Methodological Framework for Evaluation of Financial Viability of Public-Private Partnerships: Investment Risk Approach

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Abstract: The development of highway infrastructure has increasingly been shifting toward the use of public-private partnerships (PPP) and alternative methods of project financing. In such schemes, the evaluation of their financial viability is the most commonly used industry practice for assessing the potential of the project to achieve the financial targets of its various stakeholders and ultimately affects its selection for implementation. In this study, a methodological framework for the evaluation of the financial viability of revenue-generating transportation infrastructure projects is presented in terms of their investment risk, using the method of moments. The investment risk is defined as the risk of not achieving the expected infrastructure-generated profit and thus not being able to service the financing debt outstanding and/or obtain an adequate return on the investment. The framework leads to a probabilistic assessment of the financial viability which can be achieved by performing various sensitivity and scenario analyses. To illustrate the application of the proposed methodology, a comparison of various alternative scenarios of financing is undertaken coupled with a few additional sensitivity analyses, for the case of a highway project developed as a typical PPP concession.

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Introduction

Public works procurement through public-private partnerships (PPPs) is increasingly becoming the norm in most countries around the world. A combination of scarcity of public funds, the ever ending quest of private investors for new and profitable investment opportunities, and the undisputable need for new capacity and/or improvements in most public infrastructure is fostering this worldwide trend (Grimsey and Lewis 2007). In such projects, the collaboration between the different parties involved and the satisfaction of their individual interests are key factors to their successful development and completion. In light of the multitude of parameters that influences the design and economic life of infrastructure projects, it is clear that the assessment of their riskiness and their effect on the forecasted project performance has a direct effect on the attractiveness of the project and the corresponding investment decisions. The most commonly used way to evaluate such investment decisions is through the assessment of the financial viability of a project.

The purpose of this paper is to formulate and present a comprehensive methodological framework for the evaluation of the financial viability of PPP projects based on the estimation of their investment risk, estimated with the method of moments (MOM). This framework is then used to investigate the effect of various financing scenarios on the investment risk of a highway PPP project. These scenarios stem from real-life examples of project financing and aim to showcase the effect of different contributing percentages of public funds, commercial and public debt, and private equity on the final viability assessment.

The remaining sections of this paper are arranged as follows: First, a brief review of PPPs, project finance, predominant PPP financing options, financial viability measures, and investment risk is put forward. Second, the methodological framework for the evaluation of the financial viability and the solution method (MOM) are presented and discussed. Third, the methodology is applied through a numerical example, involving the development of a highway project as a PPP concession. Finally, the conclusions from this study are presented.

Public-Private Partnerships

PPPs are contractual agreements between a private party (which can comprise one or more private partners) and all or part of a government. Under such a contract the private party agrees to perform certain functions or activities that are partially or traditionally considered to be of public responsibility (Li and Akintoye 2003; Grimsey and Lewis 2007). PPPs are known worldwide with various other alternative names such as private participations in infrastructure, private-sector participation, P3, privately financed projects, and private finance initiatives (PFIs). Regardless of the names used, the basic premises behind such contractual agreements are that the public and the private partners agree to enter in

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a long-term contract, involving the procurement of (usually) public infrastructure under a project finance financing structure, with the various risks involved during the various phases of the project allocated to the party that can best handle them with the minimum cost. According to Yescombe (2007), the structure of such agreements usually falls under two general categories, namely concessions and PFI contracts, both of which have evolved to their current form from the power purchase agreements developed in the United States in the 1980s. Although both the concession and the PFI models fall under project finance financing structures, their main difference lies in the way the raised debt is repaid: in a concession agreement this cost is covered by user charging, while in the PFI model payments from the public authority are introduced for the same purpose. Furthermore, PPPs can be classified based on the legal nature of the involvement of the private sector in the project (Li and Akintoye 2003; Yescombe 2007). In that respect the various names used such as build-operate-transfer, build-transfer-operate, build-own-operate-transfer, and so on and so forth, reflect the nature of the contract and the point at which the operation (or the ownership) of the constructed facility is transferred from the public authority to the private party and back again. Finally, PPP projects can also be classified according to the nature of the contracted service and the risk transfer between the public and the private partners (Yescombe 2007). Under such a classification PPP projects can be usage- or availability based, the former meaning that facility usage risk is transferred to the private sector, while the latter meaning that the private partner assumes the risk of having the facility available for use, without considerations about the expected usage. Usage-based PPP are usually structured as concession agreements while availability-based projects are usually structured based on the PFI model.

Project Financing

PPPs are usually financed through project finance financing methods rather than traditional public sector financing. Project finance is a highly leveraged financing method, meaning that it utilizes bigger contributions of debt financing rather than equity commitment (Grimsey and Lewis 2007). Under a project financing scenario, the debt that is raised for the capital costs of a project is then repaid based on cash flows that are generated from the operation of the project. This debt is financed on a non- or limited recourse basis with the recourse (if applicable) being restricted only to the assets or cash flows of the project itself (Asenova and Beck 2003). Raising the necessary capital is usually achieved through a variety of financing options (bonds, commercial lending through bank debt, leasing, mezzanine debt, mortgage financing, etc.). The most common form of project financing debt to date is senior bank loans with other "alternative" sources however being increasingly used toward that end, especially bond financing (Nevitt and Fabozzi 2002; Asenova and Beck 2003). It is customary nevertheless for most project financings to have certain specifications for the ranges of the different types of capital present in their structuring, usually as contractual terms coming from the public authority's or the lenders' side. A very common specification of this type is the requirement that the sponsors/developers commit their own equity to the project (usually to the extent of 10–15% of the total capital costs but sometimes more than that) as a demonstration of their commitment to its successful implementation (Nevitt and Fabozzi 2002; Asenova and Beck 2003).

Financing Options for PPP Project Development

A PPP project can be undertaken using a variety of financing scenarios. These scenarios correspond to the use and contribution of different sources of capital in the project's financial structuring, and can be obtained by varying the magnitude of the public authority funds, as well as the leverage (i.e., the ratio between debt and equity) of the project. The resulting financial structures have a direct impact on the evaluation of the financial viability as they affect directly the project's cash flows. From the plethora of possible financing scenarios that can be used for the development of a highway infrastructure project, the two "extreme" cases correspond to the financing of the project with the maximum possible public funds or with the maximum possible debt financing. In both these scenarios, the public contribution or the issued debt cannot cover 100% of the initial costs, since the sponsors/developers also have to commit a minimum amount of equity in order to claim "operating rights" and also assume a (small in this case but necessary) part of the risk. The most general scenario however, and the one most usually encountered in the worldwide PPP practice, is an ad hoc combination of public funds, raised debt and committed equity based on the individual characteristics of the project, the public authority, the lenders and the investors that participate in it, as well as the international and domestic market conditions (liquidity). Obviously, different variations of these three generic scenarios (and especially the last one) can be encountered in the real PPP worldwide practice. However, these three scenarios are considered characteristic in that they represent upper and lower boundaries, as well as (a version of) the norm in PPP project financing. As a result, these scenarios usually form the basis of the analysis aiming to evaluate the significance and effect of the contributing sources of finance to the project's financial viability.

Financial Viability Measures

The financial viability of a project has a different meaning for the different stakeholders involved in its development. In PPP projects, the three parties whose interests have to be bridged in order for the project to be successfully completed and operated are the public authority, the lenders, and the equity investors.

From the public authority's point of view, project viability is usually synonymous with increasing social welfare from the project's development and achieving the best value for money (VfM) (Yescombe 2007). Most of the times, the major issue for the public authority decision makers is whether such a project will be pursued in the first place, a decision that is made well ahead of the procurement phase of the project and is justified through a cost-benefit analysis and/or the determination of the economic return of the project (including externalities). From that point on, the focus is shifted to ensuring the best VfM and affordability; this is done by undertaking comparative studies and analyses, a very popular way being through the use of a public sector comparator (PSC). In many cases, however, there is no real public sector alternative to compare the PPP project to, resulting in a situation such that if the project is not procured through a PPP it will most probably not be procured at all. As a result, the public authority usually aims to achieve the best VfM by making sure that the risk transfer between the different parties has been done in a rational and cost-effective way and by encouraging and sustaining effective competition during the bidding phase (Yescombe 2007; Grimsey and Lewis 2007).

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From the lenders' point of view, the financial viability of the project corresponds to the repayment of the issued debt and is very much dependent on the relation between the project's costs and revenues generated during its operating life. In that respect, a macroscopic analysis of the profitability of the project and the corresponding (positive) cash flows until the end of its operating life (or the time until all loans are repaid) is of much interest, along with the fulfillment of specific cover ratios (CRs) that make sure that the project can be repaying the debt as it falls due (Yescombe 2007; Grimsey and Lewis 2007). From the existing variety of CRs, the ones pertinent to such projects (and most commonly used) are the annual debt-service cover ratio (ADSCR) and the loan-life cover ratio (LLCR). The ADSCR assesses the ability of the project company to service the debt from its annual cash flows and is calculated annually (or semiannually). The LLCR is a measure for the initial assessment of the project company's ability to service the debt over its whole term. Lenders usually have a minimum ADSCR requirement which determines the maximum loan that can be raised against the project under consideration, as well as a required LLCR which is about 10% higher than the ADSCR. However, the ADSCR is more useful as a measure, as it measures the ability of the project company to service debt as it falls due (Yescombe 2007). The minimum acceptable CRs are determined by the lenders based on the perceived "riskiness" of the project and have to be fulfilled at all times for the project to be ultimately financed (Yescombe 2007). Furthermore, these CRs determine the actual leverage of the project and also to a great extend the realization of the equity investors' returns, as the project's lenders always have the first call (are senior) on the project's profits.

Finally, from the equity investor's point of view, the main interest lays on the actual profitability of the project and in particular to the profit left after the debt obligations have been fulfilled. The equity investors are the last link in the priority chain of the PPP financing in terms of gains and the first ones in terms of losses, and therefore take the biggest part of the financing risk. As a result, close attention should be paid to their measures of financial viability [equity internal rate of return (IRR) or return on equity (ROE)] in order for them to be actively involved in the project and not lose interest in it (Yescombe 2007; Grimsey and Lewis 2007).

Investment Risk

The investment risk of an infrastructure project has been defined as the probability of failure to secure a required infrastructure-generated net operating income used for servicing debt (as a minimum requirement) and/or obtaining an adequate (positive) return on the investment (Kakimoto and Seneviratne 2000). It is, by definition, a financial-type risk and clearly, failure to meet any of its two targets is synonymous with financial project failure. According to its definition, the investment risk is directly dependent on the relationship between the infrastructure-generated revenues and costs. Based on the nature of the PPP agreement, the revenues coming from the operation of the infrastructure can be generated through user charging (in the case of a concession agreement) or through payments by the public authority (in the case of a PFI contract). Furthermore, in order for the analysis to be comprehensive, all other (life cycle) infrastructure costs need to be considered such as the fixed and nonfixed operational costs (personnel salaries, public utilities, etc.), as well as the expenditures stemming from the scheduled and/or unscheduled maintenance and/or rehabilitation of the facility, based on the expected (or unexpected) "wear and tear" from its utilization and aging. Such life cycle costs can sometimes include predevelopment costs incurred by the developers of the project although these are many times treated separately and are not part of the financial analysis of the project, as far as the investment risk is concerned (Yescombe 2007; Sinha and Labi 2007). Obviously, in order for an infrastructure facility to have a positive net operating income, the life cycle revenues should exceed the life cycle costs.

The investment risk of a revenue-generating facility has been modeled in the literature based on reliability theory and the concept of strength-stress interference (Kakimoto and Seneviratne 2000). A more detailed discussion on this concept can be found in Ang and Tang (1984) and Melchers (2002). Based on this concept, the limit state function of the investment risk problem has been defined as the difference between project revenues and total project costs, all discounted into present values through the use of a discount rate that is equal to the minimum acceptable rate of return (MARR) of the equity investors (Kakimoto and Seneviratne 2000). With the limit state function defined and under specific assumptions, the investment risk can be expressed as a multidimensional probability integral of the joint probability density function of all the parameters affecting the limit state function, over the failure region of the problem where total project costs exceed project revenues. The evaluation of this integral has been undertaken by both numerical and analytical approximation methods as its precise evaluation can be challenging for a variety of reasons (Ang and Tang 1984; Melchers 2002). For the case of the investment risk, Kakimoto and Seneviratne (2000) estimated the corresponding integral with the use of the second moment method. Recently, Pantelias and Zhang (2008) demonstrated that it could also be determined through the utilization of the MOM. The MOM is a relatively new higher moment statistical method that was developed by Zhao and Ono (2001) in the areas of structural reliability and safety. It has however also been used in the evaluation of the reliability of pavement structures (Zhang and Damnjanovic 2006a) and related short-term warranty contracts (Zhang and Damnjanovic 2006b). The main advantage of the MOM over other higher moment statistical methods is that it provides better estimates of the first four moments of the limit state function and thus of the probability of failure. This is due to the fact that the point estimation takes place in standard normal space, rather than in the original probability space of the explanatory variables. Also, the evaluation of the investment risk by the MOM is characterized by computational simplicity and analytical traceability, two clear advantages over numerical techniques such as the Monte Carlo simulation (Zhang and Damnjanovic 2006b).

Framework for the Evaluation of the Financial Viability of PPP Projects

This paper proposes a methodological framework for assessing the financial viability of PPP projects by evaluating their corresponding investment risk. The framework is based on the various PPP terms and characteristics, the various financial viability criteria (and in particular the ones that are directly addressed by the investment risk), as well as the various different quantitative models of project revenues and costs and is shown in Fig. 1.

Central to the proposed framework is the realization that the determination of the financial viability of a project can be undertaken for all three parties involved through the analysis of the investment risk. The investment risk in this study is measured

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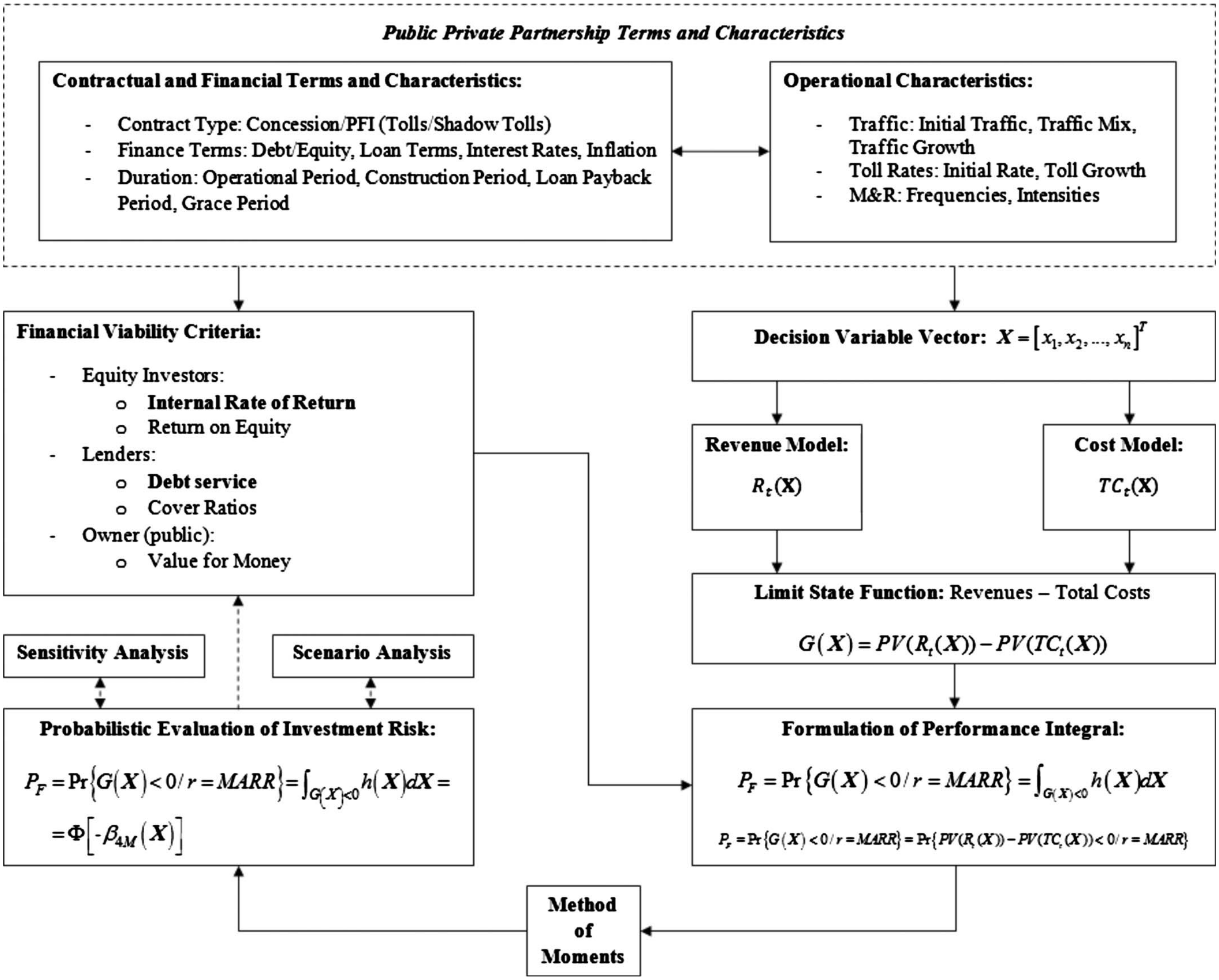

Fig. 1. Methodological framework for assessing project financial viability through the evaluation of investment risk

based on project cash flows after debt service and before equity returns and as a result corresponds to the equity IRR of the project. Therefore, according to its definition, it can be considered to directly accommodate two of the aforementioned financial viability criteria, namely the attainment of a target equity MARR and the servicing of debt by the end of the project's operational period, thus specifically addressing the general requirements of both equity investors and lenders. However, it can also be used by all project stakeholders to support their own hard decisions regarding the procurement of the project and the negotiations toward financial closure. The public authority can determine the attractiveness of the project to the private sector (which is directly related to bidding competition and thus VfM) and also use it for the development of policies and regulations regarding the procurement of such projects; the lenders can evaluate the riskiness of the project with regard to the repayment of the debt to be issued and therefore determine the leverage of the project and the other financial structuring details that will make them comfortable in financing it, such as the debt payment profile; and finally the equity investors can evaluate the likelihood of their own target returns under various scenarios and use the results to further negotiate their contribution to the project financing in order for their minimum requirements to be accommodated. The remaining of this section discusses in more detail the various parts of the framework with an emphasis on the modeling and the evaluation of the investment risk.

General Concept

From the various terms and characteristics that define a PPP agreement, parameters that are important to the analysis of the investment risk are identified and defined as the decision variables. These variables are incorporated in quantitative models that aim to capture the cash inflows (revenues) and outflows (costs) of the project. The present value (PV) of their difference, i.e., the infrastructure-generated net operating income, is defined as the limit state function of the investment risk problem. The investment risk is mathematically expressed as the probability of not obtaining a positive PV of the infrastructure-generated net operating income, conditional on the discount rate being equal to the target equity MARR. As discussed earlier, this formulation treats directly two measures of financial viability (equity IRR and debt service), and culminates in a multidimensional probability integral of the joint density function of the decision variables over the

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failure region where total project costs surpass project revenues. By evaluating this performance integral, the investment risk can be probabilistically determined providing basic information for the assessment of the project's financial viability.

Limit State Function

In more detail, the revenues $R_t(\cdot)$ and total costs $\mathrm{TC}_t(\cdot)$ at any year t of the project's operating life can be defined as functions of (n) explanatory random variables, i.e., the decision variables. These explanatory variables are considered to be elements of a random vector $\boldsymbol{X}=[x_1,x_2,\ldots,x_n]^T$ and therefore both $\mathrm{PV}(R_t)$ and $\mathrm{PV}(\mathrm{TC}_t)$ can be expressed as a function of $\boldsymbol{X}$, i.e., $\mathrm{PV}(R_t(\boldsymbol{X}))$ and $\mathrm{PV}(\mathrm{TC}_t(\boldsymbol{X}))$.

By defining the PV of the infrastructure-generated net operating income as the limit state function of the investment risk problem and assuming that the (n) explanatory variables are uncorrelated and continuous, it can be shown that

$$P_F=\Pr\{G(\boldsymbol{X})<0|r=\mathrm{MARR}\}$$

$$=\Pr\{\mathrm{PV}(R_t(\boldsymbol{X}))-\mathrm{PV}(\mathrm{TC}_t(\boldsymbol{X}))<0|r=\mathrm{MARR}\}=\int_{G(\boldsymbol{X})<0}h(\boldsymbol{X})d\boldsymbol{X} \quad (1)$$

where $G(\boldsymbol{X})=\mathrm{PV}(R_t(\boldsymbol{X}))-\mathrm{PV}(\mathrm{TC}_t(\boldsymbol{X}))$=limit state function; $\mathrm{PV}(R_t(\boldsymbol{X}))=\Sigma_{t=0}^{T}R_t/(1+r)^t$=PV of the project revenues; $\mathrm{PV}(\mathrm{TC}_t(\boldsymbol{X}))=\Sigma_{t=0}^{T}\mathrm{TC}_t/(1+r)^t$=PV of the project's total costs; r =discount rate; T=financial life of project (in years); and $h(\boldsymbol{X})$ =joint probability density function of the basic random variables in $\boldsymbol{X}$.

In the case where the explanatory variables in $\boldsymbol{X}$ are correlated and this correlation needs to be taken into account, the orthogonal transformation can be used in order to obtain their equivalent uncorrelated counterparts (Kakimoto and Seneviratne 2000; Melchers 2002; Ang and Tang 1984). Furthermore, both $R_t(\boldsymbol{X})$ and $\mathrm{TC}_t(\boldsymbol{X})$ can be quantitative models of any type, so long as the resulting formulation of the investment risk remains the same.

In this study, the revenues and total costs of the project are determined with the use of previously published models (Seneviratne and Ranasinghe 1997; Javid and Seneviratne 2000; Kakimoto and Seneviratne 2000; Pantelias and Zhang 2008) with modifications and extensions where deemed appropriate.

Revenue Model

The revenue of the facility under consideration is toll generated during the operational period of the project and as such it is traffic and toll-rate dependent. Traffic is assumed to be a stochastic variable, while toll rate is assumed to be growing steadily based on a stochastic growth factor (inflation), from its initial value at the beginning of the operating period. The toll rate is also assumed different for different vehicle classes. The percentage of the different classes in the overall traffic is assumed to remain constant for the entire life of the project.

Based on the above assumptions the tolling revenue for year t is given by

$$R_t=\begin{cases}0, & t\in[0,m]\\ \sum_{c\in\Theta}q_t^c r_t^c d_{\mathrm{ave}}, & t\in[m+1,T]\end{cases} \quad (2)$$

where q_t^c=amount of traffic for year t and traffic class c; r_t^c=toll rate for year t and traffic class c; d_{ave}=average trip length; Θ =set of all vehicle classes; and m=construction period in years. Also

$$q_t^c=\beta_c Q_t \quad (3)$$

where β_c=percentage of traffic class c and Q_t=total traffic in year t.

The total traffic Q_t for year t is assumed to be growing from its initial value Q_0 during the first year of operations based on specific annual traffic growth factors according to the following function:

$$Q_t=Q_0\prod_{j=m+1}^{t-1}(1+g_j^Q) \quad (4)$$

where g_j^Q=annual traffic growth factor for year j (where j counts the years from the end of construction until the year before t).

Furthermore, the toll rate for traffic class c will be growing from its value during the first year of operation based on a growth factor (inflation), according to the following function:

$$r_t^c=r_0^c(1+f_r)^{t-m-1} \quad (5)$$

where r_j^c=toll rate for traffic class c at year j; r_0^c=toll rate for traffic class c at the first year of operations; and f_r=annual toll-rate growth factor for all traffic classes.

Cost Model

The total cost of infrastructure development (TC) can be divided into two parts: a part coming from the consideration of the initial construction cost (IC) and the way it is initially covered and then repaid during the project's operational period; and a maintenance, rehabilitation, and operation cost (MROC), which is incurred on a yearly or interval basis from operating the facility and maintaining it at a condition that is acceptable to the traveling public (based on the contractual responsibilities of operation). Other costs that are incurred during the initial predevelopment stages of the project such as planning and/or preliminary engineering are not considered in this study, as they are often treated separately and not as part of the investment risk analysis, as discussed earlier.

Therefore, the TC at year t is represented by the following function:

$$\mathrm{TC}_t=\mathrm{IC}_t+\mathrm{MROC}_t \quad (6)$$

The IC_t depends on the total initial capital cost (TICC), the financing method and also on the terms and conditions of the mix of loans, grants, equity, etc., that are used to finance the project's development. During the years of construction, the IC_t is assumed to be equal to the part of the TICC covered by the equity committed by the developers/sponsors. During the project's operational years, it is equal to the debt repayment annuities, which can exist or not, based on the debt terms and conditions (interest rates, payback periods, grace periods, etc.). From these parameters, the debt interest rates can be assumed to be stochastic in order to reflect potential market variations in the case where they are not fixed but are floating during the duration of the debt. Furthermore, all debt is assumed to be issued on the first year of construction. Based on these assumptions, the IC_t can therefore be expressed as follows:

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$$\text{IC}_t = \begin{cases} \alpha_e d_t \text{TICC}, & t \in [0, m] \\ \dfrac{\alpha_d \text{TICC}}{\kappa}(1+i)^{\rho}, & t \in [m+1, T] \end{cases} \quad (7)$$

where α_e=portion of committed equity as a percentage of the total initial capital cost; d_t=percentage of C_0 drawn in year t of construction; α_d=portion of issued debt as a percentage of the total initial capital cost; i=interest rate of debt (where applicable); ρ=duration of the debt in years; and κ=number of debt repayment annuities (=number of repayment years).

The TICC is in essence the project financing or capital investment cost which is made over the several years of construction and therefore will be the sum of the yearly incurred construction costs growing with inflation, as follows:

$$\text{TICC} = \sum_{t=0}^{m} \sum_{\gamma \in \Gamma} \alpha_{\gamma} \text{ICC}_t \quad (8)$$

where ICC_t=initial capital cost at year t of construction; α_{γ} =portion of type of debt or equity γ as a percentage of the total initial capital cost, $\gamma=\{e,d\}$, $\gamma \in \Gamma$; and Γ=set of all possible types of capital debt in the project's financing (public funds, equity, or debt).

Also

$$\text{ICC}_t = d_t C_0 (1+f)^t \quad (9)$$

where C_0=estimated total cost of construction (excluding construction loan interest payments and fees) and f=annual price escalation rate (inflation).

The MROC_t consists of an annual operating cost (OC) and an annual maintenance and rehabilitation cost (MRC) which can be existing or nonexisting for any given year during operation based on the scheduled maintenance and/or rehabilitation activities of the project. They are both expressed in relation to the initial construction cost estimate C_0 and grow with inflation as follows:

$$\text{MROC}_t = \begin{cases} 0, & t \in [0, m] \\ \text{OC}_t + \text{MRC}_t, & t \in [m+1, T] \end{cases} \quad (10)$$

Also

$$\text{OC}_t = a_t^o C_0 (1+f)^{t-m-1} \quad (11)$$

where a_t^o=cost of operation on year t as a percentage of the total initial project cost C_0 and f=annual price escalation rate (inflation), and

$$\text{MRO}_t = \sum_{w=1}^{W} a_t^w C_0 (1+f)^{t-m-1} \quad (12)$$

where a_j^w=cost of maintenance/rehabilitation alternative w on year t as a percentage of the total initial project cost C_0; f=annual price escalation rate (inflation); and W=number of all available maintenance and rehabilitation options. The above presented cost and revenues per year t, are then discounted to the first year of construction and added together in order to determine their corresponding total NPV, as shown in Eq. (1).

Evaluation of Investment Risk

The MOM is used to evaluate the investment risk based on two steps. First, the four central moments of the limit state function are estimated by using point estimates obtained in standard normal space. These point estimates, that can be either five or seven (Zhao and Ono 2000), allow for an improvement in the accuracy of the estimation of the central moments. Second, with the use of the obtained four central moments, the reliability index and the corresponding probability of failure are estimated using existing standardized functions (Zhao and Ang 2003; Zhang and Damnjanovic 2006a). By considering all four central moments of a suitable linear approximation of the limit state function, the resulting four-moment reliability index β_{4M} can be determined by the following formula (Zhao and Ono 2001):

$$\beta_{4M} = \frac{3[\alpha_{4G^*} - 1][\mu_{G^*}/\sigma_{G^*}] + \alpha_{3G^*}\{[\mu_{G^*}/\sigma_{G^*}]^2 - 1\}}{\{[9\alpha_{4G^*} - 5\alpha_{3G^*}^2 - 9][a_{4G^*} - 1]\}^{0.5}} \quad (13)$$

where μ_{G^*}=mean; σ_{G^*}=variance; and $\alpha_{nG^*}\sigma_{G^*}^n$=$n$th dimensionless central moment of the linearly approximated limit state function G^*.

With the use of the above reliability index, the probability of failure for the investment risk problem (i.e., the investment risk) can be directly obtained by

$$P_F = \Pr\{G(\boldsymbol{X}) < 0 | r = \text{MARR}\} = \int_{G(X)<0} h(\boldsymbol{X}) d\boldsymbol{X} = \Phi[-\beta_{4M}(\boldsymbol{X})] \quad (14)$$

or in terms of the reliability of the investment by

$$R(\boldsymbol{X}) = 1 - P_F = 1 - \Phi[-\beta_{4M}(\boldsymbol{X})] \quad (15)$$

Assessment of Financial Viability

Through the use of the MOM, a probabilistic estimate of the investment risk can be obtained. This estimate corresponds to the characteristics and numerical values of the "base case" scenario for the infrastructure under consideration. Although significant, this individual risk estimate does not provide all the necessary information needed for decision making, as it does not show which of the various variables contribute mostly to the risk and what the magnitude of their contribution is. In order for all this information to be attained, various sensitivity analyses need to be undertaken aiming at identifying the variables whose change would have the most significant impact on the investment risk and as a result would pose the biggest threat on the project's financial viability. Furthermore, additional combinations of different numerical values of the underlying variables can and should also be undertaken in order to evaluate different potential scenarios that could arise or that could be pursued in implementing the project under consideration. Such scenarios could correspond, for example, to different ways of financing the project, to considering different sources of revenues or costs or considering different financial expectations from the project's stakeholders, among other alternatives.

By evaluating the investment risk for all these different scenarios and by performing the aforementioned sensitivity analyses, the financial viability can ultimately be assessed. In effect, by obtaining the probabilistic estimates of investment risk for potential changes of the project's stochastic variables and possible implementation scenarios, the project stakeholders can assess first whether these changes and scenarios are plausible or possible to actually happen and second how much they would affect their financial expectations should some or all of them actually materialized. As a final note, although the various project stakeholders have different financial expectations and therefore different financial viability measures, the evaluation of the investment risk

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Table 1. PPP Highway Project Parameters for Numerical Example

Project parameters	Units	Mean	CV (%)	Comments
General				
Concession period (T)	Years	50	N/A	
Construction period (m)	Years	5	N/A	
Operation period	Years	45	N/A	
Cost				
Initial construction (C_0)	$	1,000,000,000	20	Initial estimate
Initial operating cost (a_t^o)	%	3.5	N/A	As a % of C_0
Initial annual maintenance cost (a_t^w)	%	0.6	N/A	As a % of C_0
Rehabilitation cost (a_t^w) (years 16 and 26)	%	3.0	N/A	As a % of C_0
Annual price escalation rate (f)	%	2.5		Equal to inflation
Operational	%			
Initial AADT (Q_0)	Vehicles	35,000	10	Initial estimate
Vehicle classes (Θ):				
Cars	%	%	N/A	
Trucks	%	%	N/A	
Traffic growth (g_j^Q)	%	6.5	10	Constant
Average trip length (d_{ave})	Miles	30	N/A	
Toll rates (r_t^c):				
Cars	$/miles	0.15	N/A	
Trucks	$/miles	0.60	N/A	
Annual toll rate growth (f_r)	%	2.5	N/A	
Financing				
Construction capital draw (d_t):				
Year 1	%	10	N/A	
Year 2	%	25	N/A	
Year 3	%	40	N/A	
Year 4	%	15	N/A	
Year 5	%	10	N/A	
Public debt:	%			
Interest rate (i)	%	5.10	N/A	
Grace period	Years	10	N/A	
Payback period (κ)	Years	35	N/A	
Payment Terms		Interest plus principal in equal installments after end of grace period		
Commercial debt				
Interest rate (i)	%	5.55	10	
Grace period	Years	10	N/A	
Payback period (κ)	Years	40	N/A	
Payment terms		Interest plus principal in equal installments after end of grace period		
Economic				
Inflation rate (f)	%	2.5	10	Initial estimate
Discount rate (r=MARR)	%	12	10	Target value

Note: N/A=not applicable.

coupled with the appropriate sensitivity and scenario analyses can provide them with significant insight regarding ultimately attaining their respective financial targets and help them with the corresponding decisions and negotiations subsequently that would make the project move successfully from a planning to an implementation phase.

Numerical Example: Highway PPP Project

To illustrate its capabilities, the presented methodological framework was applied in the case of a 50 mile long, four-lane highway infrastructure project developed as a PPP concession. The operational and financial characteristics of the project are presented in Table 1 (base case), with typical values selected based on similar real-life projects, such as parts of the Trans-Texas corridor in the state of Texas [Texas DOT (TxDOT) 2004a,b].

The financing of the project is assumed to be consisting of different percentages of the following sources:

- Public funds (in the forms of grants, subsidies, or right of way (ROW);
- Equity from the developers/sponsors;
- Publicly issued debt (in the form of federal or state loans/bonds) with a fixed interest rate of 5.10%, and a duration of 35 years; and
- Commercially issued debt (in the form of bank loans/bonds) with a floating interest rate with a base value of 5.55%, and a duration of 40 years.

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Table 2. Financing Scenarios and Corresponding Investment Risk

	Percentage (%) of source of capital in the final project financing				
Scenarios	Public funds	Equity	Public debt	Commercial debt	Investment risk (%)
1	90	10	0	0	0.04
2	0	10	30	60	0.99
3	10	30	30	30	1.07

Both interest rates were based on actual financing rates for sections of the Trans-Texas Corridor (TxDOT 2004a,b). The remaining loan terms and characteristics are summarized in Table 1. All sources of finance are assumed to be used for covering the initial construction costs, as well as engineering and ROW costs. No loan refinancing, service fees, taxation, or the creation of reserve accounts are taken into consideration. Based on the previously discussed general cases, the following financing scenarios were investigated.

Scenario 1: 90% Public Funds, Minimum Equity (10%)

This scenario corresponds to the public sector financing the project to the largest possible extent. Capital costs are covered by public funds while operating, maintenance, and rehabilitation expenses are assumed by the private sector which also acts as the facility operator. In this case, the developers do not need to raise any capital in the form of debt to finance the project but just commit a minimum amount of own equity in order to showcase their active involvement and interest in the success of the project.

Scenario 2: No Public Funds, Minimum Equity (10%), 90% Debt (Commercial and/or Public)

This scenario corresponds to 100% private financing of the project. The public sector does not contribute any funds toward covering the capital costs. Instead, the developers have to commit own equity (minimum amount in this case) and raise debt for the remaining capital expenses. As in the previous case, the private sector acts as the facility operator and is obligated to cover operational, maintenance, and rehabilitation expenses. It should be noted however, that such a high leverage cannot always be realized, since it is dependent on the project's cash flows and the fulfillment of the lenders' CR requirements.

Scenario 3: Minimum Public Funds (10%), Maximum Equity (30%), 60% Debt (Commercial and/or Public)

In this scenario, the public authority contributes a minimum to the project (for example by covering the ROW costs) and the remaining capital expenses are covered by a combination of issued debt and equity from the developers, with the exact ultimate leverage of the project usually being determined based on the CRs of the lenders. The private sector acting again as the facility operator is also responsible for operational, maintenance, and rehabilitation costs.

Analysis and Results

In past similar analyses (Seneviratne and Ranasinghe 1997; Javid and Seneviratne 2000; Kakimoto and Seneviratne 2000; Pantelias and Zhang 2008), only four of the presented revenue and cost model parameters were considered to be stochastic. These were the initial construction cost estimate C_0, the initial traffic estimate Q_0, the inflation rate (f), and the discount rate $(r=\text{MARR})$. In this study two additional ones are considered, namely, the traffic growth factor (g_j^Q) and the interest rate of the commercial loan (i). Without loss of generality all six of them are assumed to be normally distributed with means and coefficients of variation as shown in Table 1, while at the same time, no correlation is assumed to exist among them. Although they can be considered a limitation, both these assumptions are based on findings from previous studies that have shown that the consideration of the actual probability distribution of the stochastic variables as well as of any potential correlation among them, does not significantly affect the results of the analysis compared to having well-estimated means and variances for the explanatory variables (Kakimoto and Seneviratne 2000).

The investment risk was estimated for the three basic financing scenarios, using the base case values of the project parameters. For the case of Scenario 2, a sensitivity analysis was also undertaken in order to highlight the effect of varying the contribution of the different sources of funds on the project's investment risk. Also, a sensitivity analysis was performed for the initial construction cost estimate by varying its mean value, as in the case where cost overruns or cost savings would be observed during the construction phase of the project. The analysis results are shown in Table 2 and Figs. 2 and 3.

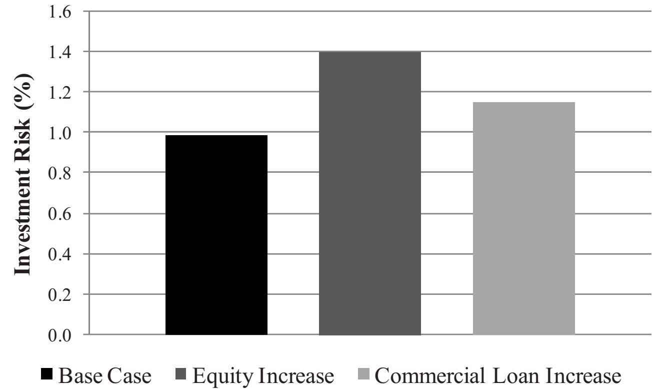

Fig. 2. Sensitivity of Financial Scenario 2 in terms of substituting public loan funds with an increase in equity or in commercial loan funds

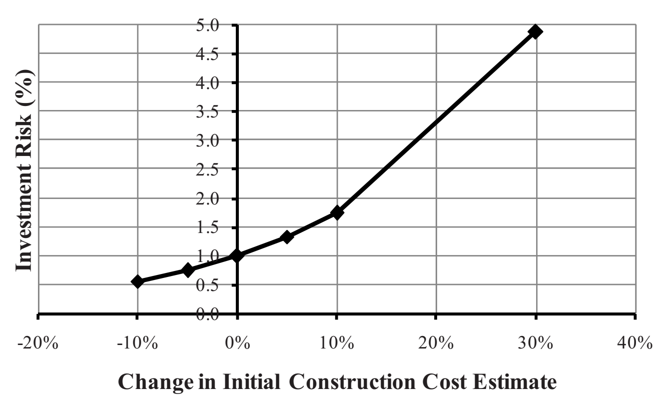

Fig. 3. Sensitivity of investment risk to changes in the initial construction cost estimate

From Table 2, it can be seen that the investment risk in the case where the public authority covers the majority of the capital costs is almost nonexistent (0.04). This means that in this case, the project most certainly will be able to repay the outstanding debt (there is none) and achieve the target 12% equity MARR that the investors are requiring from their 10% contribution to the initial capital costs. This scenario would be ideal for the equity investors, but is very hard to find in reality. Furthermore, based on the particular characteristics of this project, this scenario does not qualify as a PPP as there is practically no risk sharing between the public and the private sides. In terms of the other two scenarios and despite their differences, it can be seen that the increase of the commitment of equity increases the risk of the project, even when the contribution of public funds is part of the funding sources as shown in Scenario 3. This is expected because equity is committed early in the project and therefore affects the equity IRR calculations more significantly than the debt repayments that occur much later in the project's life.

In terms of the sensitivity analysis for Scenario 2 presented in Fig. 2, a variation in the contribution of equity and the commercial debt was investigated. Such a variation can practically correspond to a necessary measure taken in order to supplement the financing of the project in the face of a shortage in one of the available sources of debt. Such a scenario could actually correspond to the federal government not having enough funds available in order to fund all 30% of the project costs that would be funded through the public loan, but cover only 20% of them. In this case, it can be seen that in order to make up for the remaining missing funds, the contribution of more equity increases the investment risk more than the tantamount increase of the commercial loan. This is because the cost of financing through equity is always more expensive than using debt, which is also one of the main reasons that project financing is used to finance these types of capital intensive projects.

Finally, the effect of the variation of the initial construction cost estimate on the investment risk was investigated in a sensitivity analysis. This is one of many individual parameter sensitivity analyses that can be undertaken and was selected for the reason that deviations from the initial construction cost estimates are not an uncommon phenomenon in these projects (Grimsey and Lewis 2007), either due to bad estimation techniques or due to accidents, material and labor cost fluctuations, and other unexpected events that can negatively impact the actual construction costs. From the analysis, it can be seen that an increase in the initial construction cost estimate increases the investment risk while a reduction lowers it. Based on this result, the developers may want to take additional measures to ensure that the project does not go out of control in terms of its construction costs, through closer reevaluation of the construction management plans, or by hiring an external technical advisor, among other options.

All previously discussed observations validate some well-known industry experiences, such as that the preferable way of financing for a project would be that the majority of the capital expenditures should be taken care of by the public sectors. Since this scenario is highly unlikely due to the lack of public funds that is usually the driving power behind most PPP project procurements, the next best options involve the negotiation of favorable loans (with long grace periods, long payback periods, and low interest rates) and the decrease of the commitment of equity from the sponsors/developers (to the point required by the structure of the financing). In effect, the commitment of more equity to cover the project development costs is a more expensive way to supplement the financing of a project compared to an increase of the remaining available types of debt. Higher leverage results in lower risk; and varying this ratio between equity and debt could be further investigated for the determination of a theoretically optimal value of investment risk. In practice, however, the actual leverage of such projects is determined based on the lender's cover ratio requirements. Furthermore, changes in the initial construction cost estimate affect the investment risk as expected, since an increase in it creates additional capital needs that have to be covered early in the project's life while a decrease has the opposite effect.

In the terms of the financial viability of the project, it is clear that the higher the investment risk, the lower its anticipated financial viability. With this in mind, Scenario 2 containing a combination of public and commercial loans in the presence of low equity contribution leads to higher project viability compared to Scenario 3, despite the fact that in Scenario 3 the public authority is covering part of the costs. However, in both these scenarios, the resulting low investment risk denotes a high probability of achieving the target equity IRR while repaying the financing debt by the end of the project operating period, i.e., satisfying directly the measures of financial viability of both lenders and equity investors. These two measures being directly satisfied, further indirect and/or additional assessments can be made concerning the satisfaction of the ROE, CR, and VfM requirements, as discussed earlier.

Finally, from a managerial point of view, the above analysis and financial viability assessment can have the following interpretation from the various project stakeholders:

- Public authority: the public authority can use the financial viability estimate to evaluate if the project is attractive enough to the private sector for truly competitive bids to be received for it. Through them, the VfM target can be attained as well as the development of policies that regulate similar projects. For this project, the upside potential for the developer seems to be fairly robust, thus increasing the expectations for competitive bidding and ultimately achieving VfM.
- Lenders: for the lenders, this project shows that it is capable of repaying the issued debt by the end of the analysis period with a limited downside potential. This overall ability to repay the debt further enables the lenders to reevaluate and potentially renegotiate the structuring of the debt repayments in a way that their required cover ratios are also fulfilled (and/or sometimes reconsidered).
- Equity investors: for the developers that are committing private equity in the project, the assessment shows that the attainment of the required equity IRR is very probable, thus showing that the project is financially robust. With this in mind, the developers can be assured that even if they have to negotiate further the details of the financing with both the public authority (in terms of MARR adjustments or revenue sharing) and the lenders (in terms of adjusting the debt payment profile for the fulfillment of the required CR) their financial targets are not going to be jeopardized.

The results of the undertaken financial viability assessment can help in identifying potential sources of risk to the project that need to be addressed, as well as provide a basis for further negotiation of the financing details in a way that all project stakeholders achieve their respective targets, allowing that the project moves to financial closure and ultimately to implementation.

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Conclusions

In this paper, a comprehensive methodological framework for the assessment of the financial viability of PPP projects was presented. This framework is based on the evaluation of the investment risk of such projects which is probabilistically estimated with the use of the MOM. The conclusions from this study are the following:

- The financial viability of a PPP project has different meanings and measures for the various project stakeholders. However, the investment risk is central to the evaluation of a project's financial viability for all three parties involved. It directly accommodates the requirements of both lenders and equity investors, and can be used by all stakeholders and decision makers to support the hard decisions and negotiations toward financial closure and final project implementation.
- The presented methodological framework can be successfully used for the assessment of the financial viability of transportation infrastructure PPP projects through the evaluation of their investment risk with the use of the MOM. It is flexible to accommodate different types of transportation infrastructure through the use of their own cost and revenue quantitative models, even in the case where these models have a different form than the ones used in this paper, so long as the general problem formulation remains the same.
- As illustrated with the case study, the methodology is relatively easy to use and capable of analyzing a wide variety of investment options through scenario and sensitivity analyses, yielding information that can be of great value to all stakeholders, in making informed decisions on infrastructure investments. Through such analyses, the various stakeholders can investigate the effect of different parameters and implementation scenarios on the financial viability and identify possible sources of threat that need to be treated or mitigated in order for the project to be able to deliver their respective financial expectations.
- Finally, the proposed framework was not intended to solve all problems associated with the assessment of the financial viability of transportation infrastructure PPP projects. Among other potential improvements, this initial effort can further benefit from the consideration of the true probability distributions of the considered stochastic variables as well as the consideration of correlation among them. However, even in its present form, the proposed framework can enable the simultaneous assessment of a PPP project by all project stakeholders in terms of achieving their respective financial targets. The utilization of the MOM for the evaluation of the investment risk also constitutes an improvement over previous studies in this field.

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