Optimal Capital Structure Model for BOT Power Projects in Turkey

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Abstract: Interest in the Build/Operate/Transfer (BOT) scheme for infrastructure projects has been growing rapidly, and numerous projects have been implemented around the world. Through BOT projects, a government reallocates the risks and rewards in the development of large infrastructure projects to the private sector. One key aspect to the successful implementation of the BOT concept in any country is the raising of finance by project sponsors. Financial engineering techniques and capital structuring skills are required to find the proper mix of debt and equity and to achieve successful financing for the proposed project. The objective of this paper is to present a simplified model to determine the optimum equity level for decisionmakers at the evaluation stage of a BOT hydroelectric power plant (HEPP) project in Turkey, which takes place immediately after the completion of the feasibility study. The resulting model is the combination of a financial model and a linear programming model that incorporates an objective of maximizing the return of the project from the equity holder's point of view. To show versatility of the model, a real case study is conducted. Thus, this research is concerned with the determination of an equity funding level in BOT project finance. There are different equity levels found in BOT HEPP projects, and there is a need for such a model to determine optimal capital structure, which would assist the project sponsors to ensure that the equity level necessary for optimal capital structure is available prior to the project implementation stage.

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Introduction

In a Build/Operate/Transfer (BOT) project, the project sponsor, often a contractor, is responsible for, among other things, the raising of finance that is necessary for implementing the project. This exercise involves quantitative economic analysis, and the sponsor's financial adviser will prepare the financial model and cash flow analysis involving the projected revenue streams, capital expenditures, and financial charges, etc.

During the project evaluation stage, after the completion of the feasibility study, rigorous financial analysis needs to be conducted. It is important to determine the optimal capital structure, which is important for the successful raising of finance. If the active project sponsor is not capable of injecting the necessary equity to achieve the optimal debt-to-equity ratio, then they should search for additional passive investors until the equity level is enough to provide the optimal capital structure (Dias and Ioannau 1995), or other financing instruments should be implemented such as mezzanine finance. Hence, financial engineering is required in making a project viable under the constraints of financial reality.

In this context, a prototype program, *OPTIMUM*, for decisionmakers has been developed by using macros, built-in functions, and Visual Basic for Application (VBA) modules of Microsoft EXCEL'97 (Bakatjan 2000). The Solver within EXCEL contains a program to solve the linear programming models. This development enhances the usefulness of the model by providing a user friendly template for data entry. The introduction and extensive application of spreadsheet software are "great boons to financial analysts and financial engineering" as stated by Marshall and Bansal (1992). It is worthy to note that the program evaluates a project from the equity holder's (often, contractor) point of view because Jenkins and Marchesini (1999) have shown that when analysis is undertaken from different perspectives, the results of an appraisal of a power project differ.

The motivation for the model development stemmed from the realization that the determination of equity funding levels in BOT project finance is still not well researched. In addition, there are different equity levels implemented in BOT hydroelectric power plant (HEPP) projects. There is the need for such a model to determine the optimal capital structure to assist the project sponsor in the project evaluation stage in determining whether the equity level necessary for optimal capital structure would be available or not.

Formulation of Financial Model

A financial model is a mathematical expression of relationships among financial components. It is used to support decision making in project evaluation. The project viability is analyzed from the equity holders' perspective in the project.

The first step in any investment evaluation is to gather the appropriate information on the project costs and calculate the cash

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flows generated by that project. In the simplest terms, the cash flow is the difference between the money coming in and the money going out of the investment project. ‘‘Every investment opportunity can be fully described by the cash flow that it generates’’ (Marshall and Bansal 1992). The certainty of cash flow determines risk associated with the investment opportunity.

In order to calculate the value of a project over a number of years, after the estimation of the cash flows, one needs to take into account the time value of money. It is a basic principle of finance that money has time value.

Assumptions and Theoretical Framework

The following are the assumptions for the model:

1. The financing of a project is raised by a combination of equity and debt. The availability of funds is assumed to be unlimited, because there is no shortage of funds to raise debt or equity in the power sector, instead there is a lack of bankable projects (Malhotra 1997). In addition, the project in general is a simple and pure investment with a single internal rate of return (IRR). In other words, the net cash flow changes its sign only once. Thus, the net cash flow during the construction period is negative and positive during the operation period.
2. A loan is available from one source or from multiple sources with the same term of annual equal instalments. Because revenues peak quickly for power projects, it is common to employ this form of repayment (Walker and Smith 1995). Moreover, it is assumed that upfront and commitment fees, which are usually 0.5–1.5% of the loan (Wynant 1980), are included in the committed loan amount for the sake of simplicity.
3. There is a grace period of the loan which is equal to the construction duration. Generally, the grace period is equal to the construction duration because of the nonrecourse or the limited recourse financing nature; debt repayment depends only on the project’s revenue.
4. Land expropriation cost can be included in the Base Cost (BC) of the project as an additional cost.
5. The cash flows during construction are preestimated.
6. There are no value added tax (VAT), corporate, and income taxes. The only applicable tax is witholding tax of 11% (including surcharge), which is the most common tax in international lending.
7. The unit prices of electricity are a declining function during the loan repayment period and a constant value after the loan maturity.
8. Complete depreciation of the Total Project Cost (TPC) is allowed during the operation period.

Theoretical Framework

Ranasinghe (1996) has developed a simplified model to calculate TPC for infrastructure projects in developing countries, which is the starting point of the financial model developed in this section.

$$\mathrm{TPC}=\mathrm{BC}+\mathrm{EDC}+\mathrm{IDC} \tag{1}$$

where BC = the base cost or constant value cost of the project estimated at market prices of a predetermined year; EDC = the cost escalation during construction; and IDC = the interest during construction.

$$\mathrm{BC}=\sum_{j=1}^{c} A_j \quad \text{for } j=1,2,\ldots,c \tag{2}$$

$$\mathrm{EDC}=\sum_{j=1}^{c}\left[A_j\prod_{k=0}^{j}(1+\theta_k)-A_j\right] \quad \text{for } j=1,2,\ldots,c \tag{3}$$

where A_j = cash flow for jth year of construction; c = the construction duration in a year; $\theta_o=0$; and θ_k = the escalation rate for the kth year, the time period. (According to Articles 5 and 12 of the concession agreement in BOT hydropower projects in Turkey, escalation rates are equal to the United States Consumer Price All Item Index (CPI) change rate, because all prices are in U.S. dollars. Hence, the forecast escalation is taken as $\theta_k=4.1\%$).

$$\mathrm{IDC}=(1-e)\sum_{j=1}^{c}\left[A_j(1+r)^{G-j+1}\prod_{k=0}^{j}(1+\theta_k)-A_j\prod_{k=0}^{j}(1+\theta_k)\right] \quad \text{for } j=1,2,\ldots,c \tag{4}$$

where e = the equity fraction of the current value cost; G = the grace period of debt, which is equal to c; and r = the interest rate of the loan. Hence,

$$\mathrm{TPC}=e\sum_{j=1}^{c}A_j\prod_{k=0}^{j}(1+\theta_k)+(1-e)\times\left[\sum_{j=1}^{c}A_j(1+r)^{c-j+1}\prod_{k=0}^{j}(1+\theta_k)\right] \quad \text{for } j=1,2,\ldots,c \tag{5}$$

It is a common practice that equity drawings during construction are calculated as a portion of TPC (Bakatjan 2000). In other words, the financing cost (IDC and EDC) as well as BC of a project are shared between investors and lenders. Thus

$$E_i=e\left[eA_j\prod_{k=0}^{j}(1+\theta_k)+(1-e)A_j(1+r)^{c-j+1}\prod_{k=0}^{j}(1+\theta_k)\right] \quad \text{for } j=1,2,\ldots,c \tag{6}$$

where E_j = equity drawing in ith year of construction.

After the completion of construction, revenue is generated from electricity sales during the operation period, m, which is fixed as 20 years for BOT HEPPs. (This is stated in Article 14, Tender Specification for BOT HEPP Projects by the Ministry of Energy and Natural Resources.) The net annual cash available in current value given by NCA_i, can be estimated as

$$\mathrm{NCA}_i=\mathrm{PBIT}_i-\mathrm{TAX}_i+\mathrm{DEP}_i-D_i \quad \text{for } i=1,2,\ldots,m \tag{7}$$

where PBIT_i = Profit Before Interest and Tax; TAX_i = Tax; DEP_i = Depreciation; and D_i = Annual Debt Installment for ith year.

There is an 11% withholding tax including surcharge applicable for interest. As assumed, there are no income and corporate taxes.

$$\mathrm{TAX}_i=(\mathrm{PBIT}_i-\mathrm{INT}_i)\times 0.11 \quad \text{for } i=1,2,\ldots,m \tag{8a}$$

where INT_i = interest to be paid in the ith year. The writers assumed annual equal installments of debt, D_i; therefore

$$D_i=(1-e)x\mathrm{TPC}\times\frac{r(1+r)^N}{(1+r)^N-1} \quad \text{for } i=1,2,\ldots,m \tag{8b}$$

$$\text{DPR}_i = D_i \times (1+r)^{-(N-i+1)} \quad \text{for } i = 1,2,\ldots,m \qquad (8c)$$

(White et al. 1989).

DPR_i = debt principal for ith year (payment for the principal debt at ith year), and N = debt repayment period. As a rule, $N \cdot m$.

$$\text{INT}_i = D_i - \text{DPR}_i \quad \text{for } i = 1,2,\ldots,m \qquad (8d)$$

Substituting Eq. (8b) and (8c) into (8d) will result

$$\text{INT}_i = (1-e)\text{TPC} \times \frac{r(1+r)^N}{(1+r)^N - 1} \times [1-(1+r)^{-(N-i+1)}]$$

$$\text{for } i = 1,\ldots,m \qquad (8e)$$

Substituting Eq. (8e) into Eq. (8a)

$$\text{TAX}_i = \left\{ \text{PBIT}_i - (1-e)\text{TPC} \times \frac{r(1+r)^N}{(1+r)^N - 1} \times [1-(1+r)^{-(N-i+1)}] \right\} \times 0.11$$

$$\text{for } i = 1,2,\ldots,m \qquad (9)$$

Depreciation is a noncash expense: it only reduces taxable income and provides an annual tax advantage equal to the product of depreciation and the (marginal) tax rate, but it does not lead to a cash outflow from the company.

The most common method for depreciation is straight-line depreciation. Under this method, annual depreciation equals a constant proportion of the initial investment. In this model, it is assumed that TPC can be depreciable in its entirety. Thus

$$\text{DEP}_i = \frac{\text{TPC}}{m} \quad \text{for } i = 1,2,\ldots,m \qquad (10)$$

$$\text{PBIT}_i = R_i - \text{OM}_i - \text{DEP}_i \quad \text{for } i = 1,2,\ldots,m \qquad (11)$$

where R_i = annual revenue, and OM_i = annual operation and maintenance costs.

$$R_i = U_i P_i \quad \text{for } i = 1,2,\ldots,m \qquad (12a)$$

U_i = unit price of electricity (U.S. cents/kW·h, which is the electricity sale price of the project company to TEA, Turkish Electricity Authority). P_i = net annual energy production (kW·h) determined in the feasibility study. (It is agreed by the parties that the payment basis in the Power Purchase Agreement (PPA) by TEA is based on this capacity, without considering whether this level of electricity generation is achieved or not.)

There are two types of unit price: the first is tariff during the loan repayment period, the other is tariff after the loan maturity. There is a practice of using different tariffs for different years during the loan repayment period. In this model, we assume the following declining function of tariffs during the loan period for the sake of simplicity in calculations. Hence

$$U_i = U_1 \times 0.95^{(i-1)} \quad \text{for } i \leqslant N \qquad (12b)$$

$$U_i = U_2 \quad \text{for } i > N \quad \text{for } i = 1,2,\ldots,m \qquad (12c)$$

where U_1 = the highest electricity tariff for the first year of concession; and U_2 = the lowest electricity tariff for the last year of concession.

Therefore

$$U_{av} = \frac{\Sigma_{i=1}^{m} U_i}{m} = \frac{U_1 \times \Sigma_{i=1}^{N} 0.95^{(i-1)} + U_2 x (m-N)}{m}$$

$$\text{for } i = 1,2,\ldots,m \qquad (12d)$$

The lowest tariff, U_2, is defined from the condition of financial viability of the project; $\text{PBIT}_i \geqslant 0$ at the end of the concession period. Thus

$$(P_{20} x U_2 - \text{OM}_{20} - \text{DEP}_{20}) = 0$$

$$\therefore \qquad (12e)$$

$$U_2 = \frac{\text{OM}_{20} + \text{DEP}_{20}}{P_{20}}$$

Therefore, the highest tariff, U_1, will be

$$U_1 = \frac{U_{av} \times m - U_2 \times (m-N)}{\sum_{i=1}^{N} 0.95^{(i-1)}} \quad \text{for } i = 1,2,\ldots,m \qquad (12f)$$

Operation and Maintenance cost includes OM material and spare parts cost, personnel salaries, indirect costs, and insurance cost. Because the civil works portion of TPC largely depends on geologic and hydrologic condition of the project site, OM cost is a function of Electromechanical Cost (EMC) of the project. It is observed that OM is usually 3–4% of EMC in practice.

Substituting Eqs. (10) and (12a) into Eq. (11)

$$\text{PBIT}_i = U_i P_i - \text{OM}_i - \frac{\text{TPC}}{m} \quad \text{for } i = 1,2,\ldots,m \qquad (13a)$$

Consequently

$$\text{NCA}_i = 0.89(U_i P_i - \text{OM}_i) + 0.11\frac{\text{TPC}}{m} - \left[(1-e)\text{TPC} \times \frac{r(1+r)^N}{(1+r)^N - 1} \right] [0.11 + 0.89(1+r)^{-(N-i+1)}]$$

$$\text{for } i = 1,2,\ldots,m \qquad (13b)$$

The viewpoint of equity holders is focused on the main project metrics, internal rate of return and Net Present Value (NPV). The IRR and NPV are the most common and fundamental economic decision criteria employed in practice (Lohmann 1988).

The NPV from the equity holder's point of view, is

$$\text{NPV} = -\sum_{j=1}^{c} \frac{E_i}{(1+d)^{j-1}} + \sum_{i=1}^{m} \frac{\text{NCA}_i}{(1+d)^{i+c}}$$

$$\text{for } i = 1,2,\ldots,m \quad \text{for } j = 1,2,\ldots,c \qquad (14)$$

where m = concession period; c = construction duration; E_j = equity drawing in ith year of construction; NCA_i = net annual cash available in jth year of operation; and d = the discount rate.

To calculate the present value of an investment project, we discount the expected future cash flows by the rate of return offered by comparable investment alternatives. This rate of return is often referred to as the *discount rate,* hurdle rate, *or opportunity cost of capital*. It is the return forgone by investing in the project rather than investing in securities. The selection of the discount rate is one of the crucial aspects of engineering economic analysis (Park and Sharpe-Bette 1990). Marshall and Bansal (1992) defined the discount rate as the opportunity cost of money to the party considering the investment. Hence, from the equity holder's point of view, the discount rate is the interest rate generated by investing the capital in a capital market (Jackson 1996). Birge and Zhang (1999) stated that "the market price of risk is the premium that investors must receive over the risk free rate to incur the market risk." In addition, according to Lohmann and Baksh

(1993) ''the reduction in risk of ruin attained by . . . increasing the-risk adjusted discount rate.'' Because the investment cost and revenue are in current United States dollars term 12% discount rate (if United States bond yields are 9% per annum in 2000, then 3% risk premium per annum is accepted), they are generally accepted in the BOT HEPP projects in Turkey from the equity holder's point of view.

The lender's main criteria for a project's financial viability is the Debt Service Coverage Ratio (DSCR): the ratio of annual cash available at hand to annual total debt service. It is calculated as

$$\mathrm{DSCR}_i=\frac{\mathrm{PBIT}_i+\mathrm{DEP}_i-\mathrm{TAX}_i}{D_i}\quad \text{for}\quad i=1,2,\ldots,m \qquad (15a)$$

Hence

$$\mathrm{DSCR}_i=\frac{0.89(U_iP_i-\mathrm{OM}_i)+0.11\left(\frac{\mathrm{TPC}}{m}+(1-e)\mathrm{TPC}\times\frac{r(1+r)^N}{(1+r)^N-1}\times[1-(1+r)^{-(N-i+1)}]\right)}{(1-e)\mathrm{TPC}\times\frac{r(1+r)^N}{(1+r)^N-1}}\quad \text{for}\quad i=1,2,\ldots,m \qquad (15b)$$

Formulation of Linear Programming Model

Linear Programming (LP) models are extensively used in capital budgeting (Park and Sharpe-Bette 1990). The objective is to maximize IRR, ''the best way to compute a rate of return for an investment...'' (Marshall and Bansal 1992).

In this model, optimal capital structure is the mix of debt and equity that maximizes IRR from the equity holder's point of view, with the following constraints:

1. Minimum equity amount allowed by legislation is 20%. (This is stated in Article 6 of Decree No. 94/5907 of the Council of Ministers related to the implementation of the BOT Law No. 3996.)
2. IRR must be greater than the discount rate. In other words, NPV must be positive.
3. PBIT should be always greater than zero, for financial viability of the project.
4. Average DSCR should be at least equal to 1.50. Koh et al. (1999) stated that DSCR in the range of 1.10 to 1.25 is bankable, 1.30 to 1.50 is satisfactory and comfortable, and above 1.50 is preferable. Interviews with the managers of some private power companies in Turkey show that the preferred minimum average DSCR by international financial authorities is 1.50, due mainly to the current country credit rating of Turkey. (At the end of 1999, Turkey's foreign currency long-term sovereign credit rating was affirmed by Standard and Poor as ''B,'' and outlook on the long-term rating has been revised to positive to stable, this reflects the possibility of an upgrade.)
5. Average electricity tariff should be not be greater than 5.0 cents/kW·h and the highest tariff should be less than or equal to 10.0 cents/kW·h, which is the upper economic limit of the purchase price for TEA, without additional finance. The unit price of electricity in Turkey is at the same level as in developed countries, on average, 7–8 United States cents/kW·h. According to the recent survey by TEA, electricity losses during distribution could reach about 20%. For comparison purposes, the global average is 10%. Approximately 30% of the unit price is general expenses and profit for TEA. Thus, the average unit sale price of electricity should not exceed 5 cents/kW·h from TEA's perspective, $U_{av}\leqslant 5$ cents/kW·h.

In the early years of BOT development, the government pursued the policy of accepting high tariffs to boost development. However, it is clear now that there should be an upper limit for U_1 because now some financial difficulties are faced by TEA, due to the previously signed concession agreements and PPAs with high initial and average tariffs. It is obvious that electricity purchases at a higher price than the electricity tariff charged to end customers will require additional sources of funds for TEA to compensate for its losses. This, in turn, will overburden the government budget. Hence, the upper limit for U_1 should be less than the highest tariff to the end-user, $U_1\leqslant 10$ cents/kW·h.

This is a ''win-win'' solution for a BOT HEPP project: to find an optimal equity level that maximizes equity holder's IRR without sacrificing the other parties' interest.

The first constraint is a legal constraint; the subsequent two constraints determine the financial viability of the project from the equity holder's point of view. The remaining two are constraints set for lenders and purchasers of the product to feel comfortable in this deal.

Generally, IRR, DSCR, and the electricity tariff are not linear functions of equity. However, they can be approximated as linear functions of equity up to the correlation coefficient square of 0.97, which is reasonable.

Consequently, the linear programming model is

$$\text{Objective function:}\quad \text{Maximize IRR}=f(E) \qquad (16)$$

$$\text{Constraints:}\quad \text{Subject to}\quad e\geqslant 0.20 \qquad (17)$$

$$\mathrm{IRR}\geqslant 12\quad \text{or}\quad \mathrm{NPV}\geqslant 0 \qquad (18)$$

$$\text{for}\quad i=1,2,\ldots,m$$

$$\text{for}\quad j=1,2,\ldots,c$$

$$\sum_{i=1}^{m}\mathrm{DSCR}_i\geqslant 1.50\times m \qquad (19)$$

$$\text{for}\quad i=1,2,\ldots,m$$

$$U_{av}\leqslant 5\ \text{Cents/kW}\cdot\text{h} \qquad (20)$$

$$U_1\leqslant 10\ \text{cents/kw}\cdot\text{h}$$

An automated computer spreadsheet solution is suitable to model the formulation of the objective function and constraints for LP and solve the problem. *OPTIMUM*, a simplified financial and LP model using Microsoft EXCEL 97's (a popular commercial spreadsheet application) built-in functions, macros, and VBA modules, has been developed by Bakatjan (2000). In the model,

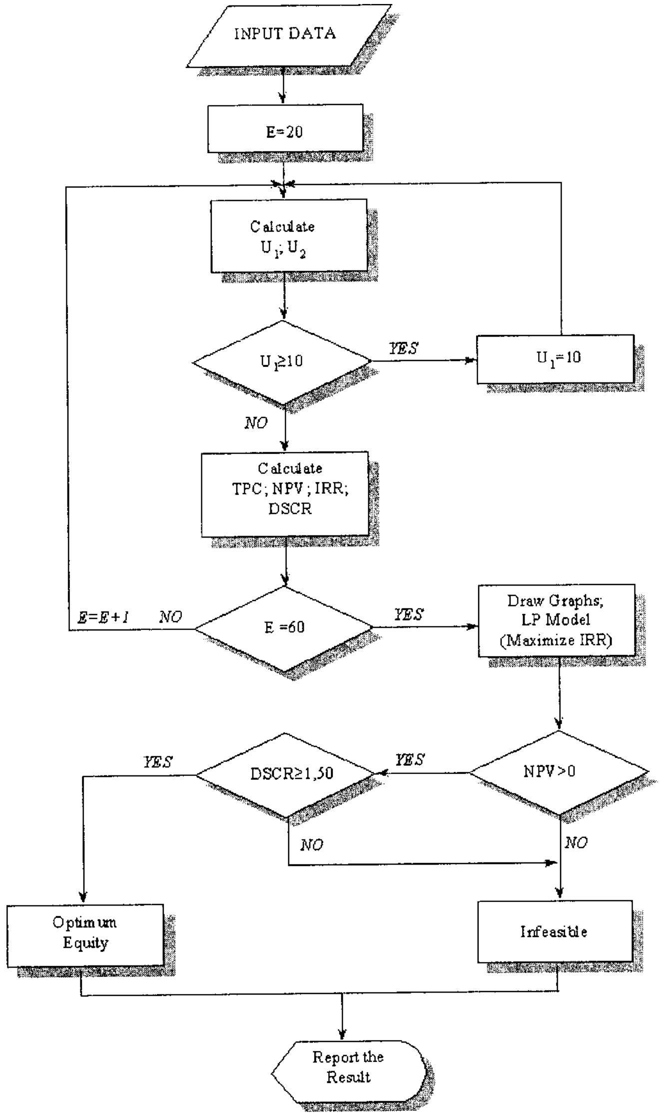

Fig. 1. Flow chart diagram for *OPTIMUM*

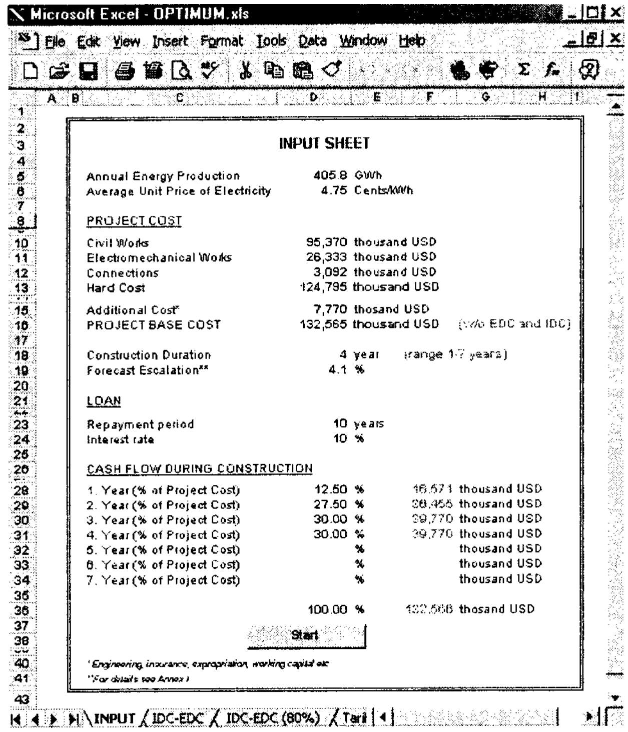

Fig. 2. Input data for base case

links between input data, the financial model, and the LP model are established by writing macros in EXCEL and a small program written in VBA to ensure automation in. After the completion of the input data, the program develops the financial model, formulates the LP objective function, and constraints automatically. Subsequently, it solves LP.

Input Data and Working Principle of Model

The model inputs are

1. Estimated base cost (in thousands of U.S. dollars)
   a. Civil works,
   b. Electromechanical works,
   c. Connections, if any (there may be a need to establish connection line(s) to the main transmission grid),
   d. Additional cost (engineering, insurance, expropriation cost, etc.).
2. Construction duration and cash flows
   a. Construction duration (c) in years,
   b. Cash flows during construction (as % of BC for each year).
3. Loan terms
   a. Loan repayment period (N, years),
   b. Loan interest rate (r, %).
4. Operation
   a. Estimated annual production (P_i, GW·h),
   b. Average unit price of electricity, cents/kW·h (this is particularly important to win the bid).

Based on the above inputs, the program automatically deals with the changing debt-to-equity ratio. Using Eq. (12e), U_2, hence, U_1, then TPC, NPV, IRR, and DSCR are calculated for each debt-to-equity ratio, and their graphs are plotted as the linear functions of equity.

The equity drawn during construction is taken as negative, and the dividend is taken as positive in the IRR equation. The solution is found using the EXCEL built-in function, which employs an iterative method that clearly depends on starting values. Theoreti-

Table 1. The Lowest and Highest Tariff Calculations at 20 and 60% Equity

Tariff calculation	20% Equity	60% Equity
Lowest tariff for last year of concession		
Annual depreciation, (thousands United States dollars)	8,519	7,821
Annual O and M cost (thousands United States dollars)	790	790
Total, DEP+OM	9,309	8,611
Annual energy production, P (GW·h)	405.8	405.8
Lowest tariff, $U_2=(\text{DEP}+\text{OM})/P$ (cent/kW·h)	2.29	2.12
Highest tariff for last year of concession		
Average tariff (cent/kW·h) to win the bid	4.75	4.75
Sum of the coefficients, $\sum_{i=1}^{10} 0.95^{(i-1)}$	8.025	8.025
Highest tariff, U_1 (cent/kW·h)	8.98	9.19

Table 2. Comparison of Interest During Construction and Total Project Cost at 20 and 60% Equity (in thousands of United States Dollars)

Construction period (year)	1	2	3	4	Total
20% Equity					
Cash flow based on base cost	16,570	36,455	39,770	39,770	132,565
Debt amount (80%)	13,257	29,164	31,816	31,816	106,053
Interest during construction	6,153	10,461	7,537	3,735	27,887
Escalation during construction	—	1,495	3,328	5,095	9,918
Total project cost (TPC = BC + IDC + EDC) = 170,370					
Cash flow during construction (*A*)	21,296	46,852	51,111	51,111	170,370
Debt drawing during construction (80%)	17,038	37,481	40,889	40,889	136,297
Equity drawing during construction (20%)	4,259	9,370	10,222	10,222	34,073
60% Equity					
Cash flow based on BC	16,570	36,455	39,770	39,770	132,565
Debt amount (40%)	6,628	14,582	15,908	15,908	53,026
Interest during construction	3,076	5,231	3,769	1,868	13,944
Escalation during construction	—	1,495	3,328	5,095	9,918
Total project cost (TPC = BC + IDC + EDC) = 156,427					
Cash flow during construction (*A*)	19,554	43,017	46,928	46,928	156,427
Debt drawing during construction (40%)	7,821	17,207	18,771	18,771	62,570
Equity drawing during construction (60%)	11,732	25,811	28,157	28,157	93,857

cally, there may be as many solutions as the power of the respective polynomial; however, it is solved for a local solution close to the assumed discount rate.

Then, using EXCEL's built-in Solver, the LP is solved, and the optimal equity level, and hence, the optimal capital structure is determined. The flow chart diagram for *OPTIMUM* is shown in Fig. 1. Based on the result, decisionmakers can decide whether to go ahead by themselves, take new sponsors to raise the equity, or use mezzanine finance for optimal capital structure immediately after the feasibility study. Hence, the model gives great advantage for promoters to start negotiation with other potential sponsors, i.e., financial institutions, both in terms of time and money.

Case Study

This section illustrates the application of *OPTIMUM* to a real-life project. The project is at the negotiation stage; hence, the results can be compared. Due to commercial confidentiality, the name and location of the project will not be mentioned. The base cost of the project is $132,565,000, with a civil works cost of $95,370,000, and an electromechanical cost of $26,333,000, including contingencies of 10% for civil works and 5% for EMC. There are also interconnections with the transmission grid, with a cost of $3,092,000 and an additional cost of $7,770,000 for engineering, insurance, expropriation, and working capital costs. The duration for construction is estimated as 4 years. It is planned that 12.5% of the total construction works is to be completed in the first year, and 27.5, 30, and 30% in the following years. According to the feasibility report, the annual net energy production is 405.8 GW·h. (This is not real net production, but it is the base for payments that will be entered in PPA.) To win the bid, the average unit price of electricity is forecast as 4.75 cents/kW·h.

The base case is the estimation based on the projected cash flows (Ross et al. 1995). Hence, the optimal capital structure of

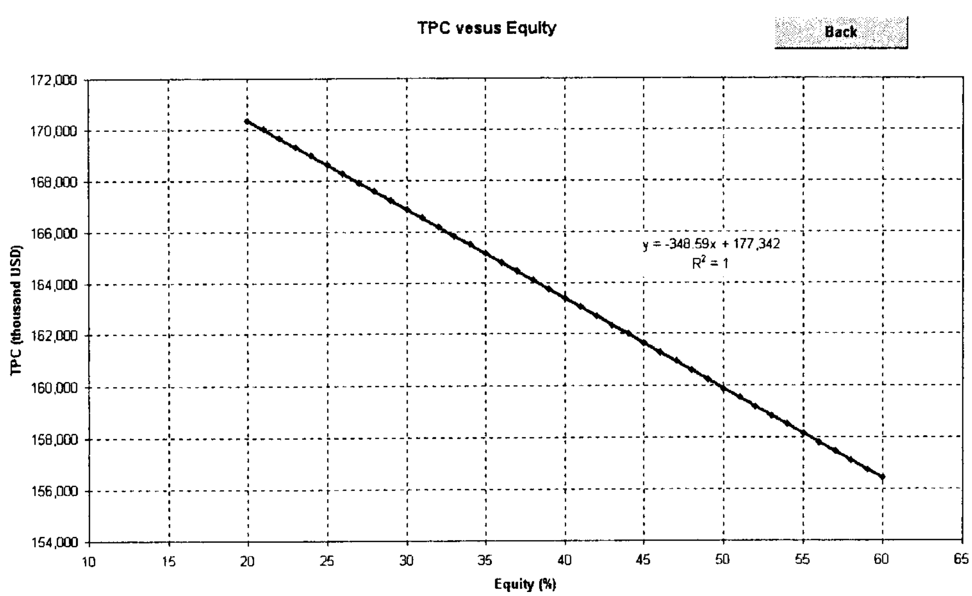

Fig. 3. TPC as function of equity

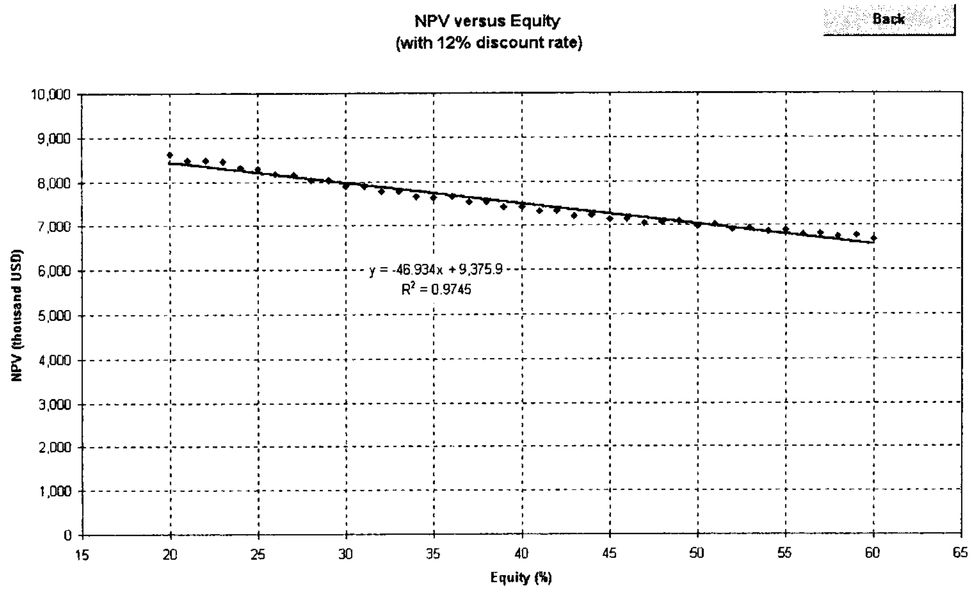

Fig. 4. NPV as function of equity

the project is determined using the forecast input data. Input data for the base case is shown in Fig. 2.

After the completion of the input, the lowest and the highest tariffs, TPC, NPV, IRR, and DSCR are calculated for each debt-to-equity ratio from 80–20 to 40–60. Calculation of the highest and the lowest tariffs and comparison of IDC and TPC at 20 and 60% equity is given in Tables 1 and 2.

Finally, TPC, NPV, IRR, and DSCR are plotted as the functions of equity level (Figs. 3, 4, 5, 6). The corresponding linear equations and correlation coefficient squares (R-squares) are shown in the figures.

Table 3. Result of Linear Programming Model

Model	Equity (%)	IRR (%)	NPV (thousands of United States Dollars)	DSCR
LP	31.69	14.94	7,888.61	1.50
Financial	31.69	14.74	7,810.30	1.47

As expected, TPC is a linear function of equity with negative slope, because less debt in capital structure means less interest during construction, accordingly, TPC is a declining function of equity. As a result, more equity means less TPC, thus, less total investment cost for a project. This is one of the reasons why the government favors high equity. With the discount rate of 12%, NPV is also a declining function of equity, with positive value for all equity levels for this particular case. Hence, it is not a critical constraint for the optimal capital structure in this case. IRR is also a declining function of equity. That is why the sponsor of the project tends to keep equity as low as possible to increase its return.

The only ascending function of equity is $DSCR_{av}$. As equity increases, debt obligation decreases; hence, $DSCR_{av}$ increases.

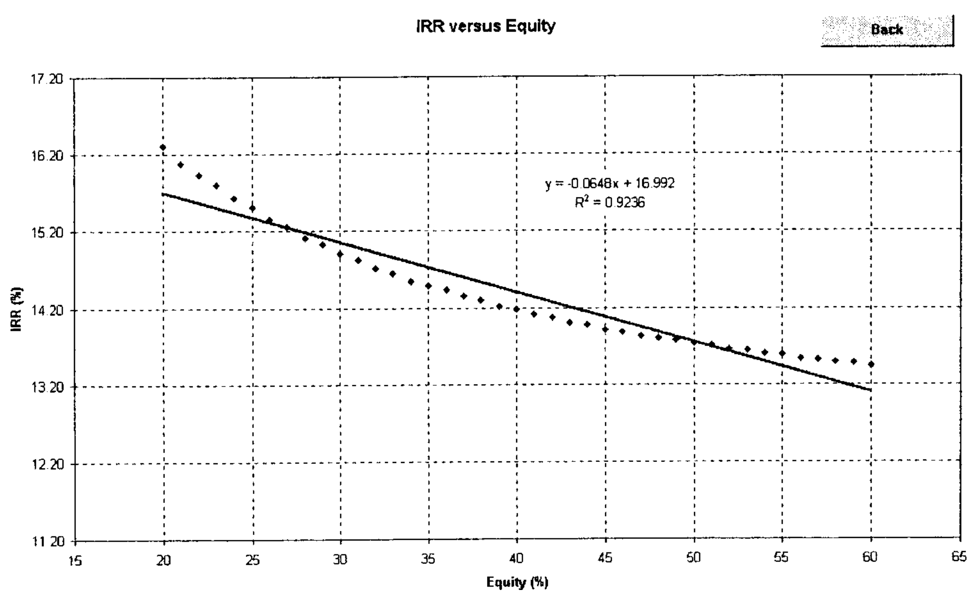

Fig. 5. IRR as function of equity

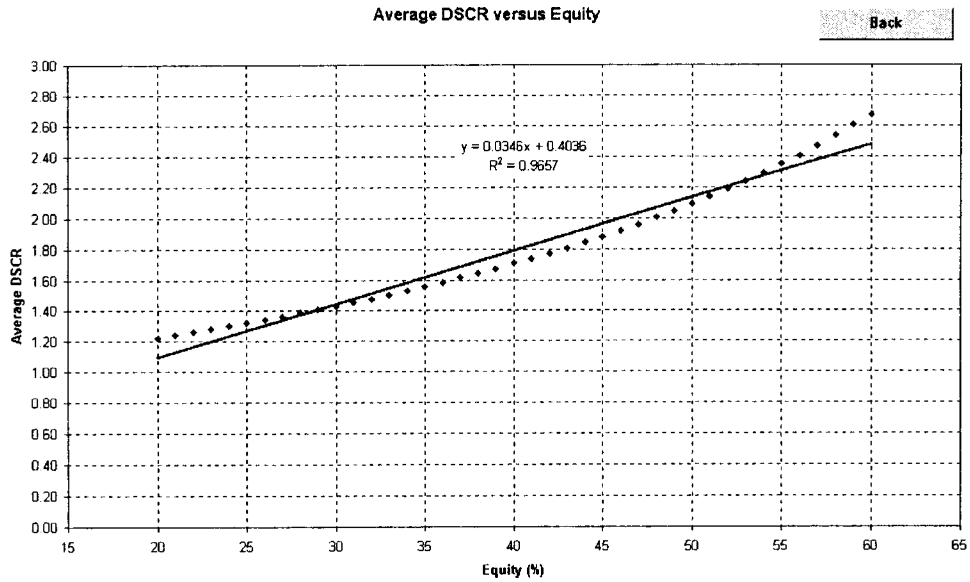

Fig. 6. $DSCR_{av}$ as function of equity

Table 4. Debt Principal and Interest Calculations at Optimal Capital Structure ($E=31.69\%$)

Debt repayment period, N (year)	1	2	3	4	5	6	7	8	9	10
Annual equal debt payment, D	18,487	18,487	18,487	18,487	18,487	18,487	18,487	18,487	18,487	18,487
Debt principal	7,128	7,840	8,624	9,487	10,435	11,479	12,627	13,890	15,279	16,806
Interest charge[a]	11,359	10,647	9,863	9,000	8,052	7,008	5,860	4,597	3,208	1,681

Note: Compounding interest factor = 0.163.

[a]On average debt beginning and end of period.

Table 5. Debt Service Coverage Ratio Calculation at Optimal Capital Structure ($E=31.69\%$)

Debt repayment period, N (year)	1	2	3	4	5	6	7	8	9	10
Profit before interest and taxes	27,579	25,745	24,004	22,349	20,774	19,281	17,860	16,513	15,231	14,013
Depreciation	8,315	8,315	8,315	8,315	8,315	8,315	8,315	8,315	8,315	8,315
Tax	1,784	1,661	1,556	1,468	1,399	1,350	1,320	1,311	1,323	1,357
Total cash available (PBIT + DEP − TAX) (C)	34,110	32,399	30,763	29,196	27,690	26,246	24,855	23,517	22,223	20,971
Debt interest payment	11,359	10,647	9,863	9,000	8,052	7,008	5,860	4,597	3,208	1,681
Debt principal payment	7,128	7,840	8,624	9,487	10,435	11,479	12,627	13,890	15,279	16,806
Total debt repayment (D)	18,487	18,487	18,487	18,487	18,487	18,487	18,487	18,487	18,487	18,487
DSCR (C/D)	1.85	1.75	1.66	1.58	1.50	1.42	1.34	1.27	1.20	1.13

Note: Average DSCR = 1.47.

Table 6. Financial Cash Flow Statement for Optimal Capital Structure from Equity Holder's Point of View (Thousands of United States Dollars)

Year	1	2	3	4	5	6	7	8	9	10	11	12	20
Electricity tariff (cent/kW·h) (average 4.75)	9.04	8.59	8.16	7.75	7.36	7.00	6.65	6.31	6.00	5.70	2.24	2.24	2.24
Annual energy production, P (GWh)	405.8	405.8	405.8	405.8	405.8	405.8	405.8	405.8	405.8	405.8	405.8	405.8	405.8
Revenue	36,684	34,850	33,109	31,454	29,879	28,386	26,965	25,618	24,336	23,118	9,106	9,106	9,106
Depreciation (linear)	8,315	8,315	8,315	8,315	8,315	8,315	8,315	8,315	8,315	8,315	8,315	8,315	8,315
O and M expenses 3% of EMC	790	790	790	790	790	790	790	790	790	790	790	790	790
Profit before interest and taxes	27,579	25,745	24,004	22,349	20,774	19,281	17,860	16,513	15,231	14,013	—	—	—
Interest charge on debt	11,359	10,647	9,863	9,000	8,052	7,008	5,860	4,597	3,208	1,681	—	—	—
Profit before tax	16,220	15,098	14,141	13,349	12,722	12,273	12,000	11,916	12,023	12,332	—	—	—
Withholding tax 11%	1,784	1,661	1,556	1,468	1,399	1,350	1,320	1,311	1,323	1,357	—	—	—
Net profit	14,436	13,437	12,585	11,881	11,323	10,923	10,680	10,605	10,700	10,975	—	—	—
Depreciation	8,315	8,315	8,315	8,315	8,315	8,315	8,315	8,315	8,315	8,315	8,315	8,315	8,315
Cash flow	22,751	21,752	20,900	20,196	19,638	19,238	18,995	18,920	19,015	19,290	8,316	8,316	8,316
Debt principal	7,128	7,840	8,624	9,487	10,435	11,479	12,627	13,890	15,279	16,806	—	—	—
Total cash available for shareholders (NCA)	15,623	13,912	12,276	10,709	9,203	7,759	6,368	5,030	3,736	2,484	8,316	8,316	8,316
(6,821) (15,007) (16,372) (16,372)	15,623	13,912	12,276	10,709	9,203	7,759	6,368	5,030	3,736	2,484	8,316	8,316	8,494

Note: Optimum equity, $E=31.69\%$; NPV@12% = 7,810.90; IRR = 14.74%.

Table 7. Average DSCR Constraint and Optimal Capital Structure

Average DSCR	Optimum equity level (%)	IRR (%)
1.50	31.69	14.94
1.45	30.24	15.03
1.40	28.80	15.13
1.35	27.35	15.22
1.30	25.91	15.31
1.25	24.46	15.41

Thus, a high $DSCR_{av}$ requirement by lenders results in high equity for the project.

Accordingly, the LP model is

Objective function: Maximize $IRR = -0.065E + 16.992$

Subject to: $E \geqslant 20$

$$-46.93E + 9{,}375.87 \geqslant 0$$

$$0.035E + 0.404 \geqslant 1.50$$

where E is the equity as percentage of TPC.

The model automatically employs the EXCEL Solver to solve the LP. The LP result is provided in Table 3, and is to be compared with the financial model's result at optimum equity. Consequently, for this particular project, equity for optimal capital structure is 31.69%.

There are slight differences between NPV, IRR, and DSCR calculated by the financial model and the linear programming model due to the linear approximation that is negligible.

Calculations of debt principal (DPR), debt interest (INT), and DSCR at the optimal capital structure ($E = 31.69\%$) are given in Tables 4 and 5. It is worthwhile to note that these parameters, as well as TPC, NPV, and IRR, are automatically calculated for each debt-to-equity ratio by *OPTIMUM*.

A cash flow statement from the equity holder's point of view is given in Table 6 for optimal capital structure. It should be noted that in the last row the equities drawn during the construction period are shown in parentheses because they are negative.

It can be concluded that the major constraint for the optimal capital structure is DSCR. The main constraints for Turkey's ratings are a fragmented political environment, very limited fiscal flexibility, and vulnerability to external shocks. According to Standard & Poor, it is possible to upgrade Turkey's rating if fiscal adjustment and disinflation measures in the IMF (International Monetary Fund) standby agreement are implemented. If Turkey's current credit rating is upgraded, then the DSCR requirement will be lowered; hence, optimum equity will fall below 25% (Table 7), near to the legal minimum requirement.

Conclusion

In this research, a prototype program *OPTIMUM* for decisionmakers is developed. The program evaluates a project from the equity holder's (often, contractor) point of view. As a result, the program allows decisionmakers to make early decisions for capital structuring, hence association structuring to get the optimal capital structure. To show the applicability of the model, a real case study is conducted.

The following conclusions are drawn from the case study:

- As expected, TPC is a function of equity with negative slope. Less debt in capital structure means less interest during construction, accordingly, TPC is a declining function of equity. As a result, more equity means less TPC, and thus less total investment cost for a project. This is one of the reasons why government favors high equity.
- With the discount rate of 12%, NPV is also a declining function of equity with positive value for all equity levels for this particular case. Hence, NPV is not a critical constraint for optimal capital structure in this case. Internal rate of return is also a declining function of equity. That is why the sponsor of the project tends to keep equity as low as possible to increase its return.
- The only ascending function of equity is the average debt service coverage ratio. As equity increases, debt obligation decreases, hence $DSCR_{av}$ increases. Thus, a high $DSCR_{av}$ requirement by lenders results in high equity in the project.

It can be concluded that the major constraint for the optimal capital structure is DSCR. According to Standard & Poor, it is possible to upgrade Turkey's current credit rating if fiscal adjustment and disinflation measures in the International Monetary Fund standby agreement are implemented. If Turkey's rating is upgraded, the DSCR requirement will be lowered, and the optimum equity could fall below 25%, near the legal minimum requirement.

References

Bakatjan, S. (2000). "Financial engineering for BOT power projects: A simplified model for optimal capital structure," MS thesis, Middle East Technical University, Ankara, Turkey.

Birge, J. R., and Zhang, R. Q. (1999). "Risk-neutral option pricing methods for adjusting constrained cash flows." *Eng. Econom.*, 44(1), 36–49.

Dias, A., Jr., and Ioannou, P. G. (1995). "Debt capacity and optimal capital structure for privately financed infrastructure projects." *J. Constr. Eng. Manage.*, 121(4), 404–414.

Jackson, T. (1996). "Risk, time and the discount rate." *The 1996 Annual Meeting of the Society for Risk Analysis-Europe*.

Jenkins, G. P., and Marchesini, M. (1999). "An analysis of electricity generation and tariff options in Ghana." *Dev. Discuss. Paper No. 702*, Harvard Institute for International Development, Cambridge, Mass.

Koh, B. S., Wang, ShouQing, and Tiong, L. K. R. (1999). "Qualitative development of debt/equity model for BOT infrastructure projects." *Proc., Int. Conf. on Constr. Proc. Reengrg. (CPR-99)*, 501–512.

Lohmann, J. R. (1988). "The IRR, NPV and the fallacy of the reinvestment rate assumptions." *Eng. Econom.*, 33(4), 303–330.

Lohmann, J. R., and Baksh, S. N. (1993). "The IRR, NPV and payback period and their relative performance in common capital budgeting decision procedures dealing with risk." *Eng. Econom.*, 39(1), 17–47.

Malhotra, A. K. (1997). "Private participation in infrastructure: Lessons from Asia's power sector." *Fin. and Dev.*, 34(4), 33–35 ⟨http://www.worldbank.org/fandd/⟩ (Nov. 10, 1999).

Marshall, J. F., and Bansal, V. K. (1992). "Valuation relationships and applications." *Financial engineering*, New York Institute of Finance, Allyn and Bacon Inc., New York, 63–103.

Park, C. S., and Sharp-Bette, G. P. (1990). *Advanced engineering economy*, Wiley, New York.

Ranasinghe, M. (1996). "Total project cost: A simplified model for decision makers." *Constr. Manage. Econom.*, 14, 497–505.

Ross, S. A., Randolph, W. W., and Jordan, B. D. (1995). "Project analysis and evaluation." *Fundamentals of corporate finance*, 3rd Ed., Richard D. Irvin Inc., Ill., 266–273.

Walker, C., and Smith, A. J. (1995). *Privatized infrastructure: The Build Operate Transfer approach*, Thomas Telford, London.

White, J. A., Agee, M. H., and Case, K. E. (1989). *Principles of engineering economic analysis*, 3rd Ed., Wiley, New York.

Wynant, L. (1980). "Essential elements of project finance," *Harvard Business Rev.*, May-June, 1980, 165–173.