Financial Viability Analysis and Capital Structure Optimization in Privatized Public Infrastructure Projects

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Abstract: Numerous public infrastructure projects have been privatized worldwide, where responsibilities, risks, and rewards are substantially reallocated between pubic and private sectors. The financial evaluation of a privatized infrastructure project is complex and challenging because of the risks and uncertainties due to the large size, long contract duration, nonrecourse financing, multiple project participants with different motives and interest, and the complexity of the contractual arrangements. Improved financial engineering techniques are required to overcome the limitations of traditional financial analysis techniques in addressing risks and uncertainties. This paper develops a methodology for capital structure optimization and financial viability analysis that reflects the characteristics of project financing, incorporates simulation and financial engineering techniques, and aims for win–win results for both public and private sectors. This quantitative methodology defines the capital structure of a privatized project in four dimensions, examines different project participants' perspectives of the capital structure, optimizes the capital structure, and evaluates the project's financial viability when it is under construction risk, bankruptcy risk and various economic risks (that are dealt with as stochastic variables), and is subject to other constraints imposed by different project participants. This methodology also evaluates the impact of governmental guarantees and supports, and addresses the issue of the equity holders' commitment to project success by initiating the concepts of equity at project risks, value of governmental loan guarantee, and project bankrupt probability during construction. A framework and a solution algorithm are provided for this proposed methodology. These research outputs will significantly facilitate both public and private sector in evaluating a privatized project's financial viability and collectively determining an optimal capital structure that safeguards their respective interests.

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Introduction

Governments worldwide have shown increasing initiatives in private finance of public infrastructure and services across a wide range of industries and sectors, including power, transportation, water supply and disposal, telecommunications, oil and gas, mining, schools, hospitals, and military training facilities. Improved deliveries of many major public works and services that would not have been possible without private finance have been widely reported. On the other hand, a number of privatized projects suffered disastrous consequences because of construction cost/duration overruns, changing market demand, depreciation of local currencies and/or reduction in tolls/tariffs by utilities. Some of them had been postponed or abandoned by the sponsors, and others had to be bailed out by the host governments (Ogunlana 1997; Ye and Tiong 2000; Abdul-Aziz 2001). These problems give the warning that innovative approaches to infrastructure privatization should be taken, one of which is a sound financial evaluation methodology.

The financial evaluation of a privatized infrastructure project is complex and challenging because of the complexity of the nonrecourse financing technique and a variety of risks and uncertainties related to project finance, which make the forecasting of cashflows very difficult. The radical reallocation of risks among project participants makes the concessionaire undertake much more and deeper risks than a mere contractor. Construction and economic risks are two major risks in a privatized infrastructure project (Ho and Liu 2002). Successful development of a privatized project requires effective management of these risks and the use of improved financial engineering techniques to explore financial opportunities.

The financial evaluation methodology proposed in this paper examines the capital structure and financial viability of a privatized infrastructure project when the project is subject to construction risk, bankruptcy risk, economic risk, and various constraints imposed by multiple project participants. It also assesses the impacts of governmental guarantees and supports, and addresses the issue of equity holders' commitment to project success. This methodology aims to achieve a public–private win–win result, i.e., it optimizes the capital structure such that the internal rate of return to equity (IRRE) is maximized while satisfying other project participants' interest and requirements, which are established as constraints. Combining simulation and financial engi-

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neering techniques, this financial evaluation methodology would facilitate both public clients and private developers in formulating an appropriate financial package for the successful development of a privatized infrastructure project.

Infrastructure Privatization and Project Finance

Governmental Initiatives in Private Finance

Laws and regulations have been enacted in many countries to facilitate private finance in public infrastructure development for improved quality, efficiency, and cost effectiveness. The claim that privatization can improve public infrastructure development is based on the following arguments: (1) the private sector is less bureaucratic and more operational efficient than the public sector and, therefore, can make timely decisions for better allocation and utilization of resources; (2) additional funds from the private sector overcome governmental budgetary restraints; (3) expertise, managerial skills, and innovative technologies from the private sector are better utilized; (4) involvement of the private sector reduces government monopolies and increases competition in public works and services; (5) the market mechanism increases the incentives toward efficiency in public organizations; and (6) sensible public-private partnerships (PPPs) minimize the competitive inequities between public and private sectors (Miller 1999; Miller et al. 2000).

Project Finance

Project finance refers to the development of a stand-alone project on a nonrecourse or limited recourse financing structure, where debt and equity used to finance the project are paid back from the cashflows generated by the project. Unlike corporate finance where lenders examine a company's general credit and use the cashflows generated by its entire asset portfolio for debt service, in project finance, lenders look primarily to the revenue stream generated by the project for repayment and to the assets of the project as collateral for their loans. Lenders have no recourse or only limited recourse to the general funds or assets of the project sponsors. The project company is a distinct legal entity; project assets, project-related contracts, and project cashflows are segregated to a substantial degree from the sponsoring entities (Merna and Dubey 1998; *Project finance in developing countries* 1999).

Project finance provides a useful financial engineering technique for the private sector to finance the project outside their balance sheet, because project sponsors may: (1) be unwilling to expose their general funds/assets to liabilities to be incurred in connection with the project or be seeking to limit their exposure in this regard; (2) try to avoid the conditions or restrictions on incurring debt contained in existing loan documents; and/or (3) not enjoy sufficient financial standing (i.e., inadequate creditworthiness or borrowing capacity) to borrow funds on the basis of their general assets (Benoit 1996; Merna and Dubey 1998).

Build/Operate/Transfer and Private Finance

A number of methods have been explored in international infrastructure privatization, including asset sale, contracting out, deregulation, build/operate/transfer (BOT), and other types of public–private partnerships. As a popular approach, BOT is the underlying methodology in a variety of privatization scenarios. A BOT project can be described as a project based on a concession that is usually granted by a public client to a consortium, the concessionaire, who is required to "build" the project with its own financial arrangements, "operate" the project during the concession period to recover its investments and obtain a certain level of profits, and to "transfer" the facilities of the project in an operational condition and usually at no cost to the client at the end of the concession period. The term BOT has generated a string of related acronyms that reflect variations of governmental interest, preference, and industrial characteristics in procurement approaches (Palaneeswaran et al. 2001): buy–build–operate (BBO), build–lease–transfer (BLT), build–own–operate (BOO), build–own–operate–maintain (BOOM), build–own–operate–transfer (BOOT), build–transfer (BT), build–transfer–operate (BTO), design–build–finance–operate (DBFO), design–build–operate–maintain (DBOM), develop–operate–transfer (DOT), lease–develop–operate (LDO), modernize–operate–transfer (MOT), rehabilitate–own–operate (ROO), rehabilitate–operate–transfer (ROT), and transfer–own–transfer (TOT).

From its definition, it is seen that BOT generates a special purpose vehicle for project finance: the concessionaire is an independent legal entity created under the government-granted concession and registered according to relevant laws of the host country. Central to BOT are the complex contractual arrangements that are designed to fit within the overall legal framework of the host country: the concessionaire enters into contracts with a variety of project participants as shown in the figures in Merna and Dubey (1998) and Dias and Ioannou (1995). These contractual arrangements define each party's roles, liabilities, and apportionment of risks and rewards. Main contractual items include those dealing with concession period, construction methods, financial arrangements, project operation, and implementation procedures in the event of default, delay or failure of construction completion, substandard performance in the operational period, and force majeure.

Capital Structure in Privatized Infrastructure Projects

Financial Instruments

Different financial instruments may be used in the acquisition of the fixed assets of a privatized infrastructure project. These include equity (permanent capital), debt (temporary capital), and mezzanine finance (quasi-equity). Equity includes common stock, retained earnings (money not paid out as dividends but reinvested in business or used to pay off debt) and unappropriated profits. Equity has the lower rank and the last claim on the assets and cashflows of the project. Debt is often structured in the form of senior debt or subordinated debt. Senior debt has higher priority than all other claims on project cashflows and assets. Subordinated debt ranks behind other unsecured loans in payment obligations. Mezzanine finance refers to a kind of financial instruments that are primarily in the form of debt but also share some qualities of equity capital. It occupies an intermediate position between debt and common equity. Mezzanine finance includes convertible bonds and preferred stock. Convertible bonds can be exchanged for a given number of shares. Preferred stock is classified as an equity security but is paid at a fixed dividend. The project company can choose not to pay the dividend on its preferred stock without being considered in default, whereas a failure to make a promised interest payment on a debt issue will constitute an event of default. Preferred stock is a perpetual debt apart

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from the nonpayment option. Only when the project company runs into trouble do the equity-like features of these hybrid claims kick in. Therefore, preferred stock does not reflect a proportional claim on the project's net assets. There are also other types of instruments such as leasing, venture capital, and aid (Merna and Dubey 1998, Culp 2002).

Capital Structure

The capital cost of a privatized infrastructure project is the combined cost of various financial instruments that finance the project. Here, the writer defines the capital structure of a privatized infrastructure project in four dimensions: (1) types of financial instruments (equity, debt, and mezzanine finance); (2) the relative amounts of different financial instruments; (3) the sources of the financial instruments (e.g., international financial institutions, commercial banks, different types of equity participants, and the general public); and (4) the corresponding contractual conditions on these financial instruments (e.g., grace period and repayment period of debt, and government loan guarantee). Each of the four dimensions can affect the total project cost and consequently the financial viability of the project. For example, the cost of equity is usually higher than that of debt because equity holders normally require a rate of return to their equity that is higher than the interest rate of debt as debt has a higher level of claim to the assets of the project company. So, a lower level of equity reduces the total cost of the project. However, a lower equity level means higher risks to debt. Banks and other financial institutions may not be willing to finance a project that seems "unbankable," or they may increase the risk premiums for a project with a low equity level. There are also advantages and disadvantages in the use of bond and commerical debt. The interest rate of debt and its repayment period can be fixed or floated, while for bonds these are generally fixed. With flexible repayment period (such as a grace period) and floating interest rate bank debt allows more financial engineering flexibility. This may be critical for the success of a privatized project that is subject to construction risks and fluctuation of revenue streams in the long-term concession period. But debt is usually more expensive and has shorter maturity period than bonds. Long-term financial instruments are important in project finance because the project generates no revenues during the construction phase and tends to build up cashflows slowly in the operation period. Therefore, in the early years of the operation period, the revenues may be minimal and not able to bear high payment of debt. Large payment of debt may be a heavy burden on the project that can seriously affect the normal operation of the project and even ruin the project. Furthermore, in countries with weak economies and/or lack of an adequate legal environment, lenders may require sovereign guarantees from the project's host government and/or the involvement of Export Credit Agencies and multilateral agencies such as the World Bank, Asian Development Bank, and International Finance Corporation to cover political and economic risks. The involvement of international institutions increases the confidence of commerical banks in the project, and consequently, they may reduce the interest rate of debt. This reduced cost of debt increases the project's financial viability.

Equity Level

The essence of the first two dimensions of the capital structure, types of financial instruments and their relative amounts, can be characterized by the term "equity level." According to the definitions of different financial instruments, the equity level of a privatized infrastructure project is defined here as the proportion of equity in the total amount of finance in the project, where only the common equity is treated as "equity." In practice, equity levels ranging from 0 to 100% have been used in different types of projects. For example, power projects tend to have an equity level of 10–30%.

Different Parties' Perspectives of Equity Level

The equity level is the most relevant variable that concerns both public and private sectors. Three major parties are concerned with the equity level: equity holders (who are the shareholders of the project), lenders (banks and other financial institutions who lend money to the project), and the government (who privatized the project and might provide guarantees or other types of support to the project). These parties have different views as to what is an appropriate equity level, and their interests are dependent to some extent on the equity level.

For equity holders, their equity is recovered together with an expected level of profit from various project activities, including advisory, design, construction, maintenance and operation, and development of project-related properties. They will consider the project "financially viable" if the IRRE is greater than their expected level. Therefore, equity holders will maximize the IRRE. They usually do not want to put a high level of equity for several reasons: (1) minimizing their risks in the project; (2) allocating their limited money in more and perhaps more profitable projects; (3) increasing the IRRE by decreasing the equity level since the interest rate of debt is usually lower than the IRRE; (4) not having enough money for a higher equity level; and (5) increasing the amount of working capital.

Lenders usually prefer a high equity level to minimize their risks as debt has a higher rank in repayment than equity investment. For lenders, a bankable project should satisfy a minimum level of annual debt service coverage ratio (DSCR), of which more discussion is provided in a following section. Lower equity level means increased risks that the minimum level DSCR may not be satisfied. Lenders may require higher risk premiums for a lower equity level. Higher risk premiums increase the cost of the project. Another important reason why lenders require a high equity level is that a higher equity level will result in a greater "ownership" of the project by equity holders, and consequently an increased incentive and commitment of them to ensure the project a success.

Four main issues concern the government in a privatized infrastructure project: (1) timely completion of construction within the budgeted cost; (2) smooth operation and quality performance in the operation period; (3) public affordability to the service and products of the project; and (4) low total project life-cycle cost. Successful addressing of these issues requires a suitable capital structure and the long-term commitment of project participants. Failure of the privatized project will impair the interest of the general public and cause significant political cost to the government. Undoubtedly, the government will require a certain minimum equity level for the long-term commitment of equity holders. However, other conditions being the same, a low total life-cycle cost means a low equity level, as the IRRE required by equity holders is usually higher than the interest rate of debt. Therefore, the government should make sure that a suitable equity level is used to satisfy the interests of equity holders, lenders, and the general public.

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Types of Equity Participation

In addition to the equity level, the types of equity participation are also a concern to lenders and the government as well. Both lenders and the government should examine the incentives of key equity holders before committing their own funds or providing sovereign guarantees. For example, an equity holder whose earnings are primarily from equity dividends in the operation period will have a longer-term view than an equity holder who obtains substantial returns for consulting and/or construction services, because the latter gets their returns at the initial stage of the project development. Short-term view equity holders may exaggerate the project's debt carrying capacity and hence raise its long-term risk. Furthermore, they may abandon or neglect the project once a reasonable return on their risk capital is earned even when they apparently have higher equity participation. The continued presence of equity holders whose equity is at project risks [refer to the following paragraph for the definition of equity at project risks (EPR)] assures more realistic cashflow projections and their realization through continuous commitment and good project management practices. The lack of long-term financing may reflect the lack of a long-term commitment by equity holders.

Equity at Project Risks

The writer defines EPR as part or total of the equity in the finance of a privatized infrastructure project, the recovery of which will be dependent on the successful management of long-term project risks and the revenue stream generated over the long-term operation period. In other words, EPR includes only that part of the equity that is exposed to long-term project risks, especially market risks. For example, it does not comprise that part of the equity that is provided by an equity holder who is part of the construction consortium of the project and that is recovered from earnings on construction activities.

Ratio of Equity at Project Risks

Based on the definition of EPR, the ratio of equity at project risks (REPR) is defined as the ratio of the amount of EPR to the total amount of equity. According to above discussion, a higher REPR increases the long-term commitment of equity holders to the success of the project. The payback period for EPR may be a signal of the underlying interests of equity holders: the shorter the pay back period, the less the commitment of equity holders

$$\text{EPR} = E - \omega \times C_T \tag{1}$$

$$\text{REPR} = \frac{\text{EPR}}{E} \times 100\% \tag{2}$$

where EPR = equity at project risks; REPR = ratio of equity at project risks; E=amount of total equity; ω=the profit margin on the construction activity; and C_T=total construction cost. Zero or negative EPR/REPR means that there is no risk equity.

Financial Viability Analysis

Indicators of Financial Viability

In addition to REPR, other key financial viability indicators can be used in the evaluation of a privatized infrastructure project. They are project bankruptcy probability during construction (PBPDC), self-financing ability (SFA), net present value (NPV), IRRE, DSCR, and loan life coverage ratio (LLCR). These indicators are discussed in the following sections.

Assumptions

The following are the assumptions in the financial evaluation of a privatized infrastructure project:

1. The project is procured through a BOT scheme, with a fixed concession period of N_c years (including a construction period of D_c years and an operation period of D_o years) and a designed life cycle of N_d years.
2. The project follows the nonrecourse principle of project finance.
3. All the financial instruments available in the project are broadly divided into equity and debt. Equity and debt are drawn at the beginning of each year of the construction period according to their relative percentage in the total construction cost of the project.
4. There are unlimited sources of debt, and there is no upfront and commitment fee. Debts from different sources have different interest rates, but have the same grace period and the same term of annual equal installments (that is N years). Under this assumption, the weighted average interest rate of all debt sources can be used as the interest rate for the debt in general

$$r_D = \frac{\sum_{i=1}^{M} (r_d^i \times q_d^i)}{\sum_{i=1}^{M} q_d^i} \tag{3}$$

where r_D=weighted average interest rate of debt; r_d^i=the interest rate of debt from source i; q_d^i=the quantity of debt from source i; and M=total number of debt sources.
5. The lower the equity level, the higher the interest rate, according to a predetermined formula

$$r_d^i = f_i(R) \tag{4}$$

where R=equity level.
6. The total project development cost is equal to the total construction cost C_T, assuming that other cost items are minimal and thus can be ignored.
7. The total construction cost C_T and the construction duration D_c are independent without correlation. The base construction cost is uniformly distributed in the construction duration.
8. Only income tax is considered.
9. The total project development cost is depreciated over the designed life cycle (N_d years) of the project.

Project Bankrupt Probability During Construction

A wide range of internal and external factors may combine to impact the construction process and result in construction risks (cost overruns, duration overruns, and noncompletion). These factors include weather conditions, ground conditions, technical difficulties, equipment breakdowns, labor issues, inflation of construction materials, financial, and managerial capabilities of the main and subcontractors. Construction risks are a serious concern to all major project participants. Construction cost overruns and/or duration overruns affect the profitability and, consequently, the debt repayment ability of the project. For example, the delay

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of construction completion not only increases interest expenses and leads to cost overruns but also defers the generation of revenues. Serious construction cost overruns and/or duration overruns could result in a project's never being completed. This would be a disaster to all project participants.

The loan agreement to a privatized project usually includes a grace period, which is often the length of the predetermined construction duration, as normally there is no revenue generated in the construction phase. However, this does not mean that the project will not be subject to bankruptcy before project completion. Lenders may impose construction-related conditions to trigger bankruptcy should adverse events occur, especially in a large infrastructure project with huge costs and a long construction period. Lenders may specify the upper limit of cost overruns or the milestone upon each loan drawdown during the construction phase as a bankruptcy condition (Ho and Liu 2002). They can terminate the loan when this condition is satisfied. Under such circumstances, unless equity holders can justify the cost overruns or schedule delays or have the ability to arrange other funding sources such as new equity injection or government rescue, the project will be bankrupted.

Here, the PBPDC is defined as the probability the construction cost overruns exceed their upper limit or the probability a milestone upon each loan drawdown exceeds its upper limit during the construction phase.

To avoid project bankruptcy before construction completion, the construction cost and duration should be examined carefully taking into consideration various risks and uncertainties, and adequate financing facilities should be arranged to avoid refinancing risks, and a workable construction schedule made to ensure in-time project completion.

Monte Carlo simulation and project evaluation techniques such as the critical path method (CPM) and the program evaluation and review technique (PERT) can be combined to establish the distributions of construction cost and duration. This is discussed in a following section entitled "Simulation as a Risk Management Tool." Given these distributions, construction cost and duration at a given confidence level can be determined. The use of a high confidence level will greatly reduce the probability and extent of cost and duration overruns, and thus the bankrupt probability of the project. Please note that underestimates of construction cost and duration may make in-time construction completion impossible, and thus demotivate construction employees. The consequences would be reduced construction quality and/or increased probabilities of cost and duration overruns.

Self-Financing Ability

Once the construction cost (at a certain confidence level) is determined, the SFA of the project needs to be examined. As defined in the following equation, the SFA indicates what percentage of the construction cost can be recovered through the net revenues earned in the operation period, subject to the financing conditions of the capital market and the equity holders' requirements of return to their investments. A high SFA represents a robust revenue-generating ability and, consequently, a stable financial status of the project in the operation period (Chang and Chen 2001)

$$\text{SFA} = \frac{\text{NPV}_R}{\text{NFV}_C} \times 100\% \tag{5}$$

where NPV_R=net present value of the net revenues in the operation period as discounted to the end of the construction period; and NFV_C=net future value of the construction costs as discounted to the end of the construction period.

A suitable discount rate should be determined in the calculation of NPV_R and NPV_C. The selection of the discount rate is one of the crucial aspects of engineering economic analysis. The discount rate is the opportunity cost of money to the party considering some investment. From the equity holders' point of view, it is the interest rate earned in a capital market. Therefore, the discount rate is equal to the risk free rate plus the market price of risk, which is the premium that investors must receive over the risk free rate to incur the market risk (Birge and Zhang 1999; Bakatjan et al. 2003)

$$r = r_f + r_p \tag{6}$$

where r=discount rate; r_f=risk free rate; and r_p=risk premium.

Equity holders usually are only responsible for the arrangement of finance (either through equity or debt) to the amount at the SFA level. The nonself-financing part is paid by the government. Here is an example of the private finance initiative projects in the United Kingdom. For a financially freestanding project (i.e., SFA=100%), the concessionaire provides full finance through a DBFO procurement model, and recovers investments and obtains profits entirely through direct charges on end users. The government only provides necessary assistance in statutory procedures without assuming other risks. For projects whose costs cannot be recovered entirely through charges on end users (i.e., SFA < 100%), the government provides subsidies for social benefits not reflected in the project cashflows, e.g., environment improvement and economic regeneration (Blackwell 2000).

Net Present Value Profit and Internal Rate of Return to Equity

From the equity holders' point of view, the net present value of their total net profit at a specific equity level R (hereinafter referred to as NPV_P as defined in the following equation) and the IRRE are the most fundamental financial decision criteria. The IRRE is the value of the discount rate at which the NPV_P is equal to zero

$$\text{NPV}_P = \sum_{j=1}^{n} \frac{\text{NATCI}_j}{(1+r)^{j+m}} - \sum_{i=1}^{m} \frac{E_i}{(1+r)^{i-1}}$$

$$\text{for } j = 1,2,\ldots,n; i = 1,2,\ldots,m \tag{7}$$

where NPV_P=net present value of the equity holders' total net profit corresponding to a specific equity level R as discounted to the beginning of the first year of the construction period; n=operation period; m=construction duration; E_i=equity drawing in the ith year of construction; NATCI_j=annual net after-tax cash inflow in the jth year of operation; and r=discount rate.

For the project to be financially viable, NPV_P must be greater than or equal to zero or the IRRE must be greater than or equal to $\text{IRRE}_{\min}$, where $\text{IRRE}_{\min}$=minimum value of IRRE required by equity holders.

In the calculation of NPV_P, construction cost and duration are fixed at values corresponding to a certain confidence level (say, 95%) as required by the project. The NPV_P is also dependent on a number of other stochastic variables such as market demand, level of tolls/tariffs (hereinafter generally referred to as sale price), operation and maintenance cost, inflation rate, and debt interest rate. Assuming that probability distributions of these variables are known (if not, these can be established based on histori-

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cal data and expert opinions), then Monte Carlo simulation can be applied to determine the distributions of NPV_P. Consequently, the NPV_P at a certain confidence level can be derived.

Debt Service Coverage Ratio and Loan Life Coverage Ratio

The NPV_P and IRRE corresponding to a certain confidence level and a specified equity level R are calculated based on the projected annual cashflows over the concession period. The annual cashflows depend on a variety of factors, such as construction cost and duration, length of concession, annual revenues, operation and maintenance costs, fluctuations in currency exchange rate and inflation rate, and the tax structure. There may be high fluctuations in annual cashflows during the concession period. Even though $NPV_p \geqslant 0$ or $IRRE \geqslant IRRE_{min}$, meaning that the project is financially feasible from an overall and long-term perspective, the project may still fail because of low revenues and high financial difficulties encountered in some years of the concession period. For example, the construction cost overruns and/or construction duration overruns may make it very difficult for the project company to get additional finance to complete the project. At times even if under construction cost and/or duration overruns the project is still financially feasible in an "overall" view, the project company just cannot get the project completed without additional finance! Therefore, the annual financial status of the project should also be examined.

A robust and stable revenue stream is critical to the project's debt carrying capacity because debt is serviced through long-term revenues over the operation period. An important indicator of the annual financial status is the annual DSCR, which is the ratio of annual cash available to annual total debt service as defined in the following equation. The DSCR reflects the project's debt carrying ability, and thus it is the lender's main criterion for a project's financial viability. Higher annual DSCR reflects stronger debt carrying ability. The more variable the revenue stream during the operation period, the less debt can be carried by the project. Reducing the variability (for instance, by a take-and-pay contract with a public utility) can increase the project's debt carrying ability. The minimum DSCR ($DSCR_{min}$) required by lenders depends on the site country, the industrial sector of the project, the market situation, and the types of lenders involved. Generally, the DSCR should be at least equal to or larger than 1.0 to be acceptable. A project is bankable when DSCR is in the range of 1.10–1.25, satisfactory, and comfortable when DSCR is between 1.30 and 1.50, and above 1.50 is preferable. The preferred minimum average DSCR of international financial institutions is 1.50 (Koh et al. 1999; Bakatjan et al. 2003; Newnan et al. 2004)

$$DSCR_j = \frac{PBIT_j + DE_j - TAX_j}{D_j} \quad \text{for } j = 1,2,\ldots,N \tag{8}$$

where $DSCR_j$=debt service coverage ratio in the jth year of operation; $PBIT_j$=profit before interest and tax; DE_j=depreciation; TAX_j=tax; D_j=debt installment; and N=debt repayment period.

Another indicator to dynamically check the project's debt carrying ability is the LLCR (Steiner 1996). The LLCR measures periodically (e.g., annually) the net present value of future project income over the maturity period of the loan against the remaining amount of debt until debt is totally repaid. The LLCR should be at least greater than 1 for the project to be bankable

$$LLCR_k = \frac{\sum_{j=k}^{N} \frac{(PBIT_j + DE_j - TAX_j)}{(1+r)^{j-k+1}}}{\sum_{j=k}^{N} \frac{D_j}{(1+r)^{j-k+1}}} \tag{9}$$

where $LLCR_k$=loan life coverage ratio as measured in the kth year of the loan repayment period of N years.

Value of Governmental Loan Guarantee

Governmental Loan Guarantee

In addition to investing money for the nonself-financing part of the construction cost, the government may also provide a loan guarantee for the project company when the project is too risky to be undertaken by private parties alone. Governmental loan guarantee assures lenders that the debt will be fully or partially repaid by the government if the project fails. This would reduce lenders' risk premiums that are associated with a loan. Usually, under full governmental guarantee, lenders will consider the debt risk free and the debt interest rate will be the risk free rate. Since the debt is risk free, lenders may continue to support the project even when adverse events occur. Consequently, there is little construction completion risk with a governmental loan guarantee (Ho and Liu 2002).

Please note that, on the one hand, the governmental loan guarantee reduces the cost of debt and the project completion risk. Therefore, a project that is financially unviable when there is no governmental guarantee may become financially viable when there is a government loan guarantee. On the other hand, the government loan guarantee may cause possible problems. When loans are guaranteed, project lenders and equity holders may not examine the project rigorously. The lack of due diligence may result in the selection and development of a project that is not financially feasible.

Asset to Equity Holders and Lenders

Governmental loan guarantee is an asset to equity holders and lenders as well. For equity holders, the governmental loan guarantee enhances their money-borrowing capability and reduces the cost of their borrowed money. In examining the project's financial viability using the IRRE, equity holders should reflect the value of the governmental loan guarantee in the equity value. Otherwise, they would underestimate the value of their equity. For the lenders, the governmental loan guarantee ensures the security of their loans and the corresponding earnings of interest.

Balanced Governmental Loan Guarantee

Loan guarantee is a liability to the government. The government should determine the value of its loan guarantee. The economic value of the loan guarantee is worth at least the risk premiums reduced by lenders. The value of governmental loan guarantee should be balanced by the efforts and contributions from the private sector. The value of this guarantee should be reflected in the development of the privatized project such that the public interest is protected and improved. The governmental loan guarantee should result in a project that is financially feasible in terms of low project life-cycle cost, high service quality, improved efficiency, and cost effectiveness.

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If the value of the guarantee is too large, the government oversubsidizes the project. In this case, the government may take one or both of two approaches: (1) to reduce the level of tolls/tariffs of the project so that the public users of the project enjoy cheaper services without reduced quality; and (2) to request the share of the benefits from the project that are corresponding to the value of the loan guarantee. These shared benefits can be used to better serve the public in various areas that need funding.

Calculation of Financial Variables

This part discusses how to calculate various financial variables that are needed to determine the values of key financial viability indicators, such as SFA, NPV_P, IRRE, DSCR, and LLCR. As most of these variables are treated as stochastic ones, the values of these variables and the financial indicators are corresponding to certain confidence levels as agreed by project participants.

Total Construction Cost

Ranasinghe (1996) has provided a simplified model for decision makers to calculate total project cost, which consists of three parts: (1) the base cost (constant dollar value); (2) the escalation during construction that contains the effect of inflation; and (3) the interest during construction on the borrowed funds.

For a privatized infrastructure project, C_T can be calculated in the following set of equations:

$$C_T = C_B + C_E + C_I \tag{10}$$

$$C_B = \sum_{i=1}^{m} C_B^i \tag{11}$$

$$C_E = \sum_{i=1}^{m} C_E^i = \sum_{i=1}^{m} \left\{ C_B^i \left[\prod_{k=1}^{i} (1 + e_k) - 1 \right] \right\} \tag{12}$$

$$C_I = \sum_{i=1}^{m} C_I^i = (1 - R) \times \sum_{i=1}^{m} \left\{ \left[C_B^i (1 + r_D)^{m-i+1} \prod_{k=1}^{i} (1 + e_k) \right] - C_B^i \prod_{k=1}^{i} (1 + e_k) \right\} \tag{13}$$

where C_T=total project cost as discounted to the end of the construction period; C_B=base construction cost as estimated at the beginning of the construction period; C_E=cost escalation during construction; C_I=interest cost incurred during construction; C_B^i=base cost for construction activities to be undertaken in the ith year of the construction period; C_E^i=construction cost escalation; C_I^i=interest incurred; m=construction period; e_k=construction cost escalation rate for the kth year of the construction period; $e_1=0$; R=equity level; and r_D=interest rate of debt.

Annual Equity and Debt Drawings During Construction

Equity and debt are drawn annually at the beginning of each year of the construction period according to the equity level R

$$E^i = RC_B^i \prod_{k=1}^{i} (1 + e_k)$$

$$D^i = (1 - R) C_B^i \prod_{k=1}^{i} (1 + e_k)$$

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

where E^i and D^i=equity and debt drawings in the ith year of the construction period.

Annual Net After-Tax Cash Inflow in Operation Period

Revenues are generated from tariffs/tolls in the operation period, n. It is the annual NATCI that determines the project's financial viability. The annual NATCI in current value as of the year in the operation period can be calculated as (Bakatjan et al. 2003)

$$\mathrm{ATNCI}_j = \mathrm{PBIT}_j + \mathrm{DE}_j - D_j - \mathrm{TAX}_j \quad j = 1, 2, \ldots, n \tag{14}$$

The following subsections provide some discussion of the variables that determine the value of the annual NATCI.

$\mathbf{PBIT}_j$

$$\mathrm{PBIT}_j = \mathrm{RE}_j - \mathrm{OM}_j - \mathrm{DE}_j \quad \text{for } j = 1, 2, \ldots, n \tag{15}$$

where RE_j=annual revenue; $\mathrm{RE}_j = P_j Q_j$; P_j=price of the product of the project (e.g., the unit price of electricity in a power plant or the ticket price in a transportation project); Q_j=annual production (e.g., annual energy production in a power plant or annual traffic throughput in a transportation project); and OM_j=annual operation and maintenance cost.

Market and currency risks may significantly affect the revenue stream of the project. Changes in demand and price for project output have been the leading cause of revenue and profitability problems. Variation of costs of necessary inputs for the normal operation of the project is another major market risk. Currency risks arise whenever foreign currencies, in the form of equity or debt, are used to finance the project. Such risks are associated in part with foreign exchange convertibility and the foreign exchange rate. For more details please refer to *Project finance in developing countries* (1999).

$\mathbf{DE}_j$

Depreciation is the cost of a useful asset over its estimated life. As a reflection of a sunk cost, it does not represent a cash outflow from the company. Instead, it provides an annual tax advantage by reducing the company's taxable income that is equal to the product of depreciation and the (marginal) tax rate. A number of depreciation methods are now in use, including straight line, declining balance, sum of the years' digits, double-declining balance, and the modified accelerated cost recovery system. The benefit, in terms of net present worth of choosing one depreciation method rather than another, depends on the taxpayer's opportunity cost of capital (Steiner 1996). The simplest method for depreciation is straight-line depreciation, where annual depreciation equals a constant proportion of the initial investment. Assuming that C_T is entirely depreciable in the design life n_d ($n \leqslant n_d$) of the project, then

$$\mathrm{DE}_j = \frac{C_T}{n_d} \quad \text{for } j = 1, 2, \ldots, n_d \tag{16}$$

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D_j

The total accumulated debt (including interest) at the end of the construction period P_D can be calculated in the following equation:

$$P_D = (1-R)\sum_{i=1}^{m}\left[C_B^i(1+r_D)^{m-i+1}\prod_{k=1}^{i}(1+e_k)\right] \tag{17}$$

Annual debt installment D_j can be calculated using the capital recovery factor $(A/P, r_D, n)$

$$(A/P, r_D, n) = \frac{r_D(1+r_D)^n}{(1+r_D)^n-1} \tag{18}$$

where r_D=interest rate of debt; and n=operation period.

Therefore

$$\begin{aligned} D_j &= P_D(A/P, r_D, n) \\ &= (1-R)\frac{r_D(1+r_D)^n}{(1+r_D)^n-1}\sum_{i=1}^{m}\left[C_i(1+r_D)^{m-i+1}\prod_{k=1}^{i}(1+e_k)\right] \\ & \qquad j=1,2,\ldots,n \end{aligned} \tag{19}$$

TAX_j

Tax is a cost to the project company. For simplicity, here only income tax is considered. Business income is the total revenue received minus the total cost. Please note that interest and depreciation are tax deductible (Steiner 1996; Newnan et al. 2004). Income tax is levied by means of percentages of increments of income as shown in the following equation:

$$\mathrm{TAX}_j = r_{\mathrm{tax}}^j(\mathrm{PBIT}_j - I_j) = r_{\mathrm{tax}}^j(R_j - \mathrm{OM}_j - \mathrm{DE}_j - I_j) \quad j=1,2,\ldots,n \tag{20}$$

where r_{tax}^j=income tax rate corresponding to the income level (or bracket of income); and I_j=debt interest in the jth year of the operation period.

Assuming that there are equal annual installments of debt D_j, then the annual interest can be calculated using the following equation (White et al. 1989):

$$I_j = D_j - \mathrm{DP}_j = D_j - \frac{D_j}{(1+r_D)^{(n-j+1)}} = D_j\left[1-\frac{1}{(1+r_D)^{(n-j+1)}}\right] \qquad j=1,2,\ldots,n \tag{21}$$

where DP_j=payment for the debt principal for the jth year of the operation period.

Simulation as Risk Management Tool

Major Risks in Privatized Infrastructure Projects

A privatized infrastructure project is usually characterized by high capital outlay, long lead time, and long concession period. The project is subject to a variety of risks and uncertainties in the long concession period, among which construction risk and economic risk are two major risks (Ho and Liu 2002). The construction risk is characterized by cost overrun and schedule delay. For example, the construction cost of the Channel Tunnel Project doubled, although it was expected to be less risky because of its technical simplicity (Finnerty 1996). The economic risk includes demand risk (quantity and price), variation of OM costs, fluctuation in currency exchange rate and interest rate, and inflation risk. Understanding these stochastic risk variables will result in informed decision making regarding suitable toll/tariff level and equity level, better forecasting of cashflows, and consequently sound financial viability analysis. This necessitates the use of suitable risk analysis techniques.

Monte Carlo Simulation

Capital structure optimization and financial viability analysis are based on the values of a set of stochastic variables. This requires that the project development process be modeled as a stochastic process that behaves according to predetermined or prespecified laws of probability. Each privatized infrastructure project is unique. However, most of the activities are not, because there are many procurement and management similarities (AbouRizk and Halpin 1990; Ahuja et al. 1994). Monte Carlo simulation (Mariano et al. 2000; Binder and Heermann 2002) is a useful tool to model a stochastic process where the input data are random following certain statistical distributions. In such a simulation, the computer generates large sets of outputs after running a large number of iterations with random inputs. These outputs are then statistically analyzed to measure their uncertainties and risks. The following sections discuss the applications of Monte Carlo simulation in the analysis of construction and economic risks in a privatized infrastructure project.

Construction Cost Range Estimating

Range estimating is a tool to measure uncertainties and reason with risks. It can be performed on the base construction cost of major construction activities to determine: (1) the probability of achieving an estimate of the total construction cost that is within a certain range; (2) the reason, probability, and the quantity of a cost overrun on an estimate; and (3) the value of contingencies needs to be added to be certain to a degree (say, 95%) of confidence of not having an overrun (Curran 1989). The following steps are necessary for construction cost range estimating.

1. Define the project scope and divide it into manageable work components. This can be represented by a work breakdown structure (WBS), which is usually in a chart form incorporating a number of distinct work packages. Many types of projects have standard WBSs that can be used as templates for a project under examination. When there does not exist such a WBS for the project, then a decomposition method can be employed to subdivide the major project deliverables into smaller and more manageable components until the deliverables are defined in sufficient detail to support development of project activities (planning, executing, controlling, and closing) (*A guide to the project management body of knowledge* 2000).
2. Classify each work package into two groups: (1) group one—work packages with high degree of cost certainty and (2) group two—work packages with uncertain costs.
3. Establish the statistical cost distributions of uncertain work packages. Meaningful simulation of construction costs requires the establishment of the probability distribution functions (PDFs) for uncertain work packages as well as the parameters for such functions such as the mean and standard deviation for normal distribution. Historic cost data of uncertain work packages of previous similar or comparable projects can be used as sample data after proper adjustments according to expert opinions. The cost distributions of the

Table 1. Distributions and Random Variates (Based on Ahuja et al. 1994; Taylor and Karlin 1998)

Distribution type	Probability density function (PDF) and cumulative distribution function (CDF)	Random variate X	Remarks
Uniform	$f(x)=\begin{cases}\dfrac{1}{U-L} & L\leqslant x\leqslant U\\ 0 & \text{Otherwise}\end{cases}$ $F(x)=\begin{cases}0 & x<L\\ \dfrac{x-L}{U-L} & L<x\leqslant U\\ 1 & x>U\end{cases}$	$X=L+Y(U-L)$	Uniform distribution reflects an equal likelihood of expected values ranging from a minimum L to a maximum U. It can be used whenever user decides on a lowest and highest value for a variable, but is not sure how values are distributed.
Normal	$f(x)=\dfrac{1}{\sqrt{2\pi}\sigma}e^{-(x-\mu)^2/2\sigma^2}$	$X=\mu+\sigma\cos 2\pi Y_1\sqrt{-2\log Y_2}$ $X=\mu+\sigma\sin 2\pi Y_1\sqrt{-2\log Y_2}$	Normal distribution is described by the mean μ and standard deviation σ. It is suitable for variables where values are clustered around μ, equally likely to be above or under μ.
Triangular	$f(x)=\begin{cases}\dfrac{2(x-L)}{(M-L)(U-L)} & L\leqslant X\leqslant M\\ \dfrac{2(U-x)}{(U-M)(L-M)} & M\leqslant x\leqslant U\end{cases}$ $F(x)=\begin{cases}\dfrac{(x-L)^2}{(M-L)(U-L)} & L\leqslant x\leqslant M\\ 1-\dfrac{(U-x)^2}{(U-L)(U-M)} & M\leqslant x\leqslant U\\ 0 & x<L\\ 1 & U<x\end{cases}$	$X=\begin{cases}L+\sqrt{Y(M-L)(U-L)} & 0\leqslant Y\leqslant \dfrac{M-L}{U-L}\\ U-\sqrt{(1-Y)(U-M)(U-L)} & \dfrac{M-L}{U-L}<Y\leqslant 1\end{cases}$	Triangular distribution shows values ranging from a minimum L to a maximum U with a clustering around an expected value M (mode) that is different from the mean. The range from L to M is often different from M to U.
Exponential	$f(x)=\begin{cases}\dfrac{1}{\mu}e^{-x/\mu} & 0\leqslant x\leqslant\infty\\ 0 & \text{Otherwise}\end{cases}$ $F(x)=\begin{cases}1-e^{-x/\mu} & 0\leqslant x\leqslant\infty\\ 0 & \text{Otherwise}\end{cases}$	$X=-\mu\ln(1-Y)$	Exponential distribution is described by the mean μ. It is commonly used in reliability engineering, because it represents both phenomenological and empirical behaviors.
Beta	$f(x)=\begin{cases}\dfrac{\Gamma(\delta+\gamma)(x-L)^{\delta-1}(U-x)^{\gamma-1}}{\Gamma(\delta)\Gamma(\gamma)(U-L)^{\delta+\gamma-1}} & L\leqslant x\leqslant U\\ 0 & \text{Otherwise}\end{cases}$ $\Gamma(z)\equiv\int_0^{\infty}t^{z-1}e^{-1}dt$ for all $z>0$	This is somewhat complicated. See Ahuja et al. (1994) for details.	Beta distribution is defined by the minimum value L, maximum value U, and two shape parameters δ and γ. The PDF of beta distribution can attain varied shapes to represent cases where the most likely value is close to the pessimistic or optimistic value. The beta distribution is also bounded between two points, making it more suitable for finite modeling of activity times as used in PERT.

Note: Y, Y_1, and Y_2 are random numbers on [0, 1].

uncertain work packages can be determined empirically after appropriate statistical analysis. Then, a statistical distribution can be fitted to this collected sample data and relevant parameters calculated. There are a number of statistical distributions to choose from, some of which are presented in Table 1. Goodness of fit test should be performed: (1) by visually comparing either the empirical cumulative distribution function (CDF) with the fitted (theoretical) CDF, or the histogram of the sample data with that of the theoretical PDF of the selected statistical distribution; and/or (2) by taking either the chi-square test or the Kolmogorov–Smirnov test (Chakravarti et al. 1967; Rees 2001; Kelton et al. 2004). However, if there

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is not enough data to derive the distributions, expert knowledge can be explored to assign subjective distributions to uncertain work packages.

4. Establish the statistical distribution of the total construction cost of the project. This takes the following steps: (1) simultaneously generate uniform random number on the interval [0,1] for each uncertain work package; (2) transform the random number into relevant statistical distribution of each uncertain work package and calculate the corresponding cost of each work package; (3) calculate the total construction cost in this iteration by adding the costs of all uncertain and certain work packages; (4) repeat steps (1)–(3) for a great number of iterations to generate the sample data of the total construction cost; (5) establish the PDF and CDF of the total construction cost and calculate relevant parameters; and (6) conduct the goodness of fit test.
5. Calculate the construction cost at a given confidence level and predict percent overrun probability. Assume that the PDF and CDF of the base construction cost are $f(C_B)$ and $F(C_B)$, respectively. Then, the base construction cost at a confidence level a can be calculated as $C_B^a = \int_0^a f(C_B)d(C_B) = F^{-1}(a)$, and the percent overrun probability of C_B^a is $1-a$.

Simulation of Construction Duration

Critical Path Method

The most commonly used tools for scheduling are network-basked, one of which is the CPM (Wiest and Levy 1977). The CPM breaks down a construction project into distinct work activities, arranges them into a logical sequence, estimates the duration of each activity, and displays the work plan using precedence diagrams or arrow diagrams. It then determines the minimum possible duration of the project using forward pass and backward pass calculations based on the logic and criticality for the activities. The CPM is a deterministic tool in that it assumes only one value for the duration of each activity and thus it does not provide a measure of uncertainty associated with the estimate of a particular milestone in the project or with the estimate of the project completion time.

Program Evaluation and Review Technique

In the PERT, activity definition, precedence relations, and network building are similar to the CPM. However, PERT attempts to estimate the uncertainties in project scheduling by taking the optimistic (D_O), most likely (D_M) and pessimistic (D_P) time estimates to approximate the mean (μ) and variance (σ^2) of each work activity time (Wiest and Levy 1977)

$$\mu = (D_O + 4D_M + D_P)/6 \tag{22}$$

$$\sigma^2 = [(D_P - D_O)/6]^2 \tag{23}$$

The PERT determines the critical path based on the mean time of each activity without considering the variance. The variance is used after the path is determined to assign a level of uncertainty with the mean of the determined event. This results in a "merge event bias" that lead to an optimistic estimation of the mean of the project completion time compared to the true mean time (Ahuja et al. 1994).

Simulation of Program Evaluation and Review Technique Networks

Monte Carlo simulation can eliminate the limitations of the CPM and PERT in addressing risks and uncertainties. Instead of determining the path criticality of a construction project as in the CPM and PERT, Monte Carlo simulation examines activity criticality based on the statistical distribution of the time of each activity. Once the project schedule network is finalized either by a precedence diagram or an arrow diagram, and the time distribution of each activity in the network established, Monte Carlo simulation could be used to establish the statistical distribution of the construction duration using the CPM based on a random set of durations for all work activities (Ahuja et al. 1994).

Simulation of Economic Risk

As discussed in a previous section, fluctuations in market demand (price and quantity), OM costs, interest rate, currency exchange rate, and inflation constitute the economic risks for the project. Sample data of OM costs can be generated from historical data of similar projects with appropriate adjustments, while sample data of other economic variables can be derived by analyzing the economic data of the country where the project is located. Statistical distributions of these economic risk variables can then be established using Monte Carlo simulation based on their sample data.

Financial Evaluation Methodology

Public–Private Win–Win Principle

The capital structure is one of the critical issues to be solved in a privatized infrastructure project because it affects: (1) the total life-cycle cost of the project, and hence its financial viability; and (2) the interests of different parties to the project and consequently, their motivations and commitments to the success of the project, for different project participants have different views on the capital structure. A privatized project should achieve "win–win" results for both public and private sectors. That is, capital structure optimization should reflect the different interests, concerns, and requirements of all participants and the project should be financially viable from the perspectives of both public and private sectors.

Capital Structure Optimization and Financial Viability Analysis

As discussed in previous sections, the capital structure is measured in four dimensions, types of financial instruments, their relative amounts, sources, and contractual conditions, and there are several key indicators of financial viability, such as SFA, NPV_P, IRRE, DSCR, and LLCR. These dimensions and indicators are all considered in the proposed methodology (as shown in Fig. 1) for capital structure optimization and financial viability analysis.

As the most active players responsible for various project activities, equity holders play a key role toward the success of the project. Therefore, it is suitable to set up the objective as maximizing the IRRE for the benefits of equity holders, while subjecting this objective to the requirements (formulated as constraints)

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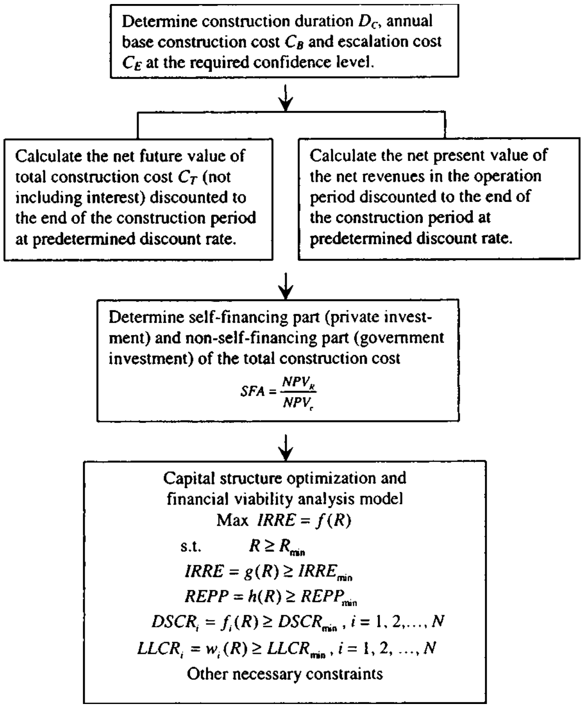

Fig. 1. Methodology for capital structure optimization and financial viability analysis

of lenders and the government. This proposed methodology guarantees win–win results for both public and private sectors.

In addition, attention should be paid to the following issues:

1. Capital structure is optimized based on the self-financing part of the construction cost. That is, the equity level is the ratio of equity to the self-financing part of the construction cost.
2. It is important to select an appropriate discount rate, cost escalation rate, and the required confidence levels for construction cost and duration. This requires a sound market analysis with the assistance of statistical techniques and simulation tools.
3. The values of IRRE, REPR, and DSCR correspond to a specified equity level R and the debt interest rate r_D, which is dependent on R. Therefore, IRRE, REPP, and DSCR can all be expressed as functions of R. These functions are not linear and iterative evaluation is necessary in solving this model.
4. Equity holders attempt to minimize their equity contributions such that maximum IRRE can be achieved, lenders seek a comfortable equity level to minimize the risks to their loans, and the government requires a certain level of equity to ensure equity holders' serious commitment to and a vested interest in the project, and a low project life-cycle cost.
5. The REPR is also an important indicator to the level of commitment of equity holders. Equity holders' profits from advisory services and construction activities should not be more than a certain percentage of the total amount of equity to ensure their long-term commitment to project success.
6. The debt interest rate r_D is risk-free rate if there is a government loan guarantee and the host country has a high credit rating. Without a government loan guarantee, r_D is risk-free rate plus a risk premium. The lower the equity level is, the higher the risk premium. Therefore, r_D can be expressed as a function of equity level R and the risk-free rate, or the base interest rate $r_B : r_D = f(r_B, R)$.
7. If $DSCR_{min}$ and $LLCR_{min}$ (minimum value of LLCR required by lenders) are the same, then satisfying $DSCR_{min}$ requirement will satisfy the $LLCR_{min}$ requirement. However, the reverse is not true.

Solution Algorithm

The solution algorithm for the proposed financial evaluation methodology is provided as follows:

1. Input data: base construction cost C_B^i, cost escalation rate e_k, construction duration D_c, market demand Q_j, price P_j, operation and maintenance cost OM_j, inflation rate r_I, base debt interest rate r_B, self-financing ability SFA, required minimum equity level R_{min}, construction profit margin ω, required minimum ratio of equity at project risks $REPR_{min}$, minimum allowable debt service coverage ratio $DSCR_{min}$, income tax rate r_{tax}, and debt interest r_D as a function of base interest r_B and equity level $R : r_D = f(r_B, R)$.
2. Let $k=1$ and $R_k = R_{min}$.
3. Calculate annual equity drawing E_i^k, debt drawing $D_i^k, REPR_k, DSCR_k, NPV_p^k$, and $IRRE_k$.
4. Let $k=k+1$ and $R_k = R_k + 1\%$. If $R_k = 1$ go to step 5. Otherwise, go to step 3.
5. Draw the following graphs: REPR versus R, DSCR versus R, NPV_P versus R, and IRRE versus R.
6. Select all combinations of $(R_k, REPR_k, DSCR_k)$, where $REPR_k \geqslant REPR_{min}$ and $DSCR_k \geqslant DSCR_{min}$. If this set is empty, go to step 7. Otherwise, go to step 8.
7. Indicate that the project is not financially viable. Go to 11.
8. Indicate that the project is financial viable.
9. Let $R_o = \max(R_k)$. R_o is the optimal equity level.
10. Output the results corresponding to $R_o : E_i^o, D_i^o, REPR_o, DSCR_o, NPV_p^o$, and $IRRE_o$.
11. Stop.

Financial Evaluation Framework

A framework for capital structure optimization and financial viability analysis (as shown in Fig. 2) has been developed based on the discussions in the previous sections. This framework can be divided into twp parts: (1) simulation-based input data modeling; and (2) capital structure optimization and financial viability analysis.

Simulation-Based Input Data Modeling

This part has two steps: (1) simulation of construction risks and (2) simulation of economic risks. The simulation techniques needed for Steps 1 and 2 have been discussed in the section entitled "Simulation as a Risk Management Tool." The main purposes of input data modeling are: (1) to determine the statistical distributions of various construction and economic risk variables with the assistance of statistical and simulation techniques, including base construction cost C_B, construction duration D_C, construction cost escalation rate e, base debt interest rate r_B, OM cost, currency exchange rate r_E, inflation rate r_I, market demand Q, and price P; (2) to determine the values of these risk variables at the required confidence levels; and (3) to determine the SFA of the project.

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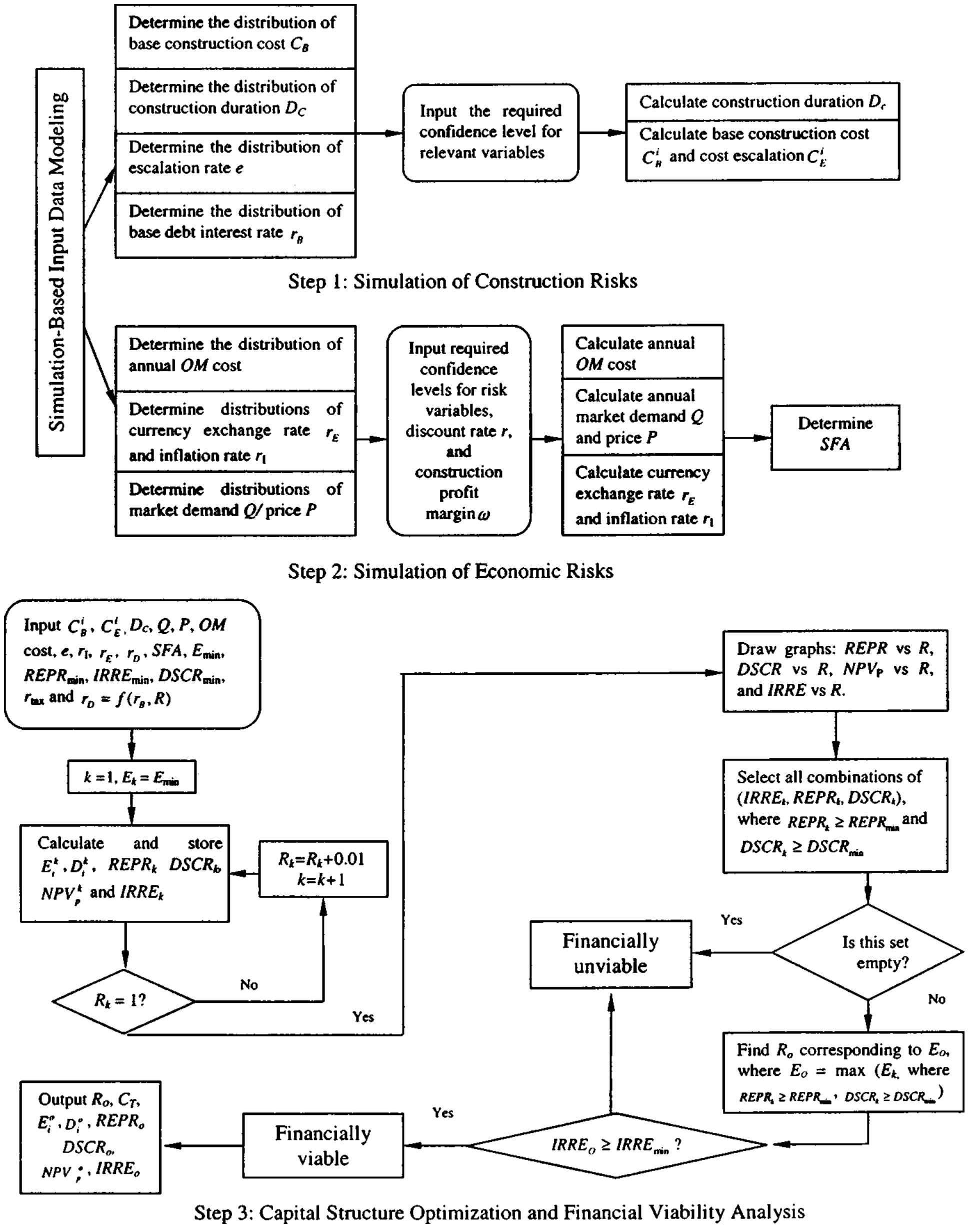

Fig. 2. Framework for capital structure optimization and financial viability analysis

Capital Structure Optimization and Financial Viability Analysis

In Step 3, optimization and financial viability analysis techniques (as discussed in the previous sections) are deployed to determine the optimal equity level that maximizes the IRRE and satisfies the requirements of the government and lenders.

Conclusions

Many public infrastructure projects across a wide range of industries have been privatized worldwide for improved quality, efficiency, and effectiveness. Construction and economic risks are two major types of risks in a privatized project, where the capital structure affects not only the total life–cycle cost of the project that in turn affects its financial viability, but also affects the motivation and commitment of different participants to the success of the project. Long-term commitment of equity holders is a prerequisite to effective and efficient project development. Innovative risk management and financial engineering techniques are needed to address the radical reallocation of risks, responsibilities, and rewards between pubic and private sectors. The financial evaluation methodology proposed in this paper follows a public–private win–win principle, considering the interests, concerns, and requirements of different participants. This quantitative methodology reflects the characteristics of project finance and incorporates simulation and financial engineering techniques. It optimizes the capital structure and evaluates the financial viability of a project when the project is under construction risk, bankruptcy risk, and various economic risks, and is subject to other constraints imposed by different participants such as minimum equity level, minimum DSCR, and minimum REPR. This methodology also evaluates the impact of governmental guarantees and supports, and addresses the issue of equity holders' commitment to project success by initiating the concepts of equity at project

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risks, value of governmental loan guarantee, and project bankrupt probability during construction. These research outputs will significantly facilitate both public and private sector in evaluating a privatized project's financial viability and collectively determining an optimal capital structure that safeguards their respective interests.

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