TRAINING COURSE

ON

RESERVOIR OPERATION

(UNDER WORLD BANK AIDED HYDROLOGY PROJECT)

Module 12

Economic and Financial Analysis of Hydropower Projects

BY

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ECONOMIC AND FINANCIAL ANALYSIS OF HYDROPOWER PROJECTS

1.0 INTRODUCTION

A project is justified from a national economic view point if it has positive net economic benefits, provided that the services of such a project are considered of high enough priority for implementation compared with the use of valuable resources for other purposes. The results of an economic analysis do not, however provide sufficient information on financial viability during the course of each project's actual construction and operation. The main differences between financial and economic analysis of a hydropower project are highlighted in Table 1.

Table 1: A Comparison of Economic and Financial Analysis

Item	Economic analysis	Financial analysis
Focus	Net returns to Society	Net returns to equity capital or to private group or individual.
Purpose	To justify investment on basis of appropriate economic criteria (B/C ratio, annual cost, internal rate of return)	To determine the needs for financing the project and handling the flow of costs, revenues and subsidies during operation.
Period	Period of analysis based on project life, economic life	Period for capital recovery based on terms of financing. Usually it is less than period of economic analysis.
Discount rate	Opportunity cost of capital, social time preference rate	Marginal cost of money, market borrowing rate. It depends on type of financing e.g. bank loan, general bonds, credit rating of sponsor.
Inflation	Effect of inflation on increase in cost & benefit is not considered	Effect of inflation on prices is considered on a year by year basis.
Equivalence	Weighing and discounting technique are used to obtain annual equivalent value of costs and benefits over period of analysis	Analysis carried out on year to year basis considering inflation, price and interest rate variations.
Prices	May require 'Shadow prices' (e.g. monopoly in markets, external effects, overvalued currency, unemployment factor)	It is assumed that markets are perfect or that administered prices have compensated for imperfection.
Taxes	Part of total societal benefits	Cost of production.
Subsidies	Part of total societal costs	Source of revenues.
Loans	A transfer payment; transfer a claim to resource flow	Increase capital resources available.
Interest or loan repayment	A transfer payment	A financial cost; decreases capital resources available.
Benefits	Hydropower benefits are based on cost of alternative (with similar capacity and annual energy)	Revenue of hydropower project is based on actual sale contracts. Dependable capacity is an important issue.

2.0 ECONOMIC ANALYSIS OF SMALL HYDRO PROJECTS

Following features affect the economic and financial feasibility of small hydro-electric projects:

- ⇨ In general, it has high installation cost per kW,
- ⇨ Other purposes (irrigation, flood control etc.) are not combined with small hydro project,
- ⇨ Generally, it is considered non-essential project,
- ⇨ It has little or non peaking capacity and generally it is run-of-river type,
- ⇨ It has less transmission cost due to proximity to load consumption centre.

Small hydro project's economic evaluation is based on benefit/cost ratio. Benefits of small hydro are :

- ⇨ Sale of capacity and energy accruing out of firm capacity and energy in the project.
- ⇨ Savings accruing in costs of fossil fuel and oil in thermal power plants due to displacement by hydro generation.
- ⇨ Savings accruing on account of energy losses in transmission from central station up to the area being served by the proposed hydrostation.

In economic evaluation, present value or annual equivalent value of all the benefits accruing over the life time of the project is considered.

The power being sold has an energy value and a capacity value. If project has capacity to meet energy requirements during the peak load requirement of the purchaser, the energy generated has a capacity value. The capacity value is determined by calculating the cost savings of the purchaser by not constructing or postponing other generation plants to meet peak power requirements. The energy value of the project (if capacity value is absent in the project) is the cost of energy produced from an alternative project.

The cost of a small hydro project consists of :

(a) Operation cost (labour, water),
(b) Maintenance cost (labour, repair, lubricants, consumables),
(c) Replacement cost (plant equipment) (sinking fund),
(d) Taxes, and
(e) Insurance.

As load factor increases, the O & M costs increase due to more wear on the machines. Other costs are fixed regardless of load factor and have a decreasing cost per kilowatt hour generated as the load factor increases.

In economic analysis, uncertainty lies in estimation of life of project components, cost of project, escalation rates and value of energy at a future date. Therefore, sensitivity analysis is an important part of economic evaluation.

2.1 Economic Analysis of Hydropower As A Component of Power System

Scope of power development is governed by the increase in the regional demand. We have to plan for extension of the system capacity such that the lowest annual cost of energy is obtained. Hydro plants, steam plants, gas plants, nuclear plants are alternative units of increment. Choice of an alternative for inclusion in energy system will depend upon cost comparison of energy system with and without the alternative.

When hydropower is a component of multipurpose river valley project, it is necessary to have an estimate of power benefits. In such case, hydropower benefit is measured in terms of the cost of power from alternative source most likely to be used in the absence of multipurpose project. The alternative project could be a single purpose hydropower project or a plant using other fuel. The cost of alternative should be based on entire energy system design.

Value of firm hydro	=	Cost of alternative source
	=	Cost of capacity + Cost of annual energy generation - transmission cost and losses
Value of secondary hydro	=	additional cost of alternative source for such generation
Indirect benefits	:	due to additional economic activity in the region
Intangible benefits	:	comfort and convenience due to power and conservation of non-renewable resources

A storage type hydroplant helps in regulated releases in downstream. Benefits due to regulated releases should also be included as benefits of hydro project.

Steps:

(1) Project the power capacity requirements for different years.

(2) Work out the most economic sequence of various projects (Thermal, Hydro, Nuclear etc. including the multipurpose hydropower) project that will meet the capacity requirement in different years. Call it sequence A.

(3) Work out the most economic sequence of various projects without including the multipurpose project. Call it sequence B. In order to find the most economic sequences in step (2) and step (3), one may have to investigate some dozen alternative sequences.

(4) Find the total annual cost figures of both the sequences.

(i) Interest + depreciation on all plants with exception of multipurpose project,

(ii) O & M cost of all plants completed during period of analysis + variable O & M cost on the remainder of system completed before period of analysis,

(iii) Annual cost of fuel for the entire system.

Note: The sequence with the hydropower component of multipurpose project (sequence A) should not include any cost of hydropower. The sequence without the hydro-component of multipurpose project (sequence B) should include all system costs. The annual costs will differ from year to year.

(5) Find the difference in annual cost of the two sequences.

(6) Calculate present worth of the difference in annual costs. This is the benefit of the hydro-component of the multipurpose project.

(7) To find benefit-cost ratio of hydro component, cost of hydro component will have to be evaluated. This will be equal to separable cost of hydro component (power plant, turbines, penstock) + allocated cost (dam spillway etc).

3.0 GOVERNMENT OR INDUSTRIAL SPONSOR - SALE TO REGIONAL UTILITY

In this example, the hydroelectric plant whose parameters are indicated in Table 1 is considered to produce all its energy for sale to a regional electric utility. The annual costs of $176,389 in Table 1 are composed to $148,167 in fixed costs for capital recovery over a 20-year period and $28,222 in variable costs for operation and maintenance. These components are based on the charges of Table 2 applying to a public sponsor or a private sponsor having equivalent borrowing terms and tax concessions. As shown by Table 2, the costs for a private sponsor not having these advantages would be much higher.

Table 3 assumes that the variable costs (which are subject to inflation) increase at 7% per year and that the selling price for energy starts at 2 cents/kwh and escalates at 8.5% per year. For each year except the first, the total revenue exceeds the total costs and the net revenue (or "profit") is positive. In this example applying to a public project, the favourable financial results are obvious. In an example where unfavourable results persist for a number of years before net revenues are achieved, the overall financial results may be examined in terms of present value. The computations are shown in the last two columns of Table 3.

The present values shown in the last column of Table 3 were obtained using a discount rate of 7%. It may be desirable to carry out the computation of net present value with higher discount rates, in order to recognize two problems in the estimates : (1) the uncertainties of the future net revenues, when inflation is included ; and (2) the lower values of these escalated future net revenues in terms of constant dollars.

Table 1: Parameters for a Typical Small Hydroelectric Site

1. Installed capacity	1.50 mW
2. Dependable capacity	0.15 mW
3. Unit cost of construction	$800 per kW
4. Construction cost	$1,200.000
5. Investment cost	$1,411,100
6. Plant factor	0.62
7. Annual output	8,146,800 kWh
8. Annual costs	$176,389 (12.5% of investment cost)

Table 2: Annual Costs as a Percentage of Investment

Cost Component	Private Project	Public Project
	Fixed Charges	
Cost of money	14.00	7.00
Amortization	1.00	2.50
Property taxes	5.00	(not applicable)
Replacements	0.50	0.50
Insurance	0.50	0.50
Total fixed charges	21.00%	10.50%
	Operating Costs	
Supplies and services	0.40	0.40
Maintenance	0.90	0.90
Salaries	0.45	0.45
Office expenses	0.15	0.15
Miscellaneous	0.10	0.10
Total operating costs	2.00%	2.00%
Total annual cost	23.00%	12.50%

Note: This table is based on a 20-year period of financing. Amortization is based on a sinking fund with interest at the cost of money.

Table 3: Comparison of Costs and Revenues and Present Value of Hydroplant

Year	Fixed Costs[a]	Variable Costs[b]	Total Costs	Selling Price per kWh[c]	Gross Revenue	Net Revenue	Present Value Factor[d]	Net Present Value
1	$148,167	$28,222	$176,389	0.020	$162,936	$(13,453)	0.935	$(12,579)
2	148,167	32,312	180,479	0.023	187,376	6,897	0.873	6,021
3	148,167	34,573	182,740	0.025	203,670	20,930	0.816	17,079
4	148,167	36,994	185,161	0.027	219,964	34,803	0.762	26,520
5	148,167	39,583	187,750	0.030	244,404	56,654	0.712	40,338
6	148,167	42,354	190,521	0.032	260,698	70,177	0.666	46,738
7	148,167	45,317	193,484	0.035	285,138	91,654	0.623	57,100
8	148,167	48,491	196,658	0.038	309,578	112,920	0.582	65,719
9	148,167	51,885	200,052	0.041	334,019	133,967	0.544	72,878
10	148,167	55,517	203,684	0.045	366,606	162,922	0.508	82,764
11	148,167	59,404	207,571	0.049	399,193	191,622	0.475	91,020
12	148,167	63,562	211,729	0.053	431,780	220,051	0.444	97,707
13	148,167	68,011	216,178	0.057	464,368	248,190	0.414	102,751
14	148,167	72,772	220,939	0.062	505,101	284,162	0.388	110,255
15	148,167	77,865	226,033	0.067	545,835	319,802	0.362	115,768
16	148,167	83,317	231,484	0.073	594,716	363,232	0.338	122,772
17	148,167	89,149	237,316	0.080	651,744	414,428	0.316	130,959
18	148,167	95,389	243,556	0.086	700,624	457,068	0.295	134,835
19	148,167	102,066	250,233	0.094	765,799	515,566	0.276	142,296
20	148,167	109,211	257,378	0.102	830,973	573,595	0.258	147,988
Net present value =								$1,598,925

[a]Fixed costs are 10.5% of investment cost of $1,411,110

[b]Variable costs are 2% of investment cost initially; escalation at 7%

[c]Price escalation at 8.5%

[d]Present value factors for 7% interest rate.