrigation and the inundation of forest area due to reservoir, it is necessary for the planners to know which of the two is preferable, and by how much ? Such cases involve quantification of the benefits and costs against each objective as well as attaching appropriate weights to make them comparable. Numerous methodologies have been advocated to solve the multiobjective problems. These include the Weighting and Constraint techniques, the Surrogate Worth Trade-off (SWT) Method, the STEM (STEp Method), the Goal Programming and Compromise Programming. The selection of the best compromise solution is a crucial task for water resources planners.

10.0 COST ALLOCATION IN MULTIPURPOSE PROJECTS

In case of multipurpose water resources projects, the cost associated with a project is divided among several uses and/or different groups of beneficiaries. For example, the share of flood control in the cost of a multipurpose project must be distinguished from those for irrigation. The problem assumes critical significance when the costs and benefits of a project are spread over more than one state which is quite often the case. Thus, an objective basis of cost allocation is needed to avoid inter-state or inter-group disputes. The procedure for dividing total financial cost among the responsible heads is called cost allocation. Once a formula for allocating costs is established, it needs to be incorporated into a legally binding cost-sharing agreement.

Cost allocation is a part of financial analysis. It requires assignment of total cost among project purposes and division of purpose cost among user groups. Each group assigned a cost is called a cost center. Each distinct physical portion of the project is called a project element. The direct costs are the costs of project elements serving only one cost center. If an element serves more than one cost center, the difference in its cost with and without serving a center is the separable cost of that element with respect to that cost center, and is determined from project designs with and without the cost center's being served. The difference between total project cost and the sum of the separable costs is the nonseparable cost. Nonseparable costs include joint costs and common costs. Joint costs occur when a project element contributes to the production of more than one output. Common costs are indirect or other fixed costs which must be paid for, but cannot be associated with any production operation.

All methods of cost allocation require selection of a measurable unit that is reasonably indicative of cost center responsibility for the nonseparable costs. When the nonseparable costs are allocated in proportion to the measured quantity associated with the respective cost centers, this item is called the cost allocation vehicle. Different vehicles may be selected for allocating difference kinds of nonseparable cost. Various methods of cost allocation differ in two sense (i) the type of vehicle used for allocation, and (ii) the amount which needs to be allocated. A vehicle may be based on equal units, unit of use, priority of use, net benefit, alternative cost, or smaller of benefit or alternative cost. The amount to be allocated may be total cost, total cost-minus direct cost, or total cost minus separable cost. The various methods are designed in combination of a vehicle and the amount to be allocated. Commonly used methods are the remaining-benefits method, alternative justifiable-expenditure method, and use-of-facilities method. Strictly speaking, there is no unique method of cost allocation in conflicting situations, because each party tends to favour the allocation shifting the largest share of the joint costs to others. The essence of cost allocation is successful resolution of the conflicting interests among the parties.

10.1 Historical View of Cost Allocations 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 could have been incurred in constructing a separate structure solely for that object 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. Later on, in 1952 this was changed in favour of a new method based on the ultimate utility of water for various purposes. Flood control as a separate purpose was eliminated. Subsequently, at 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 the 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.

In the case of 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, cost of Stage I of works had been allocated equally between flood control and irrigation since the same storage capacity could be used equally for both the functions.

In April 1967, the Government of India recommended the adoption of the facilities used method for the allocation of joint costs of multi-purpose river valley projects. The alternative justifiable-expenditure approach was recommended by the Rashtriya Barh Ayog in 1976 for allocating costs of multi-purpose projects.

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