Valuing Investment Options from the Decision-Maker's Viewpoint in Infrastructure Projects

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Previous research has shown a chasm between the notion of real options and its application in actual project settings. The present study has combined "Prospect Theory" with "Real Options Theory" in order to enhance financial valuations in infrastructure projects. "Loss aversion" and "Risk Seeking" are two phenomena of the prospect theory which deviate the decision maker's valuation from the real options valuation. The effect of these two phenomena in the decision maker's valuation is modeled in this study. The results show that a project with a positive net present value can have a negative value when prospect theory is included in the modeling. Furthermore, a new method for computing volatility is also presented based on simulation. The project in this study, including the waiting option has a positive value, however when the costs during the waiting period is added, the attractiveness of the investment is diminished.

Keywords: Real Options Theory, Prospect Theory, Volatility, Infrastructure Projects, Risk Aversion

Introduction

Investment decision making under risk is one of the most important aspects in the success of infrastructure projects. Real Options Valuation (ROV) is an investment decision making analytical tool for valuing management flexibility under risk. This method was developed in 1973 in the finance theory and gradually found applications in infrastructure projects. However, lately the extension of this method's application in infrastructure projects has faced some restrictions and has motivated the inception of this study. The construction industry has some specific characteristics which distinguish it from the finance industry. For example project targets such as cost, time and quality are initially agreed between the owner and the contractor in the construction industry. Therefore the contractor tries not to trespass the aforementioned targets during the project duration, which makes him to be more loss averse in comparison to the finance industry executors. However, the real options theory (ROT) does not consider these effective factors such as loss aversion in its valuation and therefore the estimated value of options by ROT differentiates from the decision maker's subjective estimation in the construction industry.

Primarily, this study will describe the construction industry's considerations for options "in" projects. It will customize the Black-Scholes model by considering the costs during the option's delay period and improving the achievement of volatility. Afterwards, it will combine the Black-Scholes Method (BSM) with Prospect Theory (PT) in order to obtain the value of option from the decision-maker's viewpoint. Finally, the modeling results show the difference between the real options value and the investor's subjective value of the option. Therefore the difference between the decision maker's viewpoint of the option value and the BSM's results is explained systematically based on PT. This study contributes to the research in the construction industry by offering an enhanced model based on the ROV and PT for valuing investment options and considering "Loss aversion" and "Risk Seeking". Additionally, project manager advisors can give better counseling for exercising options in the projects by considering the decision maker's behavioral characteristics.

Background

In 2002, Richard de Neufville pointed out the distinction between two categories of options including "in project" and "on project" options. Deferring, abandoning, or accelerating the project are options on project while options in project are related to design and construction decisions. In 2008, Chen & Zhang dealt with a mix of public and private risks in the real option valuation procedure for an information technology (IT) investment. Their proposed procedure was applied to an Enterprise Resource Planning(ERP) project in a construction company(Chen, Zhang et al. 2009). In 2012, Garvin & Ford offered six propositions which shows the characteristics of infrastructure projects and the need for further investigation to bridge the chasm between the notion of real options and its application in actual project settings(Garvin and Ford 2012). In 2004, Miller and Shapira applied insights from behavioral decision theory to explain how managers value call and put options. They discussed the implications of these findings for the management of real options and suggested directions for developing descriptive real option theory (Miller and Shapira 2004). In 2014, Chan & Leicht considered conceptual design in public-private partnership infrastructure projects which involves decision-making under risk and uncertainty under the frame of a contract. Chan & Leicht used tradespaces to allocate contractual risk in flexible design concepts(Chan and Leicht 2014). In 2015, Knight et al used a prospect theory-based real options analysis to evaluate the worth of an option to extend the service life (ESL options) of an aluminum structure from twenty to twenty-five years(Knight, Collette et al. 2015). However, in accordance with the literature review and Garvin & Ford's declaration in 2012, the effect of "Loss aversion" and "Risk Seeking" on ROV has not yet been considered in infrastructure projects, and this study has targeted this subject.

Real Options Analysis (ROA) Method

There has been a recent trend for increasing the flexibility in infrastructure projects, to allow a more progressive adaptation to changing market conditions, thus decreasing the overall risk affecting these investments(Martins, Marques et al. 2013). The flexibility is introduced through real options. These options are possibilities of change that one develops in the planning and design stage, allowing the infrastructure (and service) to cope with future uncertainty. The central premise of real options theory is that, if future conditions are uncertain and changing the strategy later incurs substantial costs, then having flexible strategies and delaying decisions can have value when compared with making all strategic decisions during pre-project planning(Ford, Lander et al. 2002). BSM, Binomial Lattice and Decision Tree Analysis are usually used in valuing options for infrastructure projects. The BSM is one of the most common tools for valuing options which gives an estimate of the price of European-style option. It provides a closed-form analytic formula, elucidates the intrinsic relationship between variables and provides insights into the key drivers for the valuation. The BSM is used in this study and its input variables are project total cost (K), present value of project income (S0), Risk-free Interest Rate (r), Asset Return Volatility (σ) and the Dividend Payout Rate (q).

Volatility Estimation

Volatility (σ) is the most difficult parameter to estimate among BSM assumptions. In the domain of financial options, volatility is defined as the standard deviation of the rate of return of the stock in question. Unlike financial options, there is no single, theoretically justified approach for calculating the volatility coefficient in projects(Lewis, Eschenbach et al. 2008). Copeland and Antikarov (2001) presented a method to estimate the volatility parameter in ROA. This method uses simulation to develop a hypothetical distribution of one-period returns because of the unavailable historical distribution of returns. On each simulation trial, the value of the underlying real asset is estimated at two different points in time. The ratio of these two estimated underlying asset values produces an estimate of the rate of return. However, the simulation estimation method presented by Copeland and Antikarov (2001) systematically overstates the project volatility(E Brandão, Dyer et al. 2012). The adjustment necessary to remove the overestimation bias proposed by Brandão (2012) is taken into account in this study. Note that the use of these methods requires estimates of probability distribution parameters for the variables that cause uncertainty in the value of future cash flows. An enhanced method for computing volatility is further presented in this study in order to improve the valuation of volatility and facilitate the combination of BSM with the PT's mathematical model.

Limitations of Real Options Method in the Construction Industry

Garvin & Ford (2012) have addressed some barriers of real options adoption and use in the construction industry. These barriers prevent or severely limit project managers from capturing the potential benefits of real options and thereby improving infrastructure management and project performance. The following table has briefly stated some viewpoint differences between the project manager and real options theory.

Table 1

Comparison of the real options & decision maker's viewpoint with regard to valuing options

Title	Real Options Viewpoint	Decision Maker's Viewpoint
Value	The Value of a project is solely its financial value and the objective is to maximize this financial profit.	As option holders, project managers do not necessarily seek to maximize project value. Project managers manipulate the value of underlying assets that are the basis of option value, thereby decreasing option values(Garvin and Ford 2012).
Risk Probability	Many repeated bets are possible. Probabilistic perspective presumes that decisions are made based on the average of many possible outcomes and managers seek to improve the average.	Project managers make one-shot choices because most opportunities to use a specific option occur infrequently and often only once per project(Garvin and Ford 2012).
Upside & Downside Risk (Opportunity & Threat)	Opportunities and threats with equal abstract financial values have equal amount of impact on decision making.	Losses loom larger than gains(Tversky and Kahneman 1992). Project managers are risk averse in valuing real options(Garvin and Ford 2012).
Required Resources	The amount of resources is not a modeling concern in valuing options.	Project managers have inadequate resources to fully exploit real options(Garvin and Ford 2012).

Prospect Theory

Daniel Kahneman and Amos Tversky created "Prospect Theory" in 1979 and developed it in 1992 as a psychologically more accurate description of decision making, comparing to the expected utility theory. Prospect theory is a behavioral economic theory that describes the way people choose between probabilistic alternatives that involve risk, where the probabilities of outcomes are known. The model is descriptive and tries to model real-life choices, rather than optimal decisions. Their studies eventuate to a mathematical model based on five independent phenomena influencing an individual's decision(Tversky and Kahneman 1992). These phenomena are as follow:
Framing effect: there is much evidence that variation in the framing of options (e.g., in terms of gains or losses) yield systematically different preferences.
Nonlinear preference: the difference between probabilities of .99 and 1.00 has more impact on preferences than the difference between 0.10 and 0.11.
Source dependence: People's willingness to bet on an uncertain event depends not only on the degree of uncertainty but also on its source. People often prefer a bet on an event in their area of competence over a bet on a matched chance event, although the former probability is vague and the latter is clear.
Risk seeking: People often prefer a small probability of winning a large prize over the expected value of that prospect. Risk seeking is prevalent when people must choose between a sure loss and a substantial probability of a larger loss.
Loss aversion: Losses loom larger than gains. The observed asymmetry between gains and losses is far too extreme to be explained by income effects or by decreasing risk aversion(Tversky and Kahneman 1992).
Based on various experiments carried out to quantify the above phenomenal effects on an individual's decision making, a mathematical model is presented as shown in the following formula. This formula transforms the objective probability and values into subjective ones.

$$V(O) = \sum \pi(p_i)v(x_i) \tag{1}$$

$$v(x) = \begin{Bmatrix} x^{\alpha}, & if\ x \geq 0 \\ -\lambda(-x)^{\beta}, & if\ x < 0 \end{Bmatrix} \tag{2}$$

$$\pi(p_i) = \frac{p_i^c}{\left(p_i^c + \left(1 - p_i^c\right)\right)^{1/c}} \tag{3}$$

α and β are free parameters that vary between 0 and 1 and modulate the curvature of the subjective value functions (the weighting functions for gains and losses will be different as long as $\alpha \neq \beta$). The λ parameter specifies loss aversion, with larger values expressing larger loss aversion. Parameter c is equal to γ for positive payoffs and δ for negative payoffs. Also, decision making in this study is assumed to be deterministic. That is, the decision maker should always choose the options with the larger subjective value. The selected values for parameters α (α=β), λ, γ, δ in this study are 0.88, 2.25, 0.61, 0.69 respectively as proposed by Tversky & Kahneman (1992).

Case study

Engineering consultancy firms are involved in pre-investment services (e.g. feasibility studies), design services (e.g. drawings), and services during the realization phase (e.g. cost and quality control) of engineering and construction projects. Engineering consultancy firms are characterized as being highly knowledge-intensive, and involving a high degree of customization(Kreitl, Urschitz et al. 2002). Consider a situation where an engineering consultancy participates in an international tender for project management services. Due to circumstances such as the long distance between the consultants' central office and the project site, the project will probably encounter difficulties in the flow of information and communication. This situation brings the option to invest in an information technology platform (such as ERP) in order to overcome the probable difficulties. On the other hand, the large amount of cost required to develop such a software, it's probable ineffectiveness, lack of background experiences in the company and the company's personnel resistance will make the decision making challenging. Anyway, there is a specific duration until the announcement of the tender's winner and as time goes on the exact demands of the client and project will become more transparent. The ERP investment opportunity has a waiting option, in which the project scope can become clearer. Although some amount of money is expended during the waiting period of this investment, but such expense shall bring sufficient and timely preparation for commissioning the IT project at the specific time of decision making. This option can be modeled using the BSM and is further described in the context.

Modeling the Option

Stages such as eliciting the requirements (e.g. the project charter or definition), definition of customer, architectural, functional, design and other requirements, feasibility study and so on are included in the abovementioned waiting period. Such activities will impose some amount of cost, which will be returned along with a suitable profit if the project is executed; otherwise such costs would be considered as a loss. The essence of such a cost is similar to submission of a performance bond by a contractor to the employer as a guarantee to participate in a BOT project. The employer would exercise the bond if the contractor terminates the project. Huang and Pi (2013) extended the classical Black-Scholes-Merton call option model in order to consider the effect of performance bonding on the valuation of a project(Huang and Pi 2013). The pricing formula for a European-style call option with performance bonding is presented below:

$$d_2 = \frac{\ln\left(\frac{S_0}{K-B}\right) + \int_{t_0}^{t_1}\left[r(u) - q(u) - \frac{1}{2}\sigma^2(u)\right]du}{\sqrt{\int_{t_0}^{t_1}\sigma^2(u)du}} \tag{4}$$

$$d_1 = d_2 + \sqrt{\int_{t_0}^{t_1}\sigma^2(u)du} \tag{5}$$

$$C_0 = S_0 e^{-\int_{t_0}^{t_1} q(u)\,du} N(d_1) - K e^{-\int_{t_0}^{t_1} r(u)\,du} N(d_2) - B e^{-\int_{t_0}^{t_1} r(u)\,du} N(-d_2) \tag{6}$$

Where C_0 is the time-0 payoff of the call option, K denotes the project's total cost, S_0 is the project's expected value at time 0, parameter r is the risk-free rate of return, q is the project's dividend payout rate, B is the bond value and finally t_0 and t_1 are the present time and deadline for the project execution.

Input data

The IT projects in construction industry have a very extensive scope and can have various cost and revenue. Therefore, without exactly specifying the project scope in this case study, the project can either be economical or unfeasible. As the objective of this study is to investigate challenging decision making situations, the IT project with a net present value not much bigger or smaller than zero is of our interest. Thereby, the input values have been chosen regarding this objective and according to the specific case study. The estimation for the input values is given in Table 2.

Table 2

Estimations for real options input values

Title	Value	Description
Total Cost (K)	250,000 $	The cost value is at time t_1. Software development duration is 2 years.
Total Revenue (S0)	200,000 $	The revenue value is calculated at time t_0. The operation duration until full amortization is 8 years.
Risk-free Interest Rate (r)	0.25	Chosen according to the average historical inflation value in Iran.
Waiting Duration (t_1-t_0)	0.5 (Year)	

Methodology

The methodology of this study consists of two main sections. Firstly, the volatility parameter is computed through simulation, in which a distribution would be extracted for volatility instead of a single number. Subsequently, the algorithm for combining the ROT and PT will be presented. The modeling carried out in this study is done by the MATLAB 2014(a) program.

Computing Volatility's Distribution through Simulation

Despite the works of Brandão & Dyer (2012) on removing the overestimation bias of the volatility parameter, there are still some questionable assumptions in its valuation. In the previous valuation methods the question of "How to compute the Volatility" is transformed to "How to estimate the project's future cost & revenue". However, estimating the cost or revenue is essentially a difficult task, due to the lack of historical information; meaning that similar past events are extremely rare and finding them is very difficult. The fact that projects are unique by definition, reduces the relevance and reliability of statistical aggregates derived from probability-based analysis(Pender 2001). In this study the standard deviation of cost or revenue is computed stochastically through a three-point estimation. The most likely, best-case and worst-case estimation of the standard deviation is estimated in accordance with a unit cost or revenue. Table 3 shows a sample of these estimations used in this study.

Table 3

Three-point estimations for the standard deviation of a unit revenue or cost

Revenue			Cost		
best-case	most likely	worst-case	best-case	most likely	worst-case
0.1	0.3	0.5	0.2	0.4	0.6

Successively, random numbers are generated using the relevant triangular distribution and each of them are used to create a lognormal distribution of future cost or revenue. In fact Wall (1997) showed that the project's cost and revenue estimations are better represented by lognormal distributions(Wall 1997). Subsequently, the lognormal distributions produce random numbers for cost and revenue and therefore numerous stochastic cash flows are produced. The procedure for obtaining the volatility distribution is algorithmically represented in Figure 1. Note that if the arithmetic mean and standard deviation of a lognormal distribution is E[X] and Var[X] respectively, then a transformation with regard to the formulations (7) & (8) should be made to create a lognormal distribution with its scale and location parameters σ and μ(Crow and Shimizu 1988). The value of E[X] is equal to 1 and Var[X] is the random number chosen according to the triangular distributions.

$$\mu = \ln(E[X]) - \frac{1}{2}\sigma^2 \quad (7)$$

$$\sigma^2 = \ln(1 + \frac{Var[X]}{E[X]^2}) \quad (8)$$

Combining Real Options & Prospect Theory

Figure 1 shows the algorithmic structure for computing volatility's distribution and combining the two mentioned theories. The first row in the figure is associated with the various input data, including the prospect theory's parameters, BSM input data, triangular distribution parameters and the complementary data for forming the project cash flow. In order to study the BSM's behavior against volatility, sensitivity analysis is carried out through the modeling. Also the volatility's distribution is computed by the method explained in the previous section. After producing various stochastic cash flows, the relevant distributions of volatility, option value (using BSM) and project's present value is attainable. The probabilities and values regarding the present value of the project would then be used in the prospect theory's model and result in the decision maker's subjective value of the project.

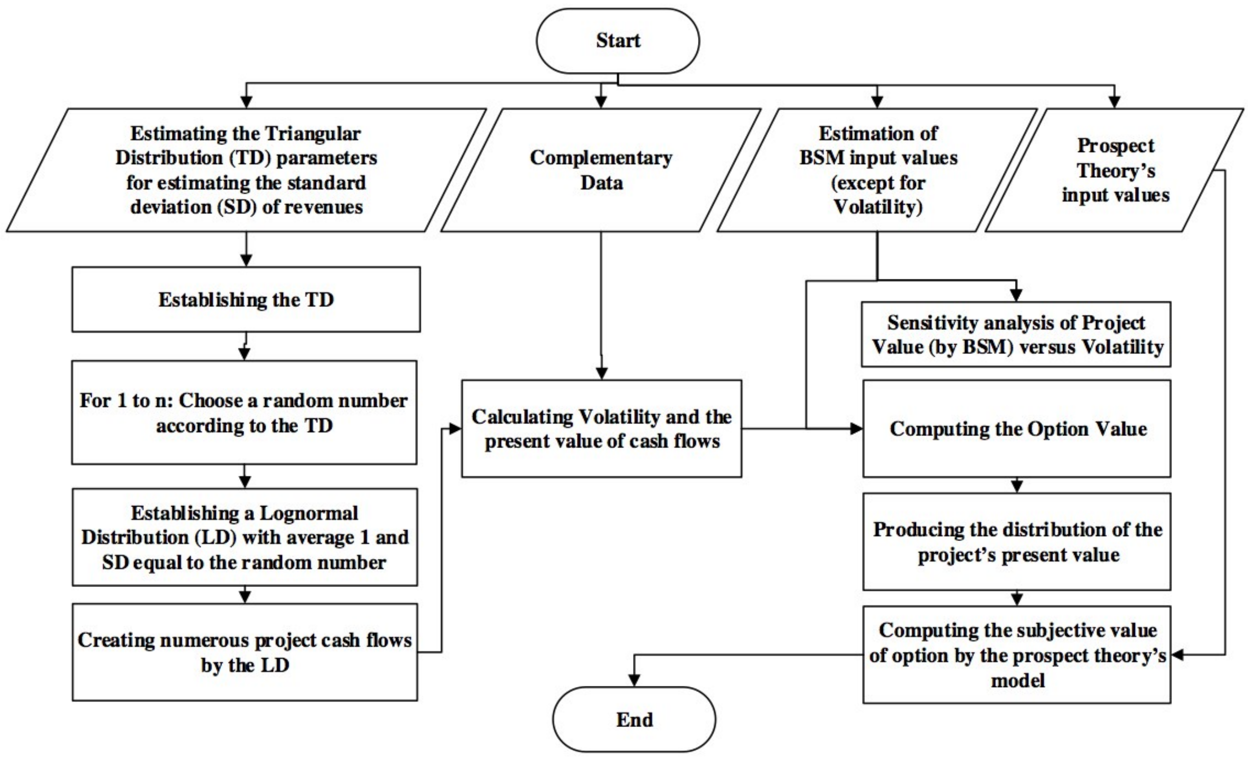

Figure 1: Algorithm of the research method.

Results

Table 4 and Figure 2 present the study's results. The present value of the project is computed with the traditional Discounted Cash Flow (DCF) method (obviously without the value of option to wait) and has a value of 266 $. This value would not vary by changing the value of parameter B as observed in table 4, because the sum of B and K's net present value is fixed. The net present value of the project from the decision maker's viewpoint is negative on contrary to the value computed from DCF method. By adding the waiting option value using the BSM, the project value will be positive; however the effect of parameter B would diminish the attractiveness of the option and make the total project value negative. Figure 2(d) shows the sensitivity analysis of BSM's output with respect to volatility and reinforces the effectiveness of volatility and its direct effect on the option value.

Table 4

Project's Net Present Value (NPV) for zero & non-zero values of B (Values in $).

Viewpoint of the:	Method	B=0	B=20000
Model	DCF	266	266
Decision maker	DCF	-670	-670
Model	BSM	1333	-1050
Decision maker	BSM	958	-1270

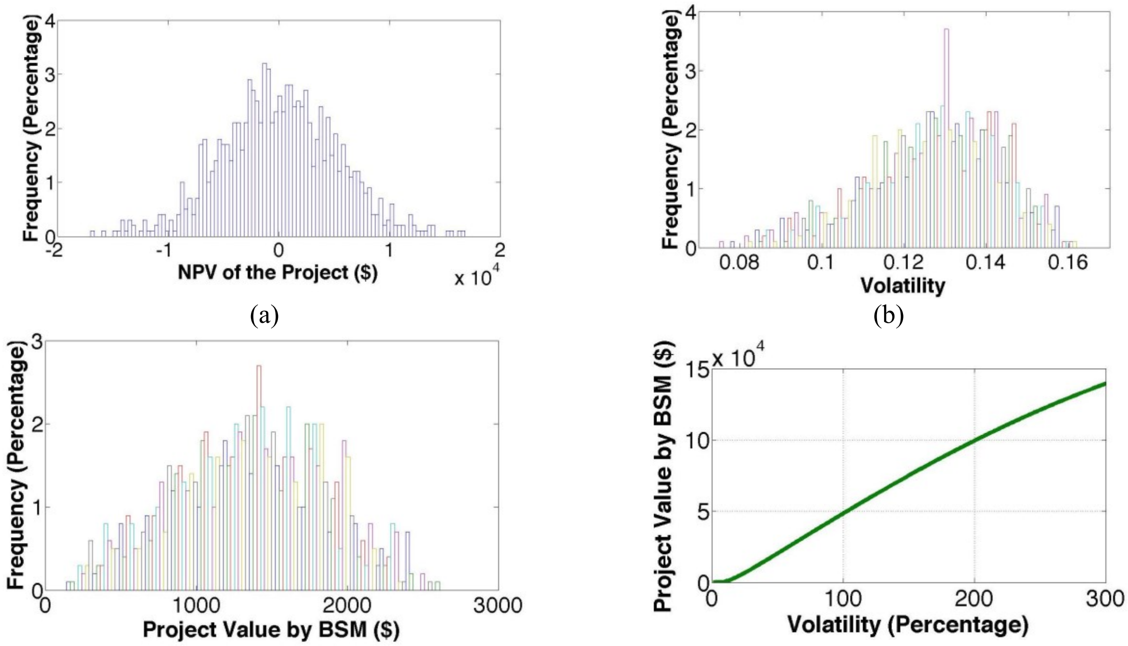

Figure 2: (a) NPV distribution of the project computed by DCF method; (b) Distribution of volatility computed by simulation; (c) Option value's distribution computed by BSM; (d) Sensitivity analysis of BSM's output with regard to volatility (B is 0 in all the figures).

Discussion

According to the literature review and Garvin & Ford's declaration in 2012, the effect of "Loss aversion" and "Risk Seeking" on real options valuation has not yet been considered in infrastructure projects. The present study has combined the Prospect Theory with Real Options Theory in order to enhance financial and option valuations in infrastructure projects. This combined valuation method, results in the decision maker's viewpoint (subjective valuation) of the project and option value. "Loss aversion" and "Risk Seeking" are two phenomena of the prospect theory which deviate the decision maker's valuation from the real options valuation. The difference between the objective and subjective valuation of options, partially explains the existing chasm between the notion of real options and its application in actual project settings. The results show that a project with a positive net present value can have a negative value when prospect theory is included in the modeling. It could not be concluded that either of the objective or subjective values are wrong or right, however the existing gap which is systematically computed, can lead further research to approximating these two values. For example, better counseling can be given to decision makers for utilizing options based on knowing their psychological motivations for decision making and its effect on their decision results.

Additionally, a new method for computing volatility is presented based on simulation. As explained in the literature review for the developments in the calculation of project options volatility, the previous proposed methods have actually transformed the question of "How to compute the Volatility" to "How to estimate the project's future cost & revenue". Therefore the difficulty of estimating a project's future probability density function of cost and revenue still remains. The new method presented in this study, uses a three-point estimation of the standard deviation of cost (or revenue) and after on, extracts a distribution for volatility through a Monte-Carlo simulation. Obtaining a distribution for volatility has dual purpose. First, it provides the basis for obtaining a distribution for volatility and secondly it provides the prerequisite for using prospect theory's model on BSM. The analytical modeling in this study, considers the effect of the costs during the waiting period of the option in the BSM. This cost can diminish the value of the waiting option and results in a negative total value for the project.

References

Chan, P. and R. Leicht (2014). "Using Tradespaces to Allocate Contractual Risk in Flexible Design Concepts."

Chen, T., J. Zhang, et al. (2009). "An integrated real options evaluating model for information technology projects under multiple risks." International Journal of Project Management 27(8): 776-786.

Crow, E. L. and K. Shimizu (1988). Lognormal distributions: Theory and applications, M. Dekker New York.

E Brandão, L., J. S. Dyer, et al. (2012). "Volatility estimation for stochastic project value models." European Journal of operational research 220(3): 642-648.

Ford, D. N., D. M. Lander, et al. (2002). "A real options approach to valuing strategic flexibility in uncertain construction projects." Construction Management & Economics 20(4): 343-351.

Garvin, M. J. and D. N. Ford (2012). "Real options in infrastructure projects: theory, practice and prospects." Engineering Project Organization Journal 2(1-2): 97-108.

Huang, Y.-L. and C.-C. Pi (2013). "Real-Option Valuation of Build-Operate-Transfer Infrastructure Projects under Performance Bonding." Journal of Construction Engineering and Management 140(5).

Knight, J., M. Collette, et al. (2015). "Design for flexibility: Evaluating the option to extend service life in preliminary structural design." Ocean Engineering 96: 68-78.

Kreitl, G., G. Urschitz, et al. (2002). "Corporate growth of engineering consulting firms: a European review." Construction Management & Economics 20(5): 437-448.

Lewis, N. A., T. G. Eschenbach, et al. (2008). "Can we capture the value of option volatility?" The Engineering Economist 53(3): 230-258.

Martins, J., R. C. Marques, et al. (2013). "Real options in infrastructure: revisiting the literature." Journal of Infrastructure Systems.

Miller, K. D. and Z. Shapira (2004). "An empirical test of heuristics and biases affecting real option valuation." Strategic Management Journal 25(3): 269-284.

Pender, S. (2001). "Managing incomplete knowledge: Why risk management is not sufficient." International Journal of Project Management 19(2): 79-87.

Tversky, A. and D. Kahneman (1992). "Advances in prospect theory: Cumulative representation of uncertainty." Journal of Risk and uncertainty 5(4): 297-323.

Wall, D. M. (1997). "Distributions and correlations in Monte Carlo simulation." Construction Management & Economics 15(3): 241-258.