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An approach to the investment analysis of small and medium hydro-power plants

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Abstract

Hydro-power plants, as a part of infrastructure projects, play an important role in the economic-social development of countries. Since a large amount of investment is needed for construction of these power plants, which appeared to be an obstacle in these developments, however it is possible to finance these infrastructure plants by assigning these affairs to private sectors by using build operate transfer (BOT) method, which is quite well-known all around the world. This paper reviews the structure of BOT contracts and through an economic evaluation based on different percentage of investments of private sector in providing the expenses of small and medium hydro-power plants (S&M-HPP) (e.g. MHPP in "Bookan, Iran" and SHPP in "Nari, Iran"), demonstrates that by increasing the percentage the share of the private sector in the investment, the economic indices B/C and NPV improve substantially.
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1. Introduction

Hydro-power plants have a significant role in the economic-social development of the developing countries; on the other hand, in most cases, the local sources of these countries are not able to provide construction and development costs of these projects; therefore, in recent decades, these countries have focused on providing financial sources via absorbing foreign and local capitals and, ultimately, towards privatization of power plants.

One of the most ideal methods to execute hydro-power plant is to encourage private sector, particularly foreign investors, in order to participate in the projects by build-operate transfer (BOT) method. One of the main goals of this method is to lower the role of government in the execution and implementation of infrastructure projects in which the financial risks are divided among different sectors through a strong organization and, at the same time, the national interests of host country (client) are protected as well.

As the investment and financial need of development of electrical power plants and electrical networks are too high and they could not be satisfied by the traditional methods and domestic resources as well, the other methods should be applied by depending on their incomes and creation of more financial resources, through creation of domestic financial sources in order to rely on the incomes by establishing fair competitions among private sectors, and consequently, lowering the costs of electrical industrial development.

2. Profits in privatization

In privatization when government steps out of many industrial, production and services, leading the blank opportunities to be filled by the private sector, the costs would be decreased very highly.

Due to the amount and nature of participation, different experiences, depending on the strategic importance of infrastructure projects for the governments, can be used in order to attract the private sectors. The degree of participation of private sectors in providing infrastructure services is variable. Table 1 shows different types of

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Table 1
Participation method of private sector and its responsibilities based on participation strategy

Method	Ownership/assets	Operation and maintenance	Investment	Business risk	Duration (year)
Contract management	Governmental	Governmental/private	Governmental	Governmental	3–5
Lease	Governmental	Private	Governmental	Shared	8–15
BOT	Governmental/private	Private	Private	Private	20–30
Privatization	Private	Private	Private	Private	Unknown

participation of private sectors and responsibilities distribution based on their participation strategy from up to down (Shekarchi et al., 2002).

Infrastructure projects of any country form the infrastructures of its economic development and growth. In the developing countries, infrastructure projects mainly do not find a chance of an on-time execution due to high investment needed for them and also during deficit in budget and debt crisis, these are the first items which are sacrificed before public sectors' current costs. Therefore, in most cases, the local sources of these countries do not provide costs of infrastructure facilities. Thus, during the recent few decades some countries have shown an increasing attention to absorb foreign capitals for financing infrastructure projects. In addition to the problem of financing infrastructure projects, the advantages of know-how transfer, learning management experiences, product marketing and projects services, which are gained by foreign investments, emphasize the necessity of absorbing foreign investments.

The infrastructure projects in electrical power industries have two important characteristics: one is taking much time and the other need of a big amount of capital. Therefore, a long time is needed for taking results from capital for performing any activity which needs large investments. For this reason, it has a high risk for the investor.

Participation of private sectors in electrical power industries in developing countries has highly increased during past decades and this industry has been nominated as one of the infrastructure sectors in absorbing private investment, particularly in terms of high return rate of money.

During 1990–1997, the developed countries started participation in private sector in electrical power industries in different levels, from management contracts for installation or governmental ownership into privatization with built-owned-operate (BOO) methods and BOT with utilization and ownership assignment (Douglas, 2002).

3. BOT method (Sekarchi et al., 2002; Douglas, 2002; UNIDO, 1996; GIDB):

BOT is one of the most important methods, which has made infrastructure projects through participation of private sector, particularly foreign investors. The BOT contract is a contract in which the client, which usually is from government part, assigns a private firm with the credit

Table 2
Status of using BOT method

Stages of using BOT	Important executive actions
Identification	Allocation of management team and professional consultant to progress the project
	To identify the project and effective factors
	Feasibility studies
Tender/negotiation	Direct negotiations to sign tenders
	Preparation of governmental for tender
	Preparation of investors for tender
	Nominating tender winner and signing agreements
Development	Establishment of Project Company
	Selection and concluding contracts with the project factors particularly financial institutes
	Issuance of guaranty letters of the government
Execution	Execution of project by the most suitable contract
	Supervision and quality control
	Concluding standard contracts with different teams
Utilization and maintenance	Management control
	Know-how transfer and training of labor forces
	General safety
	Good environmental effects
Assignment	Desirable function of plant, issuance of maintenance guarantee letters

of executing a project or plan within a certain time. The founder of the project undertakes financial, design, construction, repair, and maintenance and utilization responsibilities of a project during a certain period. After expiration of the contract, the privileges and ownership of the project or the plant will be transferred to the government with no extra charges. The founder owns the project during the period of contract runs it and collects the income earned through offering services. These incomes are used for paying utilization costs, payment of principal and interests of loans, paying back the principal capital and the dividends considered by the investors. Table 2 shows executive steps of using BOT method and important arrangements of each stage.

In the process of executing BOT project, after official request of the client or its agent in order to establish and develop a project with this method, the investors (trustees) of private sector start studying the tender documents and feasibility of project execution and they present their offers for tender participations.

In the second stage, after holding tender, performing initial negotiations and attaining a relative certainty of productivity of the project, the trustees and/or investors who are chosen to carry out the project will establish a limited liability company as "Project Company". This, company in fact has the license of BOT project which has been established with the trustees' capital. To provide the remaining capital, the project company includes a financial agreement with bank and/or a reliable financial institute(s) which is (are) interested in giving loan in this area. Signing agreements with client (host government), executive contractor, utilizing company and financial institutes are of the most important duties of the Project Company. This company (project) usually signs an agreement with the government agents (client) to sell the products based on delivery or "take or pay" terms (particularly in electrical power purchase or energy conversion agreements) or any other condition that would protect it against the risks of decrement of income in order to put the investor(s) in the safe side.

The shareholders of the project company, which has been established for development, lenders, and purchasers of products or services presented by the project, utilizing party and the contractor to supply the facilities and execution of construction works of the project are the main shareholders of Project Company. All these partners are connected through a conventional organization, shown in Table 1 and the financial risks are divided among them.

The ordinary derivations of this method, used in privatization of infrastructure projects, are

1. build, operation and transfer (BOT),
2. build, own and operate (BOO),
3. build, own, operate and transfer (BOOT),
4. build, lease, and transfer (BLT),
5. build, operate and sale (BOS).

With respect to the foreign support attraction basis, these structures require establishing a private sector with foreign nationality for planning, financial provision, design, manufacture, utilization and management of the plant.

With respect to the fundamentals of BOT basis, a considerable part of the load burden, including undertaking responsibilities for the investment, design and building the project, will be transferred to the private sector by the government actions. This does not mean that the government's role is limited to the management and leading the project, but it also covers the supply and procurement of the organization for holding tenders as well as the process of selecting investors, which the government deals more than anything else. To determine participants' qualification, application of the offer, tender and detailed negotiations which are led to the investor's selection, these are of the most important processes which are shown in Fig. 1.

Investment assessment includes both economic and financial evaluations. The financial section includes business benefits which in addition to the government, the lenders focus on it, too. Then the economic assessment means the comparison between national costs and social benefits is much important for the government that would lead to awarding the project to the investor by the government. Both these evaluations are similar in as much that they consider the value of money and income and expenditure in their calculations. The net present value (NPV) is the most ordinary method in investment evaluation, particularly financial evaluation of the government of other countries in BOT project; furthermore the levelized value during utilization has been used as the other tool to compare the offers and technical evaluations and it is in fact an assurance of the concerned design and the technology which have been employed as well as its conformity with the international engineering standards.
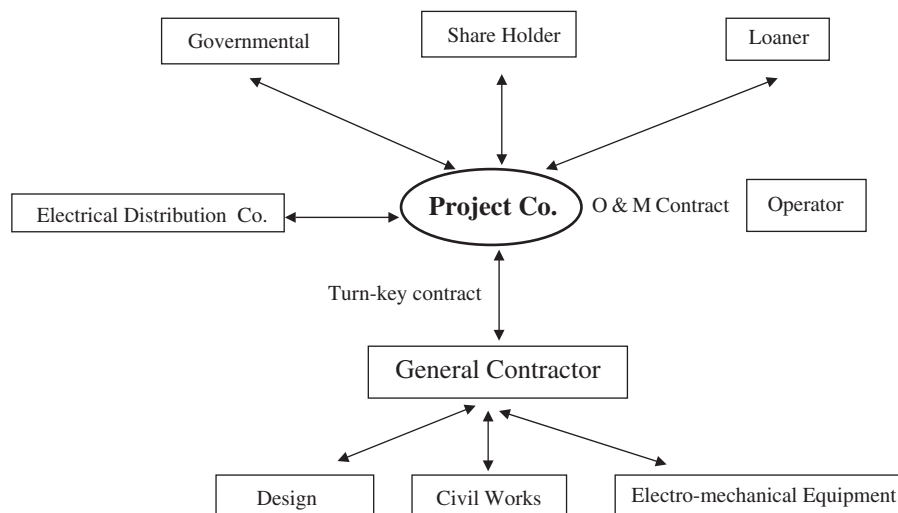

Fig. 1. Contractual structure of a BOT contract.

The liability of the project to be executed in legal terms, its non-discrepancy with the current laws of the host country, possibility to obtain necessary permits for executing the work and careful analysis of the legal effects and consequences are other subjects.

4. BOT application in hydro-power plants

With respect to the strategic importance of hydro-power plant in the economic and social development of the countries, this method has been considered in the international level for power plants, construction and development. Turkey, China, the Philippines, Malaysia, are among the countries that have paid attention to this subject (Country Report—Philippines, 1997; The Philippine BOT law, 1994; Turkish Treasury; Wang et al., 1998).

Recently, Iran has also shown attention to this issue and at present, Pareh-sar combined cycle power plant with 900 MW capacity has been already under establishment in the province of Gilan by using BOT method through joint investment of Iran, Italy and Germany. The second private power plant of the country is under establishment in Aliabad in Golestan province through a consortium made of three investors, Saudi Arabia, England and Japan.

Small and mid-size hydro-power plant projects that require less investment than large power plants have higher priority. An economic evaluation and assessment of consumption cost and the review earned by the project—based on the amount of participation of governmental and non-governmental (private sectors)—play an important role in the transfer or non-transfer to private sector when an infrastructure project, such as establishing a hydro-power plant particularly small and/or mid-size one, is being executed.

5. Economic calculation method

In this section, the method of evaluation of income and costs and, ultimately, the economic analysis of small hydro-power plants (SHPPs) and medium hydro-power plants (MHPPs) are described (Hosseini et al., 2003, 2005). The costs of the project are divided into two categories: investment and annual costs. Investment costs include civil costs, electro-mechanical equipment, power transmission line, and other indirect costs. Annual costs include the depreciation of equipment, operating and maintenance, and replacement costs. The income of the project is based solely on the sale of electrical energy.

The economic basis is considered so that the investor may receive a loan from a financial source and pay it back with a specific interest rate through annual installments during the utilization stage. The economic analysis has been calculated for fully governmental, fully private and governmental-private financings, then the economic indices including benefit to cost ratio (B/C), the NPV, US$/kW h of energy, debt service ratio (DSR), debt coverage ratio (DCR) and return on equity (ROE) have been calculated.

The interest rate has been settled as 8%–10% in order to attract foreign investment in developing countries (Hosseini et al., 2003, 2005). This rate is considered a normal rate by global financial institutes for economic feasibility studies of water resource development. In any case, the effect of interest rate changes is studied by sensitivity analysis, and the results have been presented.

5.1. Investment costs

Direct costs include civil costs, electro-mechanical equipment costs, and power transmission line costs as listed below:

- Civil costs consist of the construction and hydro-structural costs of the project, including a dam, conveyance of water system, the water penstock structure, a headpond, the forebay, the power house, the tailrace structure, the access road and any future unpredicted costs taken from the preliminary designs of a feasibility study.
- Electro mechanical equipment costs include turbines, generators, governors, gates, control systems, a power substation, electrical and mechanical auxiliary equipment, etc.
- Power transmission line costs include a power transmission line for delivering generated energy from power plant to power transmission network. The transmission line cost depends on the location, type of existing system (overhead line or cable system), and capacity of SHPPs and MHPPs as well as length of transmission lines, which have a very high affect on project costs.

Indirect costs include engineering and design (E&D), supervision and administration (S&A) and inflation costs during the construction period.

- E&D costs: these costs are affected by many parameters, such as type, size and the location where the project is being constructed. The E&D costs are usually expressed as a percentage of construction costs, including civil and equipment costs, and the amount of this percent differs from one location to another. Recently, a case study on these SHPPs and MHPPs has shown that this figure could range from 5%, for small- and medium-sized projects, to 8%, for very large-sized projects (Hosseini et al., 2003, 2005; Department of the Army, 1985).
- S&A costs: these costs include the purchase of land, management, inspection and supervision costs, and other miscellaneous costs in the region. Similar to the E&D costs, the S&A costs are expressed as a percentage of the construction costs. A recent case study on SHPPs and MHPPs has shown that this figure could be anywhere from 4% to 7% (Hosseini et al., 2003, 2005; Department of the Army, 1985).
- Inflation costs during construction: to precisely calculate the investment cost of a project, it is necessary to take

into consideration the inflation rate during the course of the project and adjust the investment cost with respect to the inflation rate. The inflation rate of future years should be determined by obtaining the average of previous years' inflation rate.

5.2. Annual costs

To obtain the net benefit of a project, annual costs, in addition to investment costs should be calculated. Annual costs include depreciation of equipment, operating and maintenance (O&M), and replacement and renovation costs.

- Depreciation of equipment: in the economic analysis of the project, depreciation and other factors affecting the equipment should be considered.
- O&M costs: these costs include salary/wages of personnel, labor, insurance, tax, duties, landscape, and consumable materials. These costs are increased only by the annual inflation coefficient. The costs which are related to the salary/wage and consumable materials make up one percent of annual investment costs, and insurance, tax, duties, charges and unpredicted cases are also taken as one percent of annual investment costs. It should be noted that to calculate investment costs, the interest rate during construction should also be considered (Hosseini et al., 2003, 2005; Department of the Army, 1985).
- Replacement and renovation costs: the main parts of the SHPPs and MHPPs, such as generator windings, turbine runners and other parts, will eventually need replacement and renovation. With respect to the nature of these SHPPs and MHPPs, the costs of renovation and reconstruction of equipment at year 25 is taken to be approximately equal to the total value of equipment at time of purchase. To estimate the costs for large-sized power plants, the percentage of wear should be determined for different sections separately so that the calculation of these costs can be done in a more precise way. Table 3 shows the necessary equipments to be replaced during operation period (Hosseini et al., 2003, 2005; Department of the Army, 1985).

5.3. Income and benefits

There are two benefits for the SHPPs and MHPPs: (1) tangible benefits and (2) intangible benefits. The tangible benefit is the sale of electrical energy. Based on approval by country regulators, the purchase of electrical energy from SHPPs and MHPPs has been guaranteed by the country's ministry of energy. The intangible benefits cover the positive environmental effects, flood control, agriculture and irrigation, fish farm pools, camps and recreation centers, etc. which eventually turn into quantitative values. The intangible benefits are not included in this economic analysis of the project, but naturally a more desirable result will be obtained for the economic indices when taking these factors into account (Hosseini et al., 2003, 2005; Department of the Army, 1985).

5.4. Financial and time specifications and methods of capital distribution

Capital depreciation period for construction costs: 50 years
Replacement and renovation of electro-mechanical equipment: 25 years
Duration of construction: 3 years
Annual interest rate: 6–20%
Annual inflation rate: 5%
Table 4 shows the capital distribution during the investment period. This table presents construction time from one to six years (Hosseini et al., 2003, 2005; Department of the Army, 1985). In this table, the

Table 4
Distribution of costs versus construction years

Construction years	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	6 (%)
1	100	–	–	–	–	–
2	77	23	–	–	–	–
3	37	56	7	–	–	–
4	16	62	18	4	–	–
5	9	49	30	9	3	–
6	6	31	40	15	6	2

Table 3
Necessary equipments to be replaced during operation period

Important items to be replaced	SHPP		MHPP	
	Replacement year	Necessity of replacement (%)	Replacement year	Necessity of replacement (%)
Construction of power plant	0	–	38	1
Turbine, generator and governor	39	18	38	24
Electrical accessories	38	80	34	50
Auxiliary system and devices	35	20	24	7
Tailrace	–	0	–	–
Switch yard	38	53	36	43

construction costs are expensed in the relevant subsequent years. Thus, with the effects of interest and inflation, the costs of the subsequent years can be predicted. Social and economic factors could also be included in this calculation. When execution activities begin, the annual payments should be expensed in the midyear, in order to lessen the effect of inflation, thus lowering the investment value. For example, according to Table 4, for a three-year construction project, the percentages of the cost in each year are as follows: 37% of capital in the middle of the first year, 56% in the middle of the second year and 7% in the middle of the third year.

6. Case studies

The case study has been done for two types of hydro-power plant; first the SHPP "Nari" is presented. This SHPP is located in the West Azarbaijan Province of Iran. The SHPP is run-off river type. And second the MHPP "Bookan" is presented. This MHPP is located in the West Azarbaijan Province of Iran. The MHPP is reservoir type and the object is to determine the economical indices.

6.1. Nari small hydro-power plant

The Nari river flow duration curve for different months is given based on the routine daily statistics of the river (Hosseini and Forouzbakhsh, 2005). After doing feasibility studies in different specialized work groups and specifying the determination of the plant layout in the preliminary phase, a channel with a 3.6-km length and a net head of 300 m is being obtained. Furthermore, there is a suitable position for construction of the regulating daily headpond before the penstock entrance at the end of the channel (Ministry of Energy of Iran, Aab-niroo Company, 2002).

There are six alternatives of headpond volumes of 0, 5000, 10 000, 15 000, 20 000 and 25 000 m³ with six different flow rate probabilities of 20%, 30%, 40%, 50%, 60% and 70% on the flow duration curve, making 36 alternatives. After surveying the flow duration curve and different sizes of headponds, 14 alternatives out of 36 are chosen as the best. Alternatives 1 and 2 have a headpond volume of 5000 m³, a designed flow rate of 0.7 m³/s and an installation capacity of 1.75 MW with a flow rate probability of 40% and 60%. Alternatives 3–8 have a headpond volume of 10 000 m³, a designed flow rate of 1 m³/s and an installation capacity of 2.5 MW with a flow rate probability of 20%, 30%, 40%, 50%, 60% and 70%. Alternatives 9–12 have a headpond volume of 15 000 m³, a designed flow rate of 1.5 m³/s and an installation capacity of 3.75 MW with a flow rate probability of 20%, 30%, 40% and 50%. Alternatives 13 and 14 have a headpond volume of 20 000 m³, a designed flow rate of 2 m³/s and an installation capacity of 5 MW with a flow rate probability of 20% and 30% (see Table 5).

The optimal energy calculations have been performed for the 14 possibilities mentioned above. The energy calculation has been designed to include the best position for calculation and evaluation of energies in peak, normal and low load and have been obtained with respect to the capacity of the reserve headponds and river flow rate. In Table 5 the results of the annual energy calculation are given for different alternatives (see Table 5).

The calculated civil works, equipment and total investment costs of the Nari SHPP have been given in Hosseini and Forouzbakhsh (2005). The economic analysis has been carried out considering costs and obtained incomes, according to the given algorithm (Hosseini et al., 2003, 2005). The economic basis is considered so that the investor may receive a loan from a financial source and pay it back with a specific interest rate through annual installments

Table 5
Economic indices of different alternatives with private sector contribution for Nari SHPP

Alternative no.	Installed capacity (kW)	Flow rate probability (%)	B/C					NPV (US$ million)					Final costs (USCent/kWh)
			$P/t^* = 1$	0.75	0.50	0.25	0	$P/t^* = 1$	0.75	0.50	0.25	0	
1	1750	40	2.39	2.18	1.97	1.77	0.97	3.50	2.97	2.45	1.92	0.09	2.79
2	1750	60	2.22	2.02	1.83	1.63	0.91	3.07	2.57	2.08	1.58	−0.22	3.15
3	2500	20	2.82	2.57	2.32	2.07	1.14	5.26	4.55	3.83	3.11	0.42	2.40
4	2500	30	2.61	2.38	2.15	1.92	1.06	4.63	3.97	3.30	2.64	0.18	2.64
5	2500	40	2.43	2.21	1.99	1.78	1.00	4.09	3.47	2.85	2.23	−0.01	2.90
6	2500	50	2.28	2.08	1.87	1.67	0.94	3.66	3.08	2.50	1.92	−0.17	3.10
7	2500	60	2.13	1.94	1.75	1.56	0.88	3.22	2.68	2.13	1.59	−0.33	3.40
8	2500	70	1.93	1.76	1.58	1.41	0.81	2.65	2.16	1.66	1.17	−0.55	3.82
9	3750	20	3.09	2.81	2.53	2.25	2.28	7.28	6.31	5.34	4.37	0.99	2.36
10	3750	30	2.67	2.43	2.19	1.95	1.12	5.83	4.98	4.14	3.29	0.42	2.80
11	3750	40	2.32	2.11	1.90	1.69	0.98	4.58	3.85	3.11	2.38	−0.07	3.28
12	3750	50	2.42	2.20	1.97	1.75	1.04	4.92	4.14	3.36	2.58	0.15	3.40
13	5000	20	2.64	2.40	2.16	1.91	1.12	7.11	6.06	5.01	3.97	0.51	2.93
14	5000	30	2.42	2.19	1.97	1.75	1.04	5.86	4.94	4.01	3.09	0.15	3.33

Note: B/C = benefit cost ratio, NPV = net present value.

during the utilization stage. The economic analysis has been calculated for fully governmental, fully private and governmental-private financings, then the economic indices including B/C, the NPV and energy cost (US$/kW h) have been calculated. The interest rate has been settled as 10% in order to attract foreign investment in developing countries (Hosseini and Forouzbakhsh, 2005). This rate is considered a normal rate by global financial institutes for economic feasibility studies of water resource development. In any case, the effect of interest rate changes is studied by sensitivity analysis, and the results have been presented in Table 6.

With respect to the results presented in Table 6 and studying economical indices, the optimal alternative with a B/C that equals 2.67, an NPV that equals US$5.83 million (for interest rate equal 10% and $P/t = 1$), a USCent/kW h that equals 2.8. With an installation capacity of 3.75 MW are very relatively proportional and the costs of kW h

energy are also at an acceptable limit. For making more clear curves of ratio B/C, NPV, different costs and energy cost versus interest rate for Nari SHPP are given in Figs. 2–5 which may be repeated for Bookan MHPP, too.

For this optimized alternative, DCR and ROE have been calculated and shown in Figs. 6 and 7 and as at the year 25 there are replacement and renovation costs a valley can be seen in the figures.

6.2. Bookan medium hydro-power plant

The simulation has been done for a period of 33 years according to the data extracted from 1964 to 1997. In this case, the monthly net output (output plus overflow) in reservoir and net height in the reservoir for the different months (the difference between the level of water in reservoir and the level of axis of the turbine have been extracted in these periods) have been extracted in this

Table 6
Economic analysis results on alternative no. 10 for Nari SHPP with different interest rates

Interest rate (%)	Unit	6	8	10	12	14	16	18	20
Annual investment	(US$ million)	0.34	0.45	0.57	0.69	0.82	0.96	1.10	1.25
O&M	(US$)	6816	8978	11 325	13 820	16 447	19 194	22 059	25 042
Total annual cost	(US$ million)	0.35	0.46	0.58	0.70	0.84	0.98	1.13	1.28
Energy cost	(USCent/kW h)	1.76	2.27	2.80	3.35	3.90	4.46	5.02	5.58
(B/C) and ($P/t = 1$)		5.11	3.60	2.67	2.08	1.68	1.40	1.20	1.04
(B/C) and ($P/t = 0.75$)		4.65	3.27	2.43	1.89	1.53	1.28	1.09	0.95
(B/C) and ($P/t = 0.5$)		4.19	2.95	2.19	1.70	1.38	1.15	0.98	0.86
(B/C) and ($P/t = 0.25$)		3.72	2.62	1.95	1.51	1.22	1.02	0.87	0.76
(B/C) and ($P/t = 0$)		2.15	1.51	1.12	0.87	0.71	0.59	0.50	0.44
(NPV) and ($P/t = 1$)	(US$ million)	15.66	9.38	5.83	3.67	2.28	1.34	0.66	0.15
(NPV) and ($P/t = 0.75$)	(US$ million)	13.90	8.20	4.98	3.03	1.77	0.91	0.30	−0.16
(NPV) and ($P/t = 0.5$)	(US$ million)	12.13	7.03	4.14	2.39	1.26	0.49	−0.06	−0.48
(NPV) and ($P/t = 0.25$)	(US$ million)	10.36	5.85	3.29	1.75	0.75	0.07	−0.42	−0.79
(NPV) and ($P/t = 0$)	(US$ million)	4.36	1.84	0.42	−0.43	−0.99	−1.37	−1.64	−1.85

Note: P/t = ratio of private sector investment to total in percent, B/C = benefit cost ratio, NPV = net present value.
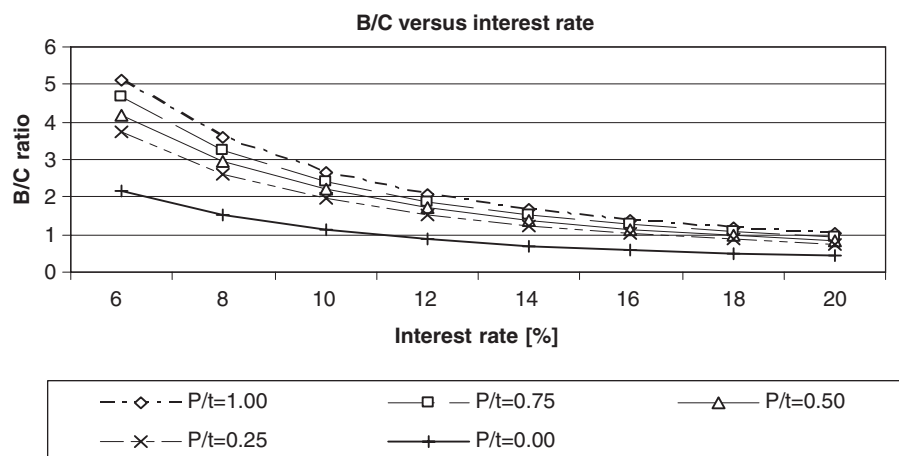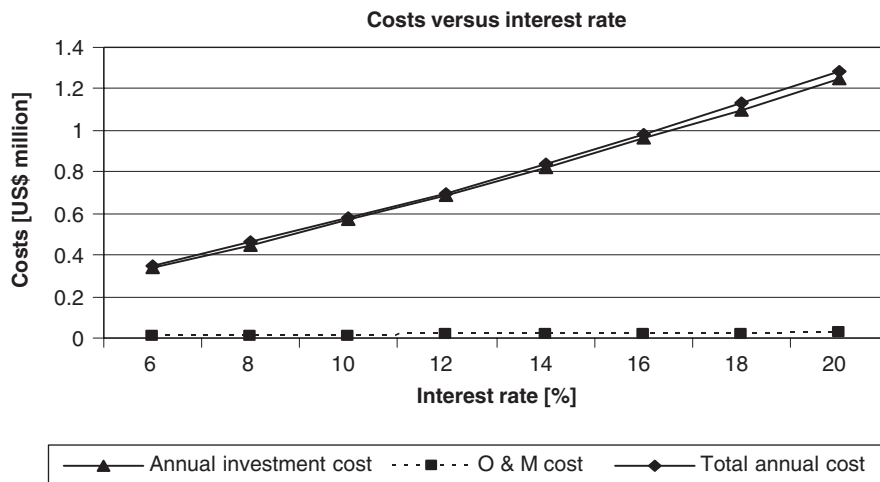

Notice: P/t = Ratio of private sector investment to total in percent
B/C = Benefit Cost Ratio

Fig. 2. Curves of ratio B/C versus interest rate for Nari SHPP.

NPV versus interest rate
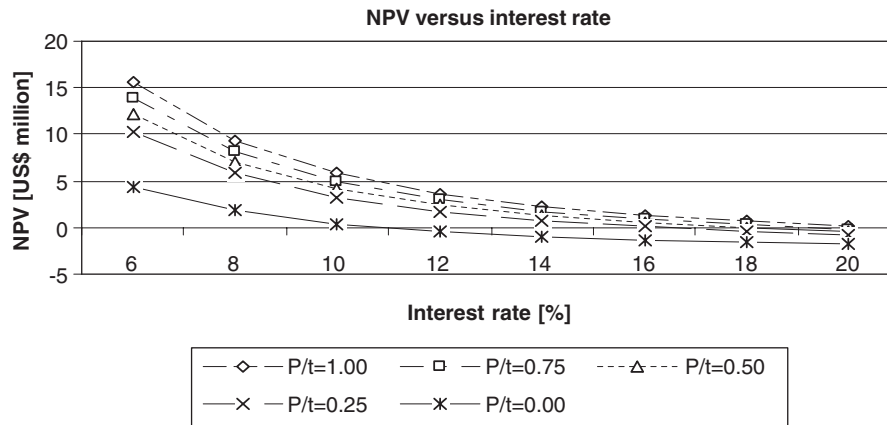
Notice: P/t = Ratio of private sector investment to total in percent
NPV = Net Present Value

Fig. 3. Curves of NPV versus interest rate for Nari SHPP.

Costs versus interest rate

Notice: O & M = Operation & Maintenance

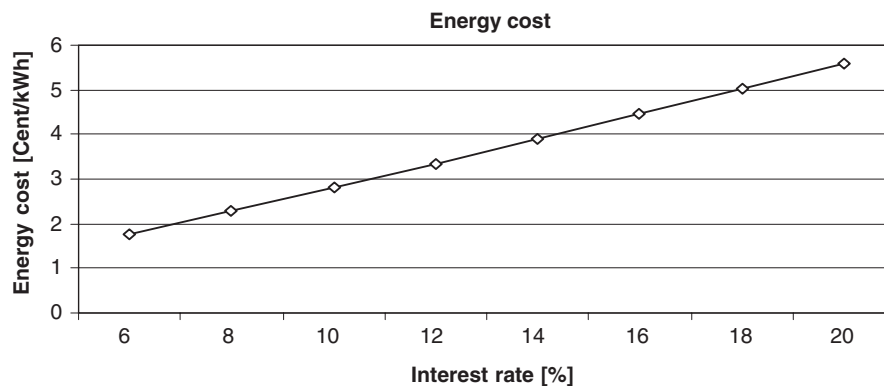Fig. 4. Different costs versus interest rate for Nari SHPP.

Energy cost


Fig. 5. Energy cost versus interest rate for Nari SHPP.

duration. According to the special specification of the plant and the feasibility study, the different alternatives, based on the expertise judgment, have been considered. In these alternatives, the calculated energy is based on the different number of the vertical Francis turbines. Ultimately, the annual energy is being drawn after getting mean value of

Value of DCR index
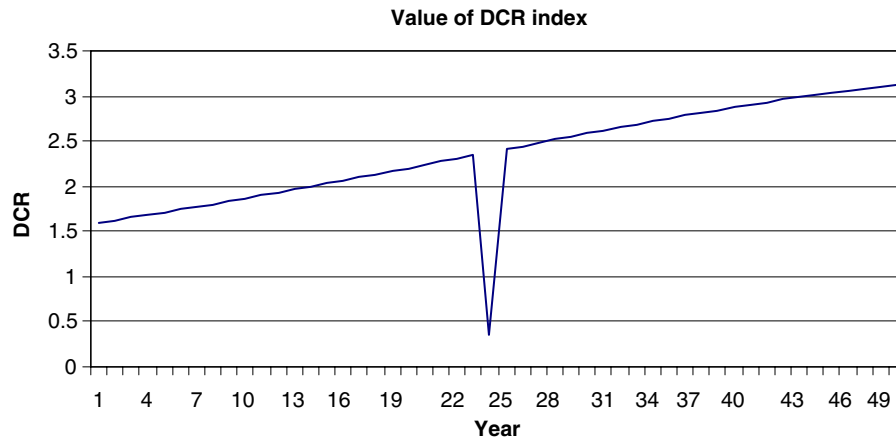
Notice: DCR = Debt Coverage Ratio

Fig. 6. DCR index value for 50 life cycle of Nari SHPP, interest rate = 10%.

Value of ROE index
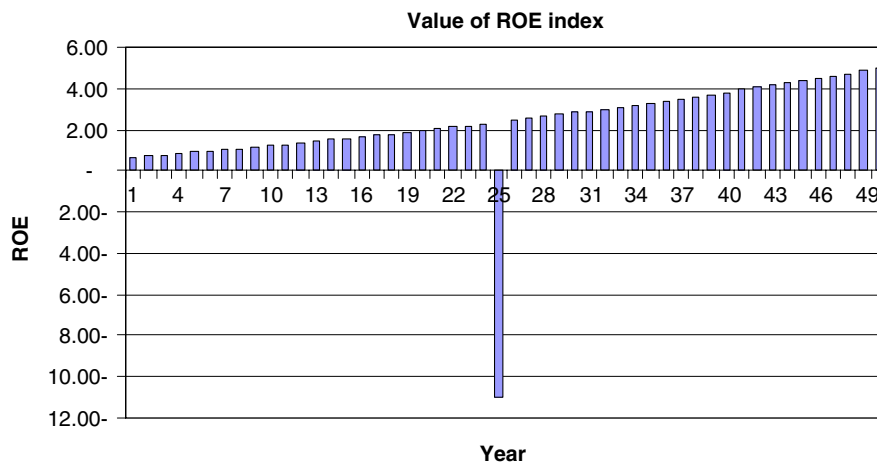
Notice: ROE = Return on Equity

Fig. 7. ROE index value for 50 life cycle of Nari SHPP, interest rate = 10%.

them (Ministry of Energy of Iran, Arab-niroo company, 2002).

The maximum level of water in the reservoir is about 1421 m, and the installation level of turbines is about 1380 m. Therefore, the max height of the MHPP is about 41 m. According to the given recommendations in USBR standards, the constraints of vertical Francis turbine are as below:

- the minimum admitted flow of turbine is about 40% of the designed rated flow,
- the maximum admitted flow of turbine is about 110% of the designed rated flow,
- the minimum operational height of turbine is about 65% of the designed operational height,
- the maximum operational height of turbine is about 125% of the designed operational height.

According to the above-mentioned points, the following results have been extracted:

- the minimum height is about 21.5 m,
- the nominal height is about 32.5 m,
- the maximum permanent overload of the generators is about 10%,
- the accessibility of the MHPP has been considered to be 98%.

Then the results of the calculations for different alternatives have been given in Table 7.

The calculated civil works, equipment and total investment costs of the Bookan MHPP have been extracted from the feasibility study (Hosseini et al., 2005).

The economic analysis has been carried out considering costs and obtained incomes, according to the given algorithm. The economic basis is considered so that the

Value of DCR index

Notice: DCR = Debt Coverage Ratio

Fig. 8. DCR index value for 50 life cycle of Bookan MHPP, interest rate = 8%.

Value of ROE index

Notice: ROE = Return on Equity

Fig. 9. ROE index value for 50 life cycle of Bookan MHPP, interest rate = 8%.

equals 2.60. With an installation capacity of 30 MW, are very relatively proportional and the costs of a kW h energy is also at an acceptable limit.

For this optimized alternative, DCR and ROE have been calculated and shown in Figs. 8 and 9 and as at the year 25 there are replacement and renovation costs a valley can be seen in the figures.

7. Conclusion

1. SHPP and MHPP are in priority in comparison with large power plants due to its mid-term investments and low capacity. For this purpose, the present paper makes an economic evaluation for different percentages of private sector's investment in providing the project costs of a 3.7 MW SHPP and a 30 MW MHPP. The results show that as the share of private sector in investment increases, the B/C and NPV economic sectors improve.

2. The extracted results of this research show that as much as the share of private sector increases the benefit increases as well. Therefore, as a proposal and final conclusion, it is better to keep the government's share in Project Company as low as possible, for instance, 10%. Then after executing a number of similar projects and assuring the good function of private companies, the share of government in investment would be reduced to zero.

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