REAL OPTIONS ANALYSIS: CAN IT IMPROVE INFRASTRUCTURE DEVELOPMENT DECISIONS?

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ABSTRACT

Increasingly, infrastructure owners worldwide are turning to the private sector to help finance needed infrastructure expansion and modernization. BOT arrangements are one mechanism for utilizing private capital for public purpose, but frequently, these projects possess managerial options, which are not directly valued by either the government or the private concessionaire because conventional valuation methods fail to capture flexibility's value. Real options analysis (ROA) has emerged over roughly the last two decades to address this limitation. Four prevailing ROA methods, which are briefly described, have surfaced from the related but independent fields of finance and decision theory, but application of these techniques to infrastructure projects remains problematic. Specifically, their assumptions and mechanics appear to limit their value to the infrastructure community. These circumstances have motivated an ongoing research program to assess the utility of ROA methods during infrastructure development decisions. A case study of the Dulles Greenway provides a forum for: (a) discussing the research program's objectives and methods, (b) illustrating the classic and the marketed asset disclaimer (MAD) approaches to value a deferment option embedded within the project, and (c) providing a preliminary assessment of whether ROA is a promising complement to traditional project analysis methods. The provisional conclusions are that ROA methods are promising for both strategic insights and credible valuation.

KEY WORDS

Real Options, Infrastructure Development Decisions, Project Delivery Methods

INTRODUCTION

THE EVOLVING INFRASTRUCTURE DEVELOPMENT LANDSCAPE

The demands to develop new and to modernize existing infrastructure facilities have prompted the global infrastructure community to rethink existing paradigms. The exclusive use of segmented delivery and tax-supported financing strategies for the development or renewal of infrastructure systems is coming to an end in the United States and worldwide. Traditional financing mechanisms have not kept pace with the growing list of infrastructure expansion, modernization and restoration requirements since federal funding has leveled or diminished (CBO 1999) and citizens have not generally supported substantial state or local tax hikes to finance such investments either. These circumstances have forced public owners to look towards other sources of capital such as user fees (or tolls) to finance facility development or improvement. Moreover, the use of private capital for infrastructure projects has become a global trend, particularly in

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emerging economies where financially challenged public administrations look toward the private sector to develop basic infrastructure (Esty 2003).

Consequently, U.S. infrastructure owners are now considering multiple means for developing or improving their real assets. One strategy is the build-operate-transfer (BOT) delivery method, which has experienced a resurrection over roughly the last fifteen years. State agencies are also becoming more receptive to unsolicited proposals from private consortiums for infrastructure projects. Currently, 20 states have enabling legislation that permits some form of public-private initiatives for transportation projects (Reinhardt 2004). For instance, the Virginia Department of Transportation (VDOT) is currently reviewing several unsolicited proposals including two proposals to rebuild 325 miles of I-81 by converting this segment to a toll road and a proposal to build 50 miles of tolled express lanes on I-95 (Reinhardt 2003).

VALUING PRIVATELY FINANCED PROJECTS THAT POSSESS MANAGERIAL OPTIONS

These changes in the infrastructure development paradigm present new challenges to public owners and private investors. Principally, the solicitation of private capital for public purpose places substantial emphasis upon a project's *economic value* for both parties. Unfortunately, traditional methods of project evaluation can often fail to consider important dimensions of such projects. Frequently, BOT projects possess managerial options, which are not directly valued by either governments or private consortiums. Without a careful appraisal of the opportunities and risks inherent in such arrangements, development may not occur at all if the project itself is undervalued because managerial flexibility is ignored or the concession agreement struck between the government and the private developer may include disproportionate subsidies since financial guarantees are given for free.

For instance, consider Table 1. In Case 1, the government offers to secure a minimum amount of user fee revenue to a concessionaire in order to improve the creditworthiness of a project financing arrangement or in effect it has written a *put option*. Clearly, this option has value, but no attempt is usually made to gauge it. If the value is substantial, then the government may have unknowingly provided the concessionaire a tremendous subsidy. Alternatively, the concessionaire may disregard or attach a conservative value to the option in light of its vagueness. In Case 2, the government has granted the concessionaire the right, but not the obligation, to expand a tolled facility or a *call option*. Again, this option undoubtedly has value, but in the absence of reasonable quantification, both parties may underestimate the economic value of the facility. In both cases, the lack of an objective measure to reconcile the expectations between the two parties is likely to result in the abandonment of justified projects, thus leading to a lose-lose situation.

Table 1: Payoff Structures for Potential Infrastructure Project Options

Payoff Structure to Private Developer	
Case 1	*Case 2*
Payoff = 0 if $A \geq G$	Payoff = I – X if $I \geq X$
Payoff = G – A if $A < G$	Payoff = 0 if $I < X$
where: A = actual revenue collected by developer G = guaranteed revenue by government	where: I = incremental revenue after expansion X = cost of expansion

REAL OPTIONS ANALYSIS METHODS & CHALLENGES

As mentioned, conventional methods for estimating a project's value cannot capture the value of the options just described. Real options analysis (ROA) has emerged over roughly the last two decades to address the limitations of traditional valuation methods and to provide a rational approach to valuing such flexibility. Various approaches to modeling real options have surfaced as the related but independent fields of finance and decision theory have wrestled with the challenges of model development. Prevailing approaches to modeling real options may be categorized as: (1) the *classic* approach, (2) the *marketed asset disclaimer (MAD)* approach, (3) the *revised classic* approach, and (4) the *hybrid (or integrated)* approach.[2] The differences between the various approaches revolve principally around the *assumptions* made and the *mechanics* involved.

Most applications of these methods have occurred in other domains, but recent interest about the subject has grown within the infrastructure community (Ford et. al. 2002; Ho and Liang 2002; Zhao and Tseng 2003). While a general consensus exists regarding the promise of real option "thinking", the application of real option models during infrastructure development decision-making remains problematic. Chiefly, real option models require genuine improvements in their ability to: (a) represent different forms of flexibility and (b) become widely accessible to infrastructure policymakers and managers. These circumstances have motivated an ongoing research program that is designed to determine to what extent ROA can improve infrastructure development decisions. In short, the writer's view is that the "jury is still out" on this verdict.

To determine whether ROA is a promising complement to traditional project analysis methods, this research's objective is *to look more closely at the utility of the prevailing ROA approaches when valuing options that are available to public and private participants in BOT infrastructure projects*. By doing so, this research will increase our collective knowledge of infrastructure development flexibility and will begin to determine what contributions real option valuation can make toward its quantification. Case studies of both international & domestic BOT arrangements, depicted in Table 2, will provide the data and the information necessary to assess the efficacy of each modeling approach. The first objective is to identify the types of options found within these projects and then to value the most common options discovered using each of the four methods. The assessment process will appraise the *robustness*, *simplicity* and *assumptions* of each model developed.

Table 2: Real Options Analysis Case Studies

Case Study	Location	Type
Indiantown Cogeneration Plant	Florida, USA	Power Plant
Florida High Speed Rail	Tampa-Orlando, Florida, USA	Rail Segment
SR 91 Express Lanes	California, USA	Toll Road
Dulles Greenway	Virginia, USA	Toll Road
Dabhol Power Plant	Maharashtra, India	Power Plant
Malaysia-Singapore Second Crossing	Malaysia and Singapore	Toll Bridge
A2 Motorway	Poland	Toll Road
Highway 407 ETR	Toronto, Canada	Toll Road

[2] These categories generally follow those proposed by Borison (2003), and the description of each approach presented later in the paper draws, in part, from his characterization of these methods.

The remainder of this paper briefly describes the four prevailing ROA methods. Then, a deferment option discovered within the Dulles Greenway case study is valued using the *classic* and *MAD* approaches to contrast the differences between these methods and to illustrate aspects of the assessment process. The paper concludes by describing future research work and discussing certain aspects of ROA that go beyond the numbers.

RESEARCH BACKGROUND

TRADITIONAL VALUATION: APPLICABILITY & LIMITATIONS

Net present value (NPV) analysis is the generally preferred method for establishing the value of an asset not set in an active market (Brealey and Myers, 2000; Finnerty, 1996; Grinblatt and Titman, 1998). Myers (1984) suggests that this method is adequate for ongoing operations since they generate relatively safe cash flows and are held for this reason, not for less tangible strategic purposes. Investments, however, often create future growth opportunities or they have contingency possibilities. In effect, the risk of subsequent cash flows can change as development proceeds or new information is received. In such cases, NPV analysis understates the value of this flexibility. Amram and Kulatilaka (1999), Trigeorgis (1999), Dixit and Pindyck (1994), Myers (1984), and others point to this shortcoming.

Infrastructure projects are frequently full of flexibility. Moreover, flexibility is often incorporated as an intuitive managerial approach to deal more effectively with uncertainty. Development routinely proceeds in stages that aim to better define project scope and discover unknown information. Preliminary planning and feasibility studies, such as geotechnical surveys and traffic volume analyses, can reveal information that may alter further decisions. Flexible design permits projects to more readily adapt to changing conditions, such as an increase in expected demand. In short, flexibility can allow a timelier and less costly response to a dynamic environment. Flexibility can add value, but it comes at a cost in terms of money, time, and complexity. Regrettably, traditional valuation methods do not adequately support analyses of the tradeoffs between flexibility and its cost.

PREVAILING REAL OPTIONS ANALYSIS METHODS

Stewart Myers coined the term "real options" in 1977, and since then, various ROA methods have emerged. Four prevailing methods are described in the following sections.

Classic Approach

The classic approach first assumes that the market is complete, so traded assets are available to hedge all types of economic risks. Therefore, a project analyst can construct a portfolio of traded assets to replicate the returns of a real option, thus the option can be valued based upon standard "no arbitrage" arguments. The "no arbitrage" assumption is pervasive among real option valuation methods. In fact, the presumption of market completeness underpins capital budgeting theory in general. In addition, this technique presumes that the value of the asset underlying the option follows a "random walk" and therefore can be described by the familiar geometric Brownian motion (GBM). This permits the use of standard tools such as the Black-Scholes equation for valuation. The mechanics of the approach are rather straightforward. First, identify the replicating (or tracking) asset or portfolio and calculate its value and volatility. Second, size the investment relative to the replicating asset(s), and finally, use the Black-Scholes equation to value the investment. Kulatilaka and Amram (1999) as well as Copeland et. al. (1994) give further explanations and examples of this approach.

MAD Approach

The MAD approach relies upon the same assumptions that justify the use of NPV analysis. Brealey and Myers (2000) comment:

> *When we value a real option by the risk-neutral method, we are calculating the option's value if it could be traded. This exactly parallels standard capital budgeting . . . a DCF calculation of project NPV is an estimate of the project's market value if the project could be set up as a mini-firm with shares traded on the stock market. The certainty equivalent (i.e. risk-neutral) value of a real option is likewise an estimate of the option's market value if it were traded.*

Thus, MAD's assumptions are no stronger than those used to value a project by NPV, and an analyst can avoid the tricky business of identifying a tracking portfolio. Most applications of this approach typically presume that the value of the asset in question follows GBM, which permits the use of recombining lattice models to solve for asset value (although this is not an absolute requirement). The approach's mechanics follow. First, build a subjective cash flow model to estimate the value of the project by NPV using a risk-adjusted discount rate. Second, assign probability distributions to the key inputs of the cash flow model, develop a distribution of asset value using Monte Carlo simulation and then estimate the volatility of asset value that corresponds to this distribution. Finally, build a risk-neutral lattice and use the developed asset value distribution to estimate the asset's value. Interestingly, Copeland et. al. (2000), original advocates of the classic approach, now subscribe to this method.

Revised Classic Approach

The revised classic approach takes account of the characteristics of the project before committing to a valuation methodology. Specifically, this approach looks more carefully at the elements contributing to project uncertainty and delineates these elements into either public (market-based) risks or private (project-specific) risks. This delineation distinctly recognizes that there are limits to the applicability of the "no arbitrage" principle. If a project is dominated by public risks, then existing assets in the economy will span changes in the value of the project (Dixit and Pindyck 1994). Therefore, an analyst should use a constructed tracking portfolio to value options. Alternatively, if the project is dominated by private risks, then the spanning assumption does not hold (Dixit and Pindyck 1994). Hence, an analyst should use decision analysis techniques to value options. This approach requires one to determine whether the real asset investment is dominated by public or private risks. If public risks dominate, apply the classic approach. If private risks dominate, apply decision analysis methods. Amram and Kulatilaka (2000) now advocate the use of this approach to value real options as opposed to the classic approach.

Hybrid Approach

The hybrid approach also recognizes that real asset investments typically possess both public and private risks; however, this methodology does not force an analyst to determine which type of risk is dominant. Instead, it is designed to accommodate both.

Smith and McCardle (1998) explain that the basic idea is to use option pricing methods to value risks that can be hedged and decision analysis procedures to value risks that cannot be hedged. Like the revised classic approach, the basic assumption is that the market is only complete enough to allow mitigating public risks. In addition, the integrated approach does not necessarily assume that public risks conform to a specific stochastic process, such as GBM. The mechanics require several steps. First, build a decision tree that represents the investment alternatives. Second, determine whether each risk is a public or a private risk. Third, for public risks: (a) identify a replicating portfolio, (b) determine the portfolio's volatility and (c) calculate the risk neutral probabilities. Fourth, for private risks, assign subjective probabilities. Fifth, develop a cash-flow model to calculate the NPV of each outcome using a risk-free discount rate. Finally, "roll back" the tree to determine the best strategy and its value. Smith and Nau (1995), the first to promulgate this approach, provide further explanation.

DISCUSSION

Leading authorities have yet to converge upon a universal approach to valuation. Such convergence, however, is very unlikely since the assumptions underlying the approaches are not sacrosanct. Foremost, the notion of market completeness is disputable, even though there is general agreement that capital markets function well (Fama 1970, 1991). Additionally, the "true" value of a non-traded asset over time is unobservable (Bodie et. al. 1999). Without empirical evidence to confirm theoretical estimates of the evolution of real asset value, project valuation methods will remain mere propositions.

Intellectual convergence and empirical validation, however, are unnecessary. Why? As Goodwin & Wright (1998) explain, "in all models, a balance has to be struck between the accuracy with which the model represents the real problem and the effort required to formulate the model". Hence, the modeling requirements are governed by the context of the application. In many respects, real option models are simply decision tools not pricing mechanisms, so the utility of a particular model to a decision-maker depends predominantly upon its *robustness* and *simplicity*. In other words, does the tool provide the proper insight on average **regardless** of simplifying assumptions?

CASE STUDY OF THE DULLES GREENWAY

The Dulles Greenway was among the first U.S. highway projects to be delivered by BOT franchise since the 19th century, and it provides a forum for illustrating two ROA methods and discussing the prospects of these techniques. The Greenway is an extension of the existing Dulles Toll Road from Dulles International Airport into Leesburg, VA in Loudoun County. The extension provides a more attractive commuter route than existing state roads from northern Virginia into the Washington, D.C. metropolitan area.

A private consortium secured the right to develop the extension as a toll road from the state in 1988. As a completely private venture, the Greenway would provide forty years of cash flows to its investors, without public subsidies. Revenues would depend almost exclusively upon toll receipts. Estimates of initial capital costs were approximately $279 million. Equity investors contributed approximately $40 million while long-term fixed rate notes provided the balance of the financing. Initial projections by the consortium forecast approximately 20,000 vehicles per day for the first year of operation at a fixed toll rate of $1.50 with traffic increasing to 34,000 vehicles per day by 1995 at the same toll rate. The project was scheduled to start construction in 1989 and operations in 1992, but difficulties in securing financing and environmental permits caused delay. Construction finally commenced in September 1993, proceeded flawlessly and ended six months ahead of schedule in September 1995. Within six months of opening, the project was in financial distress. Average daily traffic demand was an abysmally low 10,500. The toll was reduced to $1.00 in March 1996, and future toll hikes were deferred in an attempt to increase ridership. By July 1996, road usage increased to 21,000 daily travelers, but the net effect was marginal, as decreased toll rates offset the increase in ridership. The project's sponsors began discussions with their creditors in the summer of 1996 to work out a plan for deferring debt payments and restructuring loan contracts (Bailey 1996).

The investment in the Dulles Greenway was reconstructed from an *ex ante* perspective using cash flow estimates and construction costs from financial models submitted by the consortium to the state (Garvin and Cheah 2004). A traditional analysis produced a NPV of negative $86.3 million, and sensitivity analysis indicated that the attractiveness of the investment depended heavily upon the initial traffic volume.

DEFERMENT OPTION

The traditional analysis suggested that the investment decision hinged upon the initial traffic volume. Since the Greenway is effectively a commuter route between "bedroom" communities and Washington D.C., its usage will depend heavily upon residential real estate development in Loudoun County. The project's developers could consider deferring the project since deferment would allow the observation of growth in the outlying regions. The *classic* and *marketed asset disclaimer* methods are now illustrated to value this option. For this analysis, the following assumptions and estimates are used: (a) the decision timeframe is 1993, (b) the deferment option will expire in 5 years since the government will then take action to improve other commuter routes, (c) waiting to invest has negligible direct costs, (d) the exercise price (X) is the present value of the initial cost to develop the Greenway, which is $225.1 million calculated using a risk-adjusted rate, and (e) the risk-free rate (r_f) is 6%, the yield on national debt in the 1990's.

Classic Approach

The first task of the classic approach is to determine a market proxy for the value of the Greenway. Copeland and Tufano (2004) suggest that very often the underlying value of a real asset is driven by a key variable. The value of the Greenway is logically linked to the volume of commuters to/from the D.C. area, and the number of commuters is certainly linked to residential real estate development in the region. Between 1980 and 1990 Loudoun County's population increased by 50% to 86,129 residents, and the two major communities that lie along the Greenway's route, Ashburn and Leesburg, experienced even higher growth rates (US Census Bureau 1995; Leesburg EDD 2003). If these trends continue, one would expect that regional real estate developers would exploit this growth.

Hence, regional Real Estate Investment Trusts or REITS may be considered reasonable proxies for the value of the Greenway. Post Properties, Inc. is traded as a REIT, and it is the parent company of Post Apartment Homes, which owns, develops and manages upscale, garden-style apartment units primarily in the Southeast. They currently own several developments in the metropolitan D.C. area. Figure 1 depicts its monthly share price from Oct '93 to Oct '98. The annual volatility of Post was estimated as 15.21% following the approach described by Mun (2002).

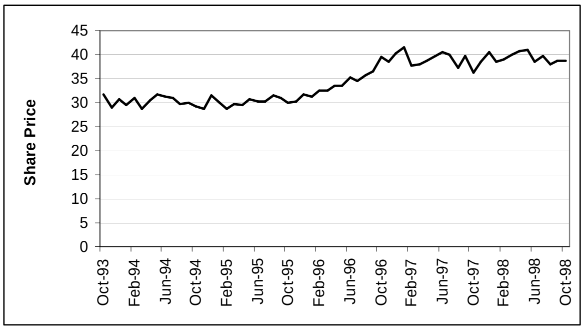

Figure 1: Monthly Share Price for Post Properties (Source: www.postproperties.com)

With volatility estimated, the next step is to size the investment relative to the market surrogate. In the early 1990's, Post held roughly 14,500 apartment units in its portfolio, and its market capitalization was about $687.8 million (PPS 1997, 1998). Based upon Loudoun County demographic data, a subjective estimate of the number of new apartment units that the region could support is 5,000. Consequently, the Greenway investment is considered 34.5% (5,000/14,500) of Post Properties; in other words, the Greenway can be thought of as a 5-year option on 34.5% of the shares of Post Properties (Borison 2003). Thus, the current value of the real asset (S_0) is $237.2 million (0.345*$687.8 million). The deferment option's value can now be calculated by the Black-Scholes equation using the five selected/calculated parameters: (1) S_0 = $237.2 million, (2) time to maturity = 5 years, (3) r_f = 6%, (4) asset volatility = 15.2% and (5) X = $225.1 million. The resulting Black-Scholes option value is $75.6 million.[3] The value-maximizing decision is clear; the value of the deferment option exceeds the value of immediate investment, which is $12.1 million ($237.2 million – $225.1 million). One might also consider the value of the project with the embedded deferment option as $87.7 million ($12.1 million + $75.6 million).

MAD Approach

This approach starts by building a subjective cash flow model of the project, so the same model employed in Garvin and Cheah (2004) is used. A subjective estimate of the project's present value of EBIT at a risk-adjusted discount rate of 15.6% and an average daily traffic (ADT) volume of 20,000 is $138.7 million; this represents S_0. The next task is to estimate the volatility of the investment via simulation. In this instance, initial ADT is the key driver of the project's value, so it is the only variable assigned a distribution. A lognormal distribution is utilized with 10th and 90th percentile points of 10,000 vehicles and 34,000 vehicles respectively, which makes this range a 90% confidence interval. Now, the value of the underlying asset is simulated to estimate its volatility, which is 75%.

The subsequent step is to construct a lattice for the value of the underlying asset to represent the projected movements of the underlying value period by period. Utilizing Cox et. al.'s (1979) approach for estimating up and down movements in asset value where u = 2.117 (the return when value goes up) and d = 0.472 (the return when value goes down) a five period (period = 1 yr.) binomial lattice is created and illustrated in Figure 2. The terminal values at the top and bottom are equivalent to u^5S_0 and d^5S_0 respectively;

[3] Those unfamiliar with the Black-Scholes equation are referred to Bodie et. al. (1999) or Amram and Kulatilaka (1999). Note also that this valuation treats the option as a European call.

note all values are \$000,000's. All other values are logical combinations of u, d and S_0. Another lattice, also shown in Figure 2, is constructed to determine the value of the project embedded with the deferral option; the terminal values are calculated by $MAX[u^5S_0 - X, 0]$, so the top value in the tree is MAX[\$5,897.7 – \$225.1, 0] = \$5,672.6. The intermediate values are determined using the risk-neutral method. For instance, the value \$2,574.0 is calculated by $MAX\{[p(5,672.6) + (1\text{-}p)(1,090.8)]exp(-r_f t)], 0\}$ where p is the risk-neutral probability of an upward movement in value and t is the time-step interval; in this case p = 0.358. The remaining values are calculated similarly. This lattice is effectively a decision strategy. As long as the value of the option to defer the project is positive, the developers should keep it "alive".[4]

					5,897.7
				2,785.9	
			1,315.9		1,315.9
		621.6		621.6	
	293.6		293.6		293.6
138.7		138.7		138.7	
	65.5		65.5		65.5
		30.9		30.9	
			14.6		14.6
				6.9	
					3.3

					5,672.6
				2574.0	
			1116.4		1,090.8
		468.9		409.7	
	192.2		152.3		68.5
77.3		56.1		23.2	
	20.5		7.8		0.0
		2.6		0.0	
			0.0		0.0
				0.0	
					0.0

Figure 2: Underlying Asset Value Lattice (Left) and Project Value with Option Lattice (Right)

The initial amount shown in the right lattice of Figure 2, \$77.3 million, is the current value of the project embedded with the deferral option. Again, the value-maximizing decision is clear, \$77.3 million > -\$86.3 million, so the project's developers should wait and see how development in the outlying regions materializes before starting the project.

DISCUSSION & FUTURE WORK

The two approaches just depicted are at opposite ends of the ROA "spectrum" since one relies completely upon market data while the other utilizes mainly subjective input, so they are quite illustrative of ROA methods. Despite these differences, both indicated that the most appropriate choice in 1993 was to defer development, so recommendation consistency exists. In addition, both methods produced project values with the same order of magnitude. Recommendation consistency and the order of magnitude of value are viewed as two determinants of *robustness*. The deferment option will also be valued by the two other prevailing approaches. If both of these methods conclude that deferment was appropriate and that value was in the range of \$10 to \$100 million, then complete recommendation consistency would exist and each method would have produced a value with the same order of magnitude. As more cases are studied, these measures of robustness will acquire additional "data points".

If the robustness of the differing modeling techniques generally holds, then most of the attention for considering the utility of the methods can be directed towards the *complexity* of the models and the validity of the underlying *assumptions*. In the classic approach, a single REIT was used as a proxy for the Greenway's value; instead, a bundle of regional REITS or another proxy altogether (such as a publicly listed home builder like Toll Brothers) could have been used. Regardless, the techniques depicted would not have changed. While the Black-Scholes equation is simple computationally, the classic approach may take infrastructure owners, engineers and builders out of their "comfort

[4] Those unfamiliar with discrete option valuation via lattice techniques are referred to Mun (2002). Note again that this valuation treats the option as a European call.

zones" to construct a tracking portfolio. More importantly, this approach ties the modeler to the presumption that asset value follows a GBM evolvement; this is quite debatable for toll roads or other types of infrastructure. Alternatively, the MAD approach utilizes valuation techniques that are familiar to the infrastructure community – subjective traffic forecasts, subjective cash flow models, risk simulation, etc. While this illustration used a recombining lattice (i.e. a discrete approximation of GBM) to forecast asset value evolution, this is not a requirement of this method. Non-recombining lattices or other stochastic models may be employed that are more representative of the behavior of the real asset's value.

The robustness, complexity and assumptions of the methods will become more transparent as the research progresses. The case studies and models will provide firsthand experience with the problems encountered when attempting to: (a) estimate risk-adjusted discount rates, (b) determine subjective probability estimates and distributions, (c) identify traded proxies for underlying asset values and (d) create discrete or continuous time models of asset value, for different types of options in different contexts. The use of authentic infrastructure projects in this work should not go unnoticed either. Much recent work has relied upon stylized examples, which can diminish the potential for real options to "take hold" since skeptics can easily claim that the conditions of the problem were designed to suit the modeler. This research will help to overcome such skepticism.

CONCLUSION

Critics of ROA often point toward the imperfections and complexities of the modeling techniques and conclude that the methods have too many limitations for them to have practical significance. This research program is designed to determine whether these critics are correct and ultimately answer the question posed in the paper's title, can ROA improve infrastructure development decisions? From a strategic perspective, it is clear that private capital will play a greater role in infrastructure financing in the future. As illustrated and discussed, BOT arrangements often possess managerial options. The mere recognition that options exist within the infrastructure development process will help both public leaders and private participants in designing more effective project execution and risk management strategies for various participants. As Olmsted (1995) points out, "the process of performing a real option analysis tends to broaden one's view of future possibilities and sharpen the logic of one's thinking about various strategic alternatives. The process itself can be more important than the particular analytic results."

From a tactical perspective, the single case illustrated in this paper suggests that ROA methods may become more than mere tools for strategic insight. In particular, the MAD approach shows promise as a technique for defining option value. It employs familiar techniques, can accommodate alternative asset evolution paths and utilizes widely accepted assumptions and methods for valuing non-traded assets. As the research continues, additional appraisal of the other ROA methods will occur and new perspectives are inevitable. If the options within BOT arrangements are not accounted for somehow, then some projects may be: (a) mistakenly eliminated as BOT candidates or (b) erroneously subsidized through public sector contributions or guarantees, since returns will be judged inadequate by straight NPV analysis. Future work in this area will help to preclude these circumstances, thus leading to an expanded market where the public and private sector can engage in fair dealings in development projects that contribute toward the betterment of both sectors and society at large.

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