

1. QUANTITY SURVEY AND COST ESTIMATION

1.1 METHODOLOGY

1.1.1 STAGES OF WORK

As already mentioned in the chapter of "Layout and Sizing" the estimation of quantities and costs is dependent on the stage of the work.

Identification Stage

During the identification stage only a preliminary estimation of quantities is possible. This work can be done on basis of the standardized structures included in the cost estimation program MHEPP. In case no standard structures are applicable, calculations have to be done by hand and the adding of additional costs. The costs of the structures are calculated according to a unit price list, which is developed on basis of international prices for civil works as well as hydro-mechanical and hydro-electrical works and equipment.

Feasibility Stage

During feasibility stage quantities are calculated with help of the preliminary design of all power plant components with corresponding tentative calculations and analyses such as stability analysis, hydraulic calculations, and structural analysis. The calculation of the major quantities, activities and material requirements is mainly dependent on their geometrical dimensions and unit requirements respectively.

The major quantities for 2 to 16 units are usually as follows:

- Cement
- Concrete
- Reinforcement
- Diaphragm walls
- Sheet piles
- Filling
- Excavation of soil and rock (dry and under water)
- Geo-textile (above and under water)
- Rip-rap/stone apron (above and under water)
- Demolishing of guide banks (above and under water)
- Gravel fill / back filling
- Steel for hydraulic structures
- Hydromechanical equipment
- Electro-mechanical equipment

The costs during feasibility stage consist of

- Direct costs
Direct costs can be calculated by multiplication of quantities with unit rates. The unit rates can be evaluated by analyzing and comparing following information:
 - Unit price list
 - Available ICB of similar projects
 - WAPDA schedule of rates
 - Budgetary prices
- Local and foreign components
- Indirect costs
Indirect costs can be calculated on the basis for the costs of different main parts in hydropower developments such as civil works (C), hydromechanical (M) and electro-mechanical (E) components. Following indirect costs have to be considered:
 - Transportation and shipment, 5% up to 10% of FOB
 - Erection charges; 5% of (É), 12% of (M)
 - Contingencies; 10% of (C) and 5% of (E)

- Engineering and supervision; allowance of 4% of (C), 2.5% of (EM)
- Administration, audit and accounts; 4% of (C)
- Miscellaneous; allowance of 1.5% of (C)
- Import charges (evaluated separately in 'Economic and Financial Analysis')
- Interest during construction (IDC) (evaluated separately in 'Economic and Financial Analysis')

The total cost of the hydropower development is the sum of the base costs, which are direct costs and indirect costs, together with the interests during construction.

Tender Stage

After the feasibility stage is finished, detailed engineering works is going according to the detailed explanations given in the chapter "Engineering Design". All power plant components are designed in detail with corresponding accurate calculations and analyses, hydraulic calculations, and structural analysis. The result of all engineering works with exact geometrical dimensions of the structures, detailed planning of auxiliary components can be found in the drawings, which are the basis for the construction work. Based on the detailed engineering drawings the exact quantities can be read. The main and most important quantities are, as already mentioned in the part of identification stage, the civil works. Therefore the needed quantities for excavation, concrete, reinforcement etc. can be derived from the detailed engineering drawings prepared during the design phase of the hydropower development. Apart from the quantities, other important items for construction have to be taken into account, such as activities, material, manpower and equipment according to their geometrical dimensions, weights and/or unit requirements respectively.

In the following a methodology is introduced suitable for the quantity survey and cost estimation for projects during feasibility stage and tender stage. As mentioned above, the main difference is in the detail of engineering design and thereby the detail of engineering drawings. In the appendix two examples are enclosed of low-head hydropower developments at River Indus in Pakistan based on the feasibility studies. The basic approach for the cost estimation is the same, it differs only in some small respects. It has to be added in this context, that the enclosed cost estimations include local as well as foreign distribution.

1.1.2 ACCURACY OF COST COMPUTATION

There are several methods for the cost computation of the main structures. Each method has its own level of accuracy. In some cases they can be calculated quite exactly, in other cases there might be still some uncertainties, which cannot be calculated exactly. In the following they are given with decreasing accuracy:

As a product of a given quantity multiplied by the appropriate unit price

- As a product of a quantity, computed by using an empirical formula, multiplied by a unit rate
- By means of an empirical cost formula
- As a fixed lump sum
- As a percentage of other costs

It is obvious, that the determination of the unit price has a considerable impact on the total costs of the hydropower development. If the estimation is too high, the hydropower project might become financially unattractive. In case the unit prices are too low, the implementation of the hydropower project becomes financially dangerous. Therefore a lot of experience is needed for the determination of the unit price. Today the unit price is derived from international standards and is frequently updated. This item is not discussed in detail in this work.

1.2 COST ESTIMATION

In this paragraph the different cost components are introduced and briefly explained. It should be mentioned in this context, that the costs are very much site specific. Depending on the local

conditions and the choice of engineering solutions, the amount and distribution of costs might differ. However the basic principle and the methodology is the same, which should be explained here. Considerations are related to a typical low head hydropower development.

The basic construction cost of a hydropower scheme are divided into main groups as:

- Preliminary works
- Civil works
- Hydraulic steel works
- Hydro-mechanical equipment
- Electro-mechanical equipment
- Transmission system
- Engineering and administration
- Other costs

The basic construction cost estimate contains all work and supply items included in the construction of permanent project works, investigation and planning costs, engineering and administration services and the cost of all preliminary works.

A contingency allowance is included as a separate item in the estimate for each project component. The purpose of this allowance is to cover minor differences between actual and estimated quantities, unforeseen items of work, possible minor changes and other contingencies.

Finally, as foreign investment would be needed, the cost estimate should be split into foreign and local components.

1.2.1 PRELIMINARY WORKS

Preliminary works consists of land compensation, site installation and environmental work and road construction.

- Land compensation costs can be assumed to be Rs. 50 per square meter. E.g. For the Jinnah HPP approximately 300,000 m² of land should have to be acquired for the construction of power plant, residential colony for Engineers and staff and the Contractor's camp.
- Site installation costs can be estimated being 20 – 25% of costs for civil works. Following are provided under the 'Site installation cost' item:
 - Mobilization and demobilization of equipment
 - Accommodations for owners, consultants and contractor's personnel and other facilities
 - Electric power distribution and lighting system, water supply and sewage treatment
 - Workshops, warehouses, sheds and yards
 - Equipping and furnishing of contractor's administrative and field offices
 - Providing and maintaining of transport facilities for personnel of owner, engineer, contractor

From camp to construction site

- Maintenance of the colony and camp including security and all other facilities
- Environmental work and road construction includes:
 - Realignment of existing roads, if necessary
 - Building of new access roads to powerhouse and important structures, such as trash racks
 - Construction of inspection roads along the head and tail race
 - Costs for a fish ladder

The sum of the above mentioned items could be considered as the total cost for preliminary works.

1.2.2 CIVIL WORKS

Based on the engineering design of the project, the quantities have been calculated for the individual work items.

The computed unit prices include the cost of labour, material and equipment, with due consideration for the local conditions. Each item should be calculated for local and foreign currency.

Usually the estimates for civil works should be established in the following sequence:

- Calculation of quantities
- Computation of unit prices

1.2.2.1 CALCULATION OF QUANTITIES

Since civil works represent the main part in the construction of a low head hydropower development, it is recommended to subdivide the main works as follows:

- Dewatering
- Powerhouse pit
- Concrete works
- Head race
- Tail race

This should be done, as there might be different contracting companies, which would be interested in different parts of the work. Contingencies for the civil works are taken as 15% of the basic cost, which reflects uncertainties of conditions and minor changes of work.

Based on the engineering design drawings, the quantities of the civil works can be calculated. If the different main working steps for the construction of the structures are known, the quantities for a complete erection can be calculated with a spreadsheet.

In the appendix examples of the civil works and the summary of cost estimates for the Jinnah Hydropower Project and the Chashma Hydropower Project are included. In the appendix Tables 1-1 to 1-5 show the cost estimations of civil works for Jinnah HPP, while civil work cost estimates for Chashma HPP can be found in Tables 1-6 to 1-9. Summaries of cost estimates are included in Table 1-10 for Jinnah and Tables 1-11 and 1-12 for Chashma.

To illustrate the principle of this approach two examples of civil works on another HPP, namely the Guddu HPP should be given. For instance the construction of the tailrace of Guddu Hydropower Project can be estimated in detail as follows:

Table 1.1: Different items for cost estimation of tail race construction [1]

Item	Total Quantity
1. Filling of embankments	
▪ filling	105,000 m ³
▪ compaction of filling	105,000 m ³
2. Excavation	

<ul style="list-style-type: none"> ▪ dry excavation ▪ excavation under water 	195,000 m ³ 950,000 m ³
3. Slope and bed protection <ul style="list-style-type: none"> ▪ supply of geotextile ▪ placing of geotextile above water level ▪ placing of geotextile under water level ▪ supply and placing of rip rap above water level ▪ supply and placing of rip rap under water level ▪ supply and placing of stone apron 	140,000 m ² 28,000 m ² 112,000 m ² 12,000 m ² 64,000 m ² 6,500 m ²
4. Road construction <ul style="list-style-type: none"> ▪ aggregate base course 	4,700 m ³
5. Minor items <ul style="list-style-type: none"> ▪ 5% of items 1-4 	

To give another example of the Guddu HPP, the cost calculation of the dewatering is also split into different activities, each having its own quantity, such as:

Table 1.2: Different items of dewatering for cost estimation [1]

Item	Total Quantity
1. Installation of dewatering system <ul style="list-style-type: none"> ▪ well drilling ▪ installation of pumps and auxiliary equipment 	1,130 m 1,650 KW
2. Operation of dewatering system <ul style="list-style-type: none"> ▪ operation of pumps ▪ repair and maintenance of pumps and auxiliary equipment ▪ maintenance and depreciation of standby aux. equipment ▪ maintenance and depreciation of standby generators ▪ energy 	17,928,00 KWh 747,000 KWd 224,000 KWd 747,000 KWd 17,928,00 KWh
3. Minor items <ul style="list-style-type: none"> ▪ 5% of items 1-4 	

All working steps for all different civil works can not be discussed in detail in this work, therefore only a few examples are picked, the full detailed work is available in the Guddu Hydropower Project Feasibility Report, which can be found at GTZ.

1.2.2.2 COMPUTATION OF UNIT PRICES

The specified prices are composite rates including labour, materials, construction, removal of site facilities, cost of equipment and cost of site management etc. by the contractor.

Based on international data basis for civil engineering works, the unit prices are calculated while considering of the local conditions as follows:

- plant crew hours
- labour crew hours
- material

with local and foreign components. It should be mentioned, that the component of local and foreign distribution has to be considered in a developing country as for example Pakistan. This can be considered as special case.

Plant Crew Hours

Plant crew hours include all equipment, necessary per unit of defined pay items. Provision of foreign, up-to-date equipment is taken into consideration to meet the requirements of the construction time schedule.

Labour Crew Hours

The amount of labour crew hours per unit of the individual pay items is being derived from the data base as well. According to the technical requirements, the labour crew hours are split into local and foreign components as follows:

Surface structures	80% local	20% foreign
Underground structures	20% local	80% foreign
Mean wages of foreign manpower	10 to 12 US\$/hour	
Mean wages of local manpower	1 US\$/hour	

Cost Of Material

The cost of material is derived by local evaluations. Some competent unit rates are listed as follows:

Table 1.3: Examples of unit rates [2]

Item	Costs
Cement	102 US\$/ton
Concrete	130.00 US\$/m ³
Gravel fill	20 US\$/m ³
Reinforcement	870 US\$/ton

Some examples of estimated unit rates (price level 1998) for civil works of main structures of Guddu HPP are listed as follows. A detailed overview is given in the Feasibility Studies of the Jinnah and Chashma Hydropower Projects, prepared by WAPDA/GTZ. It should be noted, that contingencies of 15% as considered for civil works are not included in those unit rates.

Powerhouse Pit:

Protection dams	1.2 US\$/m ³
Cofferdams Gorki-Feeder Canal	1.2 US\$/m ³
Back filling	1.2 US\$/m ³
Excavation	1.8 US\$/m ³
Erection of diaphragm walls	120 US\$/m ²

Headrace :

Canal excavation, dry	2.1 US\$/m ³
Canal excavation, under water	1.3 US\$/m ³

Tail race, slope and bed-protection:

Supply of geotextile	2.4 US\$/ m ²
Placing of geotextile above water level	0.6 US\$/ m ²
Placing of geotextile under water level	1.1 US\$/ m ²
Supply and placing of rip rap above water level	11 US\$/ m ²
Supply and placing of rip rap under water level	15 US\$/ m ²
Supply and placing of stone apron	16 US\$/ m ²

1.2.3 HYDRAULIC STEEL WORKS

Weights and prices of hydraulic steel structures can be estimated on the basis of carefully analyzed supplier tenders and available characteristic indices from the European markets for similar equipment. Hydraulic steel works can be considered as quite expensive, having an

impact on the cost proportion of transport and assembly works. Whenever it is suitable local companies can deliver some smaller components of particular items. The cost estimate should include 5% of contingencies for the main structures.

Hydraulic steel works are mainly concerned with the intake structures and with the main barrage. At the main barrage any type of gates can be used e.g. slide gates, vertical lift gates, radial gates etc. Stop logs upstream and downstream in case of emergency and cranes are also needed, as discussed in the chapter of "Engineering Design". Furthermore hydraulic steel works are used at the intake, in form of gates and trash racks.

Alternatively the estimation of the costs of hydraulic steel works can also be done as part of the concerned main structure, because it is also needed for the proper function of the structure. Anyhow, it has to be considered in one or the other category, due to sometimes enormous costs.

1.2.4 HYDRO-MECHANICAL COMPONENTS

It is known, that hydro-mechanical equipment such as hydraulic turbines, valves and governors are quoted by the suppliers at rates, which vary 100% depending on the market situation. Therefore prices have to be estimated after careful analysis and on base prices taken from recent tenders. Depending on the market situation with respect to possible suppliers in the country, an import of the turbine and all other auxiliary equipment might be needed. In Pakistan, for instance, own production resources are non-existing and a 100% foreign delivery of the complete equipment has to be assumed.

The cost of the turbine and other equipment as valves and governors is mainly dependent on the layout of the power station and the design of the hydraulic turbine. These items were already discussed in context of the chapters "Layout and Sizing" as well as "Engineering Design".

1.2.5 ELECTRO-MECHANICAL COMPONENTS

Based on the electrical layout of the low head hydropower development a cost estimation should also be carried out for the electrical components of the hydropower project. As already mentioned in the chapter "Engineering Design", the electrical equipment is mainly governed by the number of units as well as the boundary conditions established by the connecting grid.

It is known, that equipment such as generators, transformers and switchgears are quoted by the suppliers at rates, which vary by 200% depending on the market situation. In countries without their own production of the equipment in question, as it is the case of Pakistan, for instance, prices are usually at the lower end of the scale.

It can be seen in the appendix in Tables 1-13 and 1-14, in case of the Jinnah hydropower project in Pakistan prices can be elaborated after careful analysis and on base prices mainly taken from recent tenders in a country for equal or very similar equipment. It must be understood, that restriction upon access to the international markets may increase cost of concerned items significantly, sometimes up to 3 times. Contingencies of 5%, including price and physical contingencies, have to be added.

The estimation has to be carried out for the following electro-mechanical components:

- Generator
- Transformer
- High, medium and low voltage installation
- Grounding system
- Control, alarm, protection, telecommunication and watches
- Lightning and small power and emergency diesel

1.2.6 TRANSMISSION SYSTEM

Low head developments become interesting sites when connected with the national grid. For this reason, the cost estimation for the erection of the transmission system has to be taken into account. The prices can be taken from usual contracts valid in the country. The main parameter in the costs of the transmission line is the distance to the grid as well as the type of transmission line. Contingencies of 5% should be taken into account.

Nevertheless the economic cost of interconnection of a high head hydropower development with the grid has to be distinguished from the investment costs. More details on this subject are included in the above mentioned feasibility report.

1.2.7 ENGINEERING AND ADMINISTRATION COSTS

Engineering and administration should be taken in some cases to include the requirements of foreign and local consultants to do further site investigations, preparation of contract documents and supervision of the construction works. The cost of these activities can be taken as 6% of the engineering work excluding the preliminary works.

1.2.8 OTHER COSTS

Other costs that a private investor would have to meet include the following:

- Bank clearance charges and local insurance; it can be taken as 1% of the engineering works and engineering and administration
- Customs duty of 2% on imported equipment, machinery and plant cost, e.g. In Pakistan according to the "policy framework and package of incentives for private sector hydel power generation projects", May 1995
- Income tax of 4% on payments to the contractors in Pakistan according to above mentioned policy.

1.2.9 SUMMARY OF PROJECT COSTS

The sum of all above mentioned cost components gives the cost summary. A breakdown of the construction costs of the aforementioned Guddu Hydropower Project with 42 MW reflects the percentage of the total costs excluding escalation and interest during construction. This project can be considered as one typical example of a low head hydropower development at an existing irrigation barrage at River Indus in Pakistan. The detailed cost estimation for civil works is available as appendix to the feasibility study.

Table 1.4: Summary of Project Costs of Guddu HPP, Alternative A

Cost Group	Costs [Mio. US\$]	Percentage [%]
Land Compensation and Preliminary Works	10.480	1.3
Site Installation, Mobilization and Demobilization	45.538	5.8
Civil Works	455.377	57.7
Hydro-Mechanical Equipment	106.688	13.5
Electro-Mechanical Equipment	41.946	5.3
Transportation	7.433	0.9
Erection Charges	14.904	1.9
Contingencies	57.525	7.3
Engineering and Administration	42.388	5.4
Other Costs	6.830	0.9

It is obvious, that the costs for civil works are more than half of the project costs. Therefore the evaluation of civil work costs has an important impact on the total costs of the project.

The presented order of cost estimation in the above paragraph is one possibility to carry out the estimation for low head hydropower developments. Therefore two more examples for a low head hydropower development are enclosed in the appendix. The basic principle of the cost estimation is the same, total costs are divided into local and foreign distribution.

The materials and quantities required are computed using the engineering drawings consisting of plans and sections of all components of the project. In the examples presented, the 96 MW Jinnah Hydropower Project and the 184 MW Chashma Hydropower Project cost estimation was carried out for a feasibility study. A more detailed cost estimation is supposed to be carried out at tender stage after detailed engineering design.

2. PROJECT PHASING AND CONSTRUCTION SCHEDULE

2.1 GENERAL

The construction planning includes not only the time duration of construction activities, but also pre-construction activities. The project phasing and construction schedule is highly site specific. Especially in case of low head hydropower developments the variability of construction schedule is great, due to the variability of the different developments with numerous combination possibilities of components.

Therefore general time schedules cannot be given. For this reason the topic is discussed as general as possible in this paragraph and again the construction schedules of two case studies are included in the appendix. Again, similar to the paragraph "Quantity Survey and Cost Estimation", the low head hydropower projects Chashma with previously designed 270 MW and Jinnah with 96 MW are enclosed with all details of Feasibility Studies.

It should be mentioned in this context, that for the project phasing and construction schedule a lot of experience is needed. Therefore an engineer, who has spent some years at different construction sites, should carry out this part of the work. Because an experienced engineer might have a better knowledge about the difficulties, engineers can face during construction. An experienced engineer might also have a good basis for the estimation of usual works such as excavating, concreting etc.

The basis for the construction schedule is the quantity survey, carried out for the different main structures in the process of cost estimation, discussed in the paragraph above. Based on this quantity survey and the experience for daily progress of work in each working step the construction duration for the different items can be estimated.

The characteristic item of construction process in the project has to be studied in detail and accordingly the construction schedule has to be framed. Also keeping in view the construction methods involved with suitable equipment and machinery required for the project.

Construction areas of low head HPP are usually plain and almost without any problem of extension. It allows therefore, to locate the required camps, workshops, offices etc. very close to the construction site.

This circumstance is also of advantage in respect to the construction materials. The most important construction material for all structures is concrete. Therefore sufficient space for crushing plants and mixing plants is needed and should be also available due to a large size of the project area. The capacity of both the plants is governed by the rate of concrete placement and the size of the intermediate stockpiles. Adequate arrangements have to be incorporated in the crushing and screening plants in order to produce aggregates to meet the requirements of the grading curves. This is an urgent prerequisite to ensure the concrete quality. The concrete quality has to be controlled frequently during the construction phase. Laboratory tests have to be carried out, sufficient facilities should be made available at the construction site. Moreover during concrete transportation and placement measurements have to be taken to prevent segregation and thereby dangerous reduction of concrete quality.

However, due to a chosen large project area, the organization and the work for the three main sections of a low head hydropower project, namely head race, tailrace and powerhouse can be started simultaneously. The work in each part can also be started independently and without any disturbance.

2.2 PROJECT PHASING

There are different project phases, which have to be distinguished in connection with the tentative construction time schedule:

- Pre-construction

- Construction
- Hydro-mechanical equipment
- Electro-mechanical equipment
- Testing and commissioning

The pre-construction phasing consists in the preparation of detailed drawings and tender documents as well as in the tendering evaluation and awarding.

The construction will be discussed more in detail in the following paragraphs.

Concerning the hydro-mechanical and the electro-mechanical equipment, three different phases have to be distinguished:

- Manufacturing
- Transportation
- Installation

This equipment becomes an important part in the construction during its installation. In case equipment has to be imported from abroad, considerable time for transportation has to be planned.

The testing and commissioning phase starts, if all other works are finalized. Test operation is usually proposed for six months, the phase of commissioning is considered to be finalized after another six months.

2.3 CONSTRUCTION TIME SCHEDULE

The time schedule planning for the construction itself consists, according to the cost estimation, of several main activities, which have to be considered. These activities depend on the layout of the low head development, but in general they can be given as follows:

- Construction of camps
- Site installation and mobilization
Preliminary works
- Construction work sequences in 4 stages
 - Stage 1 : powerhouse pit and head race
 - Stage 2 : powerhouse, head race and tail race
 - Stage 3 : powerhouse, head race and tail race
 - Stage 4 : powerhouse
 - Electro-mechanical equipment
 - Switchyard
 - Transmission system

An important point is, that many activities start simultaneously at different locations to shorten the total length of the construction. This has the effect, that the logistics of the construction management becomes a decisive aspect for the success of the construction planning.

In the following the different items and activities are briefly discussed. The construction time schedules given in the appendix show the tentative construction schedules for Jinnah and Chashma Hydropower Projects. They should be studied in more detail, since they can be considered as good examples for low head developments at existing irrigation barrages in Pakistan.

There is the general tentative time schedule, which covers all works from the pre-construction phase with preliminary works to the commissioning of the project. Apart from that more detailed construction scheduling is available for the most important structures of civil works. The division of activities is mainly based on the sub-items of cost estimations for the same structures. Here

the quantities play a dominant role in connection with available construction materials. Moreover the interdependence of the activities can be recognized in the detailed time schedules.

Construction of Camps

Naturally the camps have to be equipped and furnished with all necessary facilities such as workshops, stores, offices, religious service, accommodations for contractor's and consultant's personnel, hospitals, recreation facilities etc.

Site Installation and Mobilization

The first important stage in the construction planning is the site installation. It chiefly deals with the mobilization of all equipments required for the various construction items, electric and water supplies to offices and equipment, erection of repair and maintenance workshops, stores for spare parts and materials, administration and planning office, concrete mixing plant, aggregate mixing, steel yard, carpenters yard fuel storage stores etc. The area of these items should be as close as possible to the construction site and organized in such a way that no disturbance to the construction programmes occurs. The sequence of work, which has to be carried out, determines the planning and organization of the site installation.

Preliminary Works

Before the start of any major construction activity, construction, improvement and extension of roads and bridges have to be completed. This is the infrastructure prerequisite for a proper function of the construction for the next years.

Construction Sequences

This period is divided into four stages, which are outlined in the following:

Stage 1:

- Powerhouse Pit:

This stage consists mainly of works required to complete the powerhouse pit, namely filling and compaction of powerhouse cofferdams, construction of roads, installation of dewatering system, excavation of the pit and erection of diaphragm walls. Depending on progress of excavation work the concreting of unit and service blocks should be initiated.

- Headrace:

During the same time when the work for the powerhouse pit is in progress, the filling and compaction of right and left embankment of the headrace remain in progress. This work includes also the construction of service roads along the headrace embankments.

Stage 2:

- Powerhouse

This stage is mainly related to the concreting of the unit blocks and the service block. It includes also the concreting of up and down retaining walls. Simultaneously to the concreting of the unit blocks, the erection of turbine housing and draft tube lining should be done.

- Headrace:

Within this stage dredging of the canal will be completed. The slope protection starts at the end of this stage.

- Tailrace:

The filling and compaction of right and left embankment of the tailrace starts as well as the construction of service roads along the embankments.

Stage 3:

- Powerhouse:

The concreting of retaining walls and the concrete slabs should be completed in this stage. Whereas also major concrete work for the powerhouse will be completed, some final concrete finishes will be left at the end of this stage. The erection of turbine housing and draft tube is completed and installation of turbines can be started. Simultaneously erection of electrical equipment can be taken up and also the construction and erection of transmission line and switchyard can be finished. Furthermore, when the concreting has reached the required level, the dewatering system can be put out of operation and the back filling around the powerhouse pit starts.

The interior civil works in the powerhouse are scheduled in close co-ordination with the assembly works of the powerhouse equipment.

- Head race and tail race

Tailrace dredging and slope protection is completed in this stage. After this and after the back filling of the powerhouse pit excavation of the upstream and downstream cofferdams can be undertaken.

Stage 4:

- Powerhouse:

This stage is covered by the erection and commissioning of the electro-mechanical equipment such as turbines, generators, low and high voltage equipment. Also the completion of outstanding civil works of the powerhouse, such as interior finishes etc. is work of this stage.

2.4 CASHFLOW SCHEDULE OF INVESTMENT

The cash flow schedule is based on the proposed construction schedules. It is calculated with help of quantity survey and cost estimation described in the previous paragraph. Each item and its cost is connected with the construction time schedule, which gives the cash flow schedule. The calculation can be carried out with a spreadsheet. Usually the cash flow requirements do not include transmission costs of power, import duties, interest rate during construction, and price escalation. Detailed examples of yearly cash flows can be found in the appendix in TABLE 2-1 for Jinnah Hydropower Project with 8 units and in Table 2-2 for Chashma HPP with the preliminary design of 12 units.

3. ECONOMIC AND FINANCIAL ANALYSIS

3.1 GENERAL

3.1.1 SCOPE AND OBJECTIVES

It is utmost essential that after technical feasibility of any hydroelectric project, the economic and financial feasibility should be worked out in order to provide economic and financial basis for deciding whether to implement the project. Moreover, this exercise is useful to examine the promising development options in sufficient detail to determine which are most attractive.

It is also now equally important to seek the environmental and social clearance as well. There is a growing tendency to include these factors into account in the economic analysis. While these tasks are central to project feasibility and integrates all of the information into a measure of economic desirability, the level of effort involved is relatively modest. The economic and financial analysis task will take approximately five to ten percent of the total feasibility study [UACE, 1979].

An economic appraisal is based on the benefits and costs from the viewpoint of society as a whole, while a financial appraisal is viewed from the perspective of the project sponsor, and states whether the tangible value of the output of the project will be sufficient to amortize the project loan, pay operation and maintenance costs, and meet the interest on other financial obligations.

In this chapter we will discuss, step-by-step, the necessary information requirements, important issues and fundamental analytical tools for the economic and financial analysis of hydropower plants. Finally we will discuss on some case studies of Pakistani hydropower projects.

3.1.2 INFORMATION REQUIREMENTS

The economic and financial analysis, per say, are the last but not least items required to be performed in the feasibility study. Therefore, the following information must be gathered in an orderly fashion before the appraisal can be conducted [Jiandong, 1996]. At this stage some of the following information should already be available from the previous exercise. However, pertinent issues are dealt herewith as felt necessary.

1. The project costs: the capital cost of civil engineering and electromechanical equipment, operating and maintenance costs; overhaul costs; the cost of environmental and social protection measures; useful life and economic life of the civil engineering and electromechanical equipment and their rate of amortization.
2. The project benefits: Information on tangible and intangible benefits from the project.
3. The construction schedule: the period of construction, planning of staged development (if any), date of commissioning, etc.
4. Hydrological and hydropower parameters: annual and seasonal energy production, dependable capacity. Existing water uses and rights and potential costs that might be incurred to assure water availability.
5. Power market analysis: the energy purchaser and sponsor; rate of capacity and energy (tariff); market prices of materials and equipment; labour costs and their shadow prices obtained from the planning department of the government. Some aspects of power market analysis are dealt in this chapter.
6. The financing: the sources of fund, its yearly installment during construction; interest rates; the basic economic and financial discount rate and rate of escalation.

7. The alternative energy sources: In general thermal power is taken as alternative source. Its construction costs; energy costs, operation and maintenance costs, fuel prices, etc.
8. The environmental and socio-economic data: Impact identification and mitigation measures, acts, policies, institutional arrangements, codes concerning environmental and socio-economic management.
9. The other cost rates: fees necessary for a license and law procedures; categories of taxes and their rates; rates of insurance, etc.

3.1.3 PUBLIC VERSUS PRIVATE OWNERSHIP

In the present global economic recession context, many governments throughout the world, especially in developing countries, are now seeking to attract private financing in the hydropower development. In this context, it is utmost important to be clear about pertinent differences between private and public ownership.

Private ownership are primarily concerned about the profit out of their investment, whereas the public ownership have other social responsibility, therefore lack of investment fund. There are two important differences between public and private project sponsors:

1. the taxes are levied on private project sponsors which increase the project cost
2. the private ownership entails high cost of capital than does public ownership due to property taxes on private ownership.

Because of the difference in the cost of capital, which can be as much as four to six percent, capital-intensive projects are not attractive to a private sponsor. The other deviation between private and public perception is the treatment of risk. Public entities rarely consider risk where as the private investor is mainly focused upon risk. The public sector is the guarantor as well as the financier. Private sector finance is risk averse. Investors need to assure themselves that the risk of non-repayment of the debt is effectively zero. The private investor is risk averted. J. Rashid (1994) has indicated a number of risks in private perceptions which are as follows:

- Sovereign risk
- Country risk
- Political risk
- Foreign exchange risk
- Inflation risk
- Interest risk
- Operating performance
- Project risk

In addition to this there might be land ownership and water right problems. The point of the above discussion is that even under complete liberalizations the public and private sectors will have some deviations in perception. In this regard some form of state control, by regulation, has to be maintained [Rashid, 1994].

Following are the additional important planning divergence in public and private perceptions:

- Time horizon: The private investor has inherently short time horizons, long term projections are viewed with suspicion.
- Revenue requirement: The private sector is profit oriented, whereas the public sector is socially responsible to maintain the utility without additional burden to the customers.
- System reliability considerations: Private concern will be with cost minimization and upon return maximization. Capacity additions are essential for system reliability, but it will raise the cost of investment. Private sector will not to add capacity in such case even when demand is

rising rapidly. The next figure shows the contradiction between long and short term planning perceptions of public and private sectors:

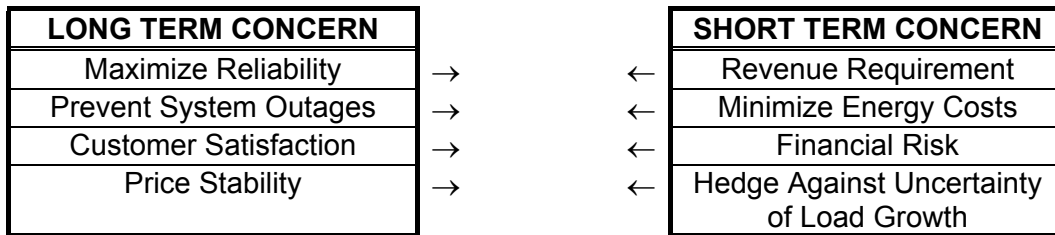


Fig. 3.1: The planning perception of public and private sectors (after Rashid, 1994)

In the view of above facts, a public sector least cost solution may result in a optimal mix which does not coincide with the least cost solution determined by the private investor (s). This would mean that the market will not be able to produce the ‘desired’ mix and will need intervention by means of regulating or transfer payments to induce the private sector to conform to the society’s optimal mix of generation. However, the state’s intervention should be brought with care so that the private sectors are attracted to invest in the hydropower development of any nation [Rashid, 1994].

3.1.4 ECONOMIC AND FINANCIAL FEASIBILITY

Economic justification deals primarily with the development and application of benefit-cost analysis. The objectives of the economic feasibility are met by relating all project benefits to project economic costs. This relationship provides relevant comparisons of the feasibility of different hydroelectric configurations at a given site.

Financial feasibility, on the other hand, takes into account the availability of funds and relates financial costs to project revenues. Project financial costs are those incurred in construction, operating, and maintaining project work and facilities, and they are elements of the total cost considered in the benefit-cost analysis (economic feasibility).

In light of the foregoing discussion, it is obvious that different decision making criteria may prevail in the public and private sectors for economic and financial feasibility study. In the following paragraphs we will investigate the possibilities to marketability of the low-head hydropower in the private and public sector's perspective.

3.2 POWER MARKET ANALYSIS

3.2.1 INSTITUTIONAL FACTORS

3.2.1.1 PURCHASING UTILITY

Marketing of hydropower energy may be possible in two ways: (1) Marketing by Investor-owned Utilities (IOU) and (2) Marketing through public utilities (PU). Marketing power to investor-owned utilities (IOU) may be complicated that if the project has significant quantities of dependable capacity. As already said that one of the objectives of an IOU is to make a profit. In fact the higher the dependable capacity the lower is its plant factor. The plant factor is the ratio of energy supplied to the installed capacity of plant to produce energy annually.

3.2.2 HYDROELECTRIC CAPACITY AND ENERGY

3.2.2.1 GENERAL

For the power market analysis of hydroelectric plants the value of development is based on two components: capacity and energy costs of the most likely alternative developments. Capacity cost is the payment made for the system reliability whereas the energy cost is to generate the revenue from a hydroelectric plant. To establish the value of a hydro project, the amount of

alternate capacity that the hydro development can substitute for or is equivalent to, must be determined, as well as the cost of the energy the project will displace or replace.

3.2.2.2 CAPACITY

A hydropower plant can substitute the equivalent amount of power from thermal plant. While dealing with the capacity of any hydropower plant there are two terms to be understood: (1) dependable capacity and (2) peaking capacity.

Dependable Capacity

As per the Federal Energy Regulatory Commission (FERC) definition, the dependable hydro capacity (Fig. 3.2) is the amount of load a hydroelectric plant can carry under adverse hydrologic conditions for the time interval and period specified for a particular system load. In another words, the dependable capacity in any month is that capacity that can be relied upon for serving system load and firm power commitments on the basis of the energy available in that month and its use as limited by the characteristics of the load to be served. [UACE, 1979].

In mixed power system, the dependable hydroelectric capacity is that capacity of the system hydroelectric plants in serving, together with the other available system capacity, the maximum annual system peak load under the adverse hydrologic conditions. The adverse hydrologic conditions are usually based on the most adverse year of record. The period of peak system load depends on the particular utility and may occur during the winter or summer months. Where a portion of storage energy is scheduled to be held as a reserve for emergency use only, the dependable capacity should also include the reserve capacity value of such energy reserve.

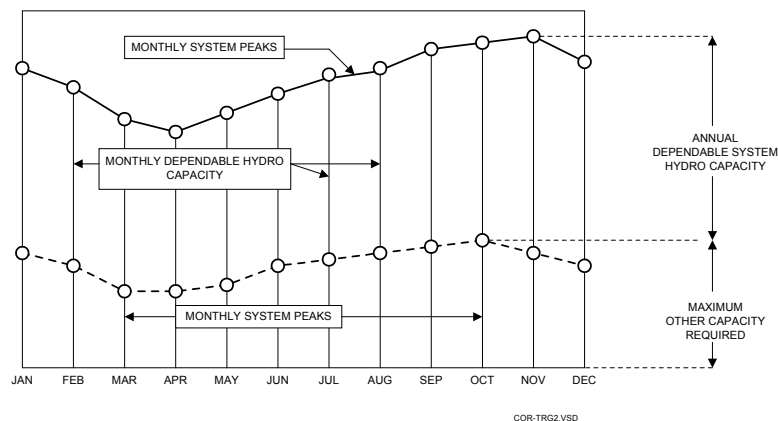


Fig. 3.2: Annual dependable system of hydro capacity.

Peaking Capability

Hydropower with storage facility is usually meant for peaking. This peaking capability increases the project value to the local utility over what it would be in run-of-the-river operation even if there is no dependable capacity. Storage capacity, turbine capacity and the flow regime must be integrated into a model by the hydrologic study to determine the amount of energy that may be shifted to peak periods.

3.2.3 CRITERIA FOR THE SUBSTITUTION OF THERMAL CAPACITY BY A HYDRO PLANT CAPACITY

In order to establish a standard of comparison by which to assess the value of hydroelectric power, an analysis has been made of the costs associated with a modern coal-fired steam station. It is now necessary to consider how the cost of hydropower can be related by the cost of thermal power [Hunter and Blackstone, 1965].

There are two criteria necessary for determining the amount of thermal capacity a hydro plant can substitute for. These are the annual flow variability in the river and the most critical period

for the utility. The measure is conservative because no consideration is given to the low forced-outage and maintenance rates of hydro plants when compared to thermal plants. It is also conservative to base the assessment on the most adverse year of record.

To consider the above factor a capacity credit of 5 to 15 percent due to low forced-outage rates and rapid emergency start-up for hydro facilities should usually be added to justify the use of hydropower against the thermal power.

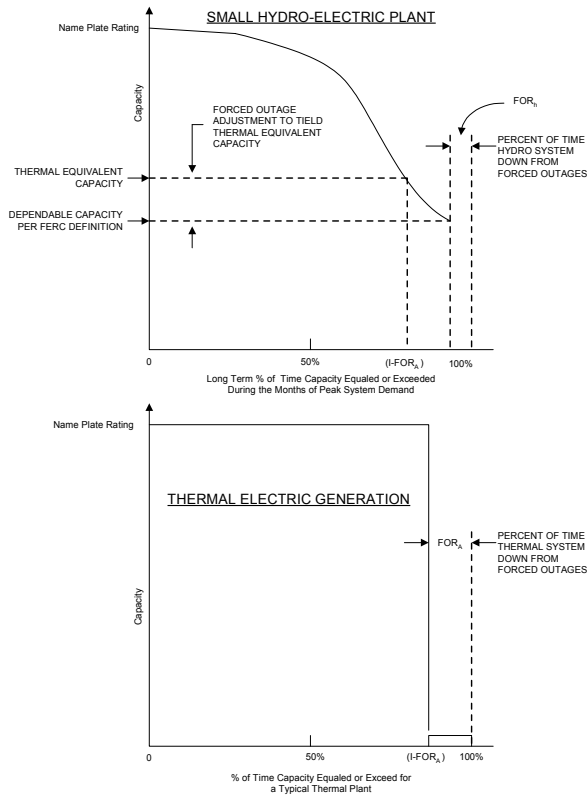


Fig. 3.3: Capacity availability curves for (a) small hydro and (b) thermal plants (source: UACE, 1979)

There is another technique that might be used to account for both adverse years and forced-outage rates. This is explained by taking an example of a small hydropower plant (Fig. 3.3) as outlined in UACE (1979). The power availability curve for the plant is prepared from daily stream flow records during the operation study as follows:

1. The critical period of utility system load must be established. This will generally include several months on either side of the system peak
2. The stream flow records during this period of the year from flow duration curve must be examined to establish if any of the periods of low flow are extremely rare occurrences during this period. If so, excluding them from the record may be justified.
3. With the stream flow records from 2 above, a histogram of the daily power producible from the proposed installation can be calculated.
4. The histogram can then be converted into the power availability curve shown in Fig. 3.3. Note that the horizontal axis of the power availability curve is equal to one minus the cumulative probability that the capacity available will be less than or equal to the stated capacity.
5. The forced-outage rate adjustment and its rationale are clearly illustrated in Fig. 3.3 by showing the power availability curve for a thermal plant. Note that this two state on-and-off

reliability model of a thermal plant is the simplest and most commonly used. The thermal-equivalent capacity can then serve as the basis for negotiating capacity credits.

The amount of dependable capacity arrived at by any of the procedures described will almost always be less than the generator nameplate rating. Depending on the specific circumstances, assigning some value to the non dependable capacity may be justified.

3.2.3.1 ENERGY

Project energy production is the amount of kilowatt-hours (kWh) input into the utility system or delivered to a final user. The power factor of generation can be an important factor in the value of energy, and, hence, it should always be stated. Because project revenues will ultimately be based on the energy delivered to the ultimate purchaser, care should be taken to account for all losses up to the point of ownership transfer. If extensive transmission is required, these losses must be included as well as step up transformer losses, generator and speed increaser losses, and station service use. Also, a loss due to forced outage should be included to avoid overstating the average annual energy output.

The seasonality of power production can be portrayed as in Fig. 3.4. This curve is useful for assessing in broad terms how the project output would fit into a utility system and the effects of adding capacity. For example, if the project of Fig. 3.4 were located in a summer peaking utility, it is apparent that adding to installed generation capacity will do little to increase the project's ability to serve system peak-load.

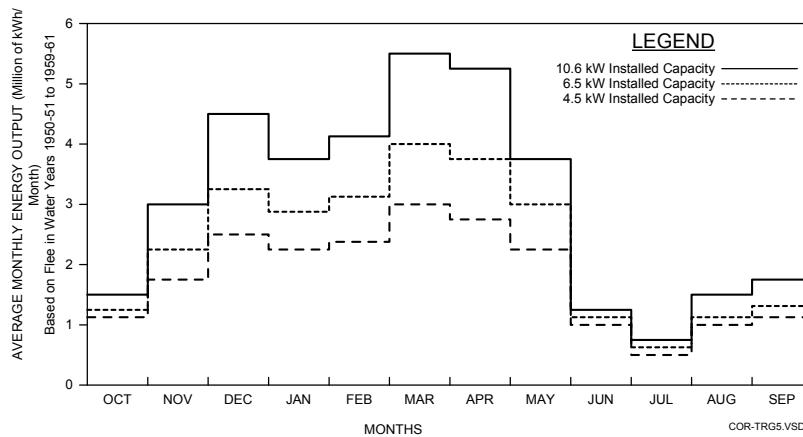


Fig. 3.4: Average monthly energy output. (source: UACE, 1979)

Energy production will vary on a yearly, monthly, and daily basis. Annual and monthly variability can be portrayed in a number of ways. One desirable method is to consider the annual energy production as a random variable and construct annual production histograms and cumulative probability distributions as in Fig. 3.5. This curve can be useful in assessing project risk.

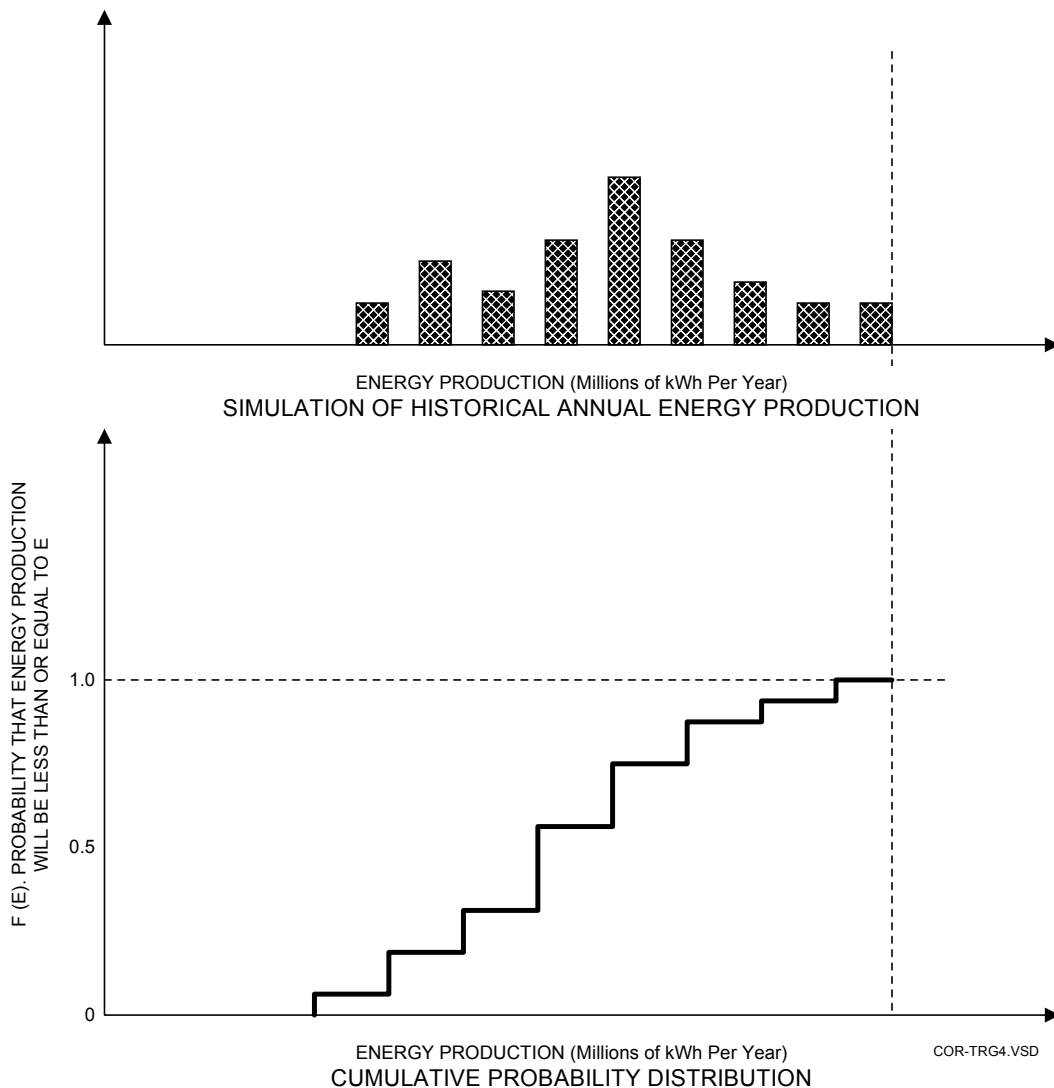


Fig. 3.5: Annual energy production histogram and cumulative probability distribution. (source: UACE, 1979)

3.2.3.2 DETERMINATION OF VALUE OF CAPACITY AND ENERGY

Value of capacity and energy output of a hydropower plant is determined based on the costs of equivalent alternatives available to the prospective power purchaser. Therefore the value of a hydropower plant can vary widely, based on the potential purchaser.

Determination Of Opportunity Cost As A Basis For Establishing Hydropower Value

The value of a hydro project is determined by the power purchaser's opportunity to reduce existing costs while maintaining the same level of service using the following procedure:

1. Equivalent situations with and without the hydropower project are determined.
2. The projects maximum value to the purchaser is determined by taking the difference in the total cost between the two cases without assigning the cost of hydropower project.

3. The difference in the total cost, after including the actual cost of the hydro project, is the net value of the project and represents the opportunity cost.

Since the project's value is established by looking at the power purchasers and the costs of their alternatives, a particular purchaser can significantly alter a project's value. For example; industrial or other end user power purchasers generally require electric service more reliable. If the reliability is not guaranteed by the hydropower plants alone then they have to maintain some sort of a standby service arrangement with the local utility. This will ultimately affect the value of a hydropower plant. On the other hand, the utility systems with higher-cost fuels will find hydropower project attractive because of the cost of fuels displaced by it. The above saying will be clarified using two simple numerical examples described in UACE (1979) as follows:

Example 1: User As Power Purchaser

Problem:

Find out the gross value of small hydro output to an end user, such as an industrial plant, municipality or irrigation district, is the maximum cost reduction the purchaser can achieve without assigning any cost to the small hydropower plant. It is to be sure that the user is receiving the same level of service from local utility before and after the addition of small hydropower output.

Expected Result:

The purchaser will find the small hydro output attractive if the actual hydro costs are less than the maximum cost reduction. If so, a net cost reduction will be achieved. This example is slightly modified but contains all the essential elements that need to be understood.

Data Input:

Fig. 3.6a specifies the load characteristics (the user load should be typified either through utility or user-metering records) of the industrial purchaser and the average monthly as well as minimum monthly power production of the small hydro project (Fig. 3.6b). The minimum monthly value will determine the billing demand. The industrial plant is assumed to have a continuous demand of 5,000 kW (Fig. 3.6a). The small hydro project has maximum production in the winter months and drops to zero during the summer. No dependable capacity is present. (Fig. 3.6c) shows the industrial purchaser's demand on the local utility system (standby service) after including the small hydropower.

A simplified utility tariff for general and standby service is shown in the next table as follows:

Table 3.1: Simplified Rate Schedule

General Service	Standby Service /Auxiliary Service
Rate: Demand charge = \$6.00 per kW demand per month Energy Charge = 3.5c per kWh per month	Rate: Same as general service.
Minimum Bill: The demand charge on 10 percent of maximum demand.	Minimum Bill: \$3.00 per kW of contract demand
Billing Demand: The maximum 15-minute measured demand during the month, but not less than 90 percent of the highest demand in the preceding three months. (This type of clause is known as a billing demand ratchet clause. The effect of a billing	Contract Demand: The maximum demand the customer will place on the utility system. The utility will not meet a demand higher than the contract demand.

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demand ratchet is to increase demand charges to a customer).

Result:

The next two tables calculate the annual utility-supplied electricity cost to the industrial purchaser with and without the small hydro project. With all things equal the maximum value of the small hydro project is

$$\begin{aligned} \$1893000 - \$1305700 &= \$587300 \\ \text{i.e. } \$587300/153400 &= 3.83 \text{ c per kWh.} \end{aligned}$$

Note that this is greater than just the energy displaced, i.e. 3.5 c per kWh. In this case the purchaser will not find the hydropower option attractive. However, this is not always the case and only the facts of the individual situation will determine the result.

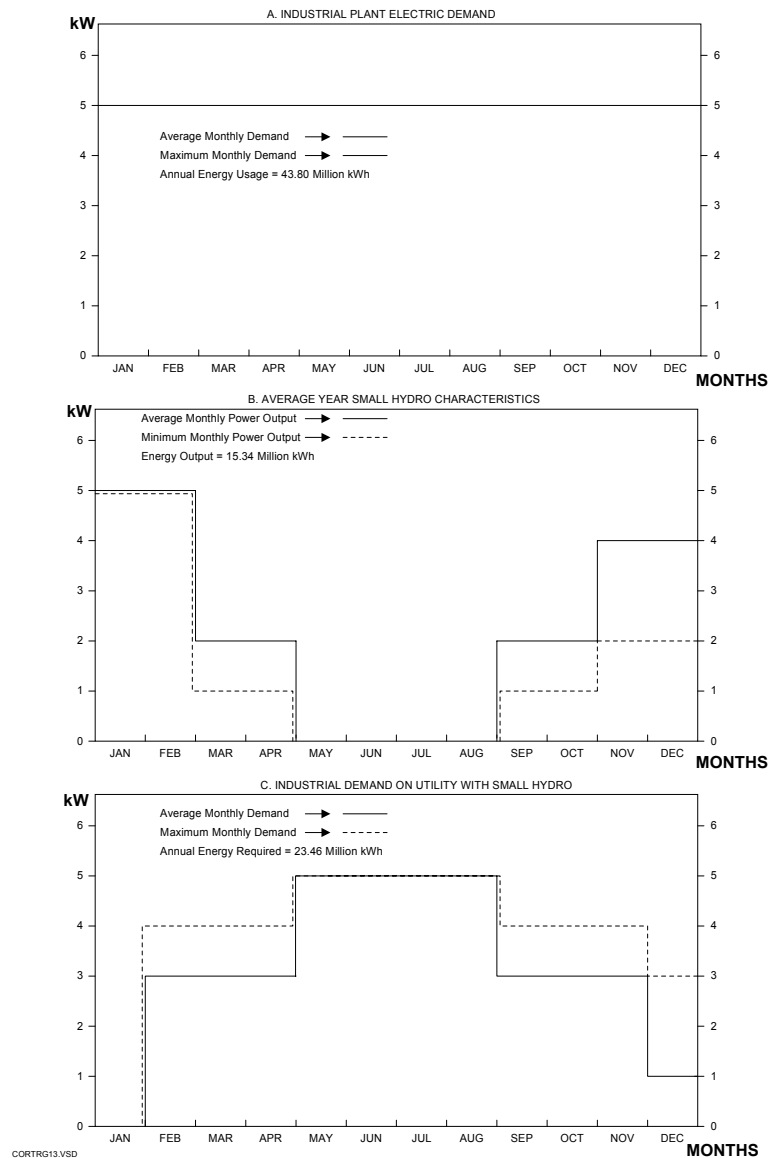


Fig. 3.6: Example demand pattern and small hydro output

Table 3.2: Example industrial general service annual charges

Month	Actual	Billing	Energy Used	Demand*	Energy**	Total***
(1)	(2)	(3)	(4)	(5)	(6)	(7)
January	5000	5000	3.72	30000	130200	160200

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February	5000	5000	3.36	30000	117600	147600
March	5000	5000	3.72	30000	130200	160200
April	5000	5000	3.6	30000	126000	156000
May	5000	5000	3.7	30000	129500	159500
June	5000	5000	3.6	30000	126000	156000
July	5000	5000	3.72	30000	130200	160200
August	5000	5000	3.72	30000	130200	160200
September	5000	5000	3.6	30000	126000	156000
October	5000	5000	3.72	30000	130200	160200
November	5000	5000	3.6	30000	126000	156000
December	5000	5000	3.72	30000	130200	160200
TOTAL			43.78	360000	1532300	1892300
*/ Calculated as Billing Demand, Column (3), times General Service Demand charge, \$ 6/hr.						
**/ Calculated as energy used, Column (4), times energy charge, 3.5 c/kWh.						
***/ Sum of (5) and (6), or the minimum bill.						
Assumptions						
1. Demand as in Fig 1.5 (a)						

Table 3.3: Example standby service annual charges for industrial user purchasing small hydro output

Month	Actual Demand (kW)	Billing Demand (kW)	Energy Used (10 ⁶ kWh)	Demand* Charge (\$)	Energy** Charge (\$)	Total*** Charge (\$)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
January !	0	0	0	0	0	15000
February	4000	4000	2.02	24000	70700	94700
March	4000	4000	2.23	24000	78050	102050
April	5000	5000	2.16	24000	75600	99600
May	5000	5000	3.72	30000	130200	160200
June	5000	5000	3.6	30000	126000	156000
July	5000	5000	3.72	30000	130200	160200
August	5000	5000	3.72	30000	130200	160200
September !!	4000	4500	2.16	27000	75600	102600
October !!	4000	4500	2.23	27000	78050	105050
November !!	4000	4500	2.16	27000	75600	102600
December !!	3000	3600	0.74	21600	25900	47500
TOTAL			28.46	294600	996100	1305700
*/ Calculated as Billing Demand, Column (3), times General Service Demand charge, \$ 6/hr.						
**/ Calculated as energy used, Column (4), times energy charge, 3.5 c/kWh.						
***/ Sum of (5) and (6), or the minimum bill.						
!/> Minimum bill effective			!!/> Billing demand ratchet clause effective			
Assumptions						
4. Demand as in Fig 1.5 (a)						
5. Rate schedule in Tab. 1.1						
6. Minimum bill = 0.1 x 5000 kW x \$ 4/kW = \$ 2000 per month						

Example 2: Utility As Purchaser

The following example illustrates how the value of power from a small hydro plant is calculated. To establish the value of power, information about both the small hydro project and the utility must be specified as shown in the next table.

Table 3.4: Data for the calculation of power value

Small Hydroelectric Project		Electric Utility	
Type	run-of-the- river	System capability	6000 MW
Installed capacity	7.5 MW	Peak	Summer and lesser winter
Plant factor	49%	Company's load duration curve see Fig.	

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Average annual energy	32.2 million kWh	
Peak production	February to August	
Dependable capacity	None	

Value of the small hydro project:

Since this hydro project has no dependable capacity, its value is based on the cost of the fuels it can displace. The energy costs for each type of fossil-fired generation are calculated below. These costs are the plant heat rate times the cost of fuels expressed in the correct units. This is:

Table 3.5: Fuel costs for different plant types

Plant Type	Average Heat Rate [Btu/kWh]	Fuel Cost [c/mil. Btu]	Energy Cost of Electricity [c/kWh]
Coal-fired steam	9,409	143.4	1.35
Combined cycle	9,044	276.5	2.5
Gas turbine	13,777	276.5	3.81

From the load duration curve (Fig. 3.7) at a minimum the small hydro plant would displace energy from base load coal-fired units. Therefore, the minimum value of the small hydro energy is 1.35 c/kWh. However, the value of this small hydro project is probably higher than this because it will frequently be displacing higher-cost electricity than that from the coal fired units. Making the assumption that the small hydro output occurs randomly with respect to the load-duration curve, the small hydro plant will be displacing energy from the three sources in proportion to the time these sources are the marginal energy source. From Fig. 3.7, it is seen that gas turbines are the marginal source 16 percent of the time, combined cycle units 44 percent of the time, and coal fired steam units 40 percent of the time.

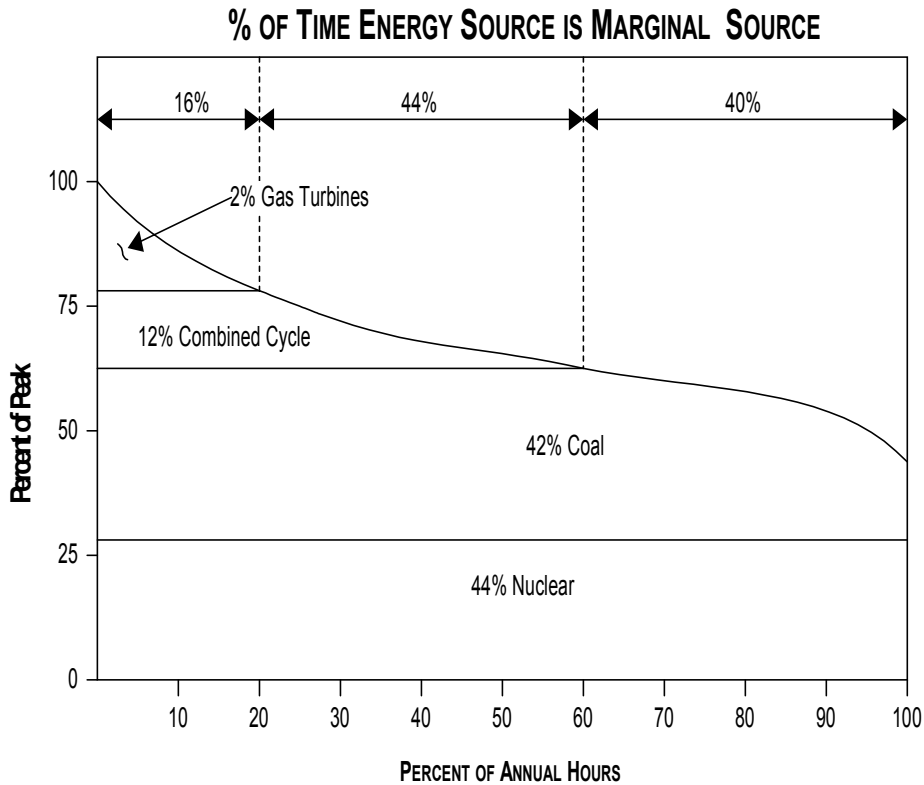


Fig. 3.7: Annual load duration curve with energy by source superimposed (used in the power value calculation)

These percentages can be used to calculate the weighted average value of small hydro output as:

$$\text{Value} = (0.16 \times 3.81) + (0.44 \times 2.50) + (0.40 \times 1.35) = 2.25 \text{ c/kWh.}$$

As is seen, this procedure substantially and justifiably increases the small hydro value.

3.2.3.3 MARKET ARRANGEMENT

The way in which small hydro output is marketed is an important factor in determining if financing will be available and at what price. It is imperative that adequate financial and legal consultation be obtained prior to entering into the actual power marketing agreement (PMA) or power purchase agreement (PPA).

As already mentioned that the hydropower is a capital intensive with long gestation period, the investors will be unwilling to assume any business or technical risk associated with the project. This means the principal and interest obligation associated with project financing must be assured with a high degree of certainty. This assurance can be obtained in four ways: (1) Occasionally the project will have sufficient financial strength on its own so that the risk to investors is acceptable without any guarantees; (2) Guarantees can be given by a creditworthy sponsor; (3) A credit-worthy power purchaser can 'guarantee' the debt service through the marketing agreement; or (4) A third party, such as a state government, can guarantee the debt service. These guarantees will generally be required for the duration of the project's financing.

Time-Of-Day Consideration

An incremental cost of electric energy is a function of the time of day. If the hydropower project has significant quantities of storage available for peaking power generation, then the marketing agreement should account for the higher value of energy displaced. This could be done either simply by adjusting a flat rate per kWh charge or by a complex rate, fully reflecting time of-day factors [UACE, 1979].

Let us discuss about the four potential types of marketing agreements available and their security effects on the project financing.

1. Cost Plus A Percentage Of Debt Service

This is a potential marketing arrangement that has been used to secure financing for hydroelectric development. In this agreement, the power purchaser and the project sponsors enter into a 'power contract' for sale of all or a portion of the electric output. The power sponsor agrees to deliver all or part of the electric output and in return the power purchaser agrees to pay 'in all events' a pro rata share of 'all costs' of the plant, plus an additional fixed percentage of the pro rata share of debt service. Following are the advantages and disadvantages of this arrangement

Table 3.6: Advantages and Disadvantages for cost plus percentage of debt service

Advantages	Disadvantages
All costs include operating costs; taxes; debt service, including principal and interest; costs of repair and replacement; costs associated with ownership, operation and maintenance etc	Due to the fixed compensation to the project sponsor at a constant amount for the duration of power contract, the fixed percentage of debt service may become a lesser percentage of the true value of the electricity.
The security of debt service repayment is obtained by power sponsor through the 'in-all-events' clause of the power contract which includes all unforeseen matters beyond the control of the power sponsor during the term of power contract agreement.	The power purchaser may receive a disproportionate share of the benefits.

2. Cost Plus A Royalty Subject To Escalation

This type of power contract has been evolved to rectify some drawbacks of the first type of power contract and to secure financing for hydroelectric development. This power contract is very similar to power contract mentioned above. The difference is that in addition to the fixed percentage of debt service as compensation, the project sponsor receives a minimum per kWh payment, which is subject to escalation.

This type of contract provides the debt service security needed to obtain funds and also recognizes the future value of the project's output which is likely to rise. This combination leads to a desirable marketing plan for the project sponsors to pursue.

3. Sales Per Kilowatt-Hour.

In this type of power contract, the power sponsor sales the project's output on a per kWh basis, with the price being subject to adjustment based on an index. The power purchaser, on the other hand, simply pay for energy actually produced without the guarantee to cover 'all costs' as well as debt service in all events. In such case, either sponsor or third-party guarantees will be necessary to obtain project financing. Consequently, except with unusually attractive projects, one of the other forms of marketing the power output should be attempted.

4. Sales Per Kilowatt-Hour With Cost Guarantee And Balancing Account.

This type of arrangement values the plant output on a per kWh basis but also provides the revenue security necessary to obtain financing. Once again, the project sponsor agrees to supply electricity that the power purchaser agrees to purchase at a per kWh rate that is indexed. In addition, to provide security for debt service, the power purchaser agrees to pay 'all costs'; the excess is used to reduce the balancing account balance, if any, with the remainder

going to the project sponsor. If the project is economically sound, at the end of the financing periods the balancing account balance should be zero.

This contract has the two desirable characteristics of providing sufficient security to obtain financing and recognizing that the future value of electricity will rise. This arrangement will also lead to greater sponsor revenues than in the cost plus escalating royalty contract described earlier. This is because a larger value will be subject to escalation.

3.3 ECONOMIC ANALYSIS

3.3.1 GENERAL

Economic analysis is one of the decision-making tools, which evaluates the time value of benefits and costs of a project in equivalent monetary terms. Economic analysis of hydropower projects concerns measuring both tangible and intangible benefits from the development and the costs expended for the implementation and maintaining the project throughout its economic life.

The objective of this type of analysis is to relate all project economic benefits to all project economic costs accruing to the project sponsor. The project's initial and recurring annual costs and annual revenues are equally important and are primary concern in the both economic and financial analysis. However, other costs and benefits not included in the project financial analysis may properly be included in the economic analysis.

The appropriate scope of the analysis depends largely on the nature of the sponsoring organization. If the sponsor is a private organization then the analysis would include items directly affecting profitability from power generation. If the sponsor is a government utility then the analysis is done in broader scope, which may include flood control, recreation or other social benefits.

3.3.2 BASIC ELEMENTS OF ECONOMIC ANALYSIS

3.3.2.1 COST AND BENEFIT STREAMS

Benefits and costs are broadly categorized as monetary and non-monetary. Most non-monetary benefits and costs can be quantified into dollar values if certain assumptions are made during the evaluation procedure. In all hydroelectric projects, the largest components of economic costs and benefits will be the present value of future cash inflows on the benefit side and the present value of the original and any future cash outlays on the cost side.[UACE, 1979].

The cost stream is composed of the capital costs, operation and maintenance costs, future replacements, quantified non-monetary costs and any other cost associated with the project affecting the project sponsor. The capital cost is the sum of money invested in a project including its interest during construction. Annual costs include the annual capital cost (the financial costs for loan amortization and interests) and the annual operating and maintenance costs, the latter involving salaries, material expenses, water fees, overhaul expenses, insurance, interim replacement and administration, etc. If the capital cost of the transmission line is included in the total investment, then the annual cost will have two parts: power generation and power supply [Jiandong, 1996].

The benefit stream will include the value of power generation, quantified non-monetary benefits accruing to the sponsor, and other benefits. The direct benefit from the energy sale may be calculated using the following expression:

$$B_e = E_e (1 - \beta)(1 - \gamma)p \quad (3.1)$$

with B_e = benefit from energy sale

E_e = effective annual energy generation, i.e. the total net energy output given out by the generator of the hydropower plant during the year after the deduction of energy loss in outage

- β = plant use factor
- γ = grid loss factor
- p = energy price

3.3.2.2 ECONOMIC LIFE OF PROJECT

The timing of the cost and benefit streams is important and must be accurately established. The economic life is the time, during which the project can be operated normally. The next table provides some information about the economic life of the water resources projects.

In Pakistan, the economic life of a hydroelectric plant is taken as 50 years and the economic life of 20, 25 and 30 years are taken for combustion turbine, combined cycle and steam turbine respectively. The number of economic life or interest period in the economic analysis is denoted by (n).

Renewal of the main parts of the equipment or capital repair in civil engineering is needed after that period. In cash flow calculations we sometimes take the calculation period to be that which may equal the economic life of the equipment, in this case the residual value of the civil engineering should be considered as a future benefit in cost-benefit analysis; or we take the calculation period to be that which equals the economic life of the civil engineering, in this case the expenses in the renewal of the main parts of the equipment must be considered as future capital investment

Table 3.7: Live in years for elements of hydraulic projects

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Barges	12	Pipes:	
Booms, log	13	Cast-iron	
Canals and ditches	75	2-4 in.	50
Coagulating basins	50	4-6 in.	65
Construction equipment	5	8-10 in.	75
Dams:		12 in. and over	100
Crib	25	Concrete	20
Earthen, concrete or masonry	150	Steel	
Loose rock	60	Under 4 in.	30
Steel	40	Over 4 in.	40
Filters	50	Transit, 6 in.	50
Flumes:		Transmission lines	30
Concrete or masonry	75	Tugs	12
Steel	50	Wood-stave	
Wood	25	14 in. and Larger	33
Fossil-fuel power plants	28	3-12 in.	20
Generators:		Pumps	18-25
Above 3000 kva	28	Reservoirs	75
1000-3000 kva	25	Standpipes	50
50 hp-1000 kva	17-25	Tanks:	
Below 50 hp	14-17	Concrete	50
Hydrants	50	Steel	40
Marine construction equipment	12	Wood	20
Meters, water	30	Tunnels	100
Nuclear power plants	20	Turbines, hydraulic	35
Penstocks	50	Wells	40-50

3.3.2.3 INFLATION

Escalation in the market value of power and project cost will occur over the project life. This escalation in price levels is composed of two components: inflation, or generalized price level increases, and real price increases due to shifts in supply-demand relationships for commodities.

If escalation is going to be included in the analysis, all the costs and benefits must be escalated in a consistent manner. Depending on the given project, different escalation rates for different portions of the project may be desirable. This is done by using the factor for the future value of a present sum with the inflation rate in the place of interest. This is:

$$P_t = P_o(1 + e)^t \quad (3.2)$$

with P_t = price t years in the future
 P_o = current price
 t = years in future
 e = inflation rate in

3.3.2.4 CASH FLOW

The benefit and costs streams over a period of economic or useful life of the project can be represented by a cash flow diagram (Fig. 3.8). This graph shows cash flow with magnitude of expenditures, plotted vertically downward arrows, and receipts, plotted vertically upward arrows, and time represented on the horizontal scale.

The basic idea for economic equivalency calculation is to convert the value of benefits and costs that occur at different times to equivalent monetary amounts, recognizing the time value of money.

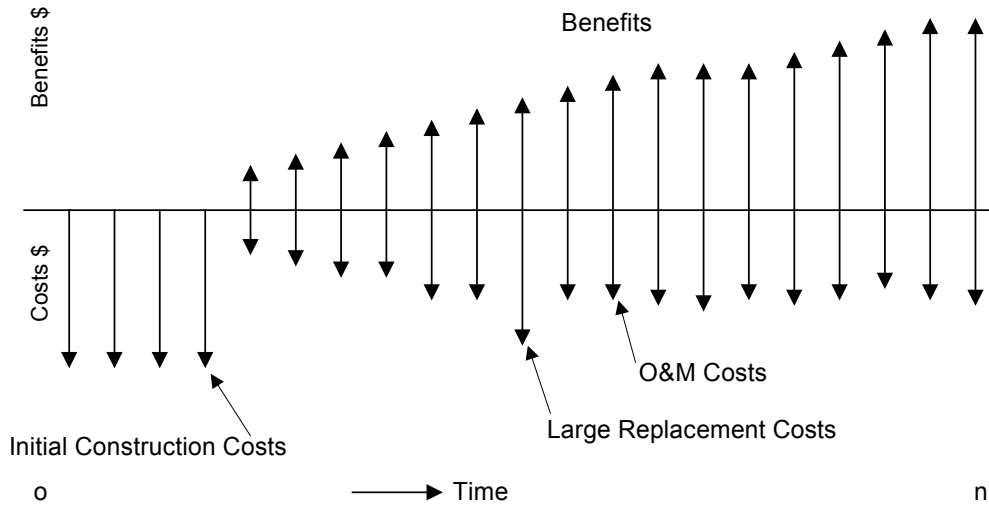


Fig. 3.8: Cash-flow diagram

Frequently used terms and their nomenclature in cash flow analysis are as follows:

Discount Rate

This is the cost of money reflecting the time value of money. The proper rate to be used for testing economic feasibility is the opportunity cost of capital to society. This is the rate of return that could be earned by investing the capital cost of the project in a venture of similar risk or an alternative marginal project. The social discount rates are different in different countries; usually it takes around 10 percent. For example, in Pakistan for the economic evaluation of hydropower plants the discount rate as minimum rate of return is taken as 12 %.

Interest Rate

This is the price paid for borrowing money expressed as a percentage of the amount borrowed or the rate of return (discount rate) applied in computing the equivalency of present worth and future worth. It is used to ascertain financial feasibility. The interest rate is set in the capital market and fluctuates with changes in the health of economy and government fiscal and monetary policies. The nomenclature for an interest rate is (*I*)

Present Value

The present value or the present worth is the value or worth obtained by discounting all future costs and revenues into the present time frame so that they can be compared on a current monetary basis. The sum of these values represents the net present value. In other words, the present value is the sum of money at the present, the value of an investment at the present, or the value of money expended in the future discounted back to the present. This is denoted by (*P*).

Future Value

This is a sum of money at a future time, the value of a future investment, or the value of an expenditure at present discounted out to that future time. The future value is expressed by (*F*).

Annual Equivalent Value

This is a discounted uniform annual amount expended or paid that is equal to a present invested amount to cover some given activity over a fixed period of time. It is usually denoted by (A).

The process of mathematically obtaining the present value of future benefits and costs is called discounting. This recognizes the time value of money in the form of the willingness to pay interest for the use of money.

Graphically the above mentioned terms are shown in the Fig 3.9.

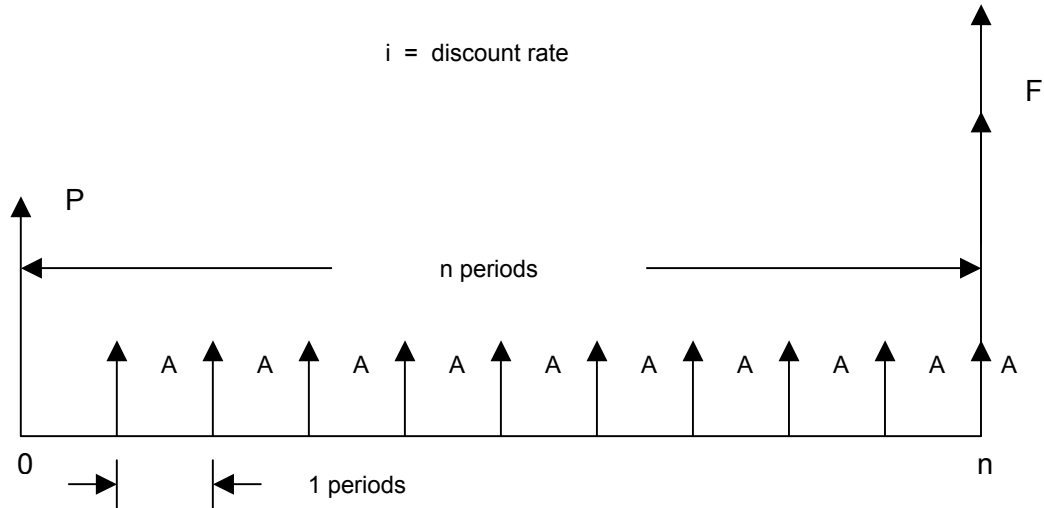


Fig. 3.9: Definition sketch of discounting terms (Warnik, 1984)

Let us briefly discuss about the discounting factors used in economic and financial analysis.

Single-Payment Compound Amount Factor (SPACE)

This is the factor to convert an initially invested amount (P) or present value into the future amount or value (F) with an interest rate of (i) for a period of (n). A functional designation for SPCAF is (F/P, i, n) and expressed as follows. The derivation of this formula is shown as below.

$$\frac{F}{P} = (1 + i)^n \tag{3.3}$$

Table 3.8: Derivation procedure of formula

Year Of Investment	Relationship Between Present And Future Value
0	$F = P$
1	$F = P + P*i = P(1 + i)$
2	$F = P(1 + i) + [P(1 + i)]i = P(1 + i)^2$
.	.
.	.
n	$F = P(1 + i)^n$

The standard functional representation introduced by the American Society for Engineering Education (ASEE) should read as: given P, find F with interest i in n period in the future. In many engineering economics literature the value of the SPCAF is given in tabular form.

Single-Payment Present Worth Factor (APPWF):

This is the factor, which converts the future accumulated amount for a given time frame with an interest rate into the present value. The functional designation of this factor is $(P/F, i, n)$ and, obviously, is the inverse of the SPCAF as shown below:

$$\frac{P}{F} = \frac{1}{(1+i)^n} \quad (3.4)$$

Uniform-Annual-Series Factors (UASF)

Sometimes cash flow of equal magnitude will occur over a series of years. This provides a means of calculating a series of equal annual payments that is equivalent or equal to a present worth P , or a future worth value, F , based on a defined interest rate of discounting for a period of n . There are four frequently used terms for UASF as follows:

- **Uniform-Series Present Worth Factor (USPWF)**

This factor is concerned with the present-worth value of a series of equal payments made over some specified period of time and discounted at rate i . Graphically, this may be represented as below (Fig. 3.10):

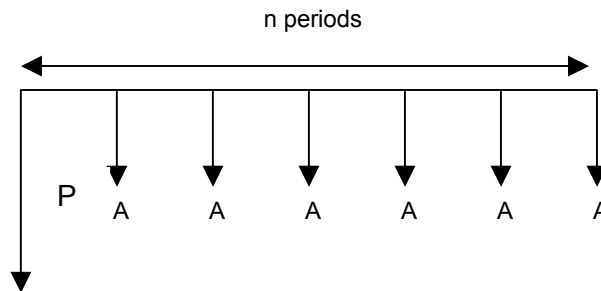


Fig. 3.10: Uniform series cash flow over a uniform period

Following the equation (3.2), the present worth of the above cash flow would be

$$P = \frac{A}{(1+i)} + \frac{A}{(1+i)^2} + \dots + \frac{A}{(1+i)^n} \quad (3.5)$$

Multiplying both sides by $(1+i)$, we get

$$P(1+i) = A + \frac{A}{(1+i)} + \dots + \frac{A}{(1+i)^{n-1}} \quad (3.6)$$

subtracting (3.5) from (3.6) and with some algebraic rearrangement, we get:

$$\frac{P}{A} = \frac{(1+i)^n - 1}{i(1+i)^n} \quad (3.7)$$

The factor $[(1+i)^n - 1] / i(1+i)^n$ is called the uniform-series present-worth factor and is functionally noted as $(P/A, i, n)$.

- **Capital Recovery Factor (CRF)**

This is the inverse of USPWF. The factor is concerned with the capital recovery amount that is also known as annual debt service in financial terms. This is the annual uniform payments that are made and discounted at the rate i from a present worth. Functionally the CRF is noted as $(A/P, i, n)$ and is equal to:

$$\frac{A}{P} = \frac{i(1+i)^n}{(1+i)^n - 1} \quad (3.8)$$

- Sinking Fund Factor (SFF)

A sinking fund is a separate fund into which payments are made to accumulate some desired amount in the future. If we multiply both sides of the equation (1.4) by P and rearrange it, then we get the following equation:

$$\frac{A}{F} = \frac{i}{(1+i)^n - 1} \quad (3.9)$$

The factor $i / [(1+i)^n - 1]$ is called the sinking fund factor (SFF) and is functionally noted as $(A/F, i, n)$.

- Compound Amount Factor (CAF)

This factor is the inverse of the sinking fund factor and is also known as the uniform-series compound-amount factor (USCAF), which is functionally noted as $(F/A, i, n)$ and is equal to :

$$\frac{F}{A} = \frac{(1+i)^n - 1}{i} \quad (3.10)$$

Compound amount is the value a series of payments compounded at rate i will have in the future.

Uniform-Gradient Series Factors (UGSF)

These factors are used to calculate present-worth or annual-equivalent amounts wherein the periodic payments are uniformly increasing (Fig. 3.11).

The present worth uniform gradient series factor (PWUGSF) is functionally noted as $P/G, i, n$ and can be determined by the expression:

$$\frac{P}{G} = \frac{(1+i)^{n+1} - (1+n*i+i)}{i^2(1+i)^n} \quad (3.11)$$

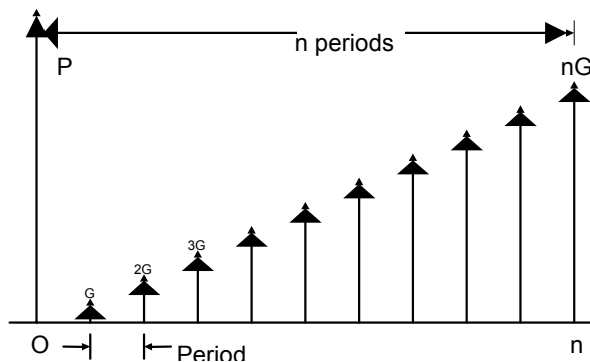


Fig. 3.11: Gradient series cash-flow diagram

3.3.2.5 ECONOMIC EVALUATION CRITERIA

A number of frequently used decision criteria are available for evaluating the economic feasibility of hydropower projects. Economic decision criteria can be grouped into two classes: those most suitable for screening and those most suitable for ranking.

Screening refers to determining if a project has an acceptable economic return. Screening the various plans will yield those that have acceptable results; all others will be rejected as

uneconomic developments. Ranking refers to determining the order of economic preference among projects. The ranking process helps to choose which is the most economically desirable project among the group of acceptable plans.

For the clear understanding of the methods of economic evaluation discussed below, we shall use a classical example presented in UACE (1979) with some modification. The parameters of a hypothetical hydropower project are:

Table 3.9: Parameters of Hydropower Project

Description	Parameters
1. Installed Capacity	2 MW
2. Annual energy production	9.8 million kWh/year
3. Plant factor	56 percent
4. Lump sum cost per kW	\$750
5. Annual O&M	\$45,000
6. Expected financing cost	10 percent
7. Construction period	2 years
8. Financing period	12 years
9. Escalation	0.0 and 7.0 percent
10. Value of energy	2.5 c/kWh

3.3.2.6 METHODS OF ECONOMIC EVALUATION:

There are four frequently used methods of economic evaluation which we shall discuss in brief below. However, there are other methods such as annual worth comparison and future worth comparison which are dealt elsewhere in the literature [Warnik, 1984, Kaplan, 1983].

Net Present Value (NPV) Comparison

The Net Present Value comparison requires converting all cash flows of net benefit to an equivalent present value. This can involve three important concepts in discounting practice: (1) salvage value, (2) future required replacement costs, and (3) project life or discounting period of analysis which is the most important element of NPV when comparing two alternatives. [Warnik, 1984]. If the project life of alternatives is different, then a least common multiple of lives must be used and identical replacement consideration made. The process of discounting all net benefit into the present value is shown in the next two tables.

Table 3.10: Example Calculation of NPV; B/C Ratio without escalation

Year	Escalation Interest		0%	Annual Energy Production Value of Energy				9800000 kWh/y 2.5 c/kWh	
	Capital Cost (\$)	Other Costs (\$)	Total Costs (\$) (2+3)	PV of Costs (\$) (4x9)	Total Benefits (\$) (6)	PV of Benefits (\$) (4x9)	Net Annual Benefits (\$) (6-4)	Present value Factor	Net Present Value (\$)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
0	600000		600000	600000	0	0	-600000	1.000	-600000
1	900000		900000	818182	0	0	-900000	0.909	-818182
2		45000	45000	37190	245000	202479	200000	0.826	165289

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3		45000	45000	33809	245000	184072	200000	0.751	150263
4		45000	45000	30736	245000	167338	200000	0.683	136603
5		45000	45000	27941	245000	152126	200000	0.621	124184
6		45000	45000	25401	245000	138296	200000	0.564	112895
7		45000	45000	23092	245000	125724	200000	0.513	102632
8		45000	45000	20993	245000	114294	200000	0.467	93301
9		45000	45000	19084	245000	103904	200000	0.424	84820
10		45000	45000	17349	245000	94458	200000	0.386	77109
11		45000	45000	15772	245000	85871	200000	0.350	70099
12		45000	45000	14338	245000	78065	200000	0.319	63726
13		45000	45000	13035	245000	70968	200000	0.290	57933
14		45000	45000	11850	245000	64516	200000	0.263	52666
				1708774		1582111.2			-126663
		NPV OF PROJECT @ 10%							-126663
		B/C							0.93

Table 3.11: Example Calculation of NPV, B/C Ratio with escalation

Year	Escalation Interest		7% 10%	Annual Energy Production Value of Energy				9800000 kWh/y 2.5 c/kWh	
	Capital Cost (\$)	Other Costs (\$)	Total Costs (\$) (2+3)	PV of Costs (\$) (4x9)	Total Benefits (\$)	PV of Benefits (\$) (4x9)	Net Annual Benefits (\$) (6-4)	Present value Factor	Net Present Value (\$)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
0	600000		600000	600000	0	0	-600000	1.000	-600000
1	963000		963000	875455	0	0	-963000	0.909	-875455
2		51521	51521	42579	280501	231819	228980	0.826	189240
3		55127	55127	41418	300136	225496	245009	0.751	184079
4		58986	58986	40288	321145	219346	262159	0.683	179058
5		63115	63115	39189	343625	213364	280510	0.621	174175
6		67533	67533	38121	367679	207545	300146	0.564	169425
7		72260	72260	37081	393416	201885	321156	0.513	164804
8		77318	77318	36070	420956	196379	343637	0.467	160309
9		82731	82731	35086	450423	191023	367692	0.424	155937
10		88522	88522	34129	481952	185813	393430	0.386	151684
11		94718	94718	33198	515689	180746	420970	0.350	147548
12		101349	101349	32293	551787	175816	450438	0.319	143524
13		108443	108443	31412	590412	171021	481969	0.290	139609
14		116034	116034	30555	631741	166357	515707	0.263	135802
	1563000	1037656	2600656	1946873	5649460	25666114			619738
					NPV of Project @ 10%		619738		
					B/C		1.32		

In the table 3.10, if we set the first year of construction as the base year, the procedure is to discount the net benefit from each year to the base year, then to obtain their cumulative sum as follows:

$$NPV = \sum_j^n \frac{B_j - C_j}{(1+i)^j} \quad (3.12)$$

where j=1,2,3.....n

A diagram of equation (3.12) is shown in Fig. 3.12 where m is the construction period; A is the annual operation and maintenance costs, B is the annual benefit; P is the annual investment and C is the total of P and A.

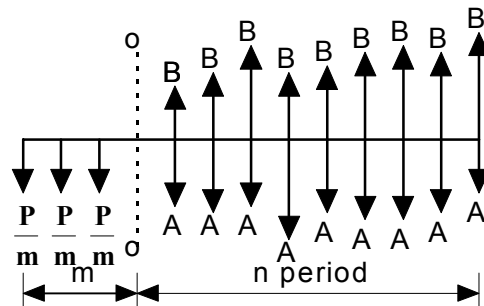


Fig. 3.12: Cash flow diagram for NPV analysis

It is to be noted the impact of an inflation in NPV illustrated in the Table 3.11. Without escalating the benefit and cost streams the project has a negative NPV while including escalation indicates an economically feasible project.

The Net Present Value criterion incorporates all of the pertinent economic data into a consistent one-figure decision rule that allows projects to be both screened and ranked. The screening decision criterion is to reject the project if the NPV is less than or equal to zero for a given discount rate. Without constraints on the amount of capital available for the project, the project with highest NPV is ranked highest. Budget constraints should be checked in this case. [UACE, 1979].

Benefit-Cost Ratio (B/C)

The Benefit-cost ratio compares the present value of future cash inflows to the present value of the original and all subsequent outflows by dividing the inflows by outflows. If the $B/C > 1$, then the project is said to be economically viable. The projects that have the ratio below one should be rejected. This is the most commonly used decision rule. The rule incorporates all the essential elements of a valid economic comparison. It can be determined using the following formula

$$\frac{B}{C} = \frac{\sum_j^n B_j / (1+i)^j}{\sum_j^n C_j / (1+i)^j} \tag{3.13}$$

In the table 3.11 the present value of the escalating present value stream of benefits is \$2.567 million and of the escalating present value stream of costs is 1.947 million. The B/C ratio is then 1.32 indicating an economical feasible project.

The B/C ratio can also be attained by converting the capital cost and its interest during the construction period to an annuity value, then

$$\frac{B}{C} = \frac{B}{(P + I) \frac{i(1+i)^n}{(1+i)^n - 1} + A} \tag{3.14}$$

- with B = annual benefit
- A = annual operation and maintenance costs
- P = total investment
- I = interest during the construction period
- n = calculation period from the first year of commissioning

Rate Of Return Comparison

Rate of return is the rate of return over an investment. In public investment economics the rate of return refers to internal rate of return (IRR), which means the interest rate that makes the net present value (NPV) equal to zero. At this interest or discount rate the benefits are equal to costs or the B/C ratio is equal to one.

If the project has IRR less than expected cost of financing used to implement the project then the project is rejected. This criterion has the appeal of being expressed as percentage that is readily comparable with the expected cost of financing. In actual practice most companies, industries, or even government agencies set a limit on interest rate, which is often called the 'minimum attractive rate of return,' (MARR). MARR is the lowest rate the decision-making entity will accept for expending investment capital. In Pakistan the MARR ranges from 8-12%. Like the NPV, internal rate of return incorporates all the pertinent economic data. The criterion does not, however, reflect any information on project scale, and, consequently, it cannot be used as the sole ranking criterion.

IRR is determined through an iteration process. In the foregoing example, for an escalated value, the NPV have been calculated with various interest rates, discount rate, and a graph is plotted (Fig 3.13). From this graph, it is clear that the IRR is equal to 15.9 % where the NPV is zero. If the government puts the MARR equal to 10 % then the project is said to be economically viable.

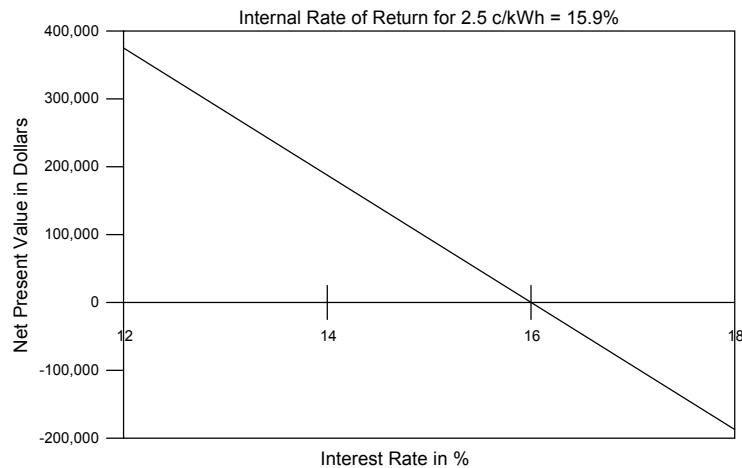


Fig. 3.13: Determination of Internal Rate of Return

Net Benefit Comparison

This is also known as the marginal costs and benefits method. This technique is useful to determine the best size of the project. There are two ways of expressing the net benefit of different alternatives requiring comparison.

In the first case the total present-worth of costs and benefits is plotted on a common axis against a scale or alternatives for development (Fig 3.14). The vertical distance between the curves represents the net benefit. The slope of the benefit curve is known as the marginal benefit and the slope of the cost curve is the marginal cost. When the two curves have the same slope, or marginal benefit equals marginal cost, the maximum net benefit is reached. This is normally the optimum size or scale to develop the project being analyzed. Under private investment policy the choice may be made to develop to a different scale based on some expected changes in economy, taxing policy, or inflation trends. In any case, net benefit can be used to compare different sizes of projects or alternatives.

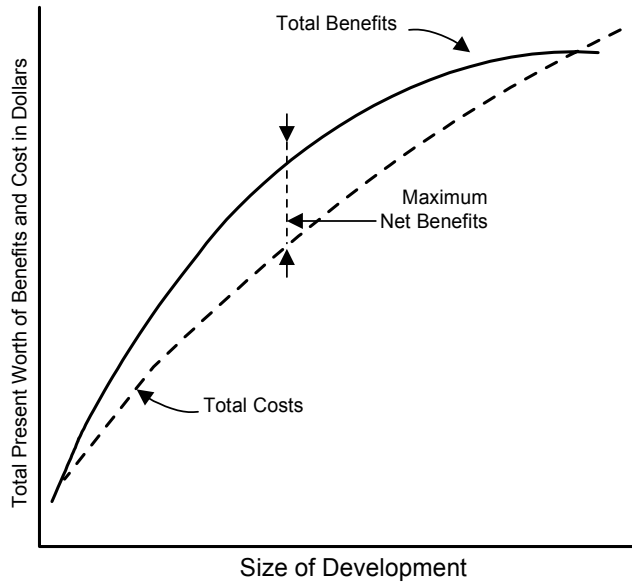


Fig. 3.14: Graphic representation of net benefit (source Warnik, 1984)

Another way of expressing net benefits is to plot the present-worth of benefits against the present-worth of costs for different scales of development or different alternatives. Fig. 3.15 shows graphically the significance of such a benefit-cost analysis.

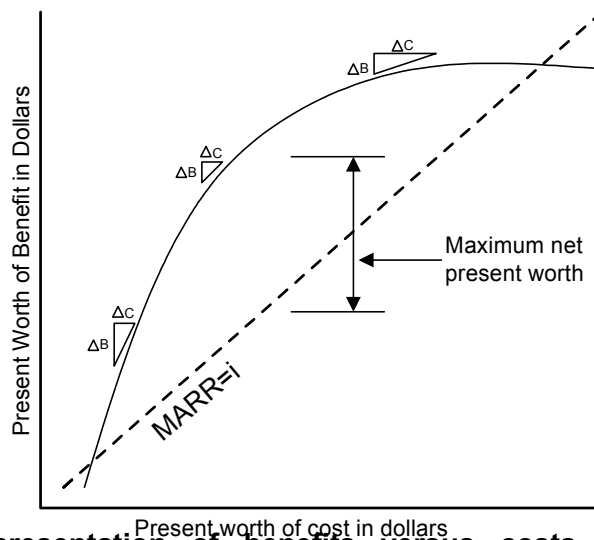


Fig. 3.15: Graphic representation of benefits versus costs for varying size of development.

Note that the 45° line represents the point where net present worth is zero and the marginal acceptable rate of return, MARR, is the i value that is used in the discounting of the benefits and costs. For the example illustrated, above the point of maximum net present worth of the unit return (benefit) from an increase in size of development is less than the present worth of unit expenditure or unit cost for that increase in size.

3.3.2.7 OTHER ECONOMIC CRITERIA AND CONSIDERATIONS

Several other decision criteria are available for evaluating investment alternatives. These include the average rate of return (ARR) and the pay back method (PB), among others. The ARR method is similar to the IRR, but does not discount future cash inflows and outflows; thus it does not take into account the time value of money. PB is actually a measure of how quickly the original investment is returned in absolute dollars, and it ignores potentially great future gains.

In applying the foregoing methods of comparison, there are further considerations that must be made and evaluated on the cost and benefit sides of analysis. These include cost of money, depreciation and amortization, interim replacement, insurance, and taxes. On the benefit or value sides of power economics, consideration must be given to the capacity value of the power and the simple energy value as well as other intangible socio-economic and environmental benefits. Some of these criteria and considerations are incorporated in the discussion of financial analysis.

3.3.2.8 CONSIDERATION OF UNCERTAINTY

Uncertainty is the lack of sureness about an outcome or quantity. Such uncertainty creates risk when an action is undertaken. In hydropower projects, uncertainty surrounds uncertain flow rate of the water, capital cost estimated, future annual costs, escalation rates, and the future value of energy. Because these quantities are not known with certainty, an outcome unfavorable to the project sponsor is possible. This risk should be analyzed and minimized to the extent feasible. Various methods are available to analyze the uncertainty in the energy related investment, however we will deal only two of them briefly here, which are highly used in practice. Readers are encouraged to refer to Kaplan (1983) for details.

Sensitivity Analysis

It is defined as the investigation of the impact on the decision criteria of variations in the important project parameters taken one at a time. The analysis is very useful for examining the degree to which the overall project desirability could be affected by changes in parameters whose values may vary.

There are many uncertainties concerning investment, income, costs, interest rate, and economic life of the plant. In order to evaluate the effects of a variable quantity, a sensitivity analysis of the NPV determined for the foregoing example was performed. The following table presents only the summary of this analysis and shows how the present worth varies with the different scenario. The base case is taken for the interest rate of 10 % and the escalation of 7 %.

From the table one may see that a change in the income has the greatest effect on the present worth and cost benefit ratio. Economic life, in this case, has also some effects in the present worth. Change in other costs (O&M costs) has insignificant influence, whereas, the investment, benefits and the interest rate are important items to check.

The sensitivity analysis provides important data for decision-making. It indicates the variable quantities to be checked to get satisfactory results. Finally there is the possibility to determine admissible limits for each variable quantity, up to which the project would still be justified in terms of economic efficiency. As shown in the table 3.12, even a pessimistic evaluation, when all costs and interest rate increase by 10 % and the benefits decrease by 10 % but the economic life taking as base case, the hypothetical hydroelectric project is still economically justifiable to implement.

Table 3.12: Sensitivity analysis for different scenario

Scenario	Escalation Interest		7% 10%	Annual Energy Production Value of Energy				9800000 kWh/y 2.5 c/kWh	
	Capital Cost (\$)	Benefits (\$)	Other Costs (\$)	Economic Life (Years)	Interest Rate (%)	NPV (\$)	B/C	Change in NPV (%)	Change in B/C (%)
Base Case	1563000	5649460	1037656	14	10	619738	1.32	0	0
Invest. + 10%	1719300	5649460	1037656	14	10	472193	1.23	-24	-7
Invest. - 10%	1406700	5649460	1037656	14	10	767284	1.43	24	8
Benef. + 10%	1563000	6214406	1037656	14	10	876400	1.45	41	10
Benef. - 10%	1563000	5084514	1037656	14	10	363077	1.19	-41	-10

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O.Cost + 10%	1563000	5649460	1141422	14	10	572597	1.29	-8	-2
O.Cost - 10%	1563000	5649460	933890	14	10	666880	1.35	8	2
Interest + 10%	1563000	5649460	1037656	14	11	489234	1.26	-21	-5
Interest - 10%	1563000	5649460	1037656	14	9	763879	1.38	23	5
Eco.Life + 10%	1563000	5649460	1037656	15,4	10	882481	1.44	42	9
Eco.Life - 10%	1563000	5649460	1037656	12,6	10	485489	1.25	-22	-5
Pessimistic	1719300	5084514	1141422	14	11	58741	1.03	-91	-22

Risk Analysis

Risk may be defined as the probability of the occurrence of an unacceptable outcome [UACE 1979]. Among the various methods of evaluation account for risk, the discount rate approach and Monte Carlo simulation technique are popular. Readers may find description of these methods in Kaplan (1983), UACE (1979), etc.

The discount rate method accounts for risk by increasing the discount rate associated with a project. An increase in the discount rate will decrease the NPV, IRR or B/C ratio. In this way a project with more risk would have to meet higher requirements in order to be judged economically feasible. Fig. 3.16 shows an example of the sensitivity analysis using discount rate.

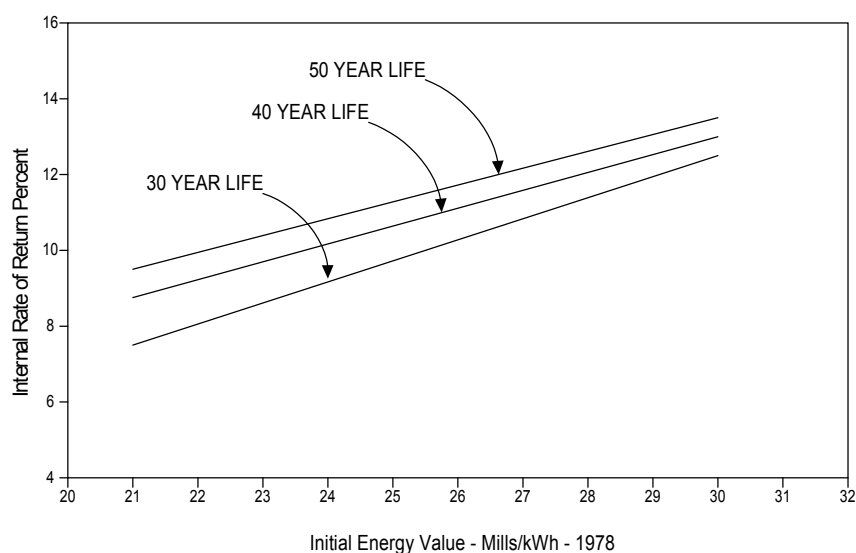


Fig. 3.16: Example of risk analysis using discount rate method

Monte Carlo simulation method considers the variation in parameters as stochastic elements. The risk analysis to be evaluated is to find the probability distribution of the criterion in terms of the variation in parameters. This method allows uncertainty in a number of the projects' parameters to be simultaneously accounted for and the impacts on the decision criteria can be quantified. Fig. 3.17 a shows a graphical example of probability distribution of a project parameter using triangular probability distribution curve and Fig. 3.17b shows an example of probability of possible outcomes from Monte Carlo Simulation.

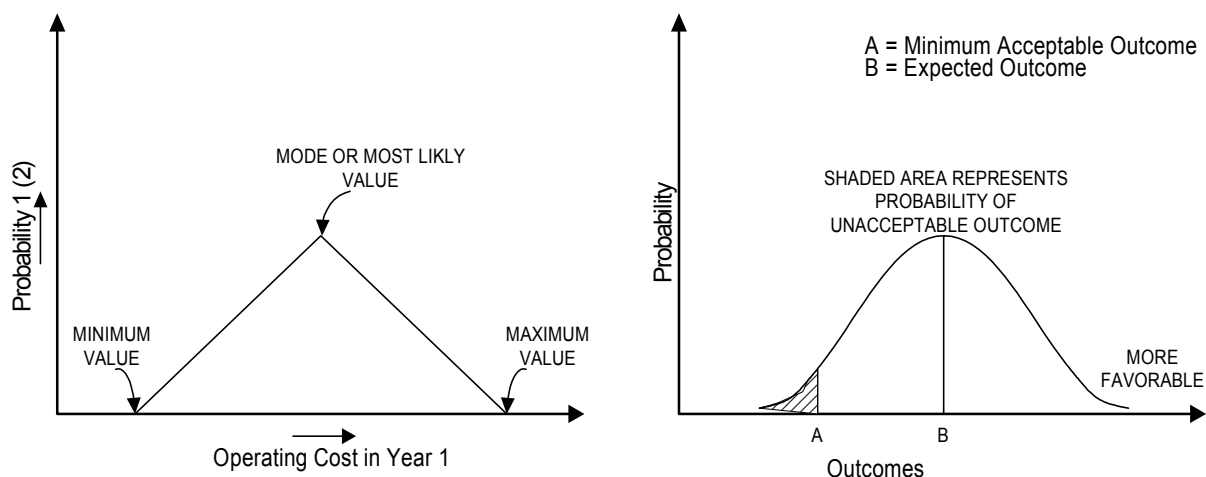


Fig. 3.17: Example of risk analysis using (a) triangular probability distribution and (b) Monte Carlo simulation.

3.3.2.9 SUMMARY OF ECONOMIC ANALYSIS PROCEDURE

The following table summarizes the steps in the economic analysis for hydropower project [UACE, 1979].

Table 3.13: Economic Analysis Procedure [UACE, 1979]

Step	Description
1	Determine if inflationary or constant dollar analysis will be used. In an inflationary analysis, establish the general escalation rate. If items such as energy values or construction costs will be escalated at a rate different than the general inflation rate, determine the appropriate rate(s)
2	Establish the project economic life
3	Assemble the unescalated cost stream (by year) for the economic life of the project. This includes the capital costs by year, operation and maintenance, replacements, quantified nonmonetary costs and other costs
4	Assemble the unescalated benefit stream (by year) for the life of the project. This includes the value of power generation, quantified nonmonetary benefits, and other benefits
5	Escalate costs and benefits as determined in step 1
6	Establish the appropriate discount rate
7	Calculate the economic evaluation criterion chosen for use

3.4 FINANCIAL ANALYSIS

3.4.1 GENERAL

Financial analysis is done to establish the financial feasibility of the hydroelectric project. Financial feasibility may be defined as a project's ability to obtain funds for implementation and repay these funds on a self-liquidating basis [UACE, 1979]. Whether a project is feasible depends on the project's characteristics, the sponsor and purchaser, the requirements of those providing funds and the overall credit market as it affects the cost of borrowing which is the important part of the study.

This cost of borrowing is generally considered to be the sum of the real interest rate that compensates the lender for surrendering the use of funds, the purchasing-power risk premium that compensates for expected inflation, the business and financial risk, and the marketability risk associated with low-liquidity of a debt security. Since the projects will usually be sensitive to the costs of financing, all of the above mentioned factors must be considered in determining financial feasibility.

In the financial analysis of capital intensive projects such as hydropower project, inflation plays two important roles:

1. it contributes to the cost of capital. High inflation rates lead to higher costs of borrowing and annual debt service requirements.
2. once the project is financed, it will generally enhance the project's net cash receipts as time passes. Since the financing plan generally fixes debt service payments, only a portion of annual costs (operation, maintenance, replacement, etc.) is subject to escalation.

Due to inflation, the first few years of operation will be more difficult financially. If the project is self-liquidating in its early years with or without inflation, then it is generally assured that the project is financially feasible.

For the project to be feasible, the minimum revenue requirement (MRR) must be met with a high degree of assurance. The project's annual MRR is the amount of funds required to pay all costs incurred by the project. This requirement is the prime consideration when project financing and the power market agreement are arranged.

3.4.2 CRITERIA FOR FINANCIAL EVALUATION

The criteria for financial evaluation consist of the determination of cost of service, financial net present value, financial internal rate of return, financial B/C ratio, the pay back period of investment and pay back period of the loan through a financial cash-flow analysis, a financial balance analysis and a cost-profit analysis. [Jiandong, 1996].

Cost of Service Calculation. Cost of service is the cost of producing electrical energy at the point of ownership transfer. It is also denoted by c/kWh as the value of energy. If the cost of service is less than the value of the energy produced, it should be possible to negotiate a marketing agreement that allows the project to be implemented while providing the needed security in debt service payments.

The cost of service is calculated using the following steps:

1. The lump-sum estimated capital cost is disbursed according to the construction period.
2. The completed cost is determined adding escalation and interest during construction
3. With the completed cost estimate and the cost of financing specified the annual debt service is determined.
4. The debt service payments plus other escalating and constant annual costs are then summed to estimate total annual cost through the project financing period.
5. The cost of service is the ratio of the total annual cost to the average annual energy production yields.

These steps have been illustrated in the following two tables taking the data from foregoing example.

TABLE 3.4.1 Annual Debt Service Calculation

Low Head Hydropower
Economic and Financial Analysis

PROJECT DATA			
Item		Amount	
Cost of Financing		10	% per year
Financing Period		12	Years
Construction Period		2	Years
Construction Cost per Year		Shown below	
Construction Cost Escalation		7	% per year
Lump-sum Project Cost Estimate		1500000	\$
Capital Cost Calculation			
Year	Unescalated Cost Estimate	Escalated to Year of Payment	Contribution to complete Cost including Interest during Construction
1	600000	600000	690000
2	900000	963000	1011150
3	0	0	0
4	0	0	0
Total	1500000	1563000	1701150
Completed Cost		1701150	
Fully amortized over 12 years at 10% interest			
Capital recovery factor		0.1468	
Annual Debt Service		249666	

Table 3.15:
Service Calculation

Cost of

Escalation		7	%	Annual Energy Production		9800000	KWh/y
Cost of finance		10	%	Value of Energy		205	C/kWh
Year of Operat.	Bond Ammort.	Other Costs	Total Costs (\$)	Average annual Energy production	Cost of Service	Value of Energy	Difference in Energy Value
(1)	(\$)	(\$)	(2-3)	(x11000000 kWh)	(cents/kWh)4/5	Cents/kWh	(%)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	249666	45000	294666	9.80	3.007	2.500	-20
2	249666	48150	297816	9.80	3.039	2.675	-14
3	249666	51521	301187	9.80	3.073	2.862	-7
4	249666	55127	304793	9.80	3.110	3.063	-2
5	249666	58986	308652	9.80	3.150	3.277	4
6	249666	63115	312781	9.80	3.192	3.506	9
7	249666	67533	317199	9.80	3.237	3.752	14
8	249666	72260	321927	9.80	3.285	4.014	18
9	249666	77318	326985	9.80	3.337	4.295	22
10	249666	82731	332397	9.80	3.392	4.596	26
11	249666	88522	338188	9.80	3.451	4.918	30
12	249666	94718	344385	9.80	3.514	5.262	33

From the table 3.15 one can see that the initial periods for the hypothetical hydropower project are difficult because the value of energy cost is far less than the cost of service. However, over the financing period the cost of service will increase only by 1.17 times, whereas, due to inflation, the value of energy will rise two folds. The value of energy will be 33 % higher than the cost of service at the end of the financing period.

Sensitivity analysis is also necessary to be performed to provide additional information for the decision makers. In the foregoing example, the cost of financing poses the uncertainty and subject to sensitivity analysis. In many cases the projects are not immediately implemented at the completion of feasibility study. Over this period the cost of financing may vary. For this reason, the project sponsor may need a sensitivity analysis of the effect the financing cost has on the cost of service. Other project parameters that may be desirable to investigate include

initial value of the project's energy, completed cost, operation and maintenance costs, and escalation rates.

As already mentioned that the project's minimum revenue requirements must be guaranteed with high degree of certainty for the project to be able to attract funds for implementation. Following are the several ways to get a security for financing:

- Marketing arrangement: The power contract should meet the following conditions:
 - The contract must require payments sufficient to cover debt service in all events.
 - The capability of the power purchaser to give this assurance must be proven.
 - The power contract should generally be in force for the length of the financing period.
- Sponsor guarantees: If the above mentioned conditions are not mentioned in the power contract, the financial integrity of the project sponsor may be used as security.
 - In case of public entity, the issuing general obligation bonds (GOB) effectively secure the debt service. The GOB are referred to the taxing power of the public entity.
 - In case of private sponsor, the security for debt service is obtained through the real assets or general credit worthiness of the borrower.
- Power production as Security: This security is used, if the expected revenue from the project is adequate to cover all expenses and debt service. If the excess of revenue over costs exceeds 25 to 30 percent of annual debt service, as a general rule the project can be financed [UACE, 1979].

3.4.3 FINANCIAL CASH-FLOW ANALYSIS

The method for financial cash-flow analysis is similar to the economic analysis. The cash-outflow includes the complete cost of the project including interest during construction and escalation, invest on fixed assets, annual operating and maintenance costs, financing for the renewal of electromechanical equipment during the calculation period, tax, royalties and insurance.

Table 3.16: Annual equivalent cost used for the pay back period calculation.

Escalation		7	%	Annual Energy Production			9800000	KWh/y
Cost of finance		10	%	Value of Energy			205	C/kWh
Year of	Bond	Other	Total	Annual	Net cash	Sum of net		
Operat.	Ammort.	Costs	Costs (\$)	Benefits (\$)	Flow (\$)	Cash flow		
	(\$)	(\$)	(2-3)	(6-4)	(8-7)			
(1)	(2)	(3)	(4)	(8)	(9)	(10)		
1	249666	45000	294666	245000	-49666	-49666		
2	249666	48150	297816	262150	-35666	-85333		
3	249666	51521	301187	280501	-20686	-106019		
4	249666	55127	304793	300136	-4658	-110677		
5	249666	58986	308652	321145	12493	-98184		
6	249666	63115	312781	343625	30844	-67340		
7	249666	67533	317199	367679	50480	-16861		
8	249666	72260	321927	393416	71490	54629		
9	249666	77318	326985	420956	93971	148600		
10	249666	82731	332397	450423	118025	266625		
11	249666	88522	338188	481952	143764	410389		
12	249666	94718	344385	515689	171304	581693		

The cash-inflow consists of revenue from energy sales, returns on the residual value of fixed assets and others. A financial discount rate or cost of financing is used to find out the financial internal rate of return, the financial B/C ratio, and the static pay back period of investment. The pay back period is equal to the total of the years when the cumulative net cash equals or is greater than the total investment without discounting. This can be calculated using annual equivalent cost method.

The table above shows an example of calculating pay back period using annual equivalent cost. The input data for this example is taken from the forgoing example.

From the above table it is evident that the hypothetical hydropower project is able to pay back all its debt immediately after the 6th year of its operation.

3.4.4 CONSIDERATION OF ENVIRONMENTAL BENEFITS

The use of hydroelectricity will reduce the use of fossil fuel for energy and may reduce environmental pollution. Other factors such as beautifying the surroundings and promotion of tourism; are the benefits, which should be solely assigned to hydropower projects.

All intangible benefits cannot be counted in terms of money. However, an approach should be made to encounter it. A long term observation of past projects and case studies may be helpful to quantify the benefits.

The following flowchart in Fig. 3.18 summarizes the procedure of economic and financial analysis.

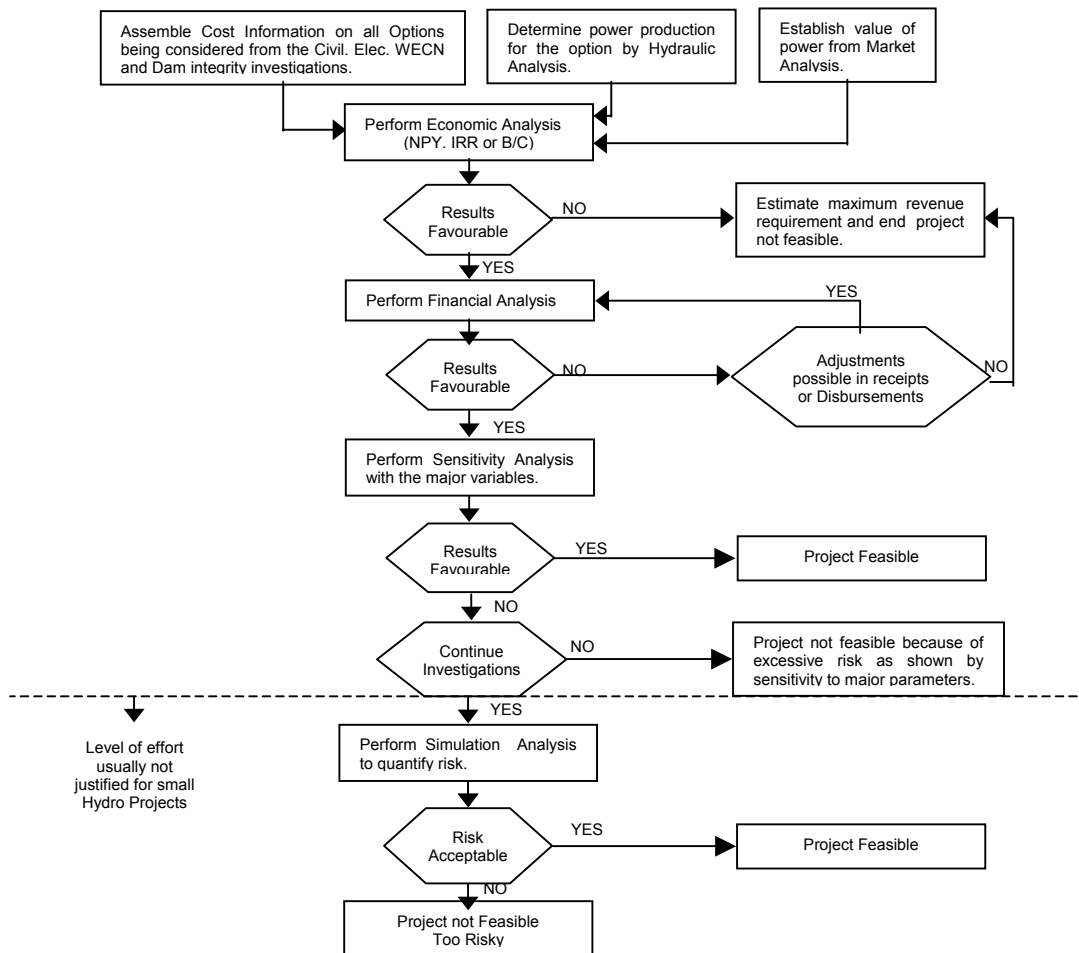


Fig. 3.18: Flow chart of the procedure of economic and financial analysis.

3.5 CASE STUDY JINNAH HYDROPOWER PROJECT, PAKISTAN

3.5.1 GENERAL

Economic analysis is a systematic and scientific approach to determine the program of action by comparing the ex-ante performance with ex-post achievements, which essentially entail major socio-economic developments in their area of influence. Economic analysis seeks to ascertain the reward for investment and provides guidelines to establish the feasibility of the

project. It is necessary that gains generated should exceed the cost of the goods and services used in its construction and operation. At least these gains must match or yield higher returns from an alternative investment. The primary objective of undertaking economic analysis is thus to determine whether the contribution of a particular project in the shape of added value benefits is adequate enough to justify use of scarce resources needed in the form of project investment costs. The economic justification of investment in a capital-intensive project depends on three factors. Firstly, there is a need for the project, secondly, where technological options are available, the project represents the most economic choice of option; and thirdly, that investment in the project will produce an acceptable return to the national economy. This process involves the assessment of project benefits and identification of project costs over the economic life of the project.

The economic evaluation of Jinnah Hydropower Project will be carried out on the basis of power and energy generated by the project. As it has been established in previous sections on optimum sizing of plants, eight units is the optimum size of the project hence the analysis will be carried out for two options i.e. six units (option-I) and eight units (option-II) of 12 MW capacity each for comparison. It is further assumed that proposed plant will run in integrated mode with the National Grid.

3.5.2 DERIVATION OF ECONOMIC COSTS AND BENEFITS

The economic analysis of the project requires that all costs and benefits must be evaluated at prices within the economy, which reflect their real worth. Major inputs into the scheme of economic analysis like costs and benefits including various components do not necessarily reflect their true opportunity cost to the economy because of distortions in market prices. Like many other developing countries, the prices of goods and services are distorted by subsidies and taxes in Pakistan too. The rate of foreign exchange has differed from its true opportunity cost. Due to disguised under-employment in agriculture and implications of minimum wage legislation in the industrial sector, the price of labour has generally been higher than its true opportunity cost. The purpose of economic analysis is, therefore, to evaluate the costs and benefits of the project at a level which reflects more accurately their true opportunity cost to the economy through techniques of accounting or shadow prices.

3.5.3 DERIVATION OF SHADOW PRICES

Shadow pricing has been used to find out true opportunity cost of capital as well as other inputs to determine the economic cost of this project to the national economy.

3.5.3.1 OPPORTUNITY COST OF CAPITAL

For the purpose of economic study, shadow price of capital is defined as the opportunity cost of funds withdrawn from other uses and is considered equal to marginal cost of capital in the economy of Pakistan. World Bank has used 10% discount rate for rural electrification projects and 12% for evaluation of Kalabagh Dam Project. A discount rate of 12% has been widely used in Pakistan for economical evaluation of public sector projects by Planning Commission since mid 60's followed by a study of Havard Advisory Group on opportunity cost of capital. For the present study also, opportunity cost of capital of 12% has been adopted for assessment of economic feasibility of the project.

3.5.3.2 SHADOW PRICE OF LABOUR

In cases where there is significant unemployment and under-employment in a local economy shadow wage rates for labour should be used which are considerably lower than actual wages paid. The objective in economic analysis is to use the opportunity cost in an alternative application. In Pakistan the situation is one of under-employment for unskilled labour rather than full scale employment since there are labour shortages in rural areas in sowing and harvesting seasons. There are no employment problems for skilled labour as there are sufficient opportunities locally and in nearby oil producing countries.

The project is located in Mianwali District of Punjab, where during harvesting period of crops, the labour supply is found to be scarce for construction or other economic activities. On the other hand the skilled labour force is not sufficient to meet the local needs of the area as observed in Mianwali city and surrounding settlements. Therefore, shadow wage rates of 1.06 and 0.65 for skilled and unskilled labour, respectively, have been used for deriving economic cost.

3.5.3.3 SHADOW PRICING OF MATERIALS

Most of the material inputs for various projects, i.e., steel, cement etc, are transported to the project site involving high freight expenditures. It is, therefore, assumed that shadow rates for material may be used as 1.1, as also used in the feasibility report of Kalabagh Dam Project and others. The results of shadow conversion factors have been applied to various components of project costs to derive adjusted economic costs.

3.5.3.4 ECONOMIC COST

The economic costs have been derived by converting financial cost with adjustments for direct transfer payments like taxes, subsidies and interest during construction besides adjustments for distortions in the market prices of traded and untraded goods used in the project works. For this study also economic costs of the project has been derived by removal of transfer payments (interest, taxes and subsidies) in addition to adjustment of cost of labour and material with appropriate shadow conversion factors. The economic cost of labour has been determined by applying shadow wage factors to the total labour cost which is equivalent to 38 percent of the local cost of the project with 40 & 60 percent as skilled and unskilled labour components respectively. The remaining components like cost of material and the locally manufactured goods 62% have been shadow priced with an appropriate conversion factor. The economic costs of Jinnah Hydro Power Project thus derived have been used in economic evaluation and summarized as follows:

Table 3.17: Economic Cost Estimate for Jinnah HPP in Million Rs.[2]

Year	6 Units	8 Units
1	1633.68	1975.23
2	1068.67	1278.71
3	1796.70	2165.51
4	1343.87	1680.58
TOTAL	5842.92	7100.03

Exchange Rate 1US\$ = Rs 40.00

3.5.4 THERMAL EQUIVALENCE

The project feasibility has been checked on the assumption that in the absence of hydropower generation, an equivalent thermal generation plant would be required to produce equivalent amount of energy per annum. A comparative study has, therefore, been undertaken and costs calculated on the basis of providing an equivalent quantum of generation from a steam generation plant using furnace oil. In this analysis benefits were computed based on the equivalent thermal generation costs that would be avoided if Jinnah was installed. Thus the savings due to avoidance of thermal plant capital investment and fuel operating costs would be benefits, attributable to the project.

3.5.4.1 DIVERSION OF EQUIVALENT THERMAL CAPACITY

The capacity of equivalent thermal electric plant has been derived in such a way that it renders directly comparable primary energy available from Jinnah Hydropower Plant. In this way a steam plant of 84 MW and 98.21 MW will be required for generating 589.29 GWh and 688.27 GWh from different options. The investment cost of steam equivalent has been estimated @ Rs. 27,160/kW. Accordingly the estimated capital cost of the plant equivalent to Rs. 2281.44

million and Rs. 2667.44 million in options I & II respectively.

3.5.4.2 FUEL COST

The F.O.B price of furnace oil is assumed to be Rs 3942 per metric ton including transportation charges with an average consumption 0.28 kg per kWh for this study. As per market survey the fuel cost has been estimated in accordance with the requirements of power demand curve in the coming years by using escalation factor at the rate of 5% per annum upto the operation of the project. The fuel cost for equivalent generation thus comes to Rs 790.61 million and Rs 923.40 million in option I and II respectively.

3.5.4.3 OPERATION AND MAINTENANCE COST

The annual operation and maintenance cost excluding establishment cost of steam electric plant has been assumed as 2% of the estimated capacity cost of the project. The total annual O&M cost in addition to fuel comes to Rs 45.63 million and Rs 53.35 million in option I and II respectively.

The serviced life of the steam plant has been assumed as 30 years in Pakistan as against 60 years of hydroelectric plant.

The savings in cost of providing equivalent steam generation have been assumed as direct economic benefits resulting from alternative source of generation and are considered for economic analysis of the project.

3.5.5 ECONOMIC BENEFITS

The economic analysis of the project has been carried out on the basis of the benefits to the overall economy as a consequence of least cost optimal development of the hydro electric potential in the country. For this purpose the benefits from the proposed steam unit have been evaluated in terms of costs foregone for providing an equivalent generation from steam plant. The installation of 72 MW and 84 MW in different options would result in three kinds of savings/benefits to the national economy as enumerated below:

- a) The first kind of benefits would be saving of capital cost of the steam power plant. This benefit is calculated in terms of annual fixed cost of equivalent steam plant amounting to Rs 570.36 million and Rs 666.86 million in option I and II respectively assuming 30 years life of the plant.
- b) The other benefit would be in the form of savings of fuel cost estimated @ Rs. 1.34 per kWh with a consumption of 0.28 kg per kWh. It may be mentioned here that furnace oil to be used for this plant would be imported by spending foreign exchange resources
- c) Lastly there would also be savings in O&M costs for steam plant which is estimated to be Rs. 45.63 and Rs. 53.35 million in options I and II respectively.

3.5.6 RESULTS OF ECONOMIC ANALYSIS

On the basis of economic costs and benefits, economic feasibility of the project has been shown in the appendix in TABLES 3-1 up to 3-3 for the proposed Jinnah Hydropower Project. The internal economic rate of return (E.I.R.R) of the project is estimated to be 17.18% and 15.95% in option I and II, which is higher than 12% opportunity, cost of capital in Pakistan.

3.5.7 SENSITIVITY ANALYSIS

Although the project has shown economic viability with 17.18% and 15.95% economic rate of return and a positive benefit cost rate of 1.29:1 in option I and II at 12% discount rate, the project is, however, susceptible to different kinds of adverse circumstances like cost over-run, delay in construction and decrease in benefits. The economic feasibility of the project has been checked against 20% cost over-run, 10% decrease in benefits as well as combined impact of both variations to see if the project remains feasible. The results show that project yields economically viable rates of return except in case of combined impact as shown in TABLES 3-5 up to 3-8.

3.5.8 JUSTIFICATION OF THE PROJECT

The project is economically justifiable in view of supplying low cost hydropower to the Mianwali district. The electricity will act as catalyst for development of basic industry, creation of employment opportunities and uplift of socio-economic conditions etc. As can be seen from tables in the appendix, that installation of six units would result in a slightly higher rate of return as compared to eight units and even qualifies the sensitivity analysis criteria, being optimum size of the plant, hence recommended for implementation. In hydropower development it is frequently determined to construct a facility which is slightly larger than the most economic option provided the return for the next larger project capacity is close to the most favourable return. An eight unit option at Jinnah provides a comparable return to a 6 unit option therefore can be considered as the recommended project size. Addition of more units reduces viability due to increasing incremental costs.

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