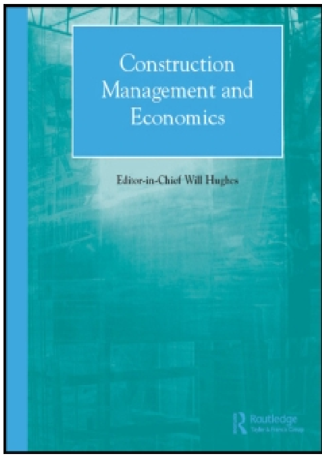

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Private sector participation in infrastructure projects: a methodology to analyse viability of BOT

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Many developing countries are now attempting to finance new infrastructure projects through private sector participation. This paper outlines a methodology based on financial and risk analyses that a government or a government utility can use to analyse the viability of private sector participation in new infrastructure projects. The water supply projects in Sri Lanka are used for the case study to outline the methodology. Financial analyses of a bulk water supply project and a water distribution project are carried out to estimate subsidy percentages that are required to make the projects viable, using a model developed for the investment analysis of all types of infrastructure project. This analysis looks at four pricing options for the bulk supply project, and sixteen procurement options for the distribution project, from the view point of the utility, for three cases of non-revenue water (35% as base case, 50% and 25% as extreme cases). The risk analysis takes into account the risk and uncertainty in non-revenue water, cost and demand estimates, rate of debt and forecasts of escalation. These analyses show that the best option for the utility is to obtain both bulk supply and distribution projects through private sector participation using BOT arrangements.

Keywords: Infrastructure, BOT, financial analysis, risk analysis, water supply, utility, investments, developing countries

Introduction

The traditional forms of investments for infrastructure projects in developing countries are budgetary allocations, bilateral and/or multilateral donor funds. Many countries are now attempting to finance new infrastructure projects through private sector participation. For example, the Government of Sri Lanka (GOSL) has stated that future investments for new infrastructure projects will be with private sector participation that take the form of build, operate and transfer (BOT) or build, own and operate (BOO) arrangements (*Daily News*, 1995). This is on the one hand due to the GOSL not having sufficient resources to undertake the large investments that are required for infrastructure projects and on the other due to the expectations of improved efficiency and innovation. These were the main reasons identified by Liddle (1997) for supporting private sector participation.

The objective of this paper is to outline a methodology based on financial and risk analyses that a government or a government utility can use to analyse the viability of private sector participation in new infrastructure projects. The water supply projects in Sri Lanka are used as a case study to outline the method.

The GOSL has continued to subsidize water supply to offset the loss of revenue due mainly to low domestic tariffs. However, what is not known is the total amount of subsidies that is required to make new infrastructure projects viable. Therefore, this paper first estimates subsidies for different procurement strategies, ranging from public sector investment with subsidized water to completely privatized water supply at prevailing subsidized tariffs, to determine the best strategy for the GOSL. Second, risk analyses of the preferred strategy are carried out. Finally, the first two steps are used, to demonstrate a methodology for exploring

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the viability of private sector participation in new infrastructure projects in developing countries.

Private sector participation

Liddle (1997) states that there are three basic ways in which a government can privatize infrastructure projects: contract out the operation and maintenance of an existing project; sell an existing facility; and, finally, contract to build, own and operate (BOO) a new project for an agreed on concession period after which the ownership would be transferred to the public sector (BOT). The BOO/BOT arrangement is the most discussed private sector participation approach in infrastructure projects (Kappaz and Causilla, 1988; McCarthy and Perry, 1989; Tiong, 1990, 1995a,b, 1996; McCarthy and Tiong, 1991; Tiong *et al.*, 1992; David and Fernando, 1994; Dias and Ioannou, 1995; Wahdan *et al.*, 1995; Shen *et al.*, 1996; Keong *et al.*, 1997; Liddle, 1997; Loh *et al.*, 1997; Tiong and Alum, 1997a,b).

Most BOO/BOT arrangements typically have a number of common issues. First, they are financed on forecast current value (nominal) cash flows and the associated risks. Hence, there has to be an accurate cash flow analysis for adequate rate of return and cash flow coverage, and a detailed analysis of risks. According to Tiong (1995b), most promoters find financing issues completely new and have to rely on external financial consultants to assist them in assembling attractive financial packages. Except for a multiple regression based model to assist in the negotiation of BOT contracts (Loh *et al.*, 1997), and a net present value based model suggested by Wahdan *et al.* (1995), authors have not seen quantitative approaches that can be used to analyse financing and conduct risk analysis of a BOT project.

Second, BOO/BOT is a limited recourse financing arrangement (Tiong, 1990, 1995a; David and Fernando, 1994; Dias and Ioannou, 1995). Limited recourse means that if a BOO/BOT project were to fail, the only recourse available to lenders would be to seize the assets of the project company and to acquire the plant. At that point the project company in all probability would be bankrupt and the plant non-functional (David and Fernando, 1994). This would result in a non-recourse situation.

Third, BOT/BOO projects have high debt to equity ratios (Kappaz and Causilla, 1988; Tiong, 1990, 1995a; David and Fernando, 1994; Dias and Ioannou, 1995; Wahdan *et al.*, 1995; Loh *et al.*, 1997). Since equity investors expect a reasonable return on their investment, Tiong (1995a) states that to promoters, equity means expensive capital. As cost of equity is higher than debt (Tiong, 1995a), the more equity a project has the higher would be the selling price of the product or service. Tiong (1995a) states also that a minimum equity is required to convince lenders that the project is creditworthy and hence financeable, and the government that the promoter is serious in the long term success of the project over the concession period. It is also argued that, from the lenders perspective, a higher level of equity represents a higher level of commitment by the borrower and lower risk exposure for lenders.

David and Fernando (1994) state that while the debt to equity ratio is generally 75 to 25, debt financing is the critical factor in determining whether a BOT project can support itself based on its revenue stream. Even though long term debt generally is cheaper than the return required by the equity, negotiating long term debt without sufficient guarantees can be difficult.

Fourth, generally a purchase/price agreement is sought that is fair and reasonable, and with the government guaranteeing performance. Fifth, foreign exchange convertibility to meet the debt payments and returns to equity investors is required. Finally, a clear understanding on impacts of changes in taxation, resources and legislation is required.

Financial model

In this section a model is developed that can be used for the investment appraisal of an infrastructure project that is financed by either public or private sector. The model is spreadsheet based, and facilitates risk analysis.

This development begins by adopting the model proposed recently by Ranasinghe (1996) to estimate total project cost given by TPC, defined as,

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

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

The base cost BC of a project consisting of n constant value annual cash flows $A_0, A_1, A_2, \ldots, A_{n-1}$, where the first cash flow A_0 is assumed to occur at time zero and the nth cash flow A_{n-1} at the end of the $(n-1)$th time period, was given as

$$\mathrm{BC} = \sum_{j=0}^{n-1} A_j \tag{2}$$

EDC is the difference between the current value cost of the project and a constant value base cost of the project (Ranasinghe, 1996). Since cost escalation is evaluated on an annual basis, the EDC was given as

$$\text{EDC} = \sum_{j=0}^{n-1} [A_j \prod_{k=0}^{j} (1 + \theta_k) - A_j] \quad (3)$$

where $\theta_0 = 0$, and θ_k is the escalation rate for the kth year (time period).

In most infrastructure development projects the clients have to contribute an equity portion (Ranasinghe, 1996). This is true even for the BOO/BOT projects where promoters have to contribute about 15–30% of the project cost as equity (David and Fernando, 1994; Tiong, 1995a). When the equity fraction of the current value cost is f, the IDC is calculated only for the borrowed funds, which is fraction (1-f) of the current value cost of the project. The *IDC*, also evaluated on an annual basis, is

$$\text{IDC} = (1 - f) \sum_{j=0}^{n-1} [A_j (1 + r)^{T-j} \prod_{k=0}^{j} (1 + \theta_k) - A_j \prod_{k=0}^{j} (1 + \theta_k)] \quad (4)$$

where r is the interest rate of the borrowed funds and T is the time at which the borrowed funds and the accrued interest on those funds are due (see Ranasinghe (1996) for details).

The net annual revenue in current value given by NR_i, can be estimated as,

$$\text{NR}_i = R_i \prod_{k=0}^{i} (1 + \theta_k^{\text{r}}) - \text{OM}_i \prod_{k=0}^{i} (1 + \theta_k^{\text{om}}) - E_i \prod_{k=0}^{i} (1 + \theta_k^{\text{e}}) \quad (5)$$

where R_i, OM_i and E_i are, respectively, annual revenue, annual operation and maintenance costs, and annual energy cost (where necessary), and θ_k^{r}, θ_k^{om} and θ_k^{e} are the forecast escalation rates.

The total project cost and the net annual revenue can be combined to form a model by which the financial viability of an infrastructure project can be analysed. The combined model in terms of net present value (NPV) is

$$\text{NPV} = -\sum_{j=0}^{n-1} \frac{[fA_j \prod_{k=0}^{j} (1 + \theta_k) + (1 - f)A_j}{(1 + y)^j} \times \frac{(1 + r)^{T-j} \prod_{k=0}^{j} (1 + \theta_k)]}{(1 + y)^j} + \frac{1}{(1 + y)^{T_s}} \sum_{i=1}^{m} \frac{NR_i}{(1 + y)^i} \quad (6)$$

where y is the discount rate, T_s is the start time of the revenue period and m is the number of annual revenue periods. Tung (1988) shows that NPV is the preferred method for selection of capital projects as it has only one simple decision criterion without exception, encounters no computational peculiarities, and requires few steps in calculation.

When D_i is the instalment of debt repayment in the ith year, Equation 6 becomes

$$\text{NPV} = -\sum_{j=0}^{n-1} \frac{fA_j \prod_{k=0}^{j} (1 + \theta_k)}{(1 + y)^j} + \frac{1}{(1 + y)^{T_s}} \sum_{i=1}^{m} \frac{\text{NR}_i - D_i}{(1 + y)^i} \quad (7)$$

This model is applicable to both publicly funded and BOT projects. Implicit in this formulation is that a BOT project will be transferred to the utility at the end of the franchise period at no or a nominal cost. In the case of equal instalments for debt repayment, we have

$$D_i = [\sum_{j=0}^{n-1} (1 - f)A_j (1 + r)^{T-j} \prod_{k=0}^{j} (1 + \theta_k) \times \frac{r(1 + r)^N}{(1 + r)^N - 1} \quad (8)$$

where N is number of annual instalments and $N < m$.

Case study

The case study uses water supply projects in Sri Lanka to outline a methodology based on financial and risk analyses that can be used by a government or a government utility to analyse the viability of private sector participation in new infrastructure projects.

The financial model developed is used to analyse four pricing options for bulk supply and sixteen options for distribution of water. The pricing options for the bulk supply of water are:

1. subsidized tariff for the bulk supply of water at zero discount rate;
2. tariff for bulk supply of water with no subsidy at zero discount rate;
3. tariff for bulk supply of water with no subsidy at 12% discount rate (a realistic financial rate of return for the water sector in Sri Lanka); and
4. tariff for bulk supply of water through BOT with no subsidy at 20% (pretax minimum acceptable rate of return (MARR) for private sector investments).

Since the distribution has to buy bulk supply, each of the four pricing options for bulk supply is assumed to have the same four options for distribution, giving sixteen procurement options for a water distribution project, as shown in Figure 1. Then, the extreme options are 'subsidized tariff for bulk supply and distribution at zero discount rate', and 'tariffs for obtaining bulk supply and distribution with private sector participation using BOT arrangement'.

The case study uses reported annual base costs, net annual revenues, estimates of annual escalation rates,

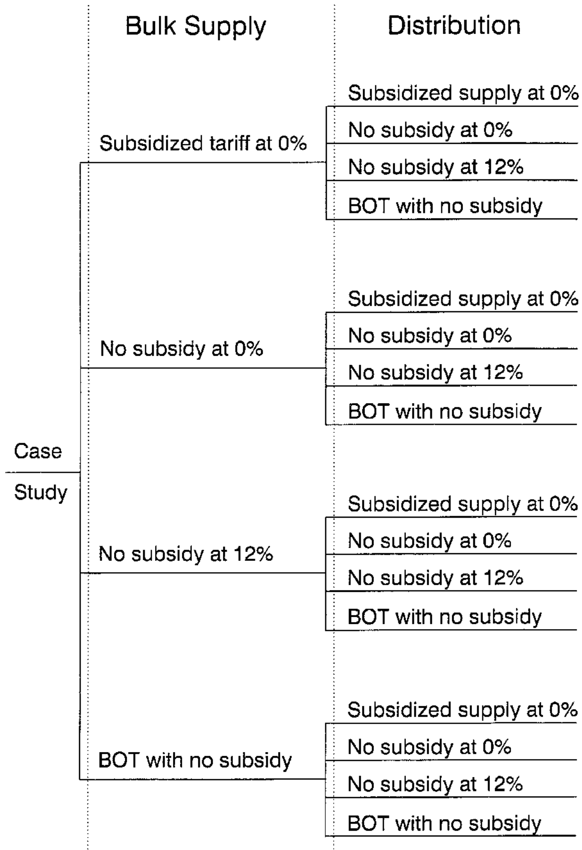

Figure 1 Options for bulk supply and distribution

and annual interest rates for borrowed funds for the water (bulk) supply project at Badulla, Sri Lanka, and the water distribution project at Kaduwela, Sri Lanka (FDR, 1993) to model the financial viability of the different options. These analyses compare different strategies for the procurement of investments for water supply and distribution by the government utility, the National Water Supply and Drainage Board of Sri Lanka.

Bulk supply project

Data from the Badulla water (bulk) supply project that was completed recently are used for the financial analysis. The total cost of the project was SLRs. 220 million, of which 75% was received as bilateral funds. The total cost estimate, which initially was around Rs. 165 million at 1992 prices, had increased considerably due to delays and claims. Even though the project is donor funded, the utility has to pay the Government Treasury 12% interest on borrowed funds. The construction duration of the project was three years. This project supplies 3 million units of water per annum. The average tariff for a unit of water supplied by the utility was estimated at Rs. 5.50 (1 US$ = SLRs. 50) at 1995 prices. The operation cost and energy cost per unit of bulk water were, respectively, Rs. 2 and Rs. 2.40 at 1994 prices. It was assumed that operation cost and energy cost had an effective cost escalation rate of 5% per annum and the annual increase in tariff will be 5%. The duration of the franchise period was assumed to be 20 years, irrespective of whether the project was carried out by the utility or the private sector. McCarthy and Perry (1989) state that in general BOT contracts for water supply are 25–30 years of duration.

When the bulk supply project is carried out by the private sector, it is assumed that the project can be completed at the estimated total cost of Rs. 165 million. This reduction reflects the efficiency of the private sector (Liddle, 1997). A debt to equity ratio of 75 to 25 (David and Fernando, 1994) was assumed, resulting in foreign equity investment equivalent to Rs. 42 million. Based on prevailing rates for senior debt and new sources that are becoming available to private sector investors in developing countries, such as subordinated debt funds for infrastructure projects (PSIDP, 1996), we have assumed an average rate of 13% for debt financing. Jeffery (1995) estimated a rate of 9% for debt financing of water supply projects in Sri Lanka. The average rate of 13% assumed for this case study is equivalent to an average rate of 9% for US$ linked debt with 6% annual depreciation of the SLRupee to the US$. The operation cost per unit of bulk water was assumed at Rs. 1.70, to reflect the efficiencies of the private sector (Liddle, 1997), while energy cost per unit remained at Rs. 2.40 at 1994 prices. The operation cost and energy cost were assumed to have effective escalation rates of 5% per annum, and annual increase in tariff was assumed to be 5%.

Analysis

When the bulk supply project is analysed under the first pricing option: (subsidized tariff of Rs. 5.50 per unit of water at 1995 prices; interest rate of 12% on the borrowed funds of the utility; zero discount rate), it is seen that 49% of the project cost needed to break even (NPV = 0) has to come as a subsidy. For all options, the subsidy was assumed as the equal annual amount that was necessary to break even for that option. Even though the present value of the future revenue stream will change with different discount rates, because the present value of the costs and subsidy also will change with the corresponding discount rate, the percentage of the subsidy required to break even always will remain the same for a set of values used for the analysis, irrespective of the discount rate. When there is no subsidy under the second pricing option, the required tariff for a unit of bulk water to break even at a zero discount rate is Rs. 10.82 at 1995 prices.

With no subsidy, to achieve a 12% financial return as envisaged by the third pricing option, the required tariff for a unit of bulk water to break even is Rs. 13.59 at 1995 prices. It has been argued frequently that since The World Bank and the Asian Development Bank insist on utilities in Sri Lanka to yield an annual return of 8% on assets (Siyambalapitiya, 1995), the financial rate of return should be considered as 8%. On the other hand, Jenkins and Harberger (1992) argue that, in public sector projects, it is the financial performance of the entire invested capital and not just the equity portion that is relevant, since both equity and debt financing come from the same source or the loans have been either explicitly or implicitly guaranteed by the government. Therefore, Jenkins and Harberger (1992) indicate that no distinction should be made between the return received by the lenders of the debt and that received by the owners of equity. Since the utility has to pay the Treasury 12% interest on borrowed funds for new infrastructure projects, it is realistic to assume the required minimum financial rate of return for the utility to be at least 12%.

When the bulk supply is from a BOT project, the required tariff for a unit of bulk water to break even is Rs. 13.45 at 1995 prices. This estimate is based on assumptions made regarding private sector efficiency and innovation (Liddle, 1997), 13% average rate of debt and an expected return of 20%, the MARR for private sector investments. Wahdan *et al.* (1995) consider that the MARR consists of: a real rate of return; compensation for inflation or depreciation of money; a premium for risk; a premium for loss of liquidity or accessibility to one's money quickly; and payment for administration costs. For example, following the reasoning of Wahdan *et al.* (1995): the required real rate of return is 3%; expectation of inflation during the franchise period is 5%; considering that most risks are assigned to the BOT arrangement, risk premium is 10%; and since there would be very few buyers of the project, liquidity premium is 2%. If we assume that administrative costs are included in cash flow projections, we obtain 20% as an acceptable nominal MARR (including inflation) for private sector investments.

A comparison between third and fourth options shows that it is more economical for the utility to obtain the bulk supply project through private sector participation using a BOT arrangement. In other words, if the utility invested project is to break even without subsidy and after paying a 12% annual interest on borrowed funds that it receives from the Treasury, it has to charge a tariff of at least Rs. 13.59 for a unit of bulk supply, whereas the utility can expect to buy bulk supplies of water from a BOT project at a tariff of about Rs. 13.45 per unit.

Distribution project

The base cost of the Kaduwela distribution project at 1992 prices was Rs. 260 million, of which Rs. 208 million was received as multilateral funds. The duration of the project was four years. The forecast annual demand for domestic and industrial/commercial consumption in million units of water for the analysis period computed from the final design report for Kaduwela distribution project (FDR, 1993) is given in Table 1. The annual consumption of water by the distribution project was estimated from the net amount of water that should be distributed. Hence, three cases are analysed for different assumptions of 'non revenue water', the term referring to production loss, when water is distributed by the utility.

As the base case, this study will assume that the non-revenue water component is 35% in the distribution of water by the utility. Expert opinion based on past experiences indicate that this is the most likely level of efficiency that will be achieved by the utility under current operations for new water supply projects. The non-revenue water component is assumed to be 50% for the second case. This reflects the view of planners such as the World Bank (IDA, 1995) and the Department of National Planning, Sri Lanka (PIP, 1996), regarding water supply projects maintained by

Table 1 Forecast annual demand for water (in millions of units)

Year	Domestic	Indust/commer	Total
1996	1.65	0.35	2.00
1997	2.10	0.65	2.75
1998	2.16	0.74	2.90
1999	2.25	0.81	3.06
2000	2.34	0.88	3.22
2001	2.45	0.93	3.38
2002	2.56	1.00	3.56
2003	2.63	1.04	3.67
2004	2.74	1.08	3.82
2005	2.82	1.12	3.94
2006	2.93	1.17	4.10
2007	3.02	1.21	4.23
2008	3.15	1.24	4.39
2009	3.26	1.28	4.54
2010	3.39	1.31	4.70
2011	3.53	1.33	4.86
2012	3.67	1.37	5.04
2013	3.91	1.44	5.35
2014	4.18	1.51	5.69
2015	4.29	1.55	5.84
2016	4.39	1.59	5.98
2017	4.43	1.60	6.03
2018	4.46	1.63	6.09
2019	4.56	1.68	6.24
2020	4.60	1.69	6.29

the utility. In the third case, the non-revenue water component is assumed to be 25%. This reflects the utility's view regarding new water supply projects. The latter two are considered as extreme views regarding efficiency in the distribution of water by the utility.

Based on prevailing tariff blocks for water, the estimated average tariff for a unit of water was Rs. 2.20 for domestic consumption, and Rs. 25 for industrial and commercial consumption, both at 1995 prices. The annual operation cost was estimated at Rs. 4.8 million at 1996 prices. It was assumed that the operation cost escalation is 5% per annum and the annual increase in tariffs is 5%. The duration of the franchise period was assumed to be 25 years whether the project is carried out by the utility or the private sector.

When the distribution of water is by the private sector, it was assumed that the base cost of the project was Rs. 221 million at 1992 prices. A debt to equity ratio of 75 to 25 was assumed for the BOT project (David and Fernando, 1994). The non-revenue water component was assumed as 20%, and the annual operation cost was assumed as Rs. 4.56 million at 1996 prices, to account for private sector efficiencies (Liddle, 1997). It was assumed that the operating cost had an effective escalation rate of 5% per annum and that the annual increase in tariffs for domestic and industrial consumption is 5%.

Similar to the analysis for the bulk supply project, we can assume four options for the water distribution project for each of the four pricing options for bulk supply. Hence, the following sections will develop models to analyse sixteen procurement options each, for the three cases of non-revenue water in the distribution of water by the utility.

Base case: 35% non-revenue water

The base case assumes that 35% non-revenue water is the most likely level of efficiency that can be achieved by the utility under current operations.

In the first option, when both bulk supply and distribution are subsidized, it is estimated that 49% of the cost of the bulk supply project and 37% of the cost of the water distribution project should be subsidized to break even at a subsidized domestic tariff of Rs. 2.20 and an industrial tariff of Rs. 25, both at 1995 prices. This option assumes that the required financial rate of return of the utility is zero. The subsidy percentages to break even for the other procurement options of the base case for subsidized domestic and industrial tariffs at 1995 prices are given in Table 2.

As illustrated in Table 2, under all bulk supply options, distribution of water by the private sector is the best decision for the utility, if non-revenue water is 35%. However, any comparison between projects carried out by the utility and the private sector should be at the financial rate of return for the utility. The subsidy of 67% for bulk supply and distribution through BOT projects is the lowest when compared with other options. For example, there is a 1% reduction in the subsidy that is required to break even

Table 2 Base case : subsidy percentages for different options

			Distribution		
			Utility		BOT
			0%	12%	20%
	Bulk supply	Tariff	35% NRW	35% NRW	20% NRW
Utility	With subsidy (49%)	Rs. 5.50	37%	45%	47%
	No subsidy, 0%	Rs. 10.82	59%	63%	62%
	No subsidy, 12%	Rs. 13.59	65%	**68%**	**67%**
BOT	No subsidy, 20%	Rs. 13.45	65%	**68%**	**67%**

Table 3 Tariff envelopes (in SLRs.) for the base case

Bulk supply	Utility at 0%		Utility at 12%		BOT at 20%	
Tariff	Domest.	Commer.	Domest.	Commer.	Domest.	Commer.
Subsidized	2.20	43.06	2.20	50.49	2.20	52.44
Rs. 5.50	8.90	25.00	11.56	25.00	12.03	25.00
Utility at 0%	2.20	69.58	2.20	77.24	2.20	76.66
Rs. 10.82	18.75	25.00	21.37	25.00	20.70	25.00
Utility 12%	2.20	83.40	2.20	91.16	2.20	89.26
Rs. 13.59	23.88	25.00	26.49	25.00	25.21	25.00
BOT at 20%	2.20	82.70	2.20	90.46	2.20	88.63
Rs. 13.45	23.62	25.00	26.23	25.00	24.98	25.00

when compared with both the bulk with return plus distribution with return option and the bulk BOT plus distribution with return option (highlighted in Table 2). This comparison shows that if the non-revenue water component is 35%, then the best decision for the utility is to obtain both bulk supply and distribution projects through BOT arrangements.

We can develop tariff envelopes for different options of the water distribution project. These envelopes will give the maximum that one tariff can be increased when the other tariff is maintained at the estimated average tariff. Table 3 gives the envelopes for tariffs at 1995 prices for different options for bulk supply and water distribution projects when the non-revenue water component is 35%.

Case 2: 50% non-revenue water

In the second case the non-revenue water component is assumed to be 50% in the distribution of water to reflect the view of planners such as the World Bank (IDA, 1995) and the Department of National Planning, Sri Lanka (PIP, 1996). We consider this case to be a pessimistic view of the efficiency of water supply projects maintained by the utility.

The subsidy percentages required to break even for the different procurement options with subsidized domestic and industrial tariffs at 1995 prices when non-revenue water is 50% are given in Table 4. The subsidy of 67% for bulk supply and distribution through BOT projects again is the lowest when compared with other options involving 50% non-revenue water. There is a 3% reduction in the subsidy that is required to break even (highlighted in Table 4). This comparison shows that if the non-revenue water component is 50% as stated by the planners, the utility should obtain both bulk supply and distribution of water through BOT projects.

Case 3: 25% non-revenue water

In the third case, the non-revenue water component is assumed to be 25% in the distribution of water. This reflects the utility's view regarding new water supply projects. We consider this case to be the optimistic view on the efficiency of the utility maintained water supply projects.

The subsidy percentages estimated with subsidized domestic and industrial tariffs at 1995 prices, for different procurement options of the water distribution project when the non-revenue water is 25%, are given in Table 4. The subsidy of 66% for bulk supply through a BOT project and distribution by the utility is the lowest when compared with other comparable options involving 25% non-revenue water (highlighted in Table 4). If the utility can improve its efficiency to a level where the non-revenue water component is 25%, then it is more viable for the utility to invest in the distribution project. Since most problems with efficiency arise in the distribution of water (Warford, 1994), the better decision for the utility is to obtain both bulk supply and distribution projects through private sector participation using a BOT arrangement, as the improvement in distribution by the utility is marginal even when the non-revenue water component is 25%.

Risk analysis

This section carries out the risk analyses of the preferred strategy by linking the developed financial model with a commercially available risk analysis package. This application demonstrates the versatility of the financial model developed: it may be extended to facilitate risk analysis of any infrastructure investment option.

The objective of this risk analysis is to determine the level of confidence in the decision to procure the water distribution project through private sector participation using a BOT arrangement. Even though the financial analysis showed that the BOT project is preferred, the dispute between planners and the utility regarding the value of non-revenue water in distribution projects maintained by the utility requires a determination of the level of confidence in the decision. Even in the

Table 4 Extreme cases : subsidy percentages for different options

		Utility				BOT
		Without return		With return		20%
Bulk supply	Tariff (Rs.)	50% NRW	25% NRW	50% NRW	25% NRW	20% NRW
Utility						
With subsidy (49%)	5.50	41%	34%	48%	43%	47%
No subsidy, 0%	10.82	62%	57%	65%	61%	62%
No subsidy, 12%	13.59	68%	63%	**70%**	**66%**	**67%**
BOT						
No subsidy, 20%	13.45	68%	63%	**70%**	**66%**	**67%**

absence of such a dispute, a risk analysis to determine the level of confidence in the preferred alternative clearly will highlight the impact of risks on that decision. Since the decision to procure the bulk supply project depends on the minimum acceptable financial rate of return of the utility, for the risk analysis we will assume that the best option is to procure the bulk supply project through a BOT arrangement.

The level of confidence in the decision is the probability at the point of nil difference between the decision to procure the water distribution project using funds available to the utility through the Treasury and the decision to obtain it through private sector participation. In other words, the probability when NPV_{prefer} is equal to zero. When the measure of preference for obtaining the water distribution project through private sector participation is NPV_{prefer}, it can be given by,

$$NPV_{prefer} = NPV_{BOT} - NPV_{utility} \qquad (9)$$

@RISK, a commercially available risk analysis package (PALISADE, 1997) is linked to the financial model to conduct the risk analysis. In addition to the decision measure given by Equation 9, @RISK requires as input, an identification of random variables in the model and a description of the risk involved in the random variables in terms of their expected values, standard deviations and probability distributions.

Since the major dispute between the planners and the utility is regarding the level of non-revenue water when the project is maintained by the utility, we will use the method suggested by Ranasinghe (1994) to quantify risk involved in that random variable. Consider a situation where the estimate of 50% non-revenue water by the planners is the 95th percentile of the distribution representing the non-revenue water component. In other words, it has a 5% probability of being exceeded. The estimate of 25% non-revenue water by the utility is the 5th percentile, meaning that it has a 95% probability of being exceeded. Assume that the most likely value or the 50th percentile of non-revenue water is 35%. From Equations 1 and 3 of Ranasinghe (1994), the expected value and standard deviation of non-revenue water when a distribution project is maintained by the utility are approximately 36% and 7.7%, respectively. Since the approximated values indicate near symmetry, we will assume a normal distribution for the simulation.

Random variables for annual water demand, escalation rates and non-revenue water components are assumed as normal distributions (N). Since annual water demand is an aggregation of individual domestic and commercial demands, it is reasonable to assume a normal distribution for the aggregate variable from the central limit theorem. All of the annual cost variables (equity and debt in current values, operation and maintenance, and average rate of debt of the private sector) are assumed as log-normal distributions (LN). This is a reasonable assumption as the log-normal distribution is positively skewed and is always on the positive scale, both being important characteristics when describing a cost variable.

The expected values, standard deviations and the assumed distributions for cost variables, escalations, rate of debt and non-revenue water components are given in Table 5, while those for annual water demand are given in Table 6. Due to the lack of data, deterministic estimates for all the random variables (annual water demand, costs, escalations, rate of debt, and non-revenue water for private sector) are assumed to be the expected values. The standard deviations reflect the efficiencies and innovations of the private sector (Liddle, 1997). There are theoretical suggestions to

Table 5 Expected values, standard deviations and probability distributions

Variable (X)	$E[X]$	σ_X	PDF
Annual current equity cash flow by the Utility			
1992 (SLRs. million)	2.00	0.8	LN
1993 (SLRs. million)	11.00	4.4	LN
1994 (SLRs. million)	26.38	10.55	LN
1995 (SLRs. million)	16.83	6.73	LN
1996 (SLRs. million)	7.25	2.9	LN
Annual current debt draw down by the Utility			
1993 (SLRs. million)	49.20	12.30	LN
1994 (SLRs. million)	92.00	23.00	LN
1995 (SLRs. million)	56.00	14.00	LN
1996 (SLRs. million)	22.18	5.55	LN
Annual current equity cash flow as BOT project			
1992 (SLRs. million)	2.13	0.43	LN
1993 (SLRs. million)	11.68	2.34	LN
1994 (SLRs. million)	28.02	5.60	LN
1995 (SLRs. million)	17.88	3.58	LN
1996 (SLRs. million)	7.72	1.54	LN
Annual current debt draw down as BOT project			
1993 (SLRs. million)	39.21	3.92	LN
1994 (SLRs. million)	73.30	7.33	LN
1995 (SLRs. million)	44.61	4.46	LN
1996 (SLRs. million)	17.70	1.77	LN
1996 O&M cost by utility (SLRs. million)	4.8	1.20	LN
1996 O&M cost as BOT project (SLRs.million)	4.56	0.46	LN
Escalation in O&M cost	0.05	0.01	N
Escalation in unit rate for bulk supply	0.05	0.01	N
Average rate of debt for BOT project	0.13	0.03	LN
Non-revenue water by the Utility	0.36	0.077	N
Non-revenue water as BOT project	0.2	0.02	N

Table 6 Expected values, standard deviations and PDFs for the annual demand in water (in millions of units)

Demand (X)	$E[X]$	σ_X	PDF
1996	2.00	0.20	N
1997	2.75	0.28	N
1998	2.90	0.29	N
1999	3.06	0.31	N
2000	3.22	0.32	N
2001	3.38	0.67	N
2002	3.56	0.71	N
2003	3.67	0.73	N
2004	3.82	0.76	N
2005	3.94	0.79	N
2006	4.10	1.23	N
2007	4.23	1.27	N
2008	4.39	1.32	N
2009	4.54	1.36	N
2010	4.70	1.41	N
2011	4.86	1.94	N
2012	5.04	2.02	N
2013	5.35	2.14	N
2014	5.69	2.27	N
2015	5.84	2.34	N
2016	5.98	2.99	N
2017	6.03	3.02	N
2018	6.09	3.05	N
2019	6.24	3.12	N
2020	6.29	3.14	N

quantify the risk involved in random variables in infrastructure investments. For example, Ranasinghe and Russell (1993) have presented a detailed methodology to quantify expert belief as expected value, standard deviation and probability distribution for an uncertain variable in economic risk analysis. However, experience in the actual use of such methods is still limited.

Three Monte Carlo simulations of the model given by Equation 9 were carried out at discount rates of 12% (realistic financial rate of return for the utility), 20% (nominal MARR for private sector investments) and 16% (verification rate). Each of the simulations were of 5000 iterations, at which point both the expected value ($E[NPV_p]$) and standard deviation (σ_{NPVp}) for NPV_{prefer} in all three simulations converged to less than 0.5%.

As more and more iterations are executed during a simulation, the generated distribution becomes more stable because the change in statistics which describes it becomes smaller and smaller. The number of iterations required to generate stable distributions varies depending on the model being simulated and the distribution functions in that model. Ranasinghe and Russell (1992) showed that the error band of the generated cumulative distribution function (CDF) from a simulation of 5000 iterations is about 2% at the 95% confidence level. The error band is the accuracy to which the CDF generated from the simulation approximates to the unknown CDF of the derived variable and at the 95% confidence level, the error band brackets the unknown CDF in 95% of all simulation samples (Ranasinghe and Russell, 1992).

The deterministic values for NPV_{prefer}, and expected values ($E[NPV_p]$) and standard deviations (σ_{NPVp}) for NPV_{prefer} from the three Monte Carlo simulations, at 12%, 16% and 20% are given in Table 7. The generated CDF for NPV_{prefer} at 20% is shown in Figure 2.

From the CDF it is seen that the probability at the point of nil difference between the private sector and the utility invested water supply projects at 20% is 0.088 (or 8.8%). In other words, the BOT project for water distribution has 0.912 (91.2%) probability of being preferred over a utility invested water distribution project at a discount rate of 20%. As given in Table 7, at 12% and 16% discount rates, the preferences for the BOT project for water supply are 0.92 (92%) and 0.916 (91.6%), respectively. The risk

Table 7 Deterministic values and statistics from risk analyses for NPV_{prefer}

Average rate of debt for BOT project is 13%			
Discount rates	12%	16%	20%
Deterministic value (NRW = 36%) (SLRs. million)	79.87	46.32	28.54
Expected value ($E[NPV_p]$) (SLRs. million)	75.79	43.87	27.26
Standard deviation (σ_{NPVp}) (SLRs. million)	57.38	32.83	20.19
Probability at point of nil difference ($NPV_{prefer} = 0$)	0.080	0.084	0.088
Preference for BOT project	0.920	0.916	0.912
Average rate of debt for BOT project is 15%			
Discount rates	12%	16%	20%
Deterministic value (NRW = 36%) (SLRs. million)	46.56	27.04	16.86
Expected value ($E[NPV_p]$) (SLRs. million)	42.61	24.40	15.42
Standard deviation (σ_{NPVp}) (SLRs. million)	62.77	37.61	24.14
Probability at point of nil difference ($NPV_{prefer} = 0$)	0.172	0.178	0.192
Preference for BOT project	0.828	0.822	0.808

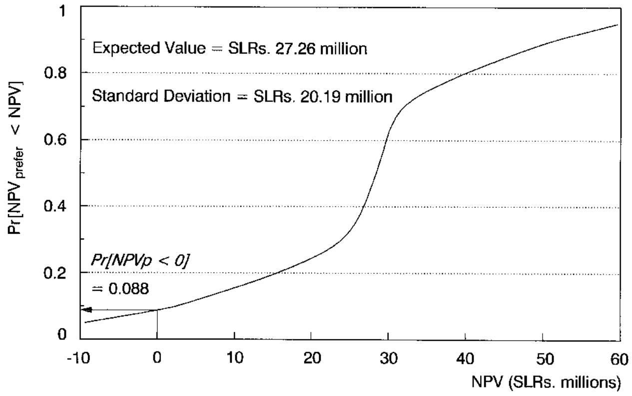

Figure 2 CDF for NPV_{prefer} at 20%

analysis confirms the conclusion from the financial analysis that the best option for the utility is to procure the water distribution project through private sector participation using a BOT arrangement.

According to David and Fernando (1994), debt financing is the critical factor in determining whether a BOT project can support itself based on its revenue stream. Therefore, a second set of Monte Carlo simulations of the model given by Equation 9 was carried out at discount rates of 12%, 16% and 20%, with the average rate of debt for the private sector assumed to be 15%. Each of these simulations also was of 5000 iterations, at which point both $E[NPV_p]$ and σ_{NPVp} for NPV_{prefer} in all three simulations converged to less than 0.5%. The deterministic values for NPV_{prefer}, and $E[NPV_p]$ and σ_{NPVp} from the three simulations, at 12%, 16% and 20%, are given in Table 7. As seen in Table 7, preferences for the BOT project for water supply at 12%, 16% and 20% discount rates are 82.8%, 82.2% and 80.8%, respectively. The risk analyses conclude that even when the average debt for the private sector is 15%, the best option for the utility is to procure the water distribution through a BOT project.

Conclusions

The objective of this paper has been to outline a methodology based on financial and risk analyses that can be used by a government or a government utility to analyse the viability of private sector participation in new infrastructure projects in developing countries.

It has been shown that the theoretical model developed facilitates appraisal of investments in new infrastructure projects financed by either public funds or through private sector participation. The model is linked readily to commercially available risk analysis software packages to facilitate risk analysis of the preferred investment decision.

The methodology of estimating subsidy percentages at prevailing subsidized tariffs provided a non-dimensional measure for comparing different procurement options. This method can be adopted to explore the viability of different procurement options for any sector that requires investments for new infrastructure projects in a developing country which has subsidized tariffs.

Both financial and risk analyses carried out on the case study show that, with realistic financial viability criteria for new investments by the utility, the procurement of bulk supply and water distribution projects in Sri Lanka should be through private sector participation using BOT arrangements.

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