Research in Transportation Economics 38 (2013) 128–138

Contents lists available at SciVerse ScienceDirect

Research in Transportation Economics

journal homepage: www.elsevier.com/locate/retrec

A simulation approach for estimating value at risk in transportation infrastructure investment decisions

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ARTICLE INFO

Article history:
Available online 12 June 2012

Keywords:
Value-at-Risk
Bootstrap simulation
Economic and financial analysis
Internal rate of return

ABSTRACT

Traditional economic analysis techniques used in the assessment of Public Private Partnership (PPP) projects are based upon the assumption that future cash flows are fully deterministic in nature and are not designed to account for risks involved in the assessment of future returns. In reality, many of these infrastructure projects are associated with significant risks stemming from the lack of knowledge about future cost and benefit streams. The fundamental premise of the PPP concept is to efficiently allocate risks between the public and the private partner. The return based on deterministic analysis may not depict a true picture of future economic outcomes of a PPP project for the multiple agencies involved. This deficiency underscores the importance of risk-based economic analysis for such projects. In this paper, the authors present the concept of Value-at-Risk (VaR) as a measure of effectiveness (MOE) to assess the risk share for the public and private entity in a PPP project. Bootstrap simulation is used to generate the risk profile savings in vehicle operating cost, and in travel time resulting from demand-responsive traffic. The VaR for Internal Rate of Return (IRR) is determined for public and private entity. The methodology is applied to a case study involving such a joint venture in India, the Mumbai Pune Expressway/National Highway 4 (MPEW/NH4), and fiscal implications from the perspective of the public and the private entities are examined. A comparison between deterministic and risk based economic analysis for MPEW/NH4 is presented. Risk analysis provides insightful results on the economic and financial implications from each participant's viewpoint.

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1. Introduction

Transportation infrastructure investments typically undertaken by the public sector have recently attracted private entities, thereby forming a joint participation commonly referred to as Public Private Partnership (PPP). There are a number of reasons for the growing trend of private participation in public projects. These include among other things: scarcity of fiscal resources at the public sector level, the perception that the private sector is more efficient in managing large projects, and the ability to share risks, thereby reducing exposure levels to financial losses for both entities.

Most investment decisions share three important characteristics in varying degrees. First, the investment is generally irreversible in that the funds invested are completely "sunk" in the project. Thus the agencies responsible for managing the project must be fully committed to the project, once the investment is made. Second, there are uncertainties over the future outcome from the investment. One way to address this is to assess the probabilities of alternative outcomes representing varying degrees of profits or losses. The third characteristic is related to timing of the investment. With proper planning, investment decisions may be postponed until credible information about future outcomes may be available. These three characteristics interact to determine the optimal decision of investors (Weston & Brigham, 1976). Experts suggest that purely public and purely private delivery mechanisms are unreliable, unstable, averse to innovation, and hence undesirable (Miller & Evje, 1999). A disparity between infrastructure needs and limited public resources has given rise to an increasing use of PPP.

India (the subject case for this paper) has, in the past, used the traditional approach of road financing, where roads are treated as publicly owned/operated facilities, and are funded from a myriad of sources including general revenue, and road user taxes. Private sector financing is being sought increasingly to fund infrastructure programs; and tolls are being applied to generate revenues.

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doi:10.1016/j.retrec.2012.05.009

However, private sector financing "cannot replace the role of the public sector, nor can it reduce the importance of rational, fair and transparent public financing system" (World Bank, 2004, p. ii). Thus, joint public–private ventures appear to be the key to the financial success of such projects.

A recent World Bank Report shows that India currently has 3.5 million kilometers (km) of roads, of which approximately 170,000 km are under the national and state highway category (mostly two-lane facilities), representing modest design standards. The National Highway System in India totaling 58,000 km of two-lane facilities, carries 45 percent of total traffic (World Bank, 2004). In spite of significant public investment on roads by the Government of India, there is a great need today for high quality, high capacity highways to accommodate the ever-increasing traffic in India's metropolitan areas.

2. Problem statement

Traditional economic analysis techniques used in the assessment of PPP projects are based upon the assumption that future cash flows are fully deterministic in nature. Thus, these are not designed to account for risks involved in the assessment of future returns. In reality, many of these infrastructure projects are associated with significant risks stemming from a lack of knowledge about future cost and benefit streams. Such projects typically involve huge initial costs, take longer to complete and are reliant on future cash flows to meet financial obligations. Most of the economic analysis techniques that are used to compute future returns, fall into two categories, i.e. predictive (*ex-ante*) or evaluative (*ex-post*) (Boardman, Greenberg, Vining, & Weimer, 2005). Predictive analysis is used to forecast the likely economic impacts of a proposed investment, whereas evaluative techniques are used to gauge the effect of the investment after it has been implemented (Cambridge Systematics, 1998). The topic of this paper is *ex-ante* analysis.

The fundamental premise of the PPP concept is to efficiently allocate risks between the public and the private partner and to deliver the project at a lower total cost to the public. The economic and financial measures derived through deterministic analysis do not reflect possible risks. The purpose of the paper is twofold: first, to demonstrate the use of risk as a measure of effectiveness (MOE) in the assessment of infrastructure project feasibility; second to demonstrate the use of this MOE, using a real world case study.

3. Modeling risk in PPP

Risk may be looked upon as the probability of occurrence of an undesirable outcome, and is defined in literature in many ways (Al-Bahar, 1988; Chapman, 1991; Hammer, 1972; Kerzner, 2005; Lowrance, 1976; Newman, 1983; Petak & Atkisson, 1982; Sanchez, 1998). While there are a variety of methods to measure risk, the choice of one depends mostly on the objectives of the analysis to be performed. For an infrastructure project, the risk measure can be quantified by determining the combined effect of risks in traffic, economic factors, cash flow needs, construction and maintenance costs, etc. Examples of risk measurement techniques include risk probability of occurrence, volatility, risk on return of capital, and value at risk. Other forms of analysis such as sensitivity and stochastic analysis, measure the tradeoff on the economic outcome (in terms of Net Present Value (NPV) and Internal Rate of Return (IRR), etc.) by altering the effects of risk factors (traffic, toll, cost etc.).

Risk can be quantified in different ways (Mun, 2006). The term "Value-at-Risk" (VaR) is one of such methods, and has been used as a decision tool for risk analysis in this paper. VaR can be defined as the maximum expected loss over a target horizon, with a given level of confidence (Jorion, 1997). VaR describes the quantile of the projected distributions of gains/losses over the target horizon. If α is the selected confidence level, VaR corresponds to the $(1-\alpha)$ lower tail level. For example for 95 percent confidence level, VaR should be such that it exceeds 5 percent of the total number of observations in the distribution. VaR can be determined as the maximum expected loss over a target horizon, with a 95 percent level of confidence as the IRR at α of 0.05 (Fig. 1).

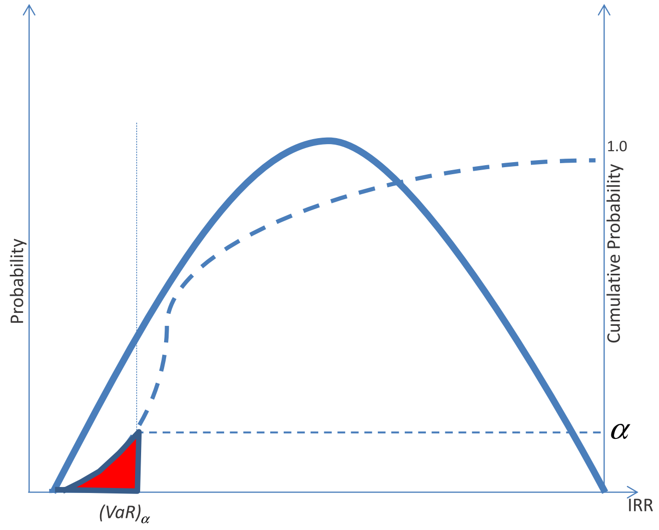

Fig. 1. Volatile factors and Value-at-Risk.

3.1. VaR estimation techniques: bootstrap simulation

With the ability to predict the consequences under different circumstances, the technique of simulation is being used increasingly to unveil the effects of risks on the MOE. The early VaR models are also referred as parametric because of the strong theoretical assumptions they impose on the underlying properties of the data.[3] One such assumption is that the density function of risk factors influencing asset returns must conform to the multivariate normal distribution.[4] Empirical evidence indicates that speculative asset price changes, especially the daily ones, are not necessarily normal.

The problems of earlier models spurred the search for better estimates of VaR. A number of recent VaR techniques are based on nonparametric statistical methods. Re-sampling techniques are often used to re-construct the distribution of a population starting from limited samples. The principle of bootstrap distribution uses re-sampling with replacement from the original sample (selected from a studied population) that results in a new distribution. An advantage of the bootstrap approach is that it can include unusual traits, such as fat tails, jumps, or other departures from normal distribution.

VaR can be computed once the price path is simulated using bootstrap, and the resulting MOE (say NPV or IRR) can be developed at the end of the selected horizon. The simulation can be carried out in the following steps.

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[3] Parametric VaR models are based on strong theoretical assumptions and rules. They impose that the distribution of the data (daily price changes) conforms to a known theoretical distribution.

[4] The normality assumption is frequently used because the normal distribution is well described; it can be defined using only the first two moments (mean and standard deviation) and it can be understood easily. Other distributions can be used, but at a higher computational cost.

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