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USING OPTIONS PRICING THEORY TO VALUE SAFETY & ERGONOMICS PROJECTS: A CASE STUDY

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ABSTRACT

This paper applies option pricing theory to value an investment in safety & ergonomics. Utilizing both traditional and perpetual call option frameworks, we quantify project value overlooked by traditional discounted cash flow techniques. In a case study format, it is shown that delaying investment allows the firm to reduce uncertainty associated with safety & ergonomic interventions; with increased costs of delaying encouraging speedier implementation.

JEL: G30, G31, G32, G39

KEYWORDS: Capital Budgeting, Options Pricing, Case Study

INTRODUCTION

The application of options pricing theory to investments in tangible assets is commonly known as real options analysis and provides a method for quantifying the value of flexibility in investment timing, while considering the impact of uncertainty. Real options analysis allows investment managers to value project abandonment, delay, expansion, and development.

Real options analysis is most appropriately applied to business decisions dependent on the value of additional information, investment timing, and cash flow uncertainty. Uncertainty is inherent in the evaluation of all safety and ergonomics (S&E) interventions; consequently, making accurate economic evaluations of such decisions can be rather difficult. Numerous sources of uncertainty exist. In particular, experts are unable to predict the precise number of workers who will develop work-related musculoskeletal disorders (WMSD) or suffer work-related injuries. In addition to the frequency of occurrences, accident severity is an important driver of costs which cannot be readily predicted. Further, no intervention is completely effective in preventing injuries. As such, the extent to which a given intervention is effective within a target population is unknown. At best, the intervention will reduce the probability an accident or WMSD will occur. This scenario of partial effectiveness introduces additional uncertainty regarding the number and severity of accidents or WMSDs that may be prevented due to an intervention.

Both accidents and WMSDs have direct and indirect costs associated with them. The most significant direct costs are medical expenses for the treatment of injuries, monies paid to employees such as disability and replacement wages, and expenses associated with rehabilitation. Generally, these expenses are translated to the company through worker's compensation insurance. The company pays an insurance premium, which is based to a varying extent on the actual injury rate experienced by the company internally. Indirect costs include expenses such as the worker's pay for the remainder of the day, lost productivity, mechanical repairs, supervisor/administration time, etc. Additional expenses include costs related to relief staffing, absenteeism, and employee turnover. Understanding these costs and their sources will allow companies to more accurately evaluate potential opportunities for avoiding or reducing costs by taking steps to prevent the accidents or WMSDs.

The purpose of this paper is to provide a detailed economic analysis of safety and ergonomics interventions similar to Lanoie and Trottier (1998). However, instead of using traditional discounted cash flow techniques, we utilize an options pricing approach to evaluate investment in S&E.

This paper is organized as follows. Section 2 reviews the literature. Section 3 lays out the principles of option pricing theory and real options. Section 4 uses a practical case study to illustrate the applicability of real options analysis techniques to investment decision making in the area of S&E. Section 5 provides concluding remarks.

LITERATURE REVIEW

The idea that discounted cash flow analysis may be insufficient to capture the true value of investment opportunities has been around for several decades. Myers (1977) was one of the first to examine this and suggest the application of option pricing theory to real investments. Dixit and Pindyck (1994) show that the ability of the firm to delay investment can affect the decision to invest, hence exposing the weakness of the net present value rule. Dixit and Pindyck espouse the use of real option analysis to capture and account for uncertainty, hence creating flexibility. They evaluate the mathematical techniques of dynamic programming and contingent claims analysis and use these techniques to model investment decisions under uncertainty. Botteron (2001) provides a general introduction to the use and benefits of real options theory by walking the reader through the practical application of the theory. The survey paper of Triantis and Borison (2001) examines the experiences of companies across different industries in the United States to better understand how real options analysis is actually applied. The authors find varying degrees of use in different industries, but overall find that real options are used as both a way of thinking and as an analytical tool.

Newton and Pearson (1994) specifically apply real option analysis to a research and development project, illustrating the value of flexibility provided by R&D. Palmer and Smith (2001) also study an application of real options, but to the health care sector, to show that although the firm incurs a loss from delay of implementation, this loss is actually more than offset by the gain of information. Block (2007) surveys Fortune 1000 companies to determine what percentage of managers actually utilize real options. Block finds 14% of respondents use real options in some form. Kyrchowski and Quelin (2010) apply real options analysis to a case study in the telecommunications industry to examine the gap that exists between theory and practice. Krychowski and Quelin find value in the option to defer investment, contrary to discounted cash flow rules.

There are a number of economic studies evaluating the costs and benefits of ergonomic interventions. However, many focus on shorter term payback periods and the development of predictive cost-benefit analysis models (Goggins, Spielholz, Nothstein, 2008). Tompa, Dolinschi, Oliveria, and Irvin (2009) found evidence that ergonomic and other musculoskeletal injury prevention interventions in manufacturing and warehousing are worth undertaking in terms of financial merits, but methodological quality of these economic evaluations could be improved. Further, Tompa, Dolinschi, and Oliveria (2006) identify a need for economic expertise in the multidisciplinary research teams evaluating workplace-based occupational health and safety interventions. Haddix, Teutsch, and Corso (2003) provide discussion in the public sector of the need for specific decision analysis and economic evaluation approach in prevention effectiveness. Niven (2002) identified problems with valuing benefits in health and safety because they frequently take many years to emerge and are difficult to measure. Additionally, healthcare managers and economists have not traditionally worked together and have inherent misunderstandings of each other's roles. This paper fills a void in the literature by providing a contemporary economic analysis technique, namely options pricing theory, to the difficult task of evaluating longer term S & E intervention investment.

DATA AND METHODOLOGY

Option Pricing Theory and Real Options

An option, broadly speaking, provides the holder with an opportunity to take a specific action, but does not require or obligate them to do so. A simple example is the financial call option on a stock, which gives the holder the option to purchase a given stock at a specified price (the exercise price) within a set time period. Hence, if conditions are favorable for the holder of the option and the trading price of the stock exceeds the exercise price of the option, the holder can choose to exercise the option to receive the net value given by:

$$C = Max[S - X, 0] \tag{1}$$

where:

C = Value of the Call Option
S = Value of the Asset (i.e. Stock Price)
X = Exercise Price

Derivatives are a class of securities in which the value of the security is derived from an underlying asset. Options are type of derivative. While options pricing theory has traditionally focused on financial securities as the underlying asset, more recently researchers have applied options pricing theory to the evaluation of real assets involving timing flexibility and uncertainty (Trigeorgis, 1996). The options pricing methods used for valuing these real opportunities have become known collectively as real options analysis. Table 1 lists the components of financial options and their corresponding interpretations under real options.

Table 1. Relating Financial Options and Investment Decisions

Stock Call Option (C)	↔	Option to Invest in a Future Project (C)
Current Value of Stock (S)	↔	Expected Present Value of the Project's Cash Flows (V)
Exercise Price (X)	↔	Expected Investment Cost (I)
Expiration Date (T)	↔	Time Horizon of the Investment Opportunity (T)
Volatility (σ)	↔	Volatility of the Project's Returns (σ)
Dividend on Stock (δ)	↔	Opportunity Cost of Delaying the Investment (δ)
Risk-free Interest Rate (r)	↔	Risk-adjusted Interest Rate (r)

Table 1 relates the components of traditional financial options to those of real options. The left hand side details the variables used in the calculation of financial options, while the right hand side of the table lists their corresponding interpretations under real option theory.

The methodology used to value financial options can be translated to real options by regarding the option as the right, but not the obligation, to invest in a future business project. The current value of the stock is analogous to the present value of the project's cash inflows. The exercise price corresponds to the investment amount to initiate the project. The expiration date represents the point in time when the investment opportunity ends due to license expiration, competitor influences, or other factors. The volatility of the stock price corresponds to the projected volatility of returns for the project. With respect to a call option, dividend payouts decrease the value of the stock thereby reducing the value of the call option. Thus, the dividend can be thought of as the income opportunity which the investor foregoes by delaying the investment.

Case Study Background

Consider the implementation of a new manual material handling (MMH) system at Société des Alcools du Québec (SAQ), the only authorized distributor of wine and liquor in Quebec, to help reduce work-related injuries. SAQ employees primarily perform order-picking activities. Cases of wine and liquor are retrieved from storage shelves and assembled into different orders for distribution to retail locations. The costs and benefits of the new MMH are highlighted in Table 2.

Table 2: Costs and Benefits of New MMH System

COSTS	BENEFITS
Forklift trucks (to move through alleys in shelving units)	**Direct cost savings** (reduced premium paid to Quebec's worker compensation board, which covers lost wages and medical expenses
Pallet trucks (to pick orders from shelves)	**Indirect cost savings** (cost of lost days in terms of lost productivity, mechanical repairs, supervisor/administration time)
Complete redesign of shelving system	**Labor Savings** (tasks eliminated by increased productivity of the MMH system)
Automatic pallet distributor (installs pallets on pallet trucks)	**Broken bottle savings** (annual costs decreased 66%, in constant dollars)
Modifications to the facility (additional room for battery storage and charging)	
Time spent for ergonomics training (teaching employees lifting/handling techniques to prevent back-related injuries)	

Table 2 details the costs and the benefits (cost savings) of the implementation of the new manual material handling (MMH) system at Société des Alcools du Québec. These costs and benefits are then quantified and used in the real option framework to determine the value of delaying the project.

RESULTS AND DISCUSSION

<u>Traditional Call Option Framework</u>

Using data from 2012, we began by framing the MMH investment as a real call option. V_0, is estimated by calculating the present value of the projects benefits at the appropriate discount rate, which in this case equals to \$2.6 million. The investment cost, I, is the present value of the costs associated with the intervention, or \$1.65 million. Consistent with the cost and benefit projections, the time to make a decision, T, is assumed to be 5 years. The risk free rate, r, is assumed to be 5.5%. The parameter used to model project uncertainty is volatility, σ. Dixit and Pindyck (1994) suggest estimating σ by using the stock price volatility of a pure play company in the specific project of interest. In this case, we utilize Columbus McKinnon Corp. (CMCO) because they specialize in manufacturing and selling the type of equipment employed in this intervention (i.e., material handling equipment including trucks and lifts). The CMCO stock price volatility and thus implied project volatility, σ, was estimated to be 64%. The table below lists the real option variables and the corresponding values associated with this project.

Table 3: Traditional Call Option Framework

Real Option Variable	Description	Value
V_0	Present discounted value of the benefit of the project	\$2.6 million
I	Present value of the costs of intervention	\$1.65 million
T	Time to make a decision	5 years
r	Risk-free rate	5.5%
σ	Uncertainty, as measured by comparable stock price volatility	64%

Table 3 lists the real call option variables, the description of each variable within the real option framework, and the associated project value. These values will then be utilized in Black-Scholes equation to determine the value of the call.

Using the above parameters, the value of the call option to invest in this project can be determined using the Black-Scholes (1973) equation.

$$Call = V_0 N(d_1) - Ie^{-rT} N(d_2) \quad (2)$$

Where

$$d_1 = \frac{\ln\left(\frac{V_0}{I}\right) + \left(r + \frac{\sigma^2}{2}\right)}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

V_0 = Present value of cash inflows
I = Investment cost
T = Time to make a decision
σ = Project value uncertainty due to cash flow volatility
r = Risk-free rate

Using Equation 2, the value for SAQ to delay their MMH investment decision is \$1.7 million. The real options literature often refers to this value as the Flexible Net Present Value (FNPV). When compared to the project's net present value (NPV) of \$0.94 million, this analysis suggests the flexibility to postpone the investment decision for five years is worth the difference between the FNPV and the traditional NPV, or \$0.84 million. As a result, even though there is a positive net present value to the project, the company may be better served to delay investment in order to acquire additional information about the project's costs and benefits.

<u>Perpetual Call Option Framework</u>

An irreversible investment decision, delayed over an infinite time horizon, may be valued using the perpetual call option framework found in Dixit and Pindyck (1995). The value of this perpetual call option, $F(V)$, is shown to be:

$$F(V) = AV^{\beta}\ for\ V \le V^* \qquad (3)$$
$$F(V) = V - I\ for\ V > V^*$$

where:

$$A = \frac{(\beta - 1)^{(\beta-1)}}{\beta^{\beta} I^{(\beta-1)}} \qquad (4)$$

and

$$\beta = \frac{1}{2} - \frac{(r-\delta)}{\sigma^2} + \sqrt{\left(\frac{(r-\delta)}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2r}{\sigma^2}} \qquad (5)$$

r = risk-free rate
σ = volatility
δ = opportunity cost factor

where δ represents the opportunity costs associated with delaying the investment decision
The critical value, V^*, is determined to be:

$$V^* = \frac{\beta}{\beta - 1} I \qquad (6)$$

In the absence of risk, V^* will be equal to I, and the NPV rule would apply. However, the presence of uncertainty implies that $\beta / (\beta - 1) > 1$, and thus $V^* > I$. In other words, when risk is present and $V^* > I$, the NPV rule is no longer appropriate and investment should be deferred until $V > V^*$. When $V > V^*$, the value of the option to invest is simply given by $V - I$ since the decision to invest would be implemented immediately.

When contemplating investment in S&E, the cost of delaying investment must be taken into account. The opportunity cost associated with injuries and accidents that could otherwise have been prevented by investing immediately in the intervention must be considered before making a decision to delay. This opportunity cost of delaying the investment, δ, may be incorporated into the real options analysis and is based on the foregone benefits of the project; that is, the costs of injuries which would be avoided by implementing this intervention, but which will continue to be incurred by the firm each year the intervention is delayed. The total benefits provided in the case study are worth \$2.6 million over 4 years. For simplicity, if we assume the \$2.6 million in benefits are evenly distributed over the 4 year period, then there is an opportunity cost of \$650,000 for each year the investment is delayed. As an overall fraction of the project's value, δ can thus be expressed as 0.25.

With many safety and ergonomics interventions there is not a preset timetable to make an investment decision. Management could choose to delay the investment for one year or ten years, without losing the option to invest later. As such, the perpetual call options framework is an appropriate model.

Using equations 3-6 yields a value for β of 2.08, with a V^* of \$3.2 million. Since the expected net present value of the project, V_0, does not exceed the critical value, V^*, the optimal decision is to delay investment rather than invest immediately.

Figure 1 shows the critical value V^* at the point where the flexible net present value (FNPV) and traditional net present value (NPV) converge. Note for all project values $V > V^*$, the FNPV and NPV are equal.

Figure 1: Project Value, V, vs. F(V), (FNPV) and Traditional NPV

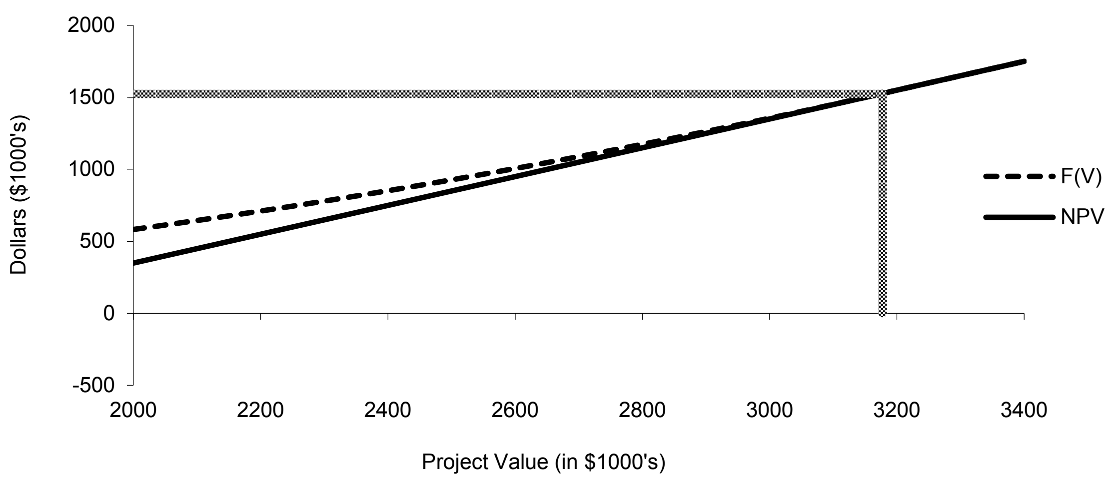

Figure 1 plots the value of the perpetual call option, F(V), (FNPV) and the value of the traditional net present value, NPV. It is shown that the two converge at the critical value, V^*=\$3.2million. For expected net present value, V_0, less than the critical value, V^*, the value of the call option is greater than the traditional NPV.

In the following sensitivity analysis, the input parameters are changed, with the corresponding response to the FNPV discussed. In Figure 2, we examine the sensitivity of the option value, F(V), to changes in the initial project value. Note F(V) increases gradually with the project value until it reaches the critical value, as is represented by the vertical line in the figure. In other words, if V0 > $3.2 million, then the benefits of implementing the MMH system today outweigh the value of delaying to gather additional information.

Figure 2: Sensitivity of F(V) to V0

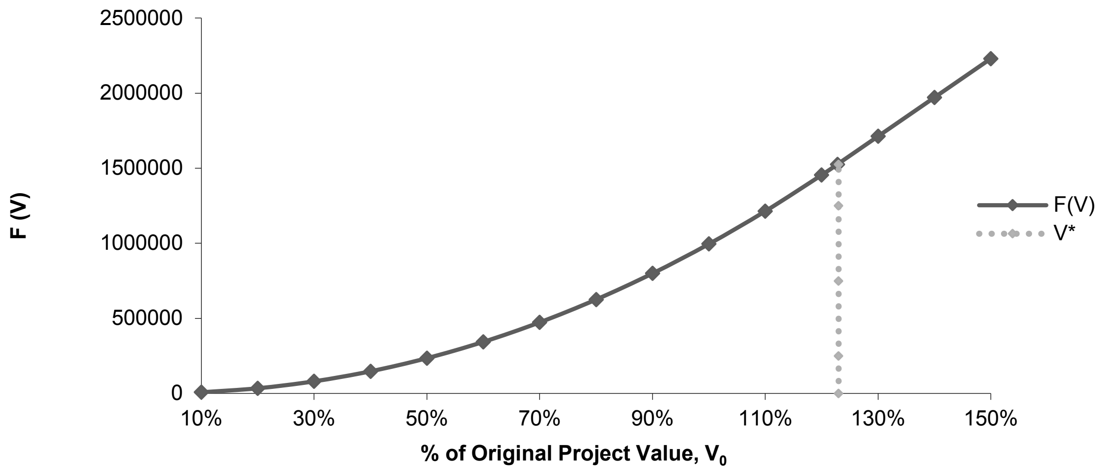

Figure 2 examines the sensitivity of the option value, F(V), to changes in the original project value, V_0. As original project value is changed, F(V) increases gradually, until it reaches the critical value, V*, at which point it increases linearly.

In Figure 3, we examine the effect of the dividend yield, or opportunity cost parameter on the option's value. As one would expect, an increasing opportunity cost reduces the option value. This continues until δ reaches 40%, at which point the value of the project exceeds the critical value, and the project would be implemented. Thus, if the work-related injury costs exceed $1 million per year, then SAQ should implement the MMH system immediately.

Figure 3: Sensitivity of F(V) to δ

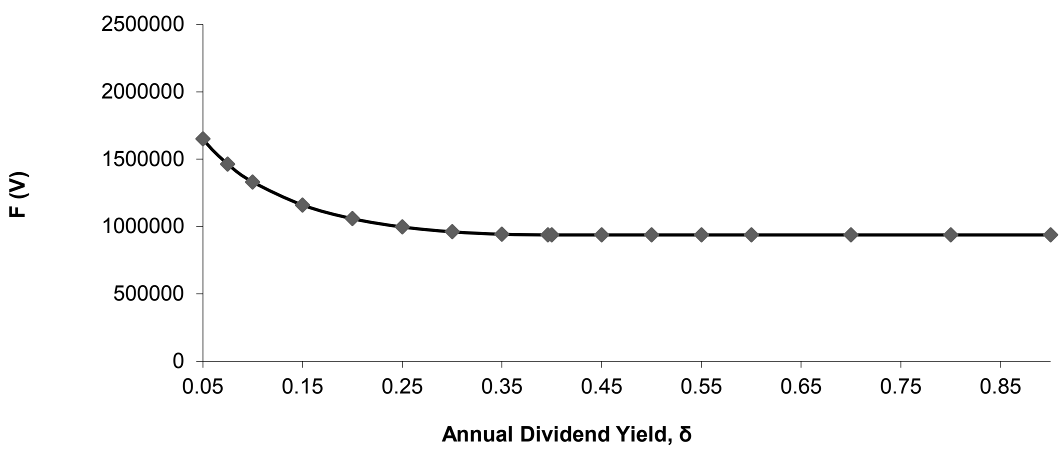

Figure 3 examines the effect of the dividend yield, or opportunity cost parameter, on option value. The increasing opportunity cost reduces the option value until the point that δ reaches .40, at which point V_0 exceeds V, indicating that the project should be implemented.*

Figure 4 shows that F(V) increases with volatility. If the volatility drops below 50%, then V > V* and SAQ should implement the MMH system. In other words, once uncertainty in the MMH benefits are reduced, management should protect its workers with appropriate interventions.

Figure 4: Sensitivity of Option Value to Volatility

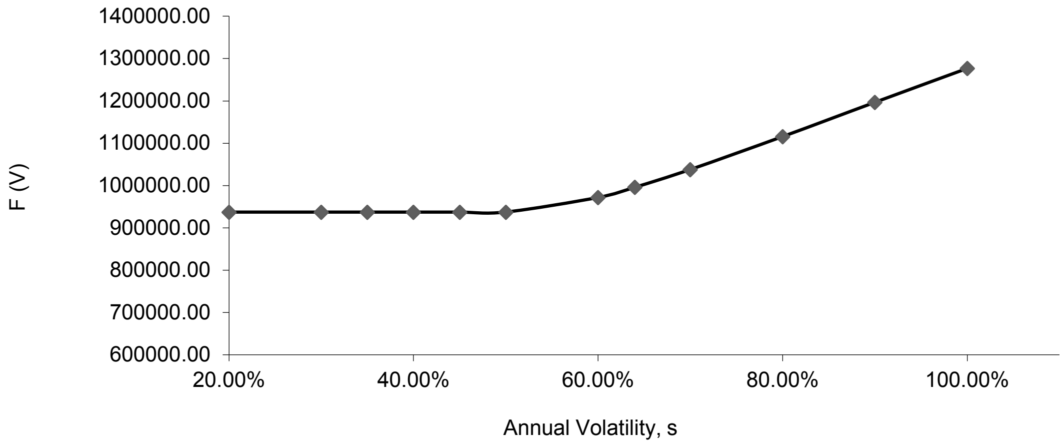

Figure 4 illustrates that option value, F(V), increases with volatility. However, if the volatility drops below 50%, then $V_0 > V^*$ and the project should be immediately implemented.

CONCLUDING COMMENTS

Traditional capital budgeting techniques are often insufficient to justify investment in S&E projects. Further, when these projects can be justified, questions often arise regarding the optimal timing of the investment decision. Using real options, the decision maker has another tool to evaluate these issues.

In the case of S&E projects, it may be especially valuable to view the option value as a measure of the worth of gathering additional information. More specifically, if analysis results in a delay decision, information should be actively collected during this delay to obtain better estimates of benefits or to reduce uncertainty. In terms of S&E intervention, this means further risk analysis, attempting to more accurately characterize the effectiveness of an intervention, and/or developing better estimates of the cost savings per prevented accident or injury. Often, this information is not freely available. As such, the decision maker should invest in additional resources to acquire this type of information and reduce the level of uncertainty. These activities may include (a) hiring outside consultants or experts, (b) developing in-house expertise regarding hazard recognition and mitigation, and/or (c) training of employees regarding unsafe work practices and conditions. Thus, the option value may be viewed as the economic worth of these investigative activities. This investigation should reduce the level of uncertainty, and potentially lead to the discovery of additional or alternative S&E interventions to protect workers.

Further, it should be noted that delaying investment in safety projects may result in additional workers being injured. Although a delay in investment may appear optimal in the short run, it does not alleviate a company from its responsibility to the health and safety of its employees. During a delay, the firm should actively investigate the proposed intervention as well as potential intermediate steps to protect workers. The investigation may yield information that will improve the efficacy of a particular intervention.

Benchmarking from financial option pricing techniques, real options are becoming a practical tool for investment decisions. However, one key difference does exist between financial versus real option valuation. The end goal of financial option pricing is to sell a marketable security, whereas, the culmination of real options should be to improve decision-making. Acquiring precise prices for financial options is a necessary condition for market makers to profitably market and sell derivative products to firms. In addition, firms need to understand more accurately how the option prices were derived, if the derivative product will mitigate targeted risks, and whether or not the market price of that derivative is justified given its potential benefits. On the other hand, real options should be viewed as just another decision-support tool to be used in combination with payback period, return on investment, net present value, and internal rate of return. The real 'bang for the buck' for real options is identifying an appropriate decision framework, recognizing the implicit/explicit real options, and calculating an enhanced project value. In other words, real options results should guide decision-makers to choose the best course of action, not necessarily to provide an 'exact' option price.

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