EVALUATING MINIMUM-TRAFFIC GUARANTEES FOR PPPs IN TURKEY BY REAL-OPTION PRICING

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Abstract

Minimum-traffic guarantees for build-operate-transfer toll-road projects are contingent liabilities that expose government to fiscal risk. Therefore, public authorities must value guarantees, thereby enabling informed decision-making about the level and type of guarantee provision. This study demonstrates the use of financial modeling and risk analysis in a toll-road project in Turkey, contributing to the narrowing of a capacity gap in the field. We present three types of guarantee, modeled as real options and evaluated by Monte Carlo simulation. We identify one criterion to determine the optimum level of guarantee for a given project, and one criterion to measure the extent to which a guarantee will reduce risk. Based on these and other complementary criteria, it is proposed that the guarantee with income ceiling is the most appropriate for the project considered here. The paper concludes with a discussion of the policy implications of the findings.

Keywords: Contingent liabilities, government guarantees, real options, cost-benefit analysis, public-private partnerships, infrastructure, Turkey.

JEL classification: G13, D61, H54, L33

Öz

Otoyol yap-işlet-devret projelerine sağlanan minimum trafik garantileri, devleti mali riske maruz bırakan koşullu yükümlülüklerdir. Dolayısıyla, garantilerin seviyesi ve çeşidi üzerinde sağlıklı karar alabilmek adına devletin bu garantileri değerlendirmesi elzemdir. Çalışma, bu alandaki kapasite açığını gidermeye katkıda bulunmak adına, Türkiye'de bir otoyol projesinin finansal modellemesi ve risk analizini gösterecektir. Üç garanti çesidi, reel opsiyonlar olarak modellenecek ve Monte Carlo simulasyonu kullanılarak değerlendirilecektir. Çalışma, optimum garanti seviyesini bulmak için ve bir garantinin risk azaltma kapasitesini ölçmek için birer kriter önermektedir. Bunlar ve diğer tamamlayıcı kriterleri göz önüne alındığında, değerlendirilen proje için, en uygun garanti olarak içinde gelir tavanı bulunduran garanti önerilmektedir. Sonuçlar çerçevesinde ilgili politika yansımaları sunulmaktadır.

Anahtar kelimeler: Koşullu yükümlülükler, devlet garantileri, reel opsiyonlar, fayda-maliyet analizi, kamu-özel işbirlikleri, altyapı, Türkiye.

INTRODUCTION

Nations demand highways. Widely accepted as a precondition of economic development, highways are appealing to voters. Faced with an inability to fund larger schemes, governments have increasingly turned to the private sector to finance and build highways, in the expectation that toll revenue will be sufficient to cover costs. An Organization for Economic Cooperation and Development (OECD) survey of global public-private partnership (PPP) projects from 1985-2009 found that road projects accounted for about one-half by value (USD 307 billion out of USD 645 billion) and one-third in number (567 out of 1,747) (OECD 2010: 26). In Europe, road projects in the same period represented more than half of all PPPs by value (USD 157 billion out of USD 303 billion).

In Turkey as of October 2015, road projects were the second-largest category of PPPs by number (29 out of 193) after energy projects (76 out of 193), and the third largest in value (USD 12 billion) after airport (USD 66 billion) and energy projects (USD 22 billion) (Ministry of Development [MOD] 2015). All road PPPs in Turkey are implemented under the build-operate-transfer (BOT) model. Clearly, road PPP projects play a major role in infrastructure development globally and in Turkey. This study focuses on toll-road BOTs in Turkey, to explore the risk to the public sector of guaranteeing private-sector partners' minimum traffic flows and revenue. Such guarantees pose a hidden risk to the fiscal stability of the country, limiting the borrowing capacity of the state and increasing its cost of borrowing (Emek 2014: 11).

Yet we have found no evidence that public bodies in Turkey calculate the real-option value of the guarantees extended to BOT project companies. Nor, indeed, is there evidence of such calculations in the academic literature. Turkey's MOD is responsible for the evaluation of all BOT projects, although it lacks the required technical capacity to do so (MOD 2013). The Ministry of Finance (MOF) is responsible for monitoring contingent liabilities incurred by central government entities, however it does not monitor those incurred under BOT projects (Emek 2014: 19).

As PPP concession contracts are not published, there is a serious lack of comprehensive empirical evidence upon which to evaluate the performance of previous BOTs in Turkey, beyond occasional audit reports (Emek 2009: 44). Hence, to the best of our knowledge, no evaluation of government guarantees to any BOT project has ever been published in the literature on Turkey.

This paper aims to highlight key issues regarding the type and the level of minimum-traffic guarantee the government should offer private-sector partners in toll-road BOT projects in Turkey. The three guarantee types to be analyzed are the plain minimum-traffic guarantee, the capped minimum-traffic guarantee, and the minimum-traffic guarantee with income ceiling. We first illustrate methods of modeling these three guarantee types as real options. The value of each type is then calculated in a Monte Carlo simulation, using real-option pricing and the Capital Assets Pricing Model (CAPM). The paper proposes a criterion by which to identify the optimum level of minimum-traffic guarantee, and a criterion by which to measure the risk-reduction capacity of a given guarantee.

The next section provides a detailed literature review, followed by a section on data and methodology explaining assumptions and analytical procedures used in the case illustration. Finally, the results of the study are used to draw overall conclusions and suggest policy implications.

LITERATURE

Currie and Velandia (2002: 2) propose that the government may take risk on behalf of the private sector if that risk is systematic. Governments may therefore provide demand guarantees to private-sector partners in BOT projects to mitigate demand risk, which is a market (systematic) risk. In the case of Turkey, the government assumes demand risk in toll-road BOT projects by guaranteeing minimum traffic volumes. According to Coşan and Büyükbaş (undated), the Gebze-İzmir Highway İzmit Bay Crossing Project entailed a government guarantee of minimum traffic flows equivalent to annual revenue of at least USD 700 million. Another example is the construction and operation of the third Bosphorus bridge, for which the government guaranteed traffic flows of at least 135,000 vehicles per day (Rodrigues et al. 2013).

Many toll-road projects are based on overly-optimistic forecasts of future use of a proposed highway (Bain 2009, Bain 2011, and Flyvbjerg et al. 2006). This optimism bias may result in unviable toll-road projects, where traffic volumes are insufficient to generate expected revenues. It is therefore crucial that the value of minimum-traffic guarantees provided to toll-road BOT projects is carefully calculated. If governments provide too generous guarantees, taxpayers will have to make up the shortfall.

Governments have to evaluate PPP projects to decide what type and level of guarantee to provide. In Turkey, however, there is no system in place for the operational measurement of the cost of contingent liabilities arising from PPPs. The proper management of contingent liabilities and associated risks in BOT projects requires the introduction of an operational measure of related cost, calculating the real-option value of guarantees extended by the government to private-sector partners.

An example of such an approach in an emerging economy is provided by Colombia. In the 1990s, the government of Colombia measured the expected fiscal costs of minimum-traffic guarantees provided under the El Cortijo-El Vino toll-road project, according to which the public sector committed to top-up the private operator's revenue if traffic fell below a certain level. Using real-option pricing techniques, the study simulated possible project outcomes to estimate expected government payments as a result of the guarantee, by making assumptions about how the key risk variable (traffic) would evolve over time, the expected growth rate of that variable, and its volatility (Lewis and Mody 1997: 136).

One means of deriving the price of risk that a government takes on in providing guarantees to BOT project participants is to conduct a Monte Carlo simulation in an empirical cost-benefit analysis of the project, calculating the expected present value (PV) of future probable guarantee payments, appropriately adjusted for risk. The academic work on the valuation of government guarantees dates back to the 1980s, with several authors arguing that the valuation of loan guarantees provided by the government requires contingent claims analysis (Baldwin et al. 1983: 342-343; and Mody and Patro 1995: 8-9). Contingent claims analysis usually refers to a general framework for the pricing of various claims that are contingent on certain triggering events or conditions, but which are not necessarily directly linked to a tradable security. Option pricing techniques, a subset of contingent claims analysis, are usually associated with pricing financial option products based on an underlying tradable security.

A guarantee is similar to a put option. For instance, the lender, being the holder of a loan guarantee, has the option to sell the debt at the contracted price, which corresponds to the strike price of the put option. An option that can be exercised only at maturity is known as a European option. The price that the holder of the option is required to pay is the option premium (value). A fair option value is equal to the PV of the cash flows received on the option.

Black and Scholes (1973) and Merton (1973) achieved a major breakthrough in the pricing of European stock options with the contingent claims valuation model, in which the underlying asset (stock) is traded on the market. However, the Black-Scholes-Merton formula for calculating the premium of a put option cannot be used to price (value) minimum traffic (or revenue) guarantees, because there is no traded underlying asset. Irwin (2003: 46) clearly sets out the reason why the Black-Scholes-Merton model cannot be used in such a case: the underlying risk variable (traffic or revenue) *is not a traded asset* and, indeed, *is not even an asset*.

The best way to calculate the value of minimum-traffic guarantees is real-option pricing. In the case of a BOT road project, the government guarantee of minimum traffic provided to the project sponsor is a real option, which can be valued using real-option pricing. Traditional capital investment appraisal techniques based on estimated expected cash flows, discounted at a risk-adjusted discount rate are not sufficient, because the real options in a BOT road project often have different risk characteristics than those of the base project and so require different discount rates (Hull 2012: 765-766; and Irwin 2003: 41). In pricing real options, the risk-neutral valuation principle is therefore applied, using the risk-free rate as the discount rate (Hull 2012: 767).

Modeling the underlying risk variable (traffic) is central to estimating the value of a minimum-traffic guarantee. The model needs to incorporate forecasts of both the expected rate of growth in the variable over time, and its volatility. In the literature, the usual assumption is that risk variables (such as revenue or traffic) follow a geometric Brownian motion (GBM). For more on the mathematics underlying GBM, see Hull (2012: 280-298); and Dixit and Pindyck (1994: 59-82). Variables following a GBM can never be negative and have constant rates of expected growth and volatility. If a variable, S, is assumed to follow a GBM, then the estimate of its value, S_T, *at any point in time* has a lognormal distribution. Therefore, the logarithm of the random return, $\ln(S_T/S_0)$, is normally distributed (Brandao et al. 2005: 75-77). This is also the model of stock price behavior presented by Hull (2012: 292-293). The assumption that traffic follows a GBM has been adopted by many authors (Irwin 2003: 42; Wibowo 2004: 399; Cheah and Liu 2006: 549; Wibowo 2006: 245; Chiara et al. 2007; Brandao and Saraiva 2008: 1173; and Jun 2010).

Assuming that traffic follows a GBM, estimates of future traffic require assumptions or estimations about the expected rate of growth and volatility (standard deviation of the growth rate). If comparable roads exist, it may be possible to estimate the future rate of growth of traffic and its volatility by extrapolating from past values. Where a government guarantee concerns a unique new project, expert opinion on forecast traffic for the initial year of operation and its expected rate of growth are likely to be available from the project feasibility study. Estimates of traffic volatility, however, are less likely to be available. Brandao and Saraiva (2008: 1175) address this potential constraint by using the volatility of gross domestic product (GDP) as a proxy for traffic volatility, based on the standard assumption that traffic is positively correlated with GDP (see also Banister 2005; and OECD 2002: 143-178).

DATA AND METHODOLOGY

Data

The case study used to illustrate the modeling and valuation of minimum-traffic guarantees is based on a proposed toll-road BOT project connecting two major cities, involving the rehabilitation and expansion of a pre-existing route. Complete project parameters are provided in the feasibility study. The appraisal is done in the current time (t=0), the construction period is three years, and operations start in the fourth year (t=4). The operational period of the project is assumed to be 20 years. Monetary values are in real terms (t=0). The investment amount is estimated to be TRY 3.2 billion. Risk-free and risk-adjusted (required) rates of return are assumed to be 6 percent and 11 percent, respectively (Uzunkaya and Uzunkaya, 2012).

Data regarding the value of time (VOT) and vehicle operating costs (VOC) for each vehicle type are taken from the feasibility study, along with average vehicle speeds—with and without the project. The feasibility study assumes an annual rate of traffic growth of 2 percent, while we assume traffic volatility to be 7.55 percent—the average volatility of Turkey’s GDP for 1987-2007 (Berument et al. 2012: 354). Table 1 presents our calculation of toll rates based on total VOT and VOC savings, according to vehicle type and section. The toll structure is assumed to be constant.

Table 1. *Tolls*

Proposed toll (t=0 TRY and with VAT)	Section 1	Section 2	Section 3
Cars	11.2	13.3	5.2
Buses & Other Commercial Vehicles	29.0	34.6	13.6
Trucks (2 or 3 axles)	22.3	26.6	10.6
Trucks (4 or more axles)	27.9	33.3	13.1

Source: Authors' calculations

Projecting and Estimating Overall Annual Traffic over Time

The feasibility study forecasts toll-free daily traffic levels by section and vehicle type, in the initial year (t=4) of operation. Capitalizing on the available data, we estimate daily traffic levels in the initial year of operation once tolls are introduced, by section and vehicle type, using a traffic-demand model adopted from Barreix et al. (2003). In a sample of 183 road projects in 14 countries, Flyvbjerg et al. (2006: 9) found that for around half, the difference between forecasted and actual traffic was more than ±20 percent. A survey of data on predicted and actual traffic usage in over 100 privately financed toll-road projects found traffic forecasts to be characterized by large errors and optimism bias (Bain 2009). Bain (2011) therefore recommends a post-model prediction interval of $\pm 10 \text{ percent} * \sqrt{n}$ constructed around a central-case traffic forecast, where n is the number of years into the forecast.

We introduced this recommended prediction interval at the post-modeling stage, around central-case estimates of daily traffic for each section and vehicle type. In our case n is 4, because the forecast is conducted for the first year of operation (t=4). So, for the initial year of operation, the prediction interval is $\pm 20 \text{ percent}$ around each central-case estimate. The risk variables in our simulation are estimated daily traffic levels in the initial year of operation, which, in keeping with Cheah and Liu (2006: 549), we assume to exhibit a lognormal distribution. Because we assume that traffic follows a GBM over time, it is appropriate to assume that traffic in the first year of operation has a lognormal distribution, since if a variable, S, is assumed to follow a GBM, then the estimate of its value, S_T, *at any point in time* has a lognormal distribution.

For each traffic risk variable, the mean of the lognormal distribution will be equal to the estimated traffic level, with a standard deviation equal to the estimated level multiplied by 20 percent divided by 3. This means that variation in the lognormal risk variable occurs between 0.8

and 1.2 times the estimated level (Table 2). Given their lognormal distribution, a traffic risk variable cannot fall below the value of the location parameter, which we set as zero. Traffic risk variables will also affect *projected* and *estimated* overall annual traffic over future years of project operation, which are based on the overall annual traffic estimate for the first year of operation. Estimated annual traffic flows for each section and vehicle type in the initial year of operation are reached by multiplying daily estimates by 365.

Table 2. *Estimated Daily Traffic Levels and Standard Deviations in t=4*

	Section 1	Section 2	Section 3
Cars	13,726 (915)*	13,850 (923)	4,347 (290)
Buses, Other Commercial Vehicles	1,486 (99)	1,822 (121)	580 (39)
Trucks (2 or 3 axles)	1,502 (100)	2,015 (134)	730 (49)
Trucks (4 or more axles)	6,448 (430)	11,016 (734)	5,102 (340)

Source: Authors' calculations
*: Values in parentheses are standard deviations

In our model, to have one single source of uncertainty over time, which is the overall annual traffic following a GBM over time; through weighted averaging, we calculate the overall annual traffic figure during the first year of operation as section-1-car-equivalent traffic (in line with Cheah and Liu 2006 and Brandao and Saraiva 2008). To find the time series of *projected* overall annual traffic, we apply the growth rate of traffic to that figure; to find the time series of *estimated* overall annual traffic, we apply the GBM.

Getting the Risk-Neutral GBM Process from its "True" Counterpart using the CAPM

To evaluate an investment under the real-options approach, the risk-neutral GBM process for the risk variable is estimated and fed into the financial model. The value of the investment is the PV of the expected net cash flows each year, discounted at the risk-free rate (Hull, 2012: 769). Similarly, the value of the real option embedded in the investment, such as a minimum-traffic guarantee, is the PV of the probable guarantee payments each year, discounted at the risk-free rate. To get to the risk-neutral stochastic process of the risk variable from its "true" stochastic process, the expected growth rate of the risk variable is reduced by the risk premium of the risk variable, which is the market price of risk for the risk variable, multiplied by the volatility of the variable. All cash flows are then discounted at the risk-free rate (Hull, 2012: 767).

In this study, because traffic is assumed to follow a GBM over time and the tolls are constant, revenues (R) will follow the same GBM as traffic. Therefore, growth rate of revenues (α) is equal to the growth rate of traffic. At the same time, the standard deviation of the growth rate of revenues (σ_R) is equal to the volatility of traffic. So, while discretely modeling the *risk-neutral* GBM process for revenues, in yearly periods, as a function of the value in the previous period, we use Equation 1, where λ is the market price of risk for revenues and $\mathcal{E} \sim N(0,1)$ is the standard Wiener process. In the risk-neutral process, revenue has a growth rate equal to $\alpha\text{-}\lambda.\sigma_R=r$, which is equal to the risk-free rate of return, instead of α, which is the growth rate of the "true" process.

$$R_{t+1} = R_t \cdot e^{\left(\alpha - \lambda \cdot \sigma_R - \frac{\sigma_R^2}{2}\right) \cdot \Delta t + \sigma_R \cdot \mathcal{E} \cdot \sqrt{\Delta t}} \qquad (1)$$

Equation 1 is modeled in Microsoft Excel, as shown in Equation 2. $\mathcal{E} \sim N(0,1)$ is modeled in Excel as NORM.S.INV(RAND()), which generates random numbers with a standard normal distribution (Irwin, 2007: 137). It is deemed appropriate to use $\Delta t=1$ year, as revenues are modeled annually, since traffic is modeled annually.

$$R_{t+1} = R_t \cdot e^{\left(\alpha - \lambda \cdot \sigma_R - \frac{\sigma_R^2}{2}\right) \cdot 1 + \sigma_R \cdot \mathrm{NORM.S.INV(RAND())} \cdot \sqrt{1}} \qquad (2)$$

The process in Equation 1 can be fully specified if we have the revenue in the initial year of operation (calculated by multiplying the constant toll and the overall annual traffic in the initial year of operation); annual growth rate of revenues; the annual standard deviation of revenues; and the market price of risk for revenues. All required parameters are available except the last (λ).

Had we had a marketed underlying asset as the risk variable, we would have derived its risk-neutral stochastic process by subtracting its risk premium from its expected rate of return. However, neither revenue nor traffic is a marketed asset. Using the CAPM, Brandao and Saraiva (2008: 1174) suggest a solution by showing that the risk premium of revenues can be estimated from the stochastic process of the value of the project. They provide an expression of $\lambda.\sigma_R$, the risk premium of revenues, in terms of the parameters that we know or estimate (Equation 3).

$$\lambda \cdot \sigma_R = (\mu - r) \cdot \frac{\sigma_R}{\sigma_P} \qquad (3)$$

where μ, the risk-adjusted (required) rate of return for the project; σ_R, the volatility of revenues (traffic); σ_P, the volatility of the project, can be estimated by means of a Monte Carlo simulation applied to the financial model without guarantees and with the "true" process of revenues (traffic). For the mathematics behind the equations above, see Irwin (2003: 45-47); Irwin (2007: 137-139); Brandao and Saraiva (2008: 1173-1175). See Hull (2012: 257-259, 280-298, 631-634, 766-768) for more on risk-neutral valuation, Brownian motions, the market price of risk, and the extension of the risk-neutral valuation framework to real options.

Estimating Project Volatility

To derive a risk-neutral process requires an informed estimate of project volatility. Both Copeland and Antikarov (2003: 249) and Brandao et al. (2005) calculate the volatility of project return for the first year of operation and use this as the volatility of the project, maintaining that the volatility will be the same in the remaining years because of the properties of the GBM assumption. We took a more rigorous approach, testing if a GBM provides a reasonable approximation of the evolution of project value by calculating period-by-period project returns. Our simulation set project returns as the forecast variables, to observe project volatility for each year. We found that standard deviations of these period-by-period returns were indeed approximately equal (the mode, median and average were 24 percent), indicating that a GBM is indeed a reasonable approximation of the evolution of project value.

With regard to determining project uncertainty, Copeland and Antikarov (2003: 239) explain that the GBM can be used to model changes in the value of a project over time, because even the most complex set of uncertainties that may affect cash flows of a real-options project can be reduced to a single uncertainty—the variability of project value over time. This means that regardless of the irregularity of the stochastic pattern of future cash flows, the project value will follow a GBM over time with constant volatility. Similarly, Brandao et al. (2005: 77) state that the assumption that the project value follows a GBM enables the modeler to combine any number of uncertainties in the financial model in a "single representative uncertainty", which is the uncertainty associated with the GBM followed by project value.

Modeling and Valuing Three Types of Minimum-Traffic Guarantee

The project agreement obliges the government to make annual guarantee payments to the project company in years that "realized" traffic (and thus revenue) falls below a certain ratio of *projected* traffic (and thus revenue). That ratio is the minimum-traffic guarantee (MTG) multiplier, referred to below simply as the MTG. We refer to this type of guarantee as the *plain guarantee*. The annual time series of "realized" traffic is the annual time series of *estimated* traffic, calculated by applying the risk-neutral GBM to overall annual traffic in the first year of operation.

R_t represents the observed revenue in year *t*—"realized" overall annual traffic multiplied by the constant toll rate. P_t represents the minimum revenue guaranteed by the government in year *t*—MTG multiplied by projected overall annual traffic and the constant toll rate. The effective revenue, *R(t)*, earned by the project company in year *t* is therefore $R(t) = \max(R_t, P_t)$, while the government guarantee payment, G_t, in year *t* is calculated as $G_t = \max(0, P_t - R_t)$. The annual guarantee payment is accordingly calculated for each year of the 20-year project. These annual guarantee payments are independent European put options, with maturities of 1 to 20 years. The overall PV of the minimum-traffic guarantee is the sum of the PVs of all 20 European put options at the risk-free discount rate.

$$PV(Guarantee) = \sum_{i=1}^{20} PV(Put\ Option_i) \qquad (4)$$

The net PV (NPV) of the project with embedded real options (guarantees) can also be calculated by discounting net cash flows, including guarantee payments, at the risk-free rate. The above calculations are for one run (trial) of a Monte Carlo simulation, whereas we ran 10,000 trials. For each of our twenty-three different scenarios, each with a different MTG (ranging from zero to 1.10), the simulation calculated present values (forecast variables) for different types of minimum-traffic guarantee, and for the project with such guarantees, to generate probability distributions of forecast variables, as well as to establish their means and volatilities. The subsequent analysis of risk under these different scenarios provided the basis for the policy recommendations presented below. For more on the use of Monte Carlo simulation in real-option pricing, see Copeland and Antikarov (2003); Irwin (2003: 43); Wibowo (2004: 399); Cheah and Liu (2006: 545); Chiara et al. (2007: 98); Irwin (2007: 138); Cebotari (2008: 17); Brandao and Saraiva (2008: 1175); Hull (2012: 769); Wibowo et al. (2012: 1403); and Rajaram et al., (2014: 108, 119).

An alternative to the plain guarantee is the *capped guarantee*, which limits government exposure to contingent liabilities. Under this type of guarantee the government stops making payments at a pre-agreed cap, which may be determined as a percentage of total investment cost. The guarantee payment (G_t) is calculated each year. However, the government makes no further payments in the years after the cap is reached. The model of an annual guarantee payment with cap (G_{uc}) for any year $t=u$ is:

$$G_{uc} = if[(\sum_{t=4}^{u} G_t) < cap, G_u, if((cap - \sum_{t=4}^{u-1} G_t) > 0, (cap - \sum_{t=4}^{u-1} G_t), 0)] \quad (5)$$

If total guarantee payments until year $t=u$ are less than the cap, then the guarantee payment with cap (G_{uc}) will be equal to the calculated guarantee payment (G_u) in year u. If not, there are two alternatives. If the sum of guarantee payments up to $t=u-1$ is less than the cap then, in year u, the guarantee payment with cap (G_{uc}) will be equal to the cap minus the sum of the calculated guarantee payments (G_t) from the first year of operation ($t=4$) until year $u-1$. If the sum of guarantee payments up to $t=u-1$ is more than the cap then, in year u, the government will not make any guarantee payment, that is, G_{uc} will be zero.

Another alternative to the plain guarantee is the *minimum-traffic guarantee with income ceiling*, which limits the overall income to the project company. Given that the tolls in our case are constant, an income ceiling is established by imposing a traffic ceiling. We calculate the traffic ceiling by multiplying projected overall annual traffic by the traffic ceiling multiplier, which is equal to one in this study. Under this form of guarantee, the government requires that where "realized" or guaranteed traffic exceeds the projected level, the corresponding excess revenue will be deposited in a contingency fund, which can be used to cover future guarantee payments for similar projects. This approach is in keeping with policies aimed at avoiding the accumulation of excessive profit by private-sector partners (Lewis and Mody 1997). Total effective income, I_t, earned by a project company subject to an income ceiling can be written as follows:

$$I_t = \min(\max(R_t, P_t), TC_t) \quad (6)$$

where TC_t is the income ceiling, in year t, imposed by the traffic ceiling. Income transferred to the contingency fund in year t, CF_t, is calculated by subtracting the total effective income (I_t) of the project company subject to an income ceiling from the total income of the project company without any income ceiling:

$$CF_t = (R_t + G_t) - I_t \qquad (7)$$

The model used to calculate guarantee payments with traffic ceiling, GTC_t, is written as follows:

$$GTC_t = if(P_t > R_t, if(P_t < TC_t, (P_t - R_t), if(TC_t > R_t, (TC_t - R_t), 0)), 0) \qquad (8)$$

Intuitively, if observed level of revenue (R_t) is bigger than the guaranteed level of revenue (P_t), there is no guarantee payment. Otherwise, if guaranteed revenue (P_t) is smaller than the income ceiling (TC_t), then the guarantee payment will be the guaranteed revenue (P_t) minus observed revenue (R_t). In such a situation, total income will in any case not exceed the income ceiling, because $P_t < TC_t$. Therefore, where the MTG is less than or equal to one, guarantee payments under the minimum-traffic guarantee with income ceiling will be the same as those under the plain guarantee. This is because at any level of guarantee where the MTG is less than or equal to one, the guaranteed revenue P_t will never exceed the income ceiling, TC_t, as the traffic ceiling multiplier is set at one. On the other hand, if the guaranteed revenue (P_t) is greater than the income ceiling (TC_t), which can only happen if the MTG is greater than one, then there are two possibilities: If the income ceiling (TC_t) is greater than observed revenue (R_t), then the guarantee payment is the income ceiling (TC_t) minus observed revenue (R_t). If the income ceiling (TC_t) is less than observed revenue (R_t), then there is no guarantee payment. In both cases, the guarantee payment is limited by the income ceiling, because the counterfactual is that the guarantee payment would have been the guaranteed revenue (P_t) minus observed revenue (R_t), where $P_t > TC_t$.

RESULTS FROM THE EVALUATION OF THREE TYPES OF MINIMUM-TRAFFIC GUARANTEE

Plain Guarantee

All NPV (project) and PV (guarantee) figures provided in this section are mean (expected) values derived from the simulation, in t=0 TRY million. The simulation results indicate that without any guarantee, the expected NPV of the project is TRY (158.5) million, while the project risk—that is, the probability that the project NPV is negative—is 67 percent (Table 3). This situation explains why a government guarantee is needed to attract private-sector participation in this project. A suggested criterion for the optimum MTG level is therefore the point at which that guarantee tips expected project NPV from negative to positive. A sensitivity analysis of expected project NPVs and expected guarantee PVs was undertaken, in which the MTG was adjusted across a range from zero to 1.10 (generating twenty-three scenarios), with corresponding project NPVs and guarantee PVs as forecast variables. MTG values greater than one are included to demonstrate the arguments when comparing the other guarantee types with the plain guarantee.

Because the expected values of guarantees up to an MTG of 0.40 are either zero or negligible, and expected project NPVs are significantly negative up to an MTG of 0.70, the corresponding values at these levels are not included in the tables below. Mean project NPV turns from negative to positive when the MTG is increased from 0.80 to 0.85. According to our criterion, this means that the optimum MTG should be between 0.80 and 0.85. Even at an MTG of 0.85, however, project risk is substantial at 55 percent. To reduce project risk to zero requires an MTG of one, at which point the mean project NPV and the mean guarantee PV equal TRY 339.2 million and 728.9 million, respectively. With a minimum MTG of one, the project is completely risk-free and probably to be very attractive to potential private-sector partners.

Table 3. ***Expected Values of NPV (Project) and PV (Guarantee) and Project Risk, with the Plain Guarantee***

MTG	NPV (Project)	Project Risk*	PV (Guarantee)
0.00	-158.5	67%	0.0
…			…
0.75	-54.7	65%	157.0
0.80	-3.5	63%	231.4
0.85	65.0	55%	317.2
0.90	142.0	32%	425.8
0.95	230.9	5%	561.3
1.00	339.2	0%	728.9
1.05	473.2	0%	935.7
1.10	621.6	0%	1146.8

*: Project risk is defined by P[(NPV(Project)<0]
Source: Authors' calculations

Capped Guarantees

Two alternative scenarios tested involved total guarantee payments capped at 10 percent and 40 percent of total nominal investment cost. Predictably, the simulation results indicate that the expected PVs of the guarantee capped at 40 percent of investment cost are more than the expected PVs of the guarantee capped at 10 percent (Table 4). However, both are much less than the expected PVs of the plain guarantee (Tables 3 and 4), demonstrating that a capped guarantee does indeed work toward reducing overall guarantee payments.

Even with an MTG of one, mean project NPV with a guarantee cap of 10 percent of investment cost is TRY (85.7) million, with corresponding project risk of 61 percent and an expected present guarantee value of TRY 103.3 million. Project mean NPV is still negative if the MTG is raised to 1.10. However, when the guarantee cap is 40 percent of investment cost, with an MTG of one, project mean NPV is TRY 26.6 million, with corresponding project risk of 51 percent and an expected present guarantee value of TRY 268.1 million.

Table 4. ***Expected Values of NPV (Project) and PV (Guarantee) and Project Risk, with Capped Guarantees***

	cap: 10% of investment cost			cap: 40% of investment cost		
MTG	NPV (Project)	Project Risk*	PV (Guarantee)	NPV (Project)	Project Risk	PV (Guarantee)
0.00	-158.5	67%	0.0	-158.5	67%	0.0
…						…
0.75	-141.4	66%	29.7	-108.9	66%	77.1
0.80	-133.8	67%	39.8	-89.3	65%	104.9
0.85	-115.8	64%	51.3	-58.7	62%	134.9
0.90	-102.5	63%	65.9	-30.4	58%	171.8
0.95	-93.7	62%	83.3	-3.1	54%	216.4
1.00	-85.7	61%	103.3	26.6	51%	268.1
1.05	-72.1	60%	132.6	66.0	46%	335.4
1.10	-51.4	58%	155.7	113.1	42%	397.3

*: Project risk is defined by P[(NPV(Project)<0]

Source: Authors' calculations

Guarantee with Income (Traffic) Ceiling

The simulation results indicate that without any guarantee, the mean NPV of the project is TRY (254.5) million and the project risk is 73 percent (Table 5). As expected, mean project NPV is lower and project risk is higher than with the plain guarantee, because the income ceiling may limit observed revenues in a given year. With this guarantee type, an MTG of greater than one can be deemed realistic, because revenues beyond the income ceiling accumulate in a contingency fund. The government may therefore offer an MTG of greater than one, in order to ensure that the guarantee type is sufficiently attractive to potential private-sector partners.

Project expected NPV turns from negative to positive when the MTG is increased from 0.85 to 0.90. According to our criterion, this means that the optimum MTG is between 0.85 and 0.90. However, even at an MTG of 0.90, project risk is 38 percent. Project risk falls to zero with an MTG of one, where the mean project NPV and the mean guarantee PV are equal to TRY million 243.1 and 728.9, respectively. In this case, the project is risk-free and probably to be very attractive to potential private-sector partners.

Table 5. ***Expected Values of NPV (Project), PV (Guarantee), and PV (Income to contingency fund), and Project Risk with the Guarantee with Income Ceiling***

MTG	NPV(Project)	Project Risk*	NPV(Guarantee)	PV(Income to contingency fund)
0.00	-254.5	73%	0.0	141.5
…				…
0.75	-149.5	72%	157.0	139.6
0.80	-99.4	70%	231.4	141.4
0.85	-33.9	61%	317.2	145.7
0.90	42.2	38%	425.8	147.0
0.95	133.4	7%	561.3	143.7
1.00	243.1	0%	728.9	141.6
1.05	243.4	0%	735.7	338.1
1.10	243.2	0%	731.7	557.2

*:Project risk is defined by P[(NPV(Project)<0]
Source: Authors' calculations

Evaluating the Risk Reduction Capacities of the Guarantee Types

One criterion by which to evaluate and compare the risk-reduction capacity of each guarantee type is the guarantee value required (or affordable) per percent reduction in project risk, as MTG moves from 0.75 to one (Figure 1). The lower the value of this parameter, the more effective the risk-reduction capacity of the guarantee type. The rationale behind this lies in the flipside of a government guarantee: that is, its value to the holder is a cost to the government. In the case of the plain guarantee, the value of this parameter is TRY 8.8 million/percent risk, calculated as follows, using the data in Table 3:

$$Guarantee\ value\ per\ percent\ risk\ reduction = \frac{728.9 - 157.0}{65 - 0} = 8.8$$

Using the data in Table 5, the value of the risk-reduction capacity parameter for the guarantee with income ceiling is TRY 7.9 million/percent risk—less than that of the plain guarantee. Using the data in Table 4, the values of this parameter for guarantees capped at 40 percent and 10 percent of investment cost are found to be TRY 12.7 and TRY 14.7 million/percent risk, respectively. According to these results, the most effective guarantee in terms of risk-reduction capacity is the one with income ceiling, followed by the plain guarantee.

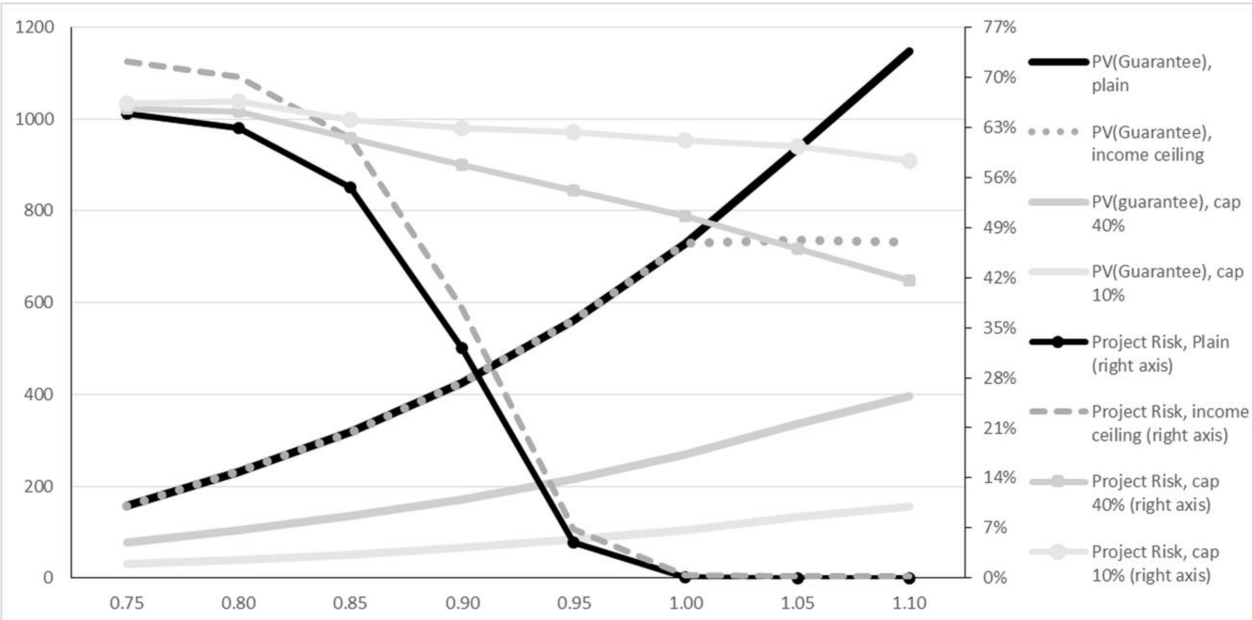

Figure 1. **PV (Guarantee) and project risk for all guarantee types**

Comparison of the Plain Guarantee and the Guarantee with Income Ceiling

Mean NPVs of the project with the income-ceiling guarantee are lower at all levels of MTG than mean NPVs of the project with the plain guarantee (Figure 2). Furthermore, the expected NPV of the project with the income-ceiling guarantee remains constant for MTGs greater than or equal to one (Figure 2), at which levels the project is also risk-free in both cases (Figure 1). Therefore, in contrast to the plain guarantee, at the same levels of MTG, the income-ceiling guarantee not only makes the project risk-free but also avoids excessive private-sector profit.

As indicated by Figure 2, the expected PVs of the income transferred to the contingency fund are around the same value for MTGs less than or equal to one. The expected PV of income transferred—around TRY 140 million—is the expected PV of cumulative excess observed revenues R_t over the income ceiling TC_t, because the guarantee payments are the same under the plain guarantee and the guarantee with income ceiling up to an MTG of one. That is why the expected PVs of the plain guarantee and of the guarantee with income ceiling are equal for MTGs less than or equal to one (Figure 1). However, if guaranteed revenue *(P_t)* is greater than the income ceiling *(TC_t)*, which can only occur if the MTG is greater than one, there is a sharp increase in the expected PV of income transferred to the contingency fund (Figure 2). This is because the income ceiling also limits the guarantee payments that would otherwise have been paid to the project company. As a result, expected PVs of the guarantee with income ceiling stabilize at MTGs greater than one (Figure 1).

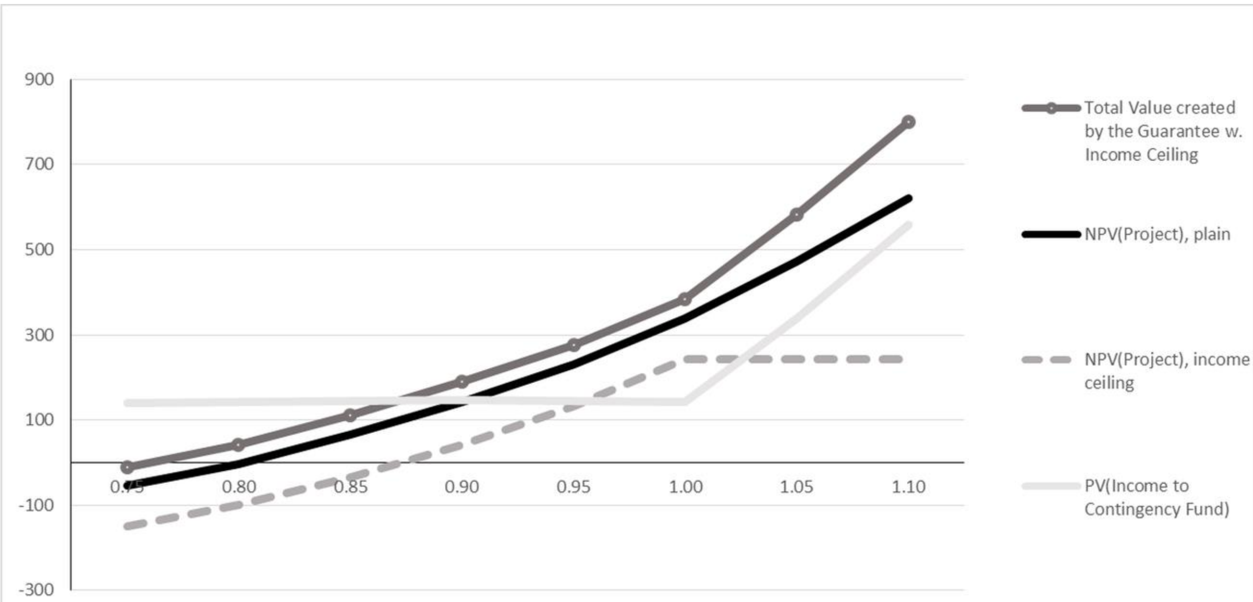

Figure 2. **Comparison of the plain guarantee and the guarantee with income ceiling**

For instance, for an MTG of 1.05, the expected PV of the income transferred to the contingency fund is TRY 338.1 million, which is about TRY 200 million in excess of the corresponding value for an MTG of one. The excess amount is equal to the difference between the expected PVs of the plain guarantee (TRY 935.7 million) and the guarantee with income ceiling (TRY 735.7 million) at the same MTG level (Tables 3 and 5). Had there not been an income ceiling, the expected NPV of the project would have been TRY 473.2 million (Table 3). On the other hand, in the case of the guarantee with income ceiling, the expected NPV of the project is approximately TRY 243 million, which is equal to that at an MTG of one. This means that in the case of the guarantee with income ceiling, setting an MTG greater than one does not necessarily result in an increase in the expected NPV of the project. The same argument holds for an MTG of 1.10. One policy option could therefore be to offer an MTG greater than one, which would bring the project risk down to zero and thereby entice private-sector participation, while avoiding excessive returns to private-sector partners and accumulating more income in the government's contingency fund.

Another point of comparison is the total value created by each guarantee type. In the case of the plain guarantee, the overall value created is mainly that of project NPV. In the case of the guarantee with income ceiling, overall value created is the project NPV plus the PV of income accumulated in the contingency fund. A comparison of the corresponding values created under each guarantee type indicates that the guarantee with income ceiling is again preferable to the plain guarantee (Figure 2).

CONCLUSIONS AND POLICY IMPLICATIONS

In a PPP project, the private partner is responsible for financing, building and operating the capital asset. In return, the government is expected to share the project risk with the project company. Risk-sharing can often be through specific contract terms, along the lines of the guarantee types discussed in this study. In practice, it is almost never the case that all project risks are transferred to the private company (Rajaram et al. 2014: 160). Indeed, as illustrated by the case presented here, PPP project risk can often be so high that private entities are wary of participating. Particularly where there is a market risk, such as the demand risk in this case, the government may therefore have no choice than to offer potential private-sector partners a demand guarantee.

This means that the government must have the necessary capacity to identify project risk, price it, and model different guarantee alternatives. Only then can the government engage in a fully informed decision-making process throughout the project cycle, avoiding any significant imbalance between financial outcomes for private-sector entities and national economic interests. A rigorous decision-making process is also key to government efforts to (re)negotiate with the private sector. As the case of Chile has shown, for example, the biggest unplanned costs associated with PPPs have come from the negotiation of concession contracts (Irwin and Mokdad 2010: 19).

This study is expected to contribute toward a closing of the public-sector capacity gap in the financial modeling and risk analysis of similar PPP projects. The methods for modeling various guarantee types and valuing guarantees using real-option pricing are also expected to be useful to academia and to professionals working in the fields of PPPs and cost-benefit analysis. Using the same methodology, further research can be carried on Turkey or other countries, in the same or different sectors.

This study can be used to decide on the optimum level of government guarantee provision, in accordance with our proposed criterion. Determining the optimum level of minimum traffic guarantees cannot be done by traditional cost-benefit analysis, because of the real-option nature of those guarantees. This study therefore augmented traditional project appraisal with real-option pricing.

From the government perspective, this study will help guide the selection of the most appropriate type and level of guarantee provision, through the systematic comparison of mean guarantee PVs and mean project NPVs corresponding to various MTG levels, for each guarantee type. Furthermore, the study suggested a criterion for measuring and comparing the risk-reduction capacities of different guarantee types. Based on these comparison criteria, our conclusion is that among the specific guarantee types tested in this study, the most efficient guarantee to be adopted by government is the guarantee with income ceiling, which will also result in the accumulation of significant income for the contingency fund. As illustrated in this study, in addition to providing guarantees to cover downside risk, governments should also share in the potential upside of a PPP project (Mody and Patro 1995). As such, revenue in excess of the income ceiling that is transferred to the contingency fund can enable the government to mitigate liquidity and credit risks.

The approach presented here will also enable government authorities to value guarantees provided by different public entities. The government can then require sponsoring public entities to make annual budgetary provision for the expected cost of probable guarantee payments, in much the same way as a bank makes provisions for loans—a policy adopted by Colombia, for example (Currie 2002: 19-20). This will avoid the principal-agent problem, in which a line ministry assumes that ultimate responsibility for any concession contract rests with the wider state (OECD 2008:109).

REFERENCES

Bain, Robert (2009). "Error and Optimism Bias in Toll Road Traffic Forecasts". *Transportation* 36/5: 469-482.

_____, (2011). "On the Reasonableness of Traffic Forecasts: A Survey of Predictive Capability". *Traffic Engineering & Control* 52/5: 213-217.

Baldwin, Carliss, Donald Lessard and Scott Mason (1983). "Budgetary Time Bombs: Controlling Government Loan Guarantees". *Canadian Public Policy Journal* 9/3: 338-346.

Banister, David (2005). *Unsustainable Transport: City Transport in the New Century.* London: Routledge.

Barreix, Alberto, Glenn P. Jenkins and Mario Marchesini (2003). "The Eje Vial Del Cono Sur Highway Project in Uruguay". *Development Discussion Papers* Paper No. 2003/02 http://www.queensjdiexec.org/publications/qed_dp_263.pdf (accessed 3.11.2015).

Berument, Hakan, Nergiz Dinçer and Zefer Mustafaoğlu (2012). "Effects of growth volatility on economic performance – Empirical evidence from Turkey" *European Journal of Operations Research* 217/2: 351–356.

Black, Fischer and Myron Scholes (1973). "The Pricing of Options and Corporate Liabilities". *Journal of Political Economy* 81: 637-659.

Brandao, Luiz E. T., James S. Dyer and Waren J. Hahn (2005). "Using Binomial Trees to Solve Real-Option Valuation Problems". *Decision Analysis* 2/2: 69–88.

Brandao, Luiz E. T. and Eduardo Saraiva (2008). "The Option Value of Government Guarantees in Infrastructure Projects". *Construction Management and Economics* 26/11: 1171-1180.

Cebotari, Aliona (2008). "Contingent Liabilities: Issues and Practice". *IMF Working Paper Series Working Paper* WP/08/245.

Cheah, Charles Y. J. and Jicai Liu (2006). "Valuing Governmental Support in Infrastructure Projects as Real Options Using Monte Carlo Simulation". *Construction Management and Economics* 24/5: 545-554.

Chiara, Nicola, Michael J. Garvin and Jan Vecer (2007). "Valuing Simple Multiple-Exercise Real Options in Infrastructure Projects". *Journal of Infrastructure Systems* 13/2: 97-104.

Copeland, Thomas and Vladimir Antikarov (2003). *Real Options: A Practitioner's Guide*. New York: Cengage Learning.

Coşan, Mehmet F. and Haluk Büyükbaş. "Gebze-İzmir Motorway, İzmit Bay Crossing Project". http://tmmmb.org.tr (accessed 21.11.2015).

Currie, Elizabeth (2002). *The Potential Role of Government Debt Management Office in Monitoring and Managing Contingent Liabilities*. Washington, DC: World Bank.

Currie, Elizabeth, and Antonio Velandia (2002). *Risk Management of Contingent Liabilities Within a Sovereign Asset Liability Framework.* Washington, DC: World Bank.

Dixit, Avinash K. and Robert S. Pindyck (1994). *Investment Under Uncertainty*. Princeton: Princeton University Press.

Emek, Uğur (2009). "Türkiye'de Altyapı Hizmetlerinin Özel Sektöre Gördürülmesi: Neden, Ne Zaman, Nasıl?". *İktisat, İşletme ve Finans* 24/284: 9-45.

_____, (2014). "Kamu-Özel İşbirliklerinin Devlet Muhasebe Sistemindeki Yeri ve Önemi". *İktisat, İşletme ve Finans* 29/337: 9-32.

Flyvbjerg, Bent, Mette S. Holm and Soren L. Buhl (2006). "Inaccuracy in Traffic Forecasts". *Transport Reviews* 26/1: 1–24.

Hull, John C. (2012). *Options, Futures and Other Derivative Securities.* Boston: Prentice Hall.

Irwin, Timothy (2003). "Public Money for Private Infrastructure: Deciding When to Offer Guarantees, Output-based Subsidies, and Other Fiscal Support". *World Bank Working Paper Series Working Paper* No. 10.

_____, (2007). *Government Guarantees: Allocating and Valuing Risk in Privately Financed Infrastructure Projects.* Washington, DC: World Bank.

Irwin, Timothy and Tanya Mokdad (2010). *Managing Contingent Liabilities in Public-Private Partnerships: Practice in Australia, Chile and South Africa.* Washington, DC: World Bank.

Jun, Jaebum (2010). "Appraisal of Combined Agreements in BOT Project Finance: Focused on Minimum Revenue Guarantee and Revenue Cap Agreements". *International Journal of Strategic Property Management* 14/2: 139-155.

Lewis, Christopher M. and Ashoka Mody (1997). "The Management of Contingent Liabilities: A Risk Management Framework for National Governments". *Dealing with Public Risk in Private Infrastructure*. Eds. Timothy Irwin et al. Washington, DC: World Bank.

Merton, Robert C. (1973). "The Theory of Rational Option Pricing". *Bell Journal of Economics and Management Science* 4: 141-183.

MOD (2013). *10. Kalkınma Planı (2014-18)*. Ankara: MOD.

_____, (2015). *Kamu Özel İşbirliği Envanteri.* www.kalkinma.gov.tr (accessed 30.10.2015)

Mody, Ashoka and Dilip Patro (1995). "Methods of Loan Guarantee Valuation and Accounting". *CFS Discussion Papers Discussion Paper* No. 116.

OECD (2002). *Report on Transport and Economic Development* Round Table Report No. 119

_____, (2008). *Public-Private Partnerships in Pursuit of Risk Sharing and Value for Money.* Paris: OECD.

_____, (2010). *Dedicated Public-Private Partnership Units: A Survey of Institutional and Governance Structures.* Paris: OECD.

Rajaram, Anand et al. (2014). *The Power of Public Investment Management: Transforming Resources into Assets for Growth.* Washington, DC: World Bank.

Rodrigues, Magnus, Ekin İnal and Turgut Cankorel (2013). "Road PPPs in Turkey". *Infrastructure Journal* http://www.chadbourne.com (accessed 12.11.2015).

Uzunkaya, Mehmet and Zeynep C. Uzunkaya (2012). *Türkiye için Ekonomik İndirgeme Oranı Tahmini*. Ankara:MOD

Wibowo, Andreas (2004). "Valuing Guarantees in a BOT Infrastructure Project". *Journal of Engineering, Construction and Architectural Management* 11/6: 395-403.

_____, (2006). "CAPM-based Valuation of Financial Government Supports to Infeasible and Risky Private Infrastructure Projects". *Journal of Construction Engineering and Management* 132/3: 239-248.

Wibowo, Andreas et al. (2012). "Modeling Contingent Liabilities Arising from Government Guarantees in Indonesian BOT/PPP Toll Roads". *Journal of Construction Engineering and Management* 138: 1403-1410