A CASE STUDY ON INVESTMENT EVALUATION OF A PRIVATE SECTOR PROJECT WITH GEOTECHNICAL RISKS

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ABSTRACT : This paper focuses on construction cost volatility for the purpose of private sector investment by use of a financial model with key indices of IRR and DSCR (Debt Service Coverage Ratio). A case project, 1,000 MW pumped storage hydropower plant, has shown that its financial impacts by cost volatility of underground works are less measured than interest rates impacts by interest rate of loans. Probabilistic analysis of costs under geotechnical conditions has been made by Indicator Kriging method. And, in the modeling of interest rates, geometric Brownian motion has been applied. Both of these impacts are measured on the same financial model.

Key words : Construction Cost, Volatility, Cashflow, Debt Service Cover Ratio

1. INTRODUCTION

In the BOT projects where normally project finance scheme is often used, construction contracts are generally made as EPC turnkey contracts which include engineering (design), procurement and construction under the single company's responsibility with fixed prices. Though plant type constructions such as thermal power generating plants, which consist largely of factory made parts and on-site installations, are developed by project finance, civil works oriented projects with abundant natural risks such as underground works still suffer from non (or limited) recourse project financing due to vague risk allocation rules between owners and contractors. In such contract structures, investors cannot foresee returns even in stochastic manner, or lenders (banks) hesitate to provide loans because of difficulties in quantifying the volatility of the asset (loan) as a part of their portfolio unless repayment guarantees by credible sponsors. Contractors' financial capacities are also limited for accepting such risky construction works as private sector companies. This paper discusses probabilistic expressions by "geostatistics" [1] for construction costs under such natural risks as geological conditions and propose a methodology to evaluate the effect of those risks by cashflow analyses which sponsors and lenders normally conduct for their investment.

2. COST VOLATILITY OF UNDERGROUND STRUCTURES

2.1 Cost volatility due to geological conditions

Among many factors of cost variations, this study focuses on cost volatility by occasional changes of support patterns of tunnels and an underground cavern for power generators. To cope with natural risks for civil works such as "unforeseeable geological condition", besides civil works insurance, price adjustment by re-measurement or change order have been generally applicable with recoursing of the risks to owners which are normally public sector entities. Having a "deep financial pocket", public sector owners have had little discussion so far on probabilistic forecasts of construction cost volatility with financial capability of price increase to the extent of normally anticipated changes of support patterns. In case of private sector companies including contractors, owners as SPCs (Special Purpose Companies) for PFI schemes and commercial banks for lending are involved, even the anticipated cost variations can be often unacceptable to their financial or investment operations unless quantitative assessment of balances of risks and returns especially in case that non (or limited) recourse loans are applied.

Under such project financing circumstances, authors have developed and propose a stochastic valuations model of cost volatility due to geological conditions by "geo-statistics".

2.2 Stochastic cost modeling of underground works

Kriging or indicator Kriging methods [2] can be applied to geometrically or dynamically estimate cost parameters such as depths of underground rock lines or payment classifications of tunnel excavation order to know costs of unforeseen work areas by using borehole data and explanatory works.

In this paper, a pumped storage hydropower plant is adopted for the case project [3] of which tailrace tunnels and an underground powerhouse cavern are analyzed for estimation of cost volatilities with changing support patterns along with tunnel driving based on RMR (Rock Mass Rating) values and corresponding rock classifications evaluated by indicator Kriging. Though details of the model are given in the reference [2], its context is described below.

Under the definitions that x_i is the location of a sample point and a value for estimation is z, information z for estimation is supposed to be given as a range of the values between a and b as the equation (1) describes.

$$z(x_i) < a \quad \text{or} \quad z(x_i) \geq b \tag{1}$$

In the next step, indicators $I\ (x_i;\ z_k)$ are defined for all values at sampling points x_i in the area where non-exceedance probabilities are acquired at previously set sill values. As shown in the equation (2), when the value x_i is estimated to exceed a sill value z_k, the indicator is given 0 whereas the indicator 1 is given when z is under z_k.

$$I(x_i; z_k) = \begin{cases} 1 & if \quad z(x) \leq z_k \\ 0 & if \quad z(x) > z_k \end{cases} \tag{2}$$

As shown in the equation (3), the expected value of indicator I $(x_i;z_k)$, which is a cumulative distribution function of $z(x)$, is independent from the locations of sampling points.

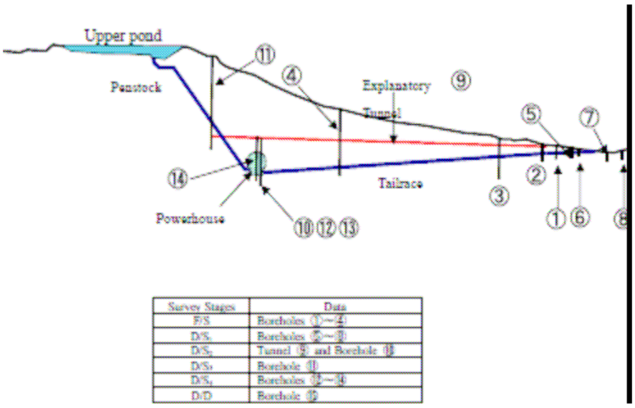
$$\begin{aligned} E[I(x_i; z_k)] &= 1 \cdot prob[z(x_i) \leq z_k] + 0 \cdot prob[z(x_i) > z_k] \\ &= prob[z(x_i) \leq z_k] \\ &= F(z_k) \end{aligned} \tag{3}$$

where, $F(z_k)$ is cumulative probability distribution function.

Non-exceedance probability $I^*(x_0;\ z_k)$ correspondent to a sill value z_k of a certain property at any targeted point is the summation of multiples by indicators $I\ (x_i;\ z_k)$ and property values z_k for all sampling points x_i in the area for analysis as given in the equations (4) with (5).

$$I^*(x_0; z_k) = \sum_{i=1}^{n} \lambda_i(z_k) I(x_i; z_k) \tag{4}$$

$$\sum_{i=1}^{n} \lambda_i(z_k) = 1 \tag{5}$$



Survey Stages	Data
F/S	Boreholes ①~④
D/S$_1$	Boreholes ⑤~⑧
D/S$_2$	Tunnel ⑨ and Borehole ⑩
D/S$_3$	Borehole ⑪
D/S$_4$	Boreholes ⑫~⑬
D/D	Borehole ⑭

Figure 1. Case project and staged surveys

where, $\lambda_i(z_k)$ is weighting multipliers when the sill is set as z_k. On the assumption that stationarity of second moment of indicator values, defining the indicator value $I\ (x;\ z_k)$ for the location x and I $(x+h;\ z_k)$ for the location with a distance of h, the indicator semi-variogram, which means a spatial distribution of indicator values between these two points, is expressed as the equation (6).

$$\gamma_{z_k}(h) = \frac{1}{2} E[I(x+h; z_k) - I(x; z_k)] \tag{6}$$

This semi-variogram is independent from locations as the equation (3) shows. Then, in order to calculate the unknown weight values in the equations (4) to (6), non-exceedance probabilities $I^*(x_0;z_k)$ are acquired as well as $\lambda_i(z_k)$ and μ by using Lagrange multiplier μ which minimizes errors.

The estimated standard deviation σ_{zk} of errors at the specific point x_0 is given as the equation (7) with vectors h_{i0} which are defined by two points x_0 and i (i=1,2,⋯, n) with surveyed information. Thus variance of RMR values is acquired.

$$\sigma_{z_k}^2 = \sum_{i=1}^{n} \lambda_i \cdot \gamma_{z_k}(h_{i0}) + \mu \tag{7}$$

Then the cost variance is given by estimated unit costs for respective rock classification which is related to RMR values. Data for RMR estimation are given on six stages by the results of exploratory tunneling and boreholes respectively as shown in Figure 1. By analyzing volatility of costs for tailrace tunnels and powerhouse cavern based on all survey processes, exceedance probabilistic distributions (risk curves) are acquired and shown in Figure 2. These probabilistic distributions appear in between absolute minimum and maximum costs which are given in the respective conditions of minimum support and fully armed supports along whole length of underground works.

According to the results by indicator Kriging, though optimistic and pessimistic scenarios can be expressed, smooth curves of probabilistic functions cannot be given based on combinations of fixed sill values and distributions by insufficient parameters such as RMR. It can be further noted that the deviations between the most likely scenario and optimistic or pessimistic scenario are not symmetrical [2].

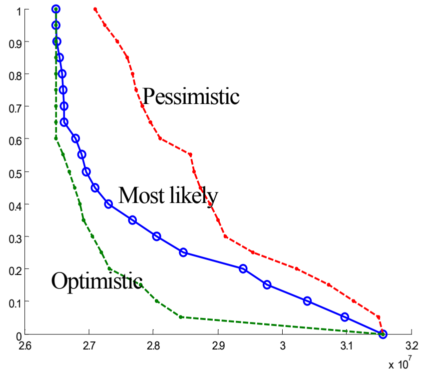


Figure 2. Exceedance probability of costs (Tailrace tunnels and powerhouse cavern)

3. CASE PROJECT ANALYSIS

3.1 Estimation method of probabilistic distribution of construction costs

When cost volatility originated from geological conditions is estimated, which can be shown as Figure 2, a new definition of volatility is necessary since the type of its distribution is unknown. Ohtsu, *et al*, proposed a new way of definition for this volatility based on the relation between construction costs and probabilities of exceedance [2]. Construction cost variation risk R is expressed as the equations (8) and (9) according to the newly developed concept.

$$R = Max\left[R_u, R_d\right] \tag{8}$$

$$\begin{aligned} R_u &= C_{0.5} - C_{0.9} \\ R_d &= C_{0.1} - C_{0.5} \end{aligned} \tag{9}$$

In the equation (8), $Max[*]$ means the maximum value of *. $C_{0.1}$, $C_{0.5}$ and $C_{0.9}$ mean construction costs at the probabilities of exceedance 0.1, 0.5, and 0.9 respectively on the risk curve. R_u and R_d represent upside and downside risks respectively in the equation (9). Since the relations between construction costs and non-exceedance probabilities are unsymmetrical, a concept that cost volatility V can be expressed as the equation (10) on the assumption that the mean value of the construction cost is $C_{0.5}$ which is coincident to the exceedance probability 0.5.

$$V = R / C_{0.5} \tag{10}$$

The risk curve in Figure 2 shows that $C_{0.5}$=27 MUSD (Millions of US Dollar) and V=(28.8-27)/27=6.7% for a couple of tailrace tunnels and an underground powerhouse cavern of the case project.

3.2 Estimation of construction cost volatility

Outlines of the case project

In addition to cost variations originated from geological conditions were discussed so far, an overall construction cost of the project include open earth works of which costs may be relatively foreseeable and fixed equipment costs under usual lump-sum contract not like underground civil works. In such project, volatility by focused underground geological conditions gives only a partial effect on the total cost. Table 1 shows the project composites and their costs.

The case project, a 1,000 MW pumped storage hydropower plant for peak power supply, is composed of an upper pond, intakes, penstocks, underground powerhouse, tailrace tunnels, outlet works and existing lower reservoir with an effective water head of 357 m. Most of structures are designed underground for environmental conservation of the local area [3].

A public sector owner with deep financial backgrounds usually procures construction works under BOQ (Bill of Quantities) type contract with payment adjustment by change of quantities. The original construction contract for civil works of the case project is also BOQ type based on FIDIC (Red book). In this study, however, development and business scheme by private sector companies is supposed to examine the possibility of such private development as an IPP (Independent Power Producer) which has recently been popular for power sector world widely.

Table 1. Cost of case project

Unit : Millions US Dollar (as of 1995)

	C_{mean}	C_{fix}	C_{var}
1. Prep. works	7.17	7.17	-
2. Environmental mitigations	9.20	9.20	-
3. Civil works	150.02	132.21	17.81
3. 1 Temporary works	7.93	7.93	-
3. 2 Upper pond	54.56	54.56	-
3. 3 Penstock tunnels	11.15	9.68	1.47
3. 4 Powerhouse	29.93	16.46	13.47
3. 5Tailrace tunnel	28.63	25.76	2.87
3. 6 Switchyard	2.89	2.89	-
3. 7 Outlet works	12.36	12.36	-
3. 8 Control buidg.	2.57	2.57	-
4. Gates / pipes	60.08	60.08	-
5. Turbine / Generator	179.47	179.47	-
6. Transmission line	30.73	30.73	-
7. Indirect/overheads	53.95	53.95	-
Total	490.62	472.81	17.81

Note : Total C_{mean}= 95.64 MUSD whereas 4.8MUSD (V=5%) and 9.6 MUSD (V=10%).

As shown in Table 1, under lump-sum contracts, no cost variation for the project is anticipated for contract lots except civil works. Thus cost variation is mainly discussed on civil works. Among civil works, upper pond, switchyard, outlet works, access roads and architectural structures which all contain open works with geological risks as well as underground works. Since these cost variations are relatively easier to know by detailed surveys and possible to make fixed price contract with large and experienced contractors without payment adjustment. This is assumed in this study and the reason that these work items are fixed costs in Table 1.

Cost variation risk of civil works

As Table 1 shows, the cost for civil works reaches only up to 30.6% of the total project cost. Furthermore, cost for support works in underground structures which gives variation share only 3.6% of the total project cost. If it is considered that a power project as a basic economic commodity supplier is run with expected returns under highly efficient and competitive circumstances, even this level of investment cost volatility must be carefully examined. Actually there is little example of a turn-key contract for such a large scaled civil construction project which contains substantial amount of underground works. This means obviously the importance of risk evaluations on underground works.

Besides geological conditions, cost volatility implies many factors such as increases of labor and material costs (market risks), delay of permits (political risks), and unforeseeable weather during construction (natural risk)[4]. Among market risks, the effect by commodity price increase on investors' returns can be alleviated with a path-through clause in the contract between a public sector power offtaker and private plant owner by use of CPI (Consumer Price Index) or WPI (Wholesale Price Index). Permit delay risks, in a sense, represent the capabilities of developers and/or contractors to deal with communications with local communities and administrative authorities. Natural risks, typically called as Force Majeure, have been compensated by civil works insurances so far.

4. EVALUATION METHOD OF INVESTMENT AND LENDING

4.1 Risks to be quantified

Since a pumped storage power plant which is usually valued as the installed capacity, power sales revenue are not regarded as risk item in this study. And the valued price of the pumped storage power plant is, as a matter of course, affected by power prices in the grid which may be largely dependent on fuel (oil , natural gas and/or coal) market prices. This study places the assumption that this kind of market volatilities are to be taken by the power offtaker and are not be discussed here.

4.2 Model for analysis

In a privately developed project, every risk is examined on a chashflow model as financial impacts. According to Graham, *et al*, who surveyed investment criteria in a business from the interviews to 392 CFOs, IRRs (Internal Rate of Return), NPV(Net Present Value), hurdle rate, payback periods, sensitivity analysis, and others in order are mainly referred to [5]. Among these criteria such as IRR, NPV and hurdle rate have a concept of discounted values in the time domain on cashflow. In the consideration of such normal practices, this study uses IRR for the investment criteria. There are plural types of IRRs such as project IRR, equity IRR and dividend IRR. Among these, IRR on equity is adopted for analysis in this study because this is the key concern by project investors. On the other hand, lenders (banks) focus on the security of loan repayment. For this purpose, normally DSCR (Debt Service Coverage Ratio) is important and focused as well in the study.

Authors developed a financial model for the case project with financial statements of the SPC (Special Purpose Company, the project owner sponsored by investors) containing a balance sheet, income statement and cashflow statement on Excell spread sheets based on the accounting rule of GAAP (Generally Accepted Accounting Principles) which is designated and regularly reviewed by FASB (Financial Accounting Standards Board). In the financial model, exchange rates (during construction and business operation), start of construction in January 1995, start of commercial operation in January 2000, 30 years of business operation, unit price of plant revenue of 7,000 MUSD/MW/month, 25% of equity of total fund, loan currencies are 1:1 for local and foreign procurement with the interest rates of 12 % and 6 % respectively as fixed value, and loan repayment period is 12 years by equal annuity repayment, are assumed. EPC (Engineering, Procurement and Construction) cost is 490.62 MUSD as given in Table 1. There are other assumptions to make a financial model which are not discussed here for the purpose of sensitivity analysis. The results of base case analysis from the model are shown in Table 2.

4.3 Results of financial analysis

Cost volatility caused by geological conditions

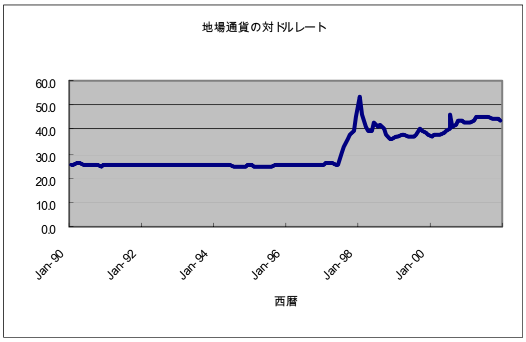
Though the volatility V of tailrace tunnel and powerhouse cavern cost was 6.7 % as mentioned in the section 3.1, a total underground cost volatility caused by geological conditions should include the effect by penstock tunnels. Due to lack of data around penstocks for indicator Kriging analysis, the total underground cost volatility is supposed as 5 % and 10 % downside for sensibility analysis on the cashflow model. C_{mean} value is regarded as the most likely cost. This analysis brought the results as shown in Table 2 with the impact by change of support patterns caused by geology on IRRs at 0.41% (V=10%) and 0.03 on DSCR downwards respectively.

Table 2. Results from financial analysis
(by geological risk)

Case	IRR on Equity	Min. DSCR
Base Case	13.28 %	1.23
V=4.8 MUSD(5%)	13.07 %	1.21
V=9.6MUSD(10%)	12.87 %	1.20

Foreign exchange risk

Before measuring currency exchange risk, macroeconomic understandings are important on this regard. The country where the case project is located changed its foreign currency policy in November 1984 from US Dollar peg to currencies basket index policy. However, the basket has been still US Dollar oriented. Anticipating the pressurized adjustment with domestic currency and US Dollar, speculators withdrew their money from the country and the government was obliged to change foreign currency exchange policy in a short time accordingly in July 1997. This resulted in the jump of exchange rate as shown in Figure 3. Since industries such as power generation business earn domestic currency in stead of hard currency expenditure for major equipment import, offtaking contract itself is required to be made



Source：IMF, International Financial Statistics

Figure 3. Historical exchange rates
(Case project country)

in hard currency basis for payment to the services as a normal practice. For this reason, this study has excluded to measure exchange rate risk.

Interest rate risk

Among many studies on floating interest rates in the market by “financial engineering”, Chan, *et al*, described various types of stochastic differential equations and their pros and cons [6]. Though domestic currency interest rates are occasionally inconsistent due to and during a large change of country’s macroeconomic structures as well as exchange rate discussion, this study discusses interest rate volatility because practically the service offtaker does not take this risk. The future forecast and historical records of interest rates are shown in Figure 4.

A simple model for floating interest rates is shown as the equation (11) where the increments of interest rates are composed of a trend line with the coefficient μ plus arithmetic Brownian motions governed by a normal distribution with the a SD (standard deviation) σ.

$$dSt / St = \mu dt + \sigma dZt \tag{11}$$

This equation has a defect that negative interest rates might be given depending on paths by Brownian motions. For this reason, a geometric Brownian motion (logarithmic normal process) is applied. With the definition that the logarithm of interest rate drifts by Brownian motions with an SD of σ, a model where the variation of interest rates are relatively narrow and not less than zero is often used. Being the logarithm of interest rates defined as $f(S,t)$ as described in the equation (12), df is given as the equation (13).

$$f(S,t) = \ell nSt\ . \tag{12}$$

After the preparation first and second order differential functions around S, the interest rate increment df is acquired as shown in the equation (13).

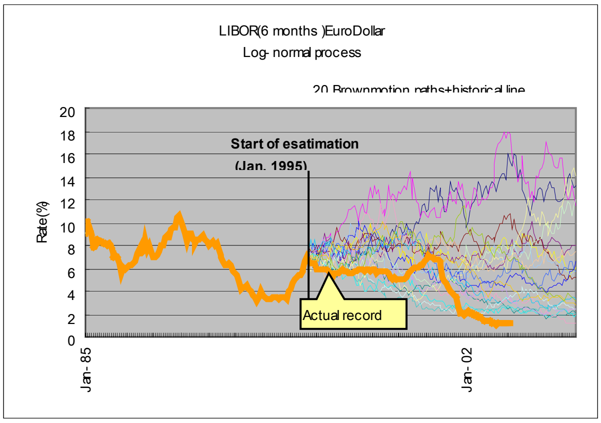


Figure 4. Historical and forcasted interest rate (LIBOR)

$$df = \left(\frac{\partial f}{\partial S} \cdot \mu S + \frac{\partial f}{\partial t} + \frac{1}{2} \frac{\partial^2 f}{\partial S^2} \cdot \sigma^2 S^2 \right) dt + \frac{\partial f}{\partial S} \sigma S dZ$$

$$= \left(\mu - \frac{1}{2} \sigma^2 \right) dt + \sigma dZ \tag{13}$$

Interest rates of LIBOR (London Inter-Bank Offered Rate) and local currency lending are forecasted according to the model (log-normal process) described above and shown in Figure 4 only for LIBOR for illusatration with 20 trial paths to know future volatility of the project cashflow. Both rates before January 1995 are historical data which are extended as actually recorded curves after the forecasts started (year 1995). The interest rate of LIBOR is expected to vary up to plus 8 % in 2004 as a forecast and of local lending rate up to plus 7 % as well. A borrower (project owner) can choose fixed interest loans at the moment of investment (year 1995). But the term rates would include the premium to the extent that banks would forecast the market rates using same method more or less. Thus, even the borrower may choose the fixed rate or relatively floating rate in 1995, he/she ought to take interest rate risk anyway accordingly.

Table 3. Cashflow analysis (interest rate risk)

Interest Rate	IRR on Equity	Min. DSCR
Base Case	13.28 %	1.23
Base +1% premium	13.02 %	1.23
Base + 5% premium	12.13 %	1.12

It is technically possible to build a cashflow model with log-normal process of floating interest rate for input. In this study, however for simplisity reason, the effects by certain interest rates premia (1% and 5% looking at the forecast) for LIBOR rates on IRRs and DSCRs are examined for sensitivity analysis as shown in Table 3. These values of the impacts by interest rate volatility on decision making for investment and lending show simillar impact levels by cost volatility caused by underground geologcal conditions shown in Table 2. Investors pay attentions to interest rate risk and may choose such quantified premium of fixed rate or take future volatility of interest rate whereas lenders check DSCR of such cashflow of the project as well for non or limited recourse loans. Likewise the efforts to quantify the cost volatility due to geological conditions may relieve underground civil works from generally thought ambiguity and may facilitate to quantify various kinds of risks by common indices on the cashflow model.

5. CONCLUSIONS

Through this case study on investment evaluation of a project to be financed in the private sector with anticipation of cost volatility due to geological conditions, learnt knowledge can be summarized as follows:

- If previously acquired geological information can be expressed in the stochastic field with volatility information of cost accordingly, a project viability for investment can be evaluated on a cashflow model in a comparative manner with other economic market risks such as floating interest rates of loans by calculating IRRs and DSCRs.

- Risk factors strongly affected by government policies such as exchange rate should be hedged by the contract with pass-through condition which may transfer such risk to the public sector service offtaker who has a relatively large financial capability.
- Cost risk of the case project was estimated lower than potential floating interest rate risk for the project.

Remained or further problems on this study are as follows:

- Risk factors such as discharge from excavated face or water inrush at fractured zones , which are hard to be expressed in the stochastic field, cannot be directly discussed in the same way of this study.
- A project with considerably large variable costs may require further discussions in alternative ways to take volatility by stochastic cashflow evaluations or to alleviate by contract clauses.

By evolution of “financial engineering”, market volatilities of various financial assets have been enabled to be quantitatively expressed with probabilities. Engineers’ efforts for such probabilistic quantification of various risks around construction will contribute to decision making by investors and lenders as well as they operate their portfolio of financial assets using financial engineering.

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