The impact of irreversibility and uncertainty on the timing of infrastructure projects*

Phuong Doan† Kojo Menyah‡

November 18, 2012

Abstract

This paper argues that because of the irreversibility and uncertainty associated with Build-Operate-Transfer (BOT) infrastructure projects, their financial evaluation should also routinely include the determination of the value of the option to defer the construction start-up. This ensures that project viability is comprehensively assessed before any revenue or loan guarantees are considered by project sponsors to support the project. We show that the framework can be used even in the context of the intuitive binomial lattice model. This requires estimating volatility directly from the evolution of the net operating income whilst accounting for the correlation between the revenue and costs functions. This approach ensures that the uncertainties usually associated with toll revenues, in particular, are thoroughly investigated and their impact on project viability is thoroughly assessed. We illustrate the usefulness of our framework with data from an actual (BOT) toll road project. The results show that by postponing the project for a couple of years the project turns out to be viable, whilst it was not, without the deferral. The evaluation approach proposed therefore provides a better framework for determining when and the extent of government financial support, if any, that may be needed to support a BOT project on the basis of project economics. The analysis may also be applicable to private sector investment projects which are characterised by irreversibility and a high rate of uncertainty.

Keywords: toll road, real option, binomial lattice model, deferral option.

JEL classification: C0, D8, G1, G3, L9, R4

*This paper is accepted for publication in the March 2013 issue of the Journal of Construction Engineering and Management.

†St. Edmund's College, University of Cambridge, Mount Pleasant, Cambridge CB3 0BN, United Kingdom. Email: ptd27@cantab.net

‡Corresponding author: Professor of Finance, London Metropolitan Business School, 84 Moorgate, London EC2M 6SQ, United Kingdom. Email: k.menyah@londonmet.ac.uk

1 Introduction

There has been a significant growth in the number of large scale infrastructure projects executed with a BOT concession agreement since the middle of the 1980's, especially in developing countries. Such agreements which are developed within the project finance framework with the private sector seem to be the natural extension to the worldwide privatisation efforts which brought private participation into activities which had previously been the preserve of governments (Grimsey and Lewis (2004)). This has largely been driven by the need to increase efficiency in the delivery of public services as well as the desire to upgrade and extend public infrastructure, in the face of increasing pressures on public funds.

BOT projects are public-private partnerships in which the private sector seeks financial benefits and the public sector focuses on socio-economic benefits (Ye and Tiong (2000b)). The use of the project finance framework for BOT projects requires that the viability of the project is thoroughly assessed and this is usually done with the discounted cash flow (DCF) method of investment appraisal (Fishbein et al. (1996)). The financial viability of a project is affected, among others, by revenue projections and the evolution of costs over time (Ye and Tiong (2000b)). This means that before a project is implemented, the expected cash flows must be deemed to be adequate to cover all costs and provide a return to equity investors. If the evaluation shows that this is not achievable, but the sponsor, nevertheless, is keen to implement the project, then revenue or loan guarantees and various types of subsidies are usually provided to the private consortium to enable the project to be implemented (Xenidis and Angelides (2005), Zhang (2005) and Kwak et al. (2009)). This approach, to the project selection decision however, fails to account for the value of the real option available to project sponsors at the evaluation stage - that is the option to defer. This deferral option is valuable in the case of an infrastructure project which becomes irreversible as soon as construction starts.

Dixit (1989) points out that, previous models of investment evaluation ignore the opportunity cost of irreversibility implying that a substantial part of the potential value of the project is ignored during the evaluation process using the traditional DCF method. Implementing an irreversible investment immediately means that the opportunity to wait for the arrival of new information before a decision on the project is made is lost because there cannot be a disinvestment when adverse conditions emerge. Therefore, failure to include the value the option to defer will lead to an investment rule which is grossly in error, when a project is irreversible.

Bernanke (1983), McDonald and Siegel (1986) and Ingersoll and Ross (1992) also show that project managers should wait a period of time before investing, if the uncertainty in the demand for the product or service is high - a feature which is common in infrastructure projects. Thus, the irreversibility and uncertainty associated with infrastructure projects require that their financial viability evaluation should, as a matter of routine, include the value of the option to defer (Stark (1990)). This, however, is not the usual approach used in the evaluation of such projects. In practice, projects tend to be deferred as a result of force majeure which could be induced by war, earthquake or political turmoil (Ng. and Bjornsson (2004)). Such force majeure deferrals are externally imposed and are therefore not the same as the proactive process of valuing the deferral option proposed by this paper.In the academic literature, the deferral option is also not routinely evaluated. For instance, Ho and Liu (2002) analysed a project which turned out not to be financially viable and then assumed that a government loan guarantee would make the project financially viable to attract lenders. Deferral option valuation is therefore not considered an integral part of the project evaluation process in infrastructure projects.

In the light of the above, we argue that by ignoring the value of the option to defer in the evaluation of infrastructure projects, project values tend to be underestimated and by implication higher subsidies and guarantees are invariably paid by sponsoring governments when such payments could have been minimised. The paper also makes a contribution to the practice of investment evaluation by using a modelling approach which is intuitive and can be used by managers because we show how the relevant information for the valuation of the deferral option can be extracted from sources available to the project management team, historical information on similar projects as well as information that is publicly available. Furthermore, unlike previous studies which tend to arbitrarily choose a volatility number, we provide a clear framework for estimating volatility which shows in a transparent way the link between the uncertainty factors in a project and its income.

We illustrate all these contributions with the case study of an actual toll road project in which the deferral option is evaluated ex-ante with information available in the proposed project documents as well as other publicly available sources and confirm that the deferral value turns an otherwise negative net present value project into a viable project. This result can potentially strengthen the position of government negotiators regarding the extent of government subsidies and revenue guarantees.

Our proposed framework of analysis is related to that suggested by Huang and Chou (2006) which involves the concessionaire having a minimum revenue guarantee and an abandonment option during the pre-construction period. It, however, differs significantly in terms of the type of option involved and when the minimum revenue guarantee is offered. In our framework, the guarantee may only be considered after the deferral option has been evaluated, because as noted by Shaanan (2005), irreversibility eliminates the abandonment option. This is evident in the results of Huang and Chou (2006) which show that increasing the level of the minimum revenue guarantee reduces the value of the option to abandon. This implies that if the government is willing to offer a guarantee, there is no need for the project company to consider the abandonment option - the government only needs to determine the level of guarantee that will make the project viable.

In the rest of the paper, Section 2 provides a critical review of studies of deferral option valuation for BOT infrastructure projects and provides additional justification for the paper. In Section 3, we outline the familiar real option binomial lattice valuation model. We then model the uncertainty in the project to provide the basis for estimating the volatility required for the binomial lattice valuation in Section 4. Section 5 presents the case study, values the deferral option and outlines the policy implications. The conclusion is provided on Section 6.

2 Review and critique of prior literature

Wooldridge et al. (2002) and Garvin and Cheah (2004) evaluated ex-post the deferral option associated with the Dulles Greenway toll road project in Virginia, USA. They assumed a five-year deferral option period and found that the deferral value turned an otherwise unprofitable project into a profitable one. There are, however, several limitations associated with these studies. The first limitation relates to the arbitrary use of a five-year deferral period (which assumes a European call option) and does not address the issue of the period for which the project could be deferred. We address this limitation by evaluating the deferral option as an American option in which the exercise date is derived as part of the valuation process.

The second limitation relates to the modelling framework and the estimation of volatility. The valuation model used is a discrete one-year binomial tree where the uncertainty (volatility) is captured by the magnitude of swing of the initial traffic volume. This essentially boils down to scenario analysis (Arboleda and Abraham

(2006)) even though, as argued by Rode and Lewis (2003), it is difficult to reduce the dynamics of a project to just a few scenarios. A few scenarios would fail to capture the complex uncertainties in a project and that is why scenario analysis is an inadequate tool for valuing the uncertainties associated with a project.

Bowe and Lee (2004) also identified ex-post, various options associated with the Taiwan High-Speed Rail Project. They found that the combined embedded options to expand, contract and defer turns a project with a negative NPV into one with a positive NPV. However, their valuation assumed that the project did not have a dividend yield - an assumption which tends to overestimate the value of options. A provision for dividend yield is made in our valuation which avoids the possible overstatement of the deferral option value.

Despite the importance of volatility in the pricing of options in general, the volatility number used in prior infrastructure real options literature is hardly ever properly justified. Ho and Liu (2002) just assumed a project volatility of 40% without outlining how it could be estimated. For the Taiwan High Speed Rail project, Bowe and Lee (2004) estimated volatility from the projected net operating revenues over the life of the concession (at 14.46%), whilst, Huang and Chou (2006) for the same project just used the average volatility of the Taiwan stock market (30%). This creates a problem in determining which valuation is a reliable measure of the extent to which embedded real options can add to the value of a project. A few papers such as Ye and Tiong (2000b) and Arboleda and Abraham (2006), use Monte Carlo simulation to create similar projects to the one being valued, by evaluating how the dynamics of the major risk factors would generate other possible NPVs, if they followed the simulated paths. The standard deviation of the simulated NPVs is then used as the volatility of the project. The dificulty with this approach is that since the NPV-at-risk is calculated with an appropriate risk-adjusted discount rate, any further adjustment for risk through real option valuation amounts to double counting

(Myers (1976)).

Copeland and Antikarov (2003) and Mun (2006) have proposed that the volatility variable used in the binomial lattice valuation can be estimated by simulating the logarithmic returns of the present value of the free cash flows associated with the project. Even though this approach appears to link the volatility estimated to the evolution of the underlying cash flows of the project, such cash flows are usually derived as the expected value cash flow for each of the years during which the project will be operational (Liou and Huang (2008)). Such cash flow estimates are therefore, unable to accurately capture the variation in the stochastic factors such as the revenue and cost functions, which ultimately determine the value of the real option. In our volatility estimation, we therefore focus on the evolution of the two key variables that affect a project's net operating income (NOI) - traffic demand and operation and maintenance cost (O&M) and how they affect a project's earnings before interest, depreciation, taxation and amortisation (EBIDTA). This helps to establish a more accurate link between how the uncertainty factors affect EBIDTA in an intuitive way for the benefit of decision makers.

3 The valuation model

The binomial lattice approach used in this paper represents what has been described as 'economically corrected' version of decision tree analysis. In this context, the binomial estimates are seen as discounted expected values of the derivatives payoffs, relative to a special probability distribution - the risk neutral probability function. This is achieved by converting the real binomial space into a pseudo probability space that has the same information as the real one but contains a new measure which imbues it with an equivalent martingale property which can be exploited to find the derivative's price. Such martingale pricing amounts to risk-neutral pricing (Epps (2000)). Therefore, the risk neutral probability cash flows can be discounted at the risk-free rate.

The main assumption underlying the risk-neutral probability approach is that the market is complete and therefore a tracking portfolio can be found from assets that are traded, in order to replicate the cash flows from the option. Whilst, this is possible in principle for infrastructure projects (if traded proxies in the market are used), it may not always be practical to find a traded proxy in the specific market of a project, whilst proxies from other markets may not be appropriate because of economic, social and cultural differences. In the absence of a suitable proxy, it is appropriate, as argued by Copeland and Antikarov (2003) to use the cash flow of the project itself as the correlated security - the so-called Marketed Asset Disclaimer (MAD).

Since the MAD approach is based on the idea that the underlying asset is not traded, the rate of return on such an asset, obtained from the periodic cash flows which the asset generates, may fall below the market equilibrium total expected return that is required in an equivalent traded financial security. This rate of return shortfall represents a dividend-type adjustment when valuing the option (McDonald and Siegel (1986)). Intuitively, the rate of return shortfall is the opportunity cost of delaying the construction of the project; what one forgoes by delaying the development of the project and reflects that part of the return to holding the option that the holder does not receive. It therefore reduces the value of the deferral option and should be taken into account in order to avoid over-valuation. However, this is ignored in most previous studies of real option valuation in toll road projects.

If the project generates a constant shortfall as a payout ratio, δ, on each ex-dividend date this will reduce the value of the underlying asset in sequential nodes of the lattice. This is intuitive because the shortfall is defined as a payout ratio on the value of the project before it goes on to the following period.

Therefore this deferral option is analogous to an American call option, which in general, is not likely to be exercised until maturity. However, because of the decline in the underlying asset value with the introduction of a significant rate of return shortfall, this American call option may be forced to be exercised earlier than its maturity date (Copeland and Antikarov (2003)). Hence, unlike previous papers that assumed that deferral options in toll road projects are European call options that do not pay dividend, this paper makes a contribution to the literature by showing that the deferral option is akin to a dividend paying American option.

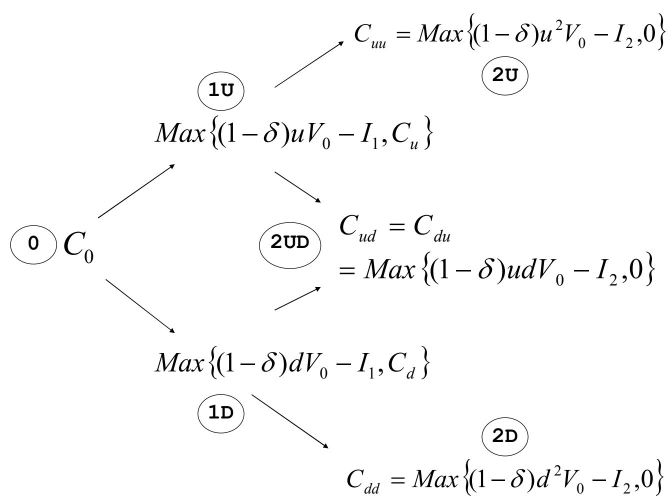


Figure 1: Binomial lattice model with dividend payment

Denoting C with subscripts u and d as the call values in the respective up and down states, Figure 1 presents a two-step lattice with investment outlay I, where the value of each node of the lattice can be calculated as:

$$C_u = \frac{pC_{uu} + (1-p)C_{ud}}{1+r} \tag{1}$$

$$C_d = \frac{pC_{ud} + (1-p)C_{dd}}{1+r} \quad (2)$$

in which the step size by which the value of the underlying asset moves up is $u = e^{\left(\sigma\sqrt{\frac{T}{m}}\right)}$ and down $d = \frac{1}{u}$; σ is the volatility of the underlying asset, T is the number of years of the option and m is the relevant step in the recombining binomial tree. In addition, with r_f as the risk-free rate, the risk-neutral probabilities of up movement (p) and down movement (q), used in valuing the option through backward induction are $p = \frac{e^r - d}{u - d}$ and $q = 1 - p$ respectively. The value of the investment opportunity at time zero is obtained as:

$$C_0 = \frac{pC_{1U} + (1-p)C_{1D}}{1+r} \quad (3)$$

where

$$C_{1U} = \max[(1-\delta)uV_0 - I, C_u] \quad (4)$$

represents the upward movement in the value of the underlying asset and

$$C_{1D} = \max[(1-\delta)dV_0 - I, C_d] \quad (5)$$

represents the downward movement in the value of the underlying asset.

4 Volatility estimation

For real options, in general, Copeland and Antikarov (2003) suggest using Monte-Carlo simulation to estimate the volatility of project cash inflows. This requires practitioners to determine the appropriate probability distributions for the stochastic factors that affect project cash flows. However, as argued by Godinho (2006), the simulation process proposed by Copeland and Antikarov (2003) requires all stochastically driven factors to be simulated, which in fact increases irrelevant risk in the present value of the project cash inflows, and therefore generates a higher volatility estimate. This arises from the inclusion of irrelevant uncertainty factors in the simulation process which then increases the riskiness of the underlying, and therefore makes the estimated volatility larger than what it should be. However,in a toll road project the volatility of the project cash inflows should only reflect the sensitivity of project income to the evolution of relevant stochastic factors that impact on such income. This requires the identification of the relevant stochastic variables, their correlation and evolution over the life of the project and not necessarily from the cash flows generated for the DCF model.

We assume that at the operation stage of a toll road investment, the relevant stochastic variables are traffic demand x and O&M cost, y. From these two variables, one can track the path of the evolution of the earnings before interest, depreciation, tax and amortisation (EBIDTA) using a discrete approximation in the binomial lattice model. With the EBIDTA determination, it is easy to account for the non-stochastic factors of depreciation, interest and tax to arrive at the NI or earnings available to project equity holders - a metric commonly used in valuation.

Different stochastic processes and distributions such as the geometric Brownian motion, log-normal and triangular distributions have been used in the prior literature to model traffic demand for toll road projects. However, we model traffic demand as a mean-reversion process. This is because even though traffic demand may increase during the initial phase of the project's life, it cannot increase beyond the road's capacity. Secondly, when a new road is built, increased usage will gradually create congestion, which may encourage some users to use other routes so as to maximise the value of their traveling time and reduce their costs. It may also encourage a government to plan a new road that can reduce traffic on a congested road. Consequently, traffic on the new road might not in the long run reach full capacity but remain at an "optimal" level which maximises road users' time value of traveling. Formally, traffic demand x will follow the process below:

$$\frac{dx_{(t)}}{x_{(t^-)}} = \eta(\overline{x} - x)dt + \sigma_x dW_{(x,t)} \tag{6}$$

where $\overline{x}$ is the designed capacity of the road as specified in the project's technical report, η is the speed at which traffic demand reaches the designed road capacity, σ_x is the instantaneous conditional standard deviation of traffic demand per unit time; $dW_{(x,t)}$ is the increment of a standard Wiener process for x.

Whilst it is widely agreed that traffic demand is stochastically driven, there is little understanding about the uncertainty features of the O&M cost in infrastructure projects. Usually, in practical BOT projects, the annual O&M cost is expressed as a percentage of capital costs (Field, R (2005)). Other studies including Ye and Tiong (2000a,b) and Schaufelberger and Wipadapisut (2003) reinforce this view by arguing that the O&M cost in infrastructure projects can be variable but still dependent on the annual capital costs. However, they do not provide a model of the evolution of the O&M cost. A model of O&M cost has been proposed by Shen and Wu (2005). They argue that the O&M cost is higher during the initial and final phases of the operating period of a project. They, therefore, propose an adjustment coefficient which has to be applied to the annual O&M cost in order to obtain the higher costs at the initial and final phases of a project's operating period. Although this modelling approach improves upon the method of estimating the O&M cost as a predetermined fraction of the capital costs at the operating stage, it is still deterministic in nature since the adjustment factors have to be estimated at the start of the operating stage of a project. However, if the future evolution of the O&M cost is stochastically driven, then its magnitude should be determined independently of the capital costs of a project. In the light of the above analysis, we model O&M cost, y, as a geometric Brownian motion because such costs are stochastically driven and increase over time given an assumption that traffic demand increases over time, leading to the increased deterioration of the road and general inflation affecting O&M costs. The process for the O&M cost is therefore modelled as:

$$\frac{dy_{(t)}}{y_{(t^-)}} = \alpha_y dt + \sigma_y dW_{(y,t)} \tag{7}$$

where α_y is the instantaneous conditional expected percent change in y per unit of time; σ_y is the instantaneous conditional standard deviation per unit time; $dW_{(y,t)}$ is the increment of a standard Wiener process for y; The correlation between the Weiner processes for traffic demand and O&M cost is defined as $\epsilon(dW_x dW_y) = 0$.

Now, assume that $\theta_{(t)}$ is the toll rate at time t. The values of $\theta_{(t)}$ are known and determined periodically by the project management, which is consistent with toll setting in actual projects. Thus, the project EBIDTA can be specified as:

$$V(x, y, t) = \theta_{(t)} x_{(t)} - y_{(t)} \tag{8}$$

To simulate EBITDA, we use Ito's Lemma for non-correlated Ito processes (Dixit and Pindyck (1994)), to find the differential of V with respect to x and y as:

$$dV_{(t)} = [\theta_{(t)}\eta(\overline{x} - x)x_{(t)} - \alpha_y y_{(t)}]dt + \theta_{(t)}\sigma_x x dW_{(x,t)} - \sigma_y y dW_{(y,t)} \tag{9}$$

giving the function characterising the evolution of the EBIDTA of the project.

To arrive at the NOI, which is essentially the free cash flow (FCF) to equity holders, we account for the non-stochastic parameters of depreciation, interest, and tax which are known from project data using the usual accounting equation. Therefore, the evolution of the values of the NOI available to equity shareholders of the project is driven by equation (9) since the other parameters included in equation (10) below are assumed not to be non-stochastic. The NOI is calculated as:

$$NOI_{(t)} = (EBIDTA_{(t)} - D_{(t)} - I_{(t)})(1 - T_{(t)}) + D_{(t)} \tag{10}$$

where $D_{(t)}, T_{(t)}, I_{(t)}$ are depreciation, tax and interest payment at time t. Using the NOI as the process characterizing the evolution of the value of the project's underlying net cash flows, any single path of evolution of EBIDTA though simulation over the life of the project will, generate a distribution of NOIs from which the returns and volatility of returns on the underlying asset can be calculated. With the simulation of the process in equation (9) and the estimates of the relevant NOIs using equation (10), we arrive at a large number of NOI stochastic paths. The mean of the volatility in these simulated paths is calculated and used in the valuation.

5 Case study: A BOT toll road

To illustrate the above analysis, we use data from an actual BOT toll road project under evaluation, which is a 260 kilometers expressway, whose identity has been kept anonymous for confidentiality reasons and we value the associated deferral option in the project. This project was used because of the availability of data. We believe that it is representative of similar projects that are characterised by irreversibility and uncertainty irrespective of where such projects may be in the world. The operation phase starting at the end of the construction period has a life of 20 years, after which the road would revert to the ownership of the host government. The project base case NPV estimate is based on a detailed forecast of traffic volumes for various types of vehicles, their sensitivity to various toll charges, the level of toll rates on existing highways and expected growth rates in traffic volumes during the concession period. The risk-free rate based on the yield on long-term government debt is 3%. The consortium contributes 20% of the project cost in the form of equity and pays corporate tax at a rate of 28%. The present value of the projected cash inflows is estimated at (US)$1277.06 million, which when compared with a total investment cost of $1278.63 million, produces a negative net present value of $1.57 million. At this stage in most toll road projects, the consortium would look for government revenue guarantees or other types of financial support to make the project viable. In our valuation model, however, we value the embedded deferral option, on the basis that the consortium has the permission from the government to defer the construction for up to the end of the third year of the concession being granted. The government is not keen to defer for more than three years because of the delay in obtaining the socio-economic benefits that would result from project completion.

Using the EBIDTA evolution in equation (9), together with other known parameters of depreciation, interest and tax, we then estimate the values of NOI at time t, with equation (10). The time interval in all the stochastic processes, Δt, is one month. The long-run optimal capacity traffic demand level, $\overline{x}$, is obtained from the technical report as 16.79 million vehicle kilometers per month. From the traffic demand records of similar expressway projects in the region, we estimate the instantaneous standard deviation of monthly traffic demand - the rate of random realization in the Weiner process for traffic demand, σ_x, as 1.62%. The reverting speed for traffic demand, η, that makes the stochastic process converge to the "optimal capacity" level is estimated through a regression. Using discrete time data in a similar project, we run the regression of $x_{(t)} - x_{(t-1)} = a + bx_{(t-1)} + \epsilon_{(t)}$ and calculate $\widehat{\eta} = -\log(1 + \widehat{b})$ to be 0.003. Using this value of η, we initiate the evolution of equation (6) in conjunction with other parameters ($\overline{x}, \sigma_x, dt$ as defined as above, and x_0 as defined below) which indicates that traffic demand will reach the long-run capacity, $\overline{x}$, after three years of operation and then fluctuate around this level. The initial value of the traffic demand process x_0 takes a random value within a certain range on the basis of evidence from other toll road projects. The studies of J.P. Morgan (1997), Standard & Poor's (2005), Flyvbjerg et al. (2006), Vassallo and Fagan (2007), and Bain (2009) show that most traffic demand forecasts are over-optimistic compared to realized traffic demand. Flyvbjerg et al. (2006) studied 183 road projects in 14 developed and developing countries during the 30 years between 1969 and 1998 and found out that for traffic forecasts in 50% of the projects studied, actual traffic demand turned out to be either 20 percent more or less than initial forecasts. Similarly, in 25% of the projects, the traffic demand forecasts varied $\pm$40% around the initial estimate and 10% of the projects had variations in the range of $\pm$60%. The above studies provide consistent evidence of optimism-bias in traffic demand forecasts for toll road projects around the globe. Mackinder and Evans (1981), UK National Audit Office (1985), World Bank (1986), and Walmsley and Pickett (1992) have also done further studies and conclude that there is also no indication that traffic forecasts have become more accurate over the last thirty year period. In the light of the above evidence, we set the lowest possible value to 0.5 times the projected x_0, and the highest possible value as 1.5 times the projected x_0 in the simulation. Traffic demand in the first month is projected in the DCF data at 6.11 million vehicle kilometers. Thus, as explained above, the traffic demand projection, x_0, will take a random value between 3.06 million and 9.17 million vehicle kilometres.

As for O&M costs, we estimate the monthly value of α_y as 0.62% and σ_y as 1.57% from the DCF data. The initial value of O&M costs in the first month of operation, y_0 , is projected in the DCF model as \$0.24 million. We assume that the O&M cost in the first month of operation, y_0, will also take a random value within the range of 0.5 and 1.5 times the starting value. Therefore, in the simulation, y_0, takes a random value of between \$0.12 million and \$0.35 million.

To simplify the model, we assume that toll rates at time t during the project's life, as well as interest, tax and depreciation values are known in the project DCF model. Simulation is carried out with ten thousand iterations in the evolution of the defined stochastic processes for x and y. Several sample paths of uncertain factors, extracted from the simulations, are displayed in Figure 2.

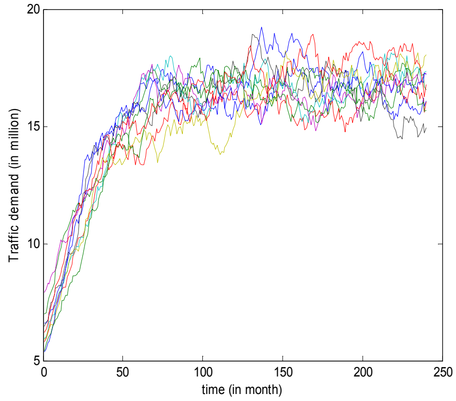
The logarithmic rate of return using the evolution of NOI generated from each iteration of the simulation is:

$$r_{NOI_{t+1}} = \ln\left(\frac{NOI_{t+1}}{NOI_{(t)}}\right) \text{ for } t \in [0, T] \tag{11}$$

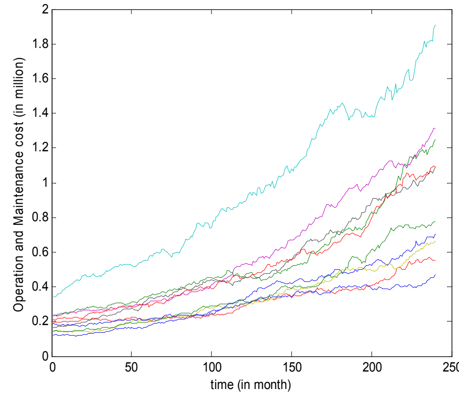
and the volatility of the underlying asset in each stochastic path from the returns of the stochastic NOI is calculated as:

$$\sigma_{NOI} = \sqrt{\frac{1}{t-1}\sum_{t=1}^{T}\left(r_{NOI_t} - \overline{r_{NOI}}\right)^2} \tag{12}$$

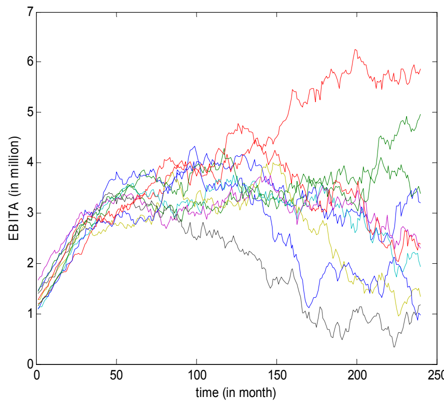
Using equation (12), the volatilities of returns of monthly NOI in ten thousand



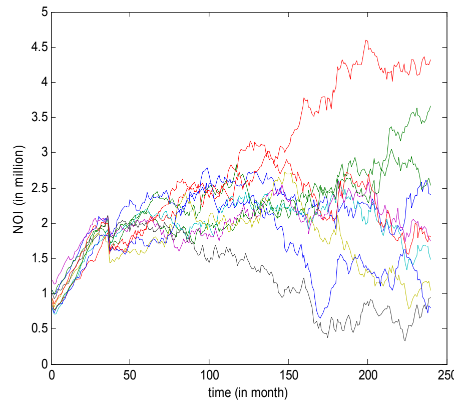
(a) Traffic demand



(b) O&M cost



(c) EBIDTA



(d) NOI

Figure 2: Sample evolution paths of uncertain factors

iterations are estimated and annualised. A distribution of these annualised volatilities is drawn and displayed in Figure 3. The mean value of the annualised volatility is estimated as 14.62% which is then used in the valuation of the deferral option.

The inputs necessary to construct a 3-step binomial lattice are calculated as $u = e^{\left(\sigma\sqrt{\frac{T}{m}}\right)} = e^{\left(0.1462\sqrt{\frac{3}{3}}\right)} = 1.16, d = \frac{1}{u} = 0.86, p = \frac{e^r - d}{u-d} = \frac{e^{0.03} - 0.86}{1.16 - 0.86} = 0.57, q = 1 - p = 0.43$. With an annual inflation rate equal to the risk-free rate $r_f = 3\%$ and $I_0 = \$1278.63$ million, the investment amounts in the following years increase with the inflation and are estimated to be $I_1 = \$1316.99$ million, $I_2 = \$1356.50$ million and $I_3 = \$1397.20$ million. The values of the underlying asset and

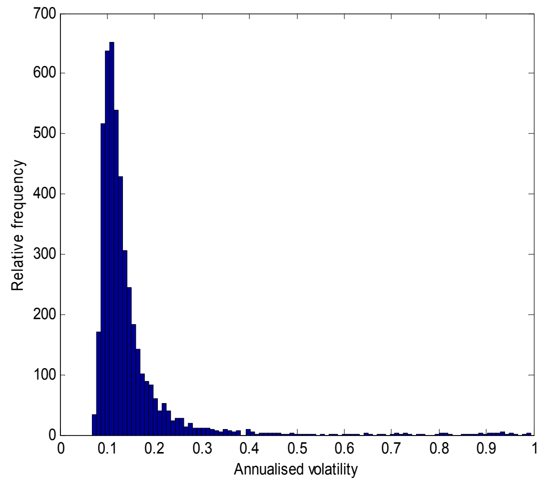


Figure 3: Annualized volatility distribution

investment opportunity at each node of the lattice are calculated with equations (1) to (5) and are displayed in Figure 4 (when dividend is not paid) and Figure 5 (when the dividend with a payout ratio of 10% is paid after each period to reflect the decline in the underlying value of the asset due to the deferral). The numbers in italics are the underlying asset values. The figures in parentheses represent the value of the investment when immediate investment is made; those in curly brackets {.} represent the investment opportunity value with option to defer up to 3 years, those in square brackets [.] represent option values when there is a deferral for 2 years, and those without parentheses are option values when there is deferal for one year.

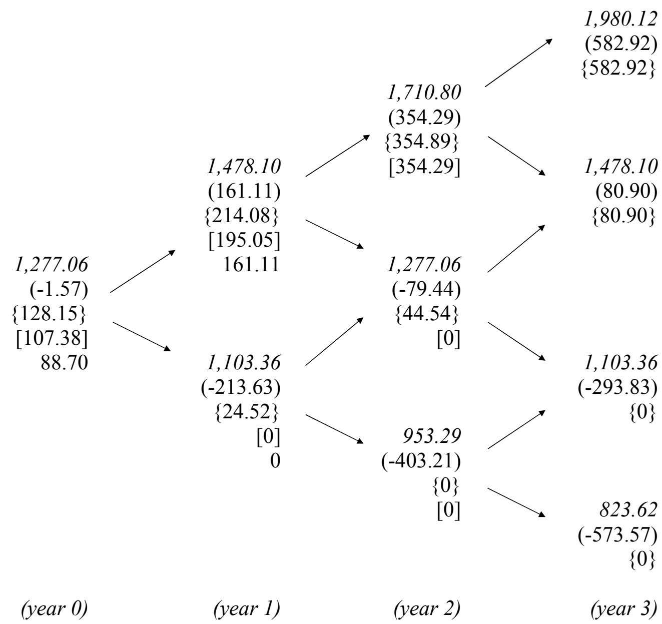


Figure 4: Investment value with deferral option, $\delta = 0$.

Over the life of the project, the equity investors expect to receive on an annual basis a rate of return equal to the cost of equity plus a premium for private risk not captured in the standard cost of capital estimates (Copeland and Antikarov (2003)). A shortfall in such returns arises from the fact that investors would actually receive a lower amount than expected, because after the payout of 10% of the project's value in each sequential period, the value of the project going forward decreases. Since the consortium has the option to defer for one, two or three years, the relevant option values for each of the years are estimated. The recombining binomial trees with 1 to 3-year maturity deferral options are displayed in Figures 6 and 7, without and with dividends respectively.

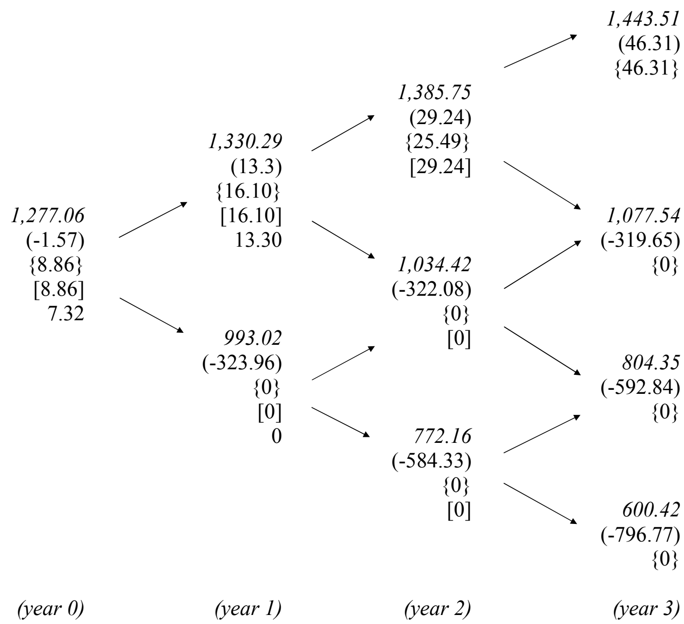


Figure 5: Investment value with deferral option, $\delta = 0.1$.

It is clear that in up movements, when the underlying asset pays no dividend, it is optimal to keep the deferral option until maturity because the time value of the option is always positive during the deferral period. In this context, an American call option is analogous to a European call option. As seen in Figure 7, an investment opportunity value including a deferral option with longer maturity has more value than that with a shorter maturity.

When the project value decreases by a 10% payout ratio after each period, the management is forced to exercise the deferral option earlier than its maturity, due to the decline in the project value at the ex-dividend date. In this project, therefore, as the underlying asset pays dividend, it is optimal to exercise the deferral option in year 2 when the value of immediate exercise of \$29.24 million is greater than the value of deferring the option until year 3 which has a value of \$25.49 million as shown in the most upper node in year 2 of lattice figure 8. Therefore, the expanded value of the investment opportunity with a 3-year deferral maturity period generates an optimal value when there is a two-year deferral which generates an associated option

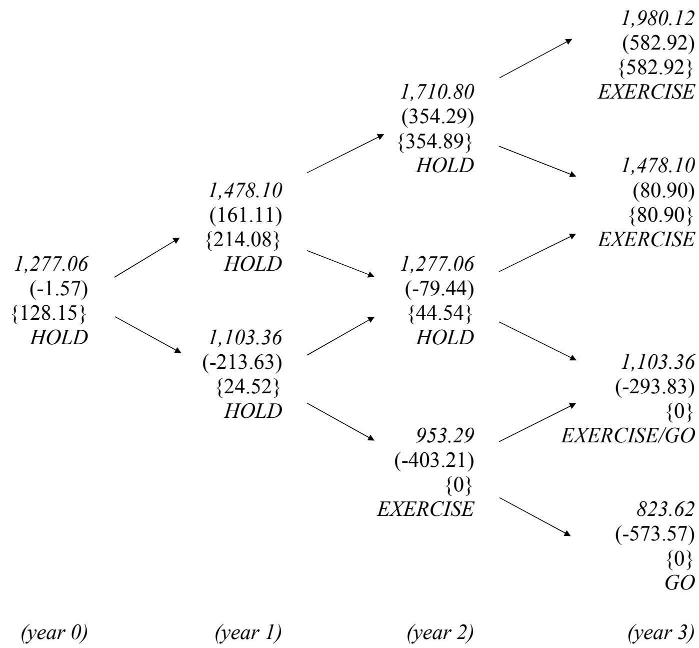


Figure 6: Decision tree with deferral option, $\delta = 0$.

value of \$8.86 million.

The deferral option values and their contribution to the managerial flexibility of the project are presented in Table 1. In the light of the above analysis and valuation results, the project which initially had a negative NPV of \$1.57 million, now has an expanded net present value of \$10.43 million including the value of the option to defer for two years, accounting for 0.82% (10.43/1277.06) of the present value of the projected cash inflows. The use of such a comprehensive valuation framework means that risk and returns are properly evaluated and the government does not underwrite risks which could be borne by the concessionaire. The policy implication is that a built in flexibility regarding when a BOT project could commence provides a better framework for assessing the viability of a project than when such flexibility is absent.

The above approach to valuation is relevant in situations where the infrastructure project is procured through a PPP arrangement. In such situations, the financial vi-

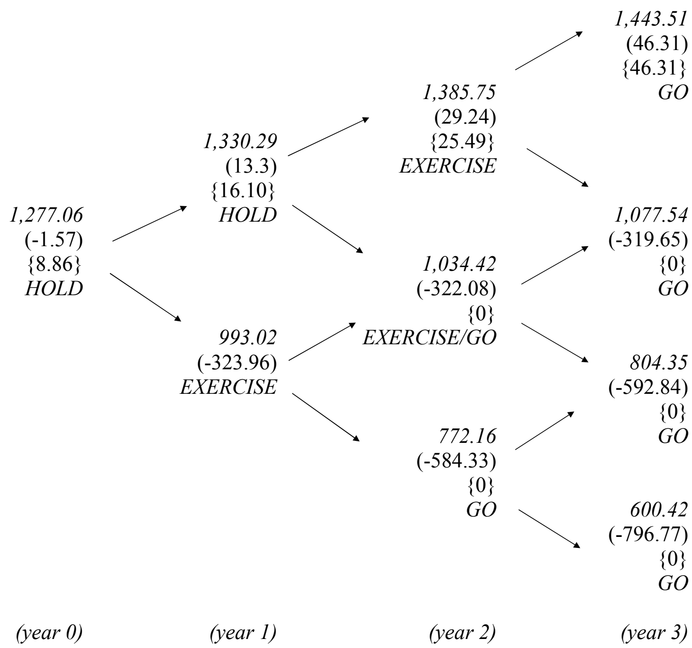


Figure 7: Decision tree with deferral option, $\delta = 0.1$.

	T = 1	T = 2	T = 3
$\sigma = 0$	90.27	108.95	129.72
	7.07%	8.53%	10.16%
$\sigma = 0.1$	8.89	10.43	10.43
	0.70%	0.82%	0.82%

Table 1: Values of the deferral option

ability of the project is important to both the project sponsor and the concessionaire. On the other hand, if the project is critical to the developmental effort of a government's investment programme and financial viability is not critical to its acceptance, then the need to evaluate the deferral option may not be important. Such projects are usually implemented under the traditional procurement method. Secondly, the analysis recognises the need to evaluate the deferral option, but it does not imply that the value of the deferral option would always ensure feasibility at a later stage if the initial discounted cash flow approach produces a negative net present value. The impact of the value of the deferral option on the expanded project net present value would largely depend on the estimate of the volatility. This is the motivation for the identification of a robust approach to estimate volatility. Our estimate of volatility produces a much lower estimate than previous studies. This suggests that our finding that deferral improves upon the viability of the project is not the outcome of using a relatively high rate of volatility as is the case in most previous studies. Furthermore, even if the valuation of the deferral option does not add any significant amount to project value, it nevertheless provides a rigorous basis for properly assessing how much government support would be required to enable the project to proceed. This is in contrast with the existing literature where after using the traditional discounted cash flow approach, if a project shows a negative net present value, a request is made for financial support or guarantee, without the evaluation of the deferral option.It therefore reinforces our argument that a comprehensive valuation is required before one can determine whether or not extra extra financial support or guarantee from the government may be needed.

6 Conclusion

This paper argues that because of the uncertainty and irreversibility associated with infrastructure projects, their evaluation should routinely incorporate the option to defer in order to obtain a comprehensive view of its economic viability before any consideration of whether or not it needs governmental subsidies or revenue guarantees. We show that by using relevant information usually available in project documents as well as market type data, we can analyse the uncertainty and estimate the volatility of the underlying project cash flows required for real option valuation. This is in contrast to previous studies that did not adequately explain the sources and type of data that could be used in real option valuation. We model the deferral decision as an American option which accounts for the underlying asset value shortfall, akin to when the project pays dividend in contrast with previous studies which just assumed a fixed exercise date and ignored the dividend component. The expanded project valuation framework used in the paper suggests that deferral option of the construction start-up has value and significantly improves upon project value. This provides a better framework for determining whether or not some type of government support is needed to take a project forward. Additionally, it provides a rigorous basis for the sharing of risks and rewards associated with BOT infrastructure schemes.

References

Arboleda, C. and Abraham, D. (2006). Evaluation of flexibility in capital investments of infrastructure systems. *Engineering, Construction and Architectural Management*, 13(3):254–274.

Bain, R. (2009). Error and optimism bias in toll road traffic forecasts. *Journal of Transportation*, 36(5):469–482.

Bernanke, B. (1983). Irreversibility, uncertainty and cyclical investment. *Quarterly Journal of Economics*, 98(1):85–106.

Bowe, M. and Lee, D. (2004). Project evaluation in the presence of multiple embedded real options: Evidence from the Taiwan High-Speed rail project. *Journal of Asian Economics*, 15(1):71–98.

Copeland, T. and Antikarov, V. (2003). *Real options: A practitioner's guide*. Penguin group, United Kingdom.

Dixit, A. (1989). Entry and exist decisions under uncertainty. *Journal of Political Economy*, 97(3):620–638.

Dixit, A. and Pindyck, R. (1994). *Investment under uncertainty*. Princeton University Press.

Epps, T. (2000). *Pricing derivative securities*. World scientific publishing Co., Singapore.

Field, R (2005). *The use of best management practices (BMPs) in urban watersheds*. DEStech Publications.

Fishbein, Greg, and Babbar, S. (1996). *Private financing of toll roads: A review of experience*. Resource mobilisation and co-financing discussion paper. World Bank, Washington DC.

Flyvbjerg, B., Holm, M., and Buhl, S. (2006). Inaccuracy in traffic forecasts. *Transport Reviews*, 26(1):1–24.

Garvin, J. and Cheah, C. (2004). Valuation techniques for infrastructure decisions. *Construction Management and Economics*, 22(4):373–383.

Godinho, P. (2006). Monte-Carlo estimation of project volatility for real options analysis. *Journal of Applied Finance*, 16(1):15–30.

Grimsey, D. and Lewis, M. (2004). *Public-Private Partnerships: The worldwide revolution in infrastructure provision and finance*. Edward Elgar, Cheltelham.

Ho, S. and Liu, L. (2002). An option pricing-based model for evaluating the financial viability of privatised infrastructure projects. *Construction Management and Economics*, 20(2):143–156.

Huang, Y. and Chou, S. (2006). Valuation of the minimum revenue guarantee and the option to abandon in BOT infrastructure projects. *Construction Management and Economics*, 24(4):379–389.

Ingersoll, J. and Ross, S. (1992). Waiting to invest: Investment and uncertainty. *Journal of Business*, 65(1):1–29.

J.P. Morgan (1997). Examining toll road feasibility studies. *Municipal Finance Journal*, 18(1):44–66.

Kwak, Y., Chih, Y., and William, C. I. (2009). Towards a comprehensive understanding of Public-Private Partnerships for infrastructure development. *California Management Review*, 51(2):51–78.

Liou, F. and Huang, C. (2008). Automated approach to negotiations of BOT contracts with the consideration of project risk. *Journal of Construction Engineering and Management*, 134(1):18–24.

Mackinder, I. and Evans, S. (1981). The predictive accuracy of british transportation studies in urban areas. *Supplementary Report No. 699. Transportation and Road Research Laboratory.*

McDonald, R. and Siegel, D. (1986). The value of waiting to invest. *Quarterly Journal of Economics*, 101(4):707–728.

Mun, J. (2006). *Real options analysis: Tools and techniques for valuing strategic investments and decisions*. John Wiley and Sons.

Myers, S. (1976). *Modern development in financial management*. Praeger, New York.

Ng., F. and Bjornsson, H. (2004). Using real option and decision analysis to evaluate investments in the architecture, construction and engineering industry. *Construction Management and Economics*, 22(5):471–482.

Rode, D. and Lewis, P. (2003). Probabilistic risk analysis and project capital structures. *Journal of Structured and Project Finance*, 9(2):65–80.

Schaufelberger, J. and Wipadapisut, I. (2003). Alternative financing strategies for Build-Operate-Transfer projects. *Journal of Construction Engineering and Management*, 129(2):205–213.

Shaanan, J. (2005). Investment, irreversibility and options: An empirical framework. *Review of Financial Economics*, 14(3):241–254.

Shen, L. and Wu, Y. (2005). Risk concession model for Build-Operate-Transfer contract projects. *Journal of Construction Engineering and Management*, 131(2):211–220.

Standard & Poor's (2002-2005). *Annual reports: Traffic forecasting risk study from 2002 to 2005*. Standard & Poor's.

Stark, A. (1990). Irreversibility and the capital budgeting process. *Management Accounting Research*, 1(3):167 – 180.

UK National Audit Office, D. (1985). *Expenditure on motorways and trunk roads*. London: NAO.

Vassallo, M. and Fagan, M. (2007). *Strategies for mitigating traffic risk in transportation concession contracts*. World conference on transport research, Berkeley.

Walmsley, D. and Pickett, M. (1992). *The cost and patronage of rapid transit systems compared with forecasts*. Research Report No. 352. Transportation Research Laboratory.

Wooldridge, C., Garvin, M., Cheah, Y., and Miller, J. (2002). Valuing flexibility in private toll road development: Analysis of the Dulles Greenway. *Journal of Structured and Project Finance*, 7(4):25–36.

World Bank (1986). *Urban transportation: A World Bank policy study*. World Bank, Washington DC.

Xenidis, Y. and Angelides, D. (2005). The financial risks in Build-Operate-Transfer projects. *Construction Management and Economics*, 23(4):431–441.

Ye, S. and Tiong, R. (2000a). Effects of tariff design in risk management of privately financed infrastructure projects. *Journal of Construction Engineering and Management*, 129(6):610–618.

Ye, S. and Tiong, R. (2000b). Government support and risk-return trade-off in China's BOT power projects. *Engineering, Construction and Architectural Management*, 7(4):421–422.

Zhang, X. (2005). Financial viability analysis and capital structure optimisation in privatised public infrastructure projects. *Journal of Construction Engineering and Management*, 131(6):656–668.