

Real Options Analysis versus Traditional DCF Valuation in Layman's Terms

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Introduction

This paper provides a contrast between traditional valuation methods and the new generation of strategic decision analytics, namely real options analysis (with Monte Carlo simulation, stochastic forecasting, and optimization). In addition, it briefly illuminates the advantages as well as the pitfalls of using each methodology. It should be clear to the reader that the new analytics described here do not completely replace the traditional approaches. Rather, the new analytics *complement* and build upon the traditional approaches—in fact, one of the precursors to performing real options and simulation is the development of a traditional model. Thus, do not ignore or discard what is tried and true—traditional approaches are not *incorrect*, they are simply *incomplete* when modeled under actual business conditions of uncertainty and risk—but complement it with more advanced analytics to obtain a much clearer view of the business reality.

There are two major takeaways from this paper. The first is the fact that real options analysis is not an equation or a set of equations. It is both an *analytical process* as well as a decision analysis *thought process*. Which leads us to the second takeaway, that 50% of the value of real options is simply *thinking about it*. Another 25% comes from generating the models and getting the right numbers, and the remaining 25% of the value of real options is explaining the results and insights to senior management, to the person beside you, or to yourself, so that the optimal decisions can and will be made when it is appropriate to do so. Therefore, this paper would have served its purpose well if it gets the reader to start thinking of the various conditions and scenarios under which these new analytics can be applied.

The paper starts by reviewing the traditional views of valuation and decision analysis, and moves on to an introduction of real options and Monte Carlo simulation. It is only intended as an introductory view into these new analytics, and is based upon the author's books, "*Real Options Analysis: Tools and Techniques, Second Edition*," (Wiley 2005), "*Modeling Risk: Applying Monte Carlo Simulation, Real Options Analysis, Forecasting, and Optimization*," (Wiley 2006), among others. Please refer to these books for more detailed and technical information on performing Monte Carlo simulation, real options analysis, time-series forecasting, and stochastic optimization. These books will also present step-by-step details on using the author's *Risk Simulator* software and *Real Options Super Lattice Solver* software for running Monte Carlo simulations, time-series forecasting, real options analysis, and optimization.

The Traditional Views of Valuation

Value is defined as the single time-value discounted number that is representative of all future net profitability. In contrast, the market price of an asset may or may not be identical to its value. The terms assets, projects, and strategies are used interchangeably throughout this paper. For instance, when an asset is sold at a significant bargain, its price may be somewhat lower than its value, and one would surmise that the purchaser has obtained a significant amount of value. The idea of valuation in creating a fair market value is to determine the price that closely resembles the true value of an asset. This true value comes from the physical aspects of the asset as well as the non-physical, intrinsic, or intangible aspect of the asset. Both aspects have the capabilities of generating extrinsic monetary or intrinsic strategic value. Traditionally, there are three mainstream approaches to valuation, namely, the market approach, the income approach, and the cost approach.

Market Approach

The market approach looks at comparable assets in the marketplace and their corresponding prices and assumes that market forces will tend to move the market price to an equilibrium level. It is further assumed that the market price is also the fair market value after adjusting for transaction costs and risk differentials. Sometimes a market-, industry-, or firm-specific adjustment is warranted to bring the comparables closer to the operating structure of the firm whose asset is being valued. These

approaches could include common-sizing the comparable firms, such as performing quantitative screening using criteria that closely resemble the firm's industry, operations, size, revenues, functions, profitability levels, operational efficiency, competition, market, and risks.

Income Approach

The income approach looks at the future potential profit or free cash flow generating potential of the asset and attempts to quantify, forecast, and discount these net free cash flows to a present value. The cost of implementation, acquisition, and development of the asset is then deducted from this present value of cash flows to generate a net present value. Often, the cash flow stream is discounted at a firm-specified hurdle rate, at the weighted average cost of capital, or at a risk-adjusted discount rate based on the perceived project-specific risk, historical firm risk, or overall business risk.

Cost Approach

The cost approach looks at the cost a firm would incur if it were to replace or reproduce the asset's future profitability potential including the cost of its strategic intangibles, if the asset were to be created from the ground up. Although the financial theories underlying these approaches are sound in the more traditional deterministic view, they cannot be reasonably used in isolation when analyzing the true strategic flexibility value of a firm, project, or asset.

Other Traditional Approaches

Other approaches used in valuation, more appropriately applied to the valuation of intangibles, rely on quantifying the economic viability and economic gains the asset brings to the firm. There are several well-known methodologies to intangible-asset valuation, particularly in valuing trademarks and brand names. These methodologies apply the combination of the market, income, and cost approaches described above.

The first method compares pricing strategies and assumes that by having some dominant market position by virtue of a strong trademark or brand recognition—for instance, Coca-Cola—the firm can charge a premium price for its product. Hence, if we can find market comparables producing similar products, in similar markets, performing similar functions, facing similar market uncertainties and risks, the price differential would then pertain exclusively to the brand name. These comparables are generally adjusted to account for the different conditions under which the firms operate. This price premium per unit is then multiplied by the projected quantity of sales, and the outcome after performing a discounted cash flow analysis will be the residual profits allocated to the intangible. A similar argument can be set forth in using operating profit margin in lieu of price per unit. Operating profit before taxes is used instead of net profit after taxes because it avoids the problems of comparables having different capital structure policies or carry-forward net operating losses and other tax-shield implications.

Another method uses a common-size analysis of the profit and loss statements between the firm holding the asset and market comparables. This takes into account any advantage from economies of scale and economies of scope. The idea here is to convert the income statement items as a percentage of sales, and balance sheet items as a percentage of total assets. In addition, in order to increase comparability, the ratio of operating profit to sales of the comparable firm is then multiplied by the asset-holding firm's projected revenue structure, thus eliminating the potential problem of having to account for differences in economies of scale and scope. This approach uses a percentage of sales, return on investment, or return on asset ratio as the common-size variable.

Practical Issues Using Traditional Valuation Methodologies

The traditional valuation methodology relying on a discounted cash flow series does not get at some of the intrinsic attributes of the asset or investment opportunity. Traditional methods assume that the investment is an all-or-nothing strategy and do not account for ***managerial flexibility***, the concept that *management can alter the course of an investment over time when certain aspects of the project's uncertainty become known*. One of the value-added components of using real options is that it takes into account management's ability to create, execute, and abandon strategic and flexible options.

There are several potential problem areas in using a traditional discounted cash flow calculation on strategic optionalities. These problems include undervaluing an asset that currently produces little or no cash flow, the nonconstant nature of the weighted average cost of capital discount rate through time, the estimation of an asset's economic life, forecast errors in creating the future cash flows, and insufficient tests for plausibility of the final results. Real options, when applied using an options theoretical framework, can mitigate some of these problematic areas. Otherwise, financial profit level metrics like NPV (net present value), or IRR (internal rate of return) will be skewed and not provide a comprehensive view of the entire investment value. However, the discounted cash flow model does have its merits.

Advantages of Using the Discounted Cash Flow

- Clear, consistent decision criteria for all projects.
- Same results regardless of risk preferences of investors.
- Quantitative, decent level of precision and economically rational.
- Not as vulnerable to accounting conventions (depreciation, inventory valuation).
- Factors in the time value of money and basic risk structures.
- Relatively simple, widely taught, widely accepted.
- Simple to explain to management: "If benefits outweigh the costs, do it!"

In reality, there are several issues that an analyst should be aware of prior to using discounted cash flow models, as shown in Table 1. The most important aspects include the business reality that risks and uncertainty abound when decisions have to be made and that management has the strategic flexibility to make and change decisions as these uncertainties become known over time. In such a stochastic world, using deterministic models like the discounted cash flow may potentially grossly underestimate the value of a particular project. A deterministic discounted cash flow model assumes at the outset that all future outcomes are fixed. If this is the case, then the discounted cash flow model is correctly specified as there would be no fluctuations in business conditions that would change the value of a particular project. In essence, there would be no value in flexibility. However, the actual business environment is highly fluid, and if management has the flexibility to make appropriate changes when conditions differ, then there is indeed value in flexibility, a value that will be grossly underestimated using a discounted cash flow model.

<i>DCF Assumptions</i>	<i>Realities</i>
Decisions are made now, and cash flow streams are fixed for the future.	Uncertainty and variability in future outcomes. Not all decisions are made today as some may be deferred to the future, when uncertainty becomes resolved.
Projects are “mini firms,” and they are interchangeable with whole firms.	With the inclusion of network effects, diversification, interdependencies, and synergy, firms are portfolios of projects and their resulting cash flows. Sometimes projects cannot be evaluated as stand-alone cash flows.
Once launched, all projects are passively managed.	Projects are usually actively managed through project lifecycle, including checkpoints, decision options, budget constraints, etc.
Future free cash flow streams are all highly predictable and deterministic.	It may be difficult to estimate future cash flows as they are usually stochastic and risky in nature.
Project discount rate used is the opportunity cost of capital, which is proportional to non-diversifiable risk.	There are multiple sources of business risks with different characteristics, and some are diversifiable across projects or time.
All risks are completely accounted for by the discount rate.	Firm and project risk can change during the course of a project.
All factors that could affect the outcome of the project and value to the investors are reflected in the DCF model through the NPV or IRR.	Because of project complexity and so-called externalities, it may be difficult or impossible to quantify all factors in terms of incremental cash flows. Distributed, unplanned outcomes (<i>e.g.</i> , strategic vision and entrepreneurial activity) can be significant and strategically important.
Unknown, intangible, or immeasurable factors are valued at zero.	Many of the important benefits are intangible assets or qualitative strategic positions.

Table 1 – Disadvantages of DCF: Assumptions versus Realities

Figure 1 shows a simple example of applying discounted cash flow analysis. Assume that there is a project that costs \$1,000 to implement at Year 0 that will bring in the following projected positive cash flows in the subsequent five years: \$500, \$600, \$700, \$800, and \$900. These projected values are simply subjective best-guess forecasts on the part of the analyst. As can be seen in Figure 1, the timeline shows all the pertinent cash flows and their respective discounted present values. Assuming that the analyst decides that the project should be discounted at a 20 percent risk-adjusted discount rate using a weighted average cost of capital (WACC), we calculate the NPV to be \$985.92 and a corresponding IRR of 54.97 percent.¹ Furthermore, the analyst assumes that the project will have an infinite economic life and assumes a long-term growth rate of cash flows of 5 percent. Using the Gordon constant growth model, the analyst calculates the terminal value of the project’s cash flow at Year 5 to be \$6,300. Discounting this figure for five years at the risk-adjusted discount rate and adding it to the original NPV yields a total NPV with terminal value of \$3,517.75.

¹ The NPV is simply the sum of the present values of future cash flows less the implementation cost. The IRR is the implicit discount rate that forces the NPV to be zero. Both calculations can be easily performed in Excel using its “NPV()” and “IRR()” functions.

The calculations can all be seen in Figure 1, where we further define w as the weights, d for debt, ce for common equity and ps for preferred stocks, FCF as the free cash flows, tax as the corporate tax rate, g as the long-term growth rate of cash flows, and rf as the risk-free rate. Even with a simplistic discounted cash flow model like this, we can see the many shortcomings of using a discounted cash flow model that are worthy of mention. Figure 2 lists some of the more noteworthy issues. For instance, the NPV is calculated as the present value of future net free cash flows (benefits) less the present value of implementation costs (investment costs). However, in many instances, analysts tend to discount both benefits and investment costs at a single identical market risk-adjusted discount rate, usually the WACC. This, of course, is flawed.

The benefits should be discounted at a market risk-adjusted discount rate like the WACC, but the investment cost should be discounted at a reinvestment rate similar to the risk-free rate. Cash flows that have market risks should be discounted at the market risk-adjusted rate, while cash flows that have private risks should be discounted at the risk-free rate. This is because the market will only compensate the firm for taking on the market risks but not private risks. It is usually assumed that the benefits are subject to market risks (because benefit free cash flows depend on market demand, market prices, and other exogenous market factors) while investment costs depend on internal private risks (such as the firm's ability to complete building a project in a timely fashion or the costs and inefficiencies incurred beyond what is projected). On occasion, these implementation costs may also be discounted at a rate slightly higher than a risk-free rate, such as a money-market rate or at the opportunity cost of being able to invest the sum in another project yielding a particular interest rate. Suffice it to say that benefits and investment costs should be discounted at different rates if they are subject to different risks. Otherwise, discounting the costs at a much higher market risk-adjusted rate will reduce the costs significantly, making the project look as though it were more valuable than it actually is.

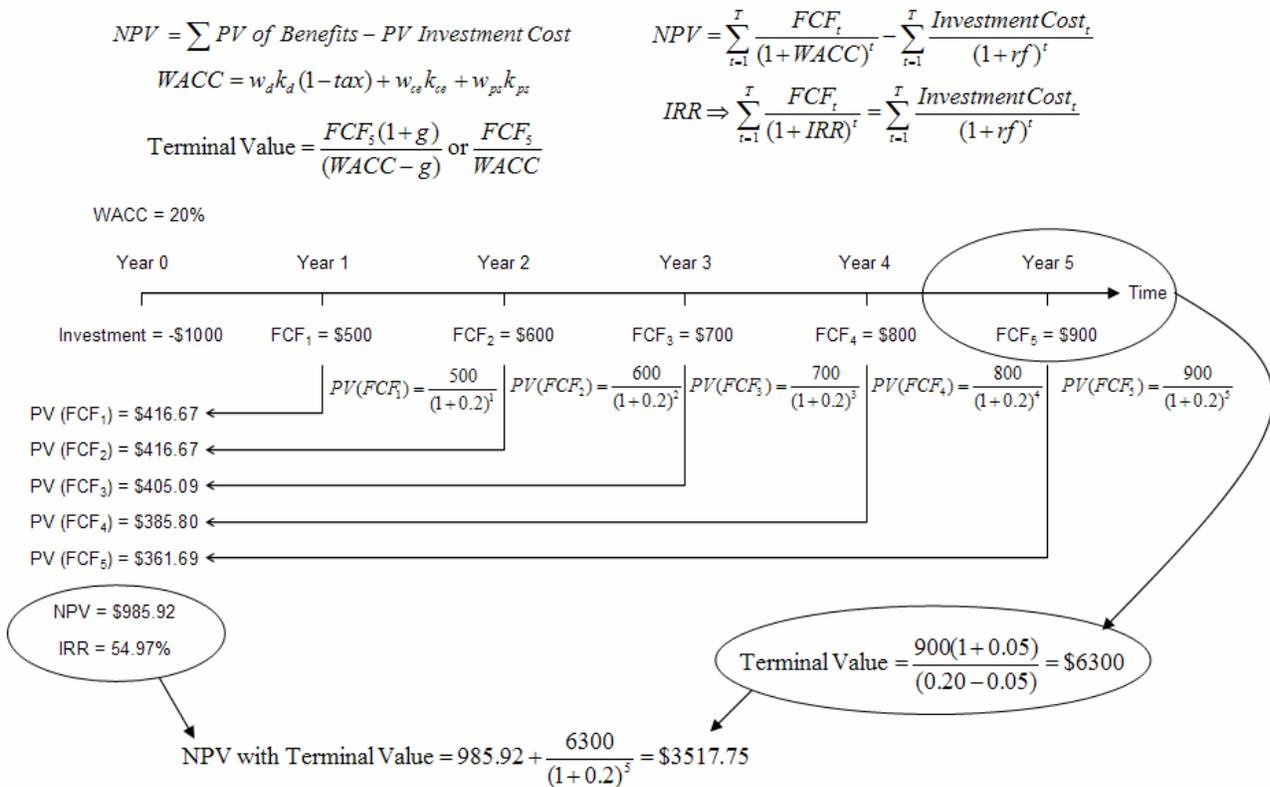


Figure 1 – Applying Discounted Cash Flow Analysis

The discount rate that is used is usually calculated from a model, such as WACC, Capital Asset-Pricing Model (CAPM), Multiple Asset-Pricing Model, or Arbitrage Pricing Theory (APT), set by management as a requirement for the firm, or defined as a hurdle rate for specific projects. In most circumstances, if we were to perform a simple discounted cash flow model, the most sensitive variable is usually the discount rate. The discount rate is also the most difficult variable to correctly quantify. Hence, this leaves the discount rate to potential abuse and subjective manipulation. A target NPV value can be obtained by simply massaging the discount rate to a suitable level.

In addition, certain input assumptions required to calculate the discount rate are also subject to question. For instance, in the WACC, the input for cost of common equity is usually derived using some form of the CAPM. In the CAPM, the infamous beta (β) is extremely difficult to calculate. In financial assets, we can obtain beta through a simple calculation of the covariance between a firm's stock prices and the market portfolio, divided by the variance of the market portfolio. Beta is then a sensitivity factor measuring the co-movements of a firm's equity prices with respect to the market. The problem is that equity prices change every few minutes! Depending on the time frame used for the calculation, beta may fluctuate wildly. In addition, for non-traded physical assets, we cannot reasonably calculate beta this way. Using a firm's tradable financial assets' beta as a proxy for the beta on a project within a firm that has many other projects is ill-advised.

There are risk and return diversification effects among projects as well as investor psychology and overreaction in the market that are not accounted for. There are also other more robust asset-pricing models that can be used to estimate a project's discount rate, but they require great care. For instance, the APT models are built upon the CAPM and have additional risk factors that may drive the value of the discount rate. These risk factors include maturity risk, default risk, inflation risk, country risk, size risk, nonmarketable risk, control risk, minority shareholder risk, and others. Even the firm's CEO's golf score can be a risk hazard (*e.g.*, rash decisions may be made after a bad game or bad projects may be approved after a hole-in-one, believing in a lucky streak). The issue arises when one has to decide which risks to include and which not to include. This is definitely a difficult task, to say the least.²

One other method that is widely used is that of comparability analysis. By gathering publicly available data on the trading of financial assets by stripped-down entities with similar functions, markets, risks and geographical location, analysts can then estimate the beta (a measure of systematic risk) or even a relevant discount rate from these comparable firms. For instance, an analyst who is trying to gather information on a research and development effort for a particular type of drug can conceivably gather market data on pharmaceutical firms performing only research and development on similar drugs, existing in the same market, and having the same risks. The median or average beta value can then be used as a market proxy for the project currently under evaluation. Obviously, there is no silver bullet, but if an analyst were diligent enough, he or she could obtain estimates from these different sources and create a better estimate. Monte Carlo simulation is most preferred in situations like these. The analyst can define the relevant simulation inputs using the range obtained from the comparable firms and simulate the discounted cash flow model to obtain the range of relevant variables (typically the NPV and IRR).

Now that you have the relevant discount rate, the free cash flow stream should then be discounted appropriately. Herein lies another problem: forecasting the relevant free cash flows and deciding if they should be discounted on a continuous basis or a discrete basis, versus using end-of-year or mid-year conventions. Free cash flows should be net of taxes, with the relevant noncash expenses added back. Because free cash flows are generally calculated starting with revenues and proceeding through

² A multiple regression or principal component analysis can be performed but probably with only limited success for physical assets as opposed to financial assets because there are usually very little historical data available for such analyses.

direct cost of goods sold, operating expenses, depreciation expenses, interest payments, taxes, and so forth, there is certainly room for mistakes to compound over time.

Forecasting cash flows several years into the future is often very difficult and may require the use of fancy econometric regression modeling techniques, time-series analysis, management hunches, and experience. A recommended method is not to create single-point estimates of cash flows at certain time periods, but to use Monte Carlo simulation and assess the relevant probabilities of cash flow events. In addition, because cash flows in the distant future are certainly riskier than in the near future, the relevant discount rate should also change to reflect this. Instead of using a single discount rate for all future cash flow events, the discount rate should incorporate the changing risk structure of cash flows over time. This can be done by either weighing the cash flow streams' probabilistic risks (standard deviations of forecast distributions) or using a stepwise technique of adding the maturity risk premium inherent in U.S. Treasury securities at different maturity periods. This bootstrapping approach allows the analyst to incorporate what the market experts predict the future market risk structure looks like.

Finally, the issue of terminal value is of major concern for anyone using a discounted cash flow model. Several methods of calculating terminal values exist, such as the Gordon constant growth model (GGM), zero growth perpetuity consul, and the supernormal growth models. The GGM is the most widely used, where at the end of a series of forecast cash flows, the GGM assumes that cash flow growth will be constant through perpetuity. The GGM is calculated as the free cash flow at the end of the forecast period multiplied by a relative growth rate, divided by the discount rate less the long-term growth rate. Shown in Figure 2, we see that the GGM breaks down when the long-term growth rate exceeds the discount rate. This growth rate is also assumed to be fixed, and the entire terminal value is highly sensitive to this growth rate assumption. In the end, the value calculated is highly suspect because a small difference in growth rates will mean a significant fluctuation in value. Perhaps a better method is to assume some type of growth curve in the free cash flow series. These growth curves can be obtained through some basic time-series analysis as well as using more advanced assumptions in stochastic modeling. Nonetheless, we see that even a well-known, generally accepted and applied discounted cash flow model has significant analytical restrictions and problems. These problems are rather significant and can compound over time, creating misleading results. Great care should be given in performing such analyses. These new analytical methods address some of the issues discussed above. However, it should be stressed that these new analytics do not provide the silver bullet for valuation and decision-making. They provide value-added insights, and the magnitude of insights and value obtained from these new methods depend solely on the type and characteristic of the project under evaluation.

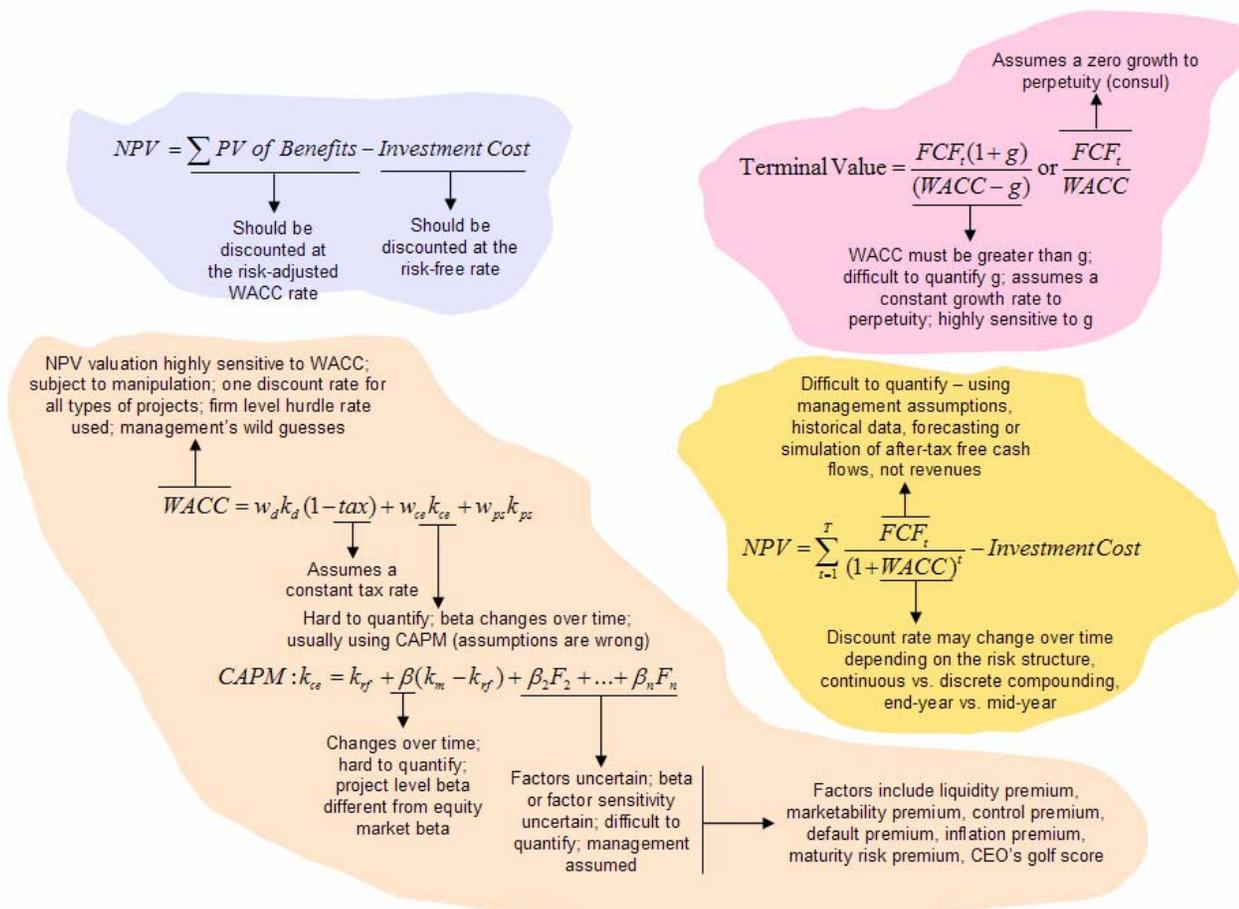


Figure 2 – The Shortcomings of DCF Analysis

The New Analytics

The applicability of traditional analysis versus the new analytics across a time horizon is depicted in Figure 3. During the shorter time period, holding everything else constant, the ability for the analyst to predict the near future is greater than when the period extends beyond the historical and forecast periods. This is because the longer the horizon, the harder it is to fully predict all the unknowns, and hence, management can create value by being able to successfully initiate and execute strategic options.

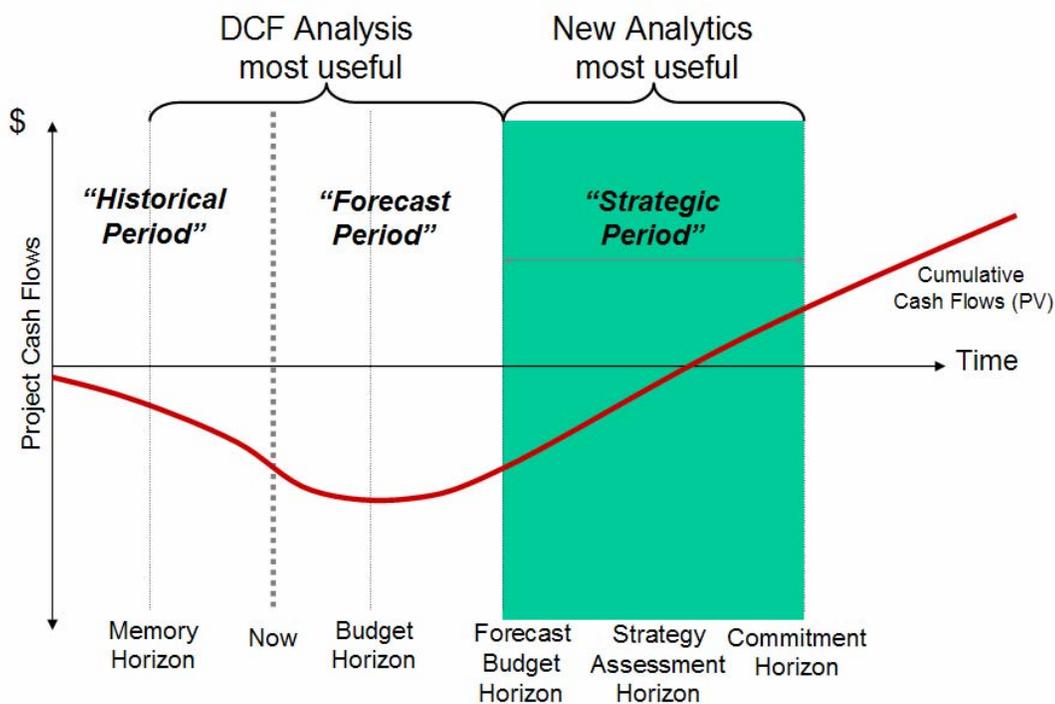


Figure 3 – Traditional Versus New Analytics

The traditional and new analytics can also be viewed as a matrix of approaches as seen in Figure 4, where the analytics are segregated by its analytical perspective and type. With regard to perspective, the analytical approach can be either a top-down or a bottom-up approach. A top-down approach implies a higher focus on macro variables than on micro variables. The level of granularity from the macro to micro levels include starting from the global perspective, and working through market or economic conditions, impact on a specific industry, and more specifically, the firm's competitive options. At the firm level, the analyst may be concerned with a single project and the portfolio of projects from a risk management perspective. At the project level, detail focus will be on the variables impacting the value of the project.

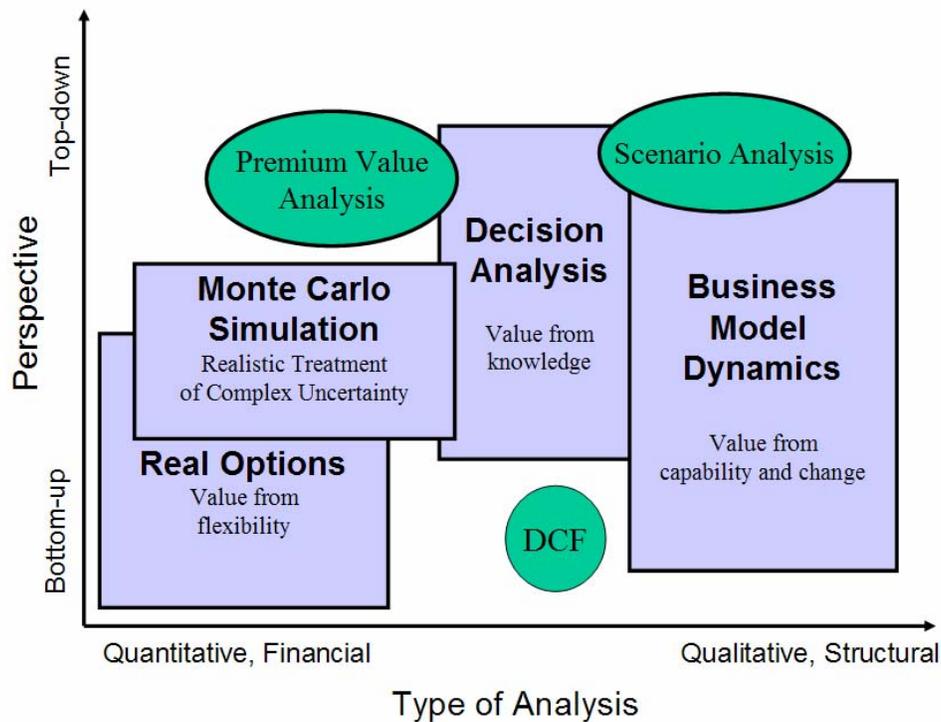


Figure 4 – An Analytical Perspective

A Paradigm Shift

In the past, corporate investment decisions were cut-and-dried. Buy a new machine that is more efficient, make more products costing a certain amount, and if the benefits outweigh the costs, execute the investment. Hire a larger pool of sales associates, expand the current geographical area, and if the marginal increase in forecast sales revenues exceeds the additional salary and implementation costs, start hiring. Need a new manufacturing plant? Show that the construction costs can be recouped quickly and easily by the increase in revenues it will generate through new and more improved products, and the initiative is approved.

However, real-life business conditions are a lot more complicated. Your firm decides to go with an e-commerce strategy, but multiple strategic paths exist. Which path do you choose? What are the options that you have? If you choose the wrong path, how do you get back on the right track? How do you value and prioritize the paths that exist? You are a venture capitalist firm with multiple business plans to consider. How do you value a start-up firm with no proven track record? How do you structure a mutually beneficial investment deal? What is the optimal timing to a second or third round of financing?

Real options are useful not only in valuing a firm through its strategic business options but also as a strategic business tool in capital investment decisions. For instance, should a firm invest millions in a new e-commerce initiative? How does a firm choose among several seemingly cashless, costly, and unprofitable information-technology infrastructure projects? Should a firm indulge its billions in a risky research and development initiative? The consequences of a wrong decision can be disastrous or even terminal for certain firms. In a traditional discounted cash flow model, these questions cannot be answered with any certainty. In fact, some of the answers generated through the use of the traditional discounted cash flow model are flawed because the model assumes a static, one-time decision-making

process while the real options approach takes into consideration the strategic managerial options certain projects create under uncertainty and management's flexibility in exercising or abandoning these options at different points in time, when the level of uncertainty has decreased or has become known over time.

The real options approach incorporates a learning model, such that management makes better and more informed strategic decisions when some levels of uncertainty are resolved through the passage of time. The discounted cash flow analysis assumes a static investment decision, and assumes that strategic decisions are made initially with no recourse to choose other pathways or options in the future. To create a good analogy of real options, visualize it as a strategic road map of long and winding roads with multiple perilous turns and branches along the way. Imagine the intrinsic and extrinsic value of having such a road map when navigating through unfamiliar territory, as well as having road signs at every turn to guide you in making the best and most informed driving decisions. This is the essence of real options.

The answer to evaluating such projects lies in real options analysis, which can be used in a variety of settings, including pharmaceutical drug development, oil and gas exploration and production, manufacturing, e-business, start-up valuation, venture capital investment, IT infrastructure, research and development, mergers and acquisitions, e-commerce and e-business, intellectual capital development, technology development, facility expansion, business project prioritization, enterprise-wide risk management, business unit capital budgeting, licenses, contracts, intangible asset valuation, and the like.

The Real Options Solution

Simply defined, real options is a systematic approach and integrated solution using financial theory, economic analysis, management science, decision sciences, statistics, and econometric modeling in applying options theory in valuing real physical assets, as opposed to financial assets, in a dynamic and uncertain business environment where business decisions are flexible in the context of strategic capital investment decision-making, valuing investment opportunities and project capital expenditures.

Real options are crucial in

- Identifying different corporate investment decision pathways or projects that management can navigate given the highly uncertain business conditions;
- Valuing each of the strategic decision pathways and what it represents in terms of financial viability and feasibility;
- Prioritizing these pathways or projects based on a series of qualitative and quantitative metrics;
- Optimizing the value of your strategic investment decisions by evaluating different decision paths under certain conditions or determining how using a different sequence of pathways can lead to the optimal strategy;
- Timing the effective execution of your investments and finding the optimal trigger values and cost or revenue drivers; and
- Managing existing or developing new optionalities and strategic decision pathways for future opportunities.

Issues to Consider

Strategic options do have significant intrinsic value, but this value is only realized when management decides to execute the strategies. Real options theory assumes that management is logical and competent and that it acts in the best interests of the company and its shareholders through the maximization of wealth and minimization of risk of losses. For example, suppose a firm owns the rights to a piece of land that fluctuates dramatically in price. An analyst calculates the volatility of prices and recommends that management retain ownership for a specified time period, where within

this period there is a good chance that the price of real estate will triple. Therefore, management owns a call option, an *option to wait* and defer sale for a particular time period. The value of the real estate is therefore higher than the value that is based on today's sale price. The difference is simply this option to wait. However, the value of the real estate will not command the higher value if prices do triple but management decides not to execute the option to sell. In that case, the price of real estate goes back to its original levels after the specified period and then management finally relinquishes its rights.

Was the analyst right or wrong? What was the true value of the piece of land? Should it have been valued at its explicit value on a deterministic case where you know what the price of land is right now, and therefore this is its value; or should it include some types of optionality where there is a good probability that the price of land could triple in value, and hence the piece of land is truly worth more than it is now and should therefore be valued accordingly? The latter is the real options view. The additional strategic optionality value can only be obtained if the option is executed; otherwise, all the options in the world are worthless. This idea of *explicit* versus *implicit* value becomes highly significant when management's compensation is tied directly to the actual performance of particular projects or strategies.

To further illustrate this point, suppose the price of the land in the market is currently \$10 million. Further, suppose that the market is highly liquid and volatile, and that the firm can easily sell it off at a moment's notice within the next five years, the same amount of time the firm owns the rights to the land. If there is a 50 percent chance the price will increase to \$15 million and a 50 percent chance it will decrease to \$5 million within this time period, is the property worth an expected value of \$10 million? If prices rise to \$15 million, management should be competent and rational enough to execute the option and sell that piece of land immediately to capture the additional \$5 million premium. However, if management acts inappropriately or decides to hold off selling in the hopes that prices will rise even further, the property value may eventually drop back down to \$5 million. Now, how much is this property really worth? What if there happens to be an *abandonment option*? Suppose there is a perfect counterparty to this transaction who decides to enter into a contractual agreement whereby for a contractual fee, the counterparty agrees to purchase the property for \$10 million within the next five years, regardless of the market price and executable at the whim of the firm that owns the property. Effectively, a safety net has been created whereby the minimum floor value of the property has been set at \$10 million (less the fee paid). That is, there is a limited downside but an unlimited upside, as the firm can always sell the property at market price if it exceeds the floor value. Hence, this strategic *abandonment option* has increased the value of the property significantly. Logically, with this *abandonment option* in place, the value of the land with the option is definitely worth more than \$10 million.

Industry Leaders Embracing Real Options

Industries using real options as a tool for strategic decision making started with oil and gas as well as mining companies, and later expanded into utilities, biotechnology, pharmaceuticals, and now into telecommunications, high-tech, and across all industries. Following are some very brief examples of how real options have been or should be used in different companies.

Automobile and Manufacturing Industry

In automobile and manufacturing, General Motors (GM) applies real options to create *switching options* in producing its new series of autos. This is essentially the option to use the cheaper resource over a given period of time. GM holds excess raw materials and has multiple global vendors for similar materials with excess contractual obligations above what it projects as necessary. The excess contractual cost is outweighed by the significant savings of switching vendors when a certain raw material becomes too expensive in a particular region of the world. By spending the additional money

in contracting with vendors a meeting their minimum purchase requirements, GM has essentially paid the premium on purchasing a *switching option*. This is important especially when the price of raw materials fluctuate significantly in different regions around the world. Having an option here provides the holder a hedging vehicle against pricing risks.

Computer Industry

In the computer industry, HP-Compaq used to forecast sales in foreign countries months in advance. It then configured, assembled, and shipped the highly specific configuration printers to these countries. However, given that demand changes rapidly and forecast figures are seldom correct, the preconfigured printers usually suffer the higher inventory holding cost or the cost of technological obsolescence. HP-Compaq can create an *option to wait* and defer making any decisions too early through building assembly plants in these foreign countries. Parts can then be shipped and assembled in specific configurations when demand is known, possibly weeks in advance rather than months in advance. These parts can be shipped anywhere in the world and assembled in any configuration necessary, while excess parts are interchangeable across different countries. The premium paid on this option is building the assembly plants, and the upside potential is the savings in making wrong demand forecasts.

Airline Industry

In the airline industry, Boeing spends billions of dollars and several years to decide if a certain aircraft model should even be built. Should the wrong model be tested in this elaborate strategy, Boeing's competitors may gain a competitive advantage relatively quickly. Because there are so many technical, engineering, market, and financial uncertainties are involved in the decision making process, Boeing can conceivably create an *option to choose* through parallel development of multiple plane designs simultaneously, knowing very well the increasing development cost of developing multiple designs simultaneously with the sole purpose of eliminating all but one in the near future. The added cost is the premium paid on the option. However, Boeing will be able to decide which model to abandon or continue when these uncertainties and risks become known over time. Eventually, all the models will be eliminated save one. This way, the company can hedge itself against making the wrong initial decision, and benefit from the knowledge gained through parallel development initiatives.

Oil and Gas Industry

In the oil and gas industry, companies spend millions of dollars to refurbish their refineries and add new technology to create an *option to switch* their mix of outputs among heating oil, diesel, and other petrochemicals as a final product, using real options as a means of making capital and investment decisions. This option allows the refinery to switch its final output to one that is more profitable based on prevailing market prices, to capture the demand and price cyclicity in the market.

Telecommunications Industry

In the telecommunications industry, in the past, companies like Sprint and AT&T installed more fiber-optic cable and other telecommunications infrastructure than any other company in order to create a *growth option* in the future by providing a secure and extensive network, and to create a high barrier to entry, providing a first-to-market advantage. Imagine having to justify to the Board of Directors the need to spend billions of dollars on infrastructure that will not be used for years to come. Without the use of real options, this would have been impossible to justify.

Utilities Industry

In the utilities industry, firms have created an *option to execute* and an *option to switch* by installing cheap-to-build inefficient energy generator *peaker* plants only to be used when electricity prices are high and to shut down when prices are low. The price of electricity tends to remain constant until it hits a certain capacity utilization trigger level, when prices shoot up significantly. Although this occurs infrequently, the possibility still exists, and by having a cheap standby plant, the firm has created the option to turn on the switch whenever it becomes necessary, to capture this upside price fluctuation.

Real Estate Industry

In the real estate arena, leaving land undeveloped creates an option to develop at a later date at a more lucrative profit level. However, what is the optimal wait time or the optimal trigger price to maximize returns? In theory, one can wait for an infinite amount of time, and real options provide the solution for the optimal timing and price trigger value.

Pharmaceutical Research and Development Industry

In pharmaceutical or research and development initiatives, real options can be used to justify the large investments in what seems to be cashless and unprofitable under the discounted cash flow method but actually creates *compound expansion options* in the future. Under the myopic lenses of a traditional discounted cash flow analysis, the high initial investment of, say, a billion dollars in research and development may return a highly uncertain projected few million dollars over the next few years. Management will conclude under a net-present-value analysis that the project is not financially feasible. However, a cursory look at the industry indicates that research and development is performed everywhere. Hence, management must see an intrinsic strategic value in research and development. How is this intrinsic strategic value quantified? A real options approach would optimally time and spread the billion dollar initial investment into a multiple-stage investment structure. At each stage, management has an *option to wait* and see what happens as well as the *option to abandon* or the *option to expand* into the subsequent stages. The ability to defer cost and proceed only if situations are permissible created value for the investment.

High-Tech and e-Business Industry

In e-business strategies, real options can be used to prioritize different e-commerce initiatives and to justify those large initial investments that have an uncertain future. Real options can be used in e-commerce to create incremental investment stages compared to a large one-time investment (invest a little now, wait and see before investing more) and creates *options to abandon* and other future growth options.

All these cases where the high cost of implementation with no apparent payback in the near future seems foolish and incomprehensible in the traditional discounted cash flow sense are fully justified in the real options sense when taking into account the strategic options the practice creates for the future, the uncertainty of the future operating environment, and management's flexibility in making the right choices at the appropriate time.

Mergers and Acquisition

In valuing a firm for acquisition, you should not only consider the revenues and cash flows generated from the firm's operations but also the strategic options that come with the firm. For instance, if the acquired firm does not operate up to expectations, an *abandonment option* can be executed where it can be sold for its intellectual property and other tangible assets. If the firm is highly successful, it can be spun off into other industries and verticals or new products and services can be eventually

developed through the execution of an *expansion option*. In fact, in mergers and acquisition, several strategic options exist. For instance, a firm acquires other entities to enlarge its existing portfolio of products or geographic location or to obtain new technology (*expansion option*); or to divide the acquisition into many smaller pieces and sell them off as in the case of a corporate raider (*abandonment option*); or it merges to form a larger organization due to certain synergies and immediately lays off many of its employees (*contraction option*). If the seller does not value its real options, it may be leaving money on the negotiation table. If the buyer does not value these strategic options, it is undervaluing a potentially highly lucrative acquisition target.

The Fundamental Essence of Real Options

The use of traditional discounted cash flow alone is inappropriate in valuing certain strategic projects involving managerial flexibility. Two finance professors, Michael Brennan and Eduardo Schwartz, provided an example on valuing the rights to a gold mine. In their example, a mining company owns the rights to a local gold mine. The rights provide the firm the option, and not the legal obligation, to mine the gold reserves supposedly abundant in said mine. Therefore, if the price of gold in the market is high, the firm might wish to start mining and, in contrast, stop and wait for a later time to begin mining should the price of gold drop significantly in the market. Suppose we set the cost of mining as X and the payoff on the mined gold as S , taking into consideration the time value of money. We then have the following payoff schedule:

$S - X$	if and only if	$S > X$
0	if and only if	$S \leq X$

This payoff is identical to the payoff on a call option on the underlying asset, the value of the mined gold. If the cost exceeds the value of the underlying asset, the option is left to expire worthless, without execution; otherwise, the option will be exercised. That is, mine if and only if S exceeds X ; otherwise, do not mine.

As an extension of the gold mine scenario, say we have a proprietary technology in development or a patent that currently and in the near future carries little or no cash flow but nonetheless is highly valuable due to the potential strategic positioning it holds for the firm that owns it. A traditional discounted cash flow method will grossly underestimate the value of this asset. A real options approach is more suitable and provides better insights into the actual value of the asset. The firm has the option to either develop the technology if the potential payoff exceeds the cost or abandon its development should the opposite be true.

For instance, assume a firm owns a patent on some technology with a 10-year economic life. To develop the project, the present value of the total research and development costs is \$250 million, but the present value of the projected sum of all future net cash flows is only \$200 million. In a traditional discounted cash flow sense, the net present value will be $-\$50$ million, and the project should be abandoned. However, the proprietary technology is still valuable to the firm given that there's a probability that it will become more valuable in the future than projected or that future projects can benefit from the technology developed. If we apply real options to valuing this simplified technology example, the results will be significantly different. By assuming the nominal rate on a 10-year risk-free U.S. Treasury note is 6 percent, and simulating the standard deviation of the projected cash flow, we calculate the value of the research and development initiative to be \$2 million. This implies that the value of flexibility is \$52 million or 26 percent of its static NPV value. By definition, a research and development initiative involves creating something new and unique or developing a more enhanced product. The nature of most research and development initiatives is that they are highly risky and involve a significant investment up-front, with highly variable potential cash flows in the future that are generally skewed toward the low end. In other words, most research and development projects fail to meet expectations and generally produce lower incremental revenues than deemed

profitable. Hence, in a traditional discounted cash flow sense, research and development initiatives are usually unattractive and provide little to no incentives. However, a cursory look at the current industry would imply otherwise. Research and development initiatives abound, implying that senior management sees significant intrinsic value in such initiatives. So there arises a need to quantify such strategic values.

The Basics of Real Options

Real options, as its name implies, uses options theory to evaluate physical or real assets, as opposed to financial assets or stocks and bonds. In reality, real options have been in the past very useful in analyzing distressed firms and firms engaged in research and development with significant amounts of managerial flexibility under significant amounts of uncertainty. Only in the past decade has real options started to receive corporate attention in general.

Why Are Real Options Important?

An important point is that the traditional discounted cash flow approach assumes a single decision pathway with fixed outcomes, and all decisions are made in the beginning without the ability to change and develop over time. The real options approach considers multiple decision pathways as a consequence of high uncertainty coupled with management's flexibility in choosing the optimal strategies or options along the way when new information becomes available. That is, management has the flexibility to make midcourse strategy corrections when there is uncertainty involved in the future. As information becomes available and uncertainty becomes resolved, management can choose the best strategies to implement. Traditional discounted cash flow assumes a single static decision, while real options assume a multidimensional dynamic series of decisions, where management has the flexibility to adapt given a change in the business environment.

Another way to view the problem is that there are two points to consider: one, the initial investment starting point where strategic investment decisions have to be made, and two, the ultimate goal, the optimal decision that can ever be made to maximize the firm's return on investment and shareholder's wealth. In the traditional discounted cash flow approach, joining these two points is a straight line, whereas the real options approach looks like a map with multiple routes to get to the ultimate goal, where each route is conjoined with others. The former implies a one-time decision-making process while the latter implies a dynamic decision-making process, wherein the investor learns over time and makes different updated decisions as time passes and events unfold.

As outlined above, traditional approaches coupled with discounted cash flow analysis have their pitfalls. Real options provide additional insights beyond the traditional analyses. At its least, real options provide a sobriety test of the results obtained using discounted cash flow and, at its best, provide a robust approach to valuation when coupled with the discounted cash flow methodology. The theory behind options is sound and reasonably applicable.

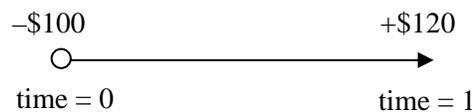
Some examples of real options using day-to-day terminology include

- Option to defer
- Option to wait and see
- Option to delay
- Option to expand
- Option to contract
- Option to choose
- Option to switch resources
- Option for phased and sequential investments

Notice that the names used to describe the more common real options are rather self-explanatory, unlike the actual model names such as a “Barone-Adesi-Whaley approximation model for an American option to expand.” This is important because when it comes to explaining the process and results to management, the easier it is for them to understand, the higher the chances of acceptance of the methodology and results.

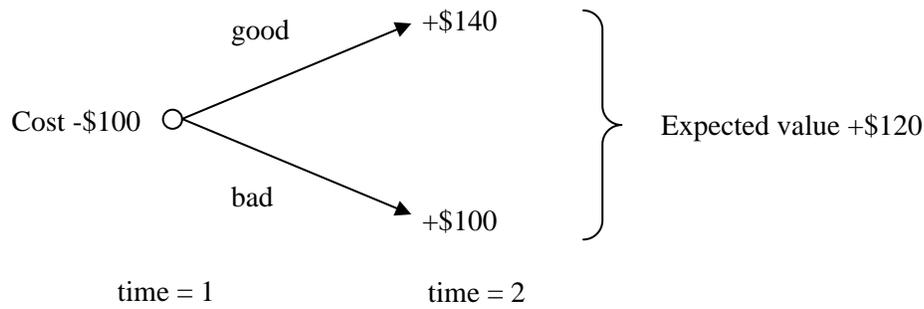
Traditional approaches to valuing projects associated with the value of a firm, including any strategic options the firm possesses, or flexible management decisions that are dynamic and have the capacity to change over time, are flawed in several respects. Projects valued using the traditional discounted cash flow model often provide a value that grossly understates the true fair-market-value of the asset. This is because projects may provide a low or zero cash flow in the near future but nonetheless be valuable to the firm. In addition, projects can be viewed in terms of owning the option to execute the rights, not owning the rights per se, because the owner can execute the option or allow it to expire should the opportunity cost outweigh the benefits of execution. The recommended options approach takes into consideration this option to exercise and prices it accordingly. Compared to traditional approaches, real options provide added elements of robustness to the analysis. Its inputs in the option-pricing model can be constructed via multiple alternatives, thus providing a method of stress testing or sensitivity testing of the final results. The corollary analysis resulting from real options also provides sanity checks without having to perform the entire analysis again from scratch using different assumptions.

The following example provides a simplified analogy to why optionality is important and should be considered in corporate capital investment strategies. Suppose you have an investment strategy that costs \$100 to initiate and you anticipate that on average, the payoff will yield \$120 in exactly one year. Assume a 15 percent weighted average cost of capital and a 5 percent risk-free rate, both of which are annualized rates. As the example below illustrates, the net present value of the strategy is \$4.3, indicating a good investment potential because the benefits outweigh the costs.



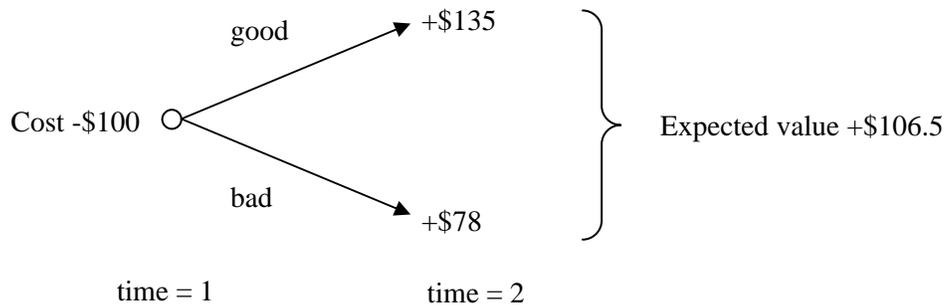
$$\text{Net Present Value} = \frac{120}{(1.15)^1} - 100 = \$4.3$$

However, if we wait and see before investing, when uncertainty becomes resolved, we get the profile below, where the initial investment outlay occurs at time one and positive cash inflows are going to occur only at time two. Let’s say that your initial expectations were correct and that the average or expected value came to be \$120 with good market demand providing a \$140 cash flow and in the case of bad demand, only \$100. If we had the option to wait a year, then we could better estimate the trends in demand and we would have seen the payoff profile bifurcating into two scenarios. Should the scenario prove unfavorable, we would have the option to abandon the investment because the costs are identical to the cash inflow (–\$100 versus +\$100), and we would rationally not pursue this avenue. Hence, we would pursue this investment only if a good market demand is observed for the product, and our net present value for waiting an extra year will be \$10.6. This analysis indicates a truncated downside where there is a limited liability because a rational investor would never knowingly enter a sure-loss investment strategy. Therefore, the value of flexibility is \$6.3.



$$\text{Net Present Value} = \frac{140}{(1.15)^2} - \frac{100}{(1.05)^1} = \$10.6$$

However, a more realistic payoff schedule should look like the example below. By waiting a year and putting off the investment until year two, you are giving up the potential for a cash inflow now, and the leakage or opportunity cost by not investing now is the \$5 less you could receive (\$140 – \$135). However, by putting off the investment, you are also defraying the cost of investing in that the cost outlay will only occur a year later. The calculated net present value in this case is \$6.8.



$$\text{Net Present Value} = \frac{135}{(1.15)^2} - \frac{100}{(1.05)^1} = \$6.8$$

Comparing Traditional Approaches with Real Options

Figures 5 – 10 show a step-by-step analysis comparing a traditional analysis with that of real options, from the analyst’s viewpoint. The analysis starts off with a discounted cash flow model in analyzing future cash flows. The analyst then applies sensitivity and scenario analysis. This is usually the extent of traditional approaches. As the results are relatively negative, the analyst then decides to add some new analytics. Monte Carlo simulation is then used, as well as real options analysis. The results from all these analytical steps are then compared and conclusions are drawn. This is a good comparative analysis of the results and insights obtained by using the new analytics. In this example, the analyst has actually added significant value to the overall project by creating optionalities within the project

by virtue of actively pursuing and passively waiting for more information to become available prior to making any decisions.

Of course, several simplifying assumptions have to be made here, including the ability for the firm to simply wait and execute a year from now without any market or competitive repercussions. That is, the one-year delay will not allow a competitor to gain a first-to-market advantage or capture additional market share, where the firm's competitor may be willing to take the risk and invest in a similar project and gain the advantage while the firm is not willing to do so. In addition, the cost and cash flows are assumed to be the same whether the project is initiated immediately or in the future. Obviously, these more complex assumptions can be added into the analysis, but for illustration purposes, we assume the basic assumptions hold, where costs and cash flows remain the same no matter the execution date, and that competition is negligible.

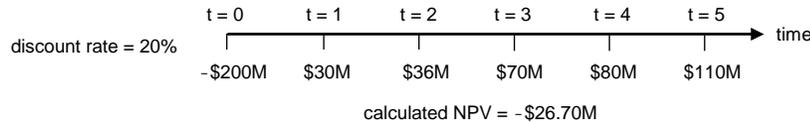
This framework comprises eight distinct phases of a successful real options implementation, going from a qualitative management screening process to creating clear and concise reports for management. The process was developed by the author based on previous successful implementations of real options both in the consulting arena and in industry-specific problems. These phases can be performed either in isolation or together in sequence for a more robust real options analysis.

Comparing Traditional Approaches and Real Options with Simulation

A. Discounted Cash Flow

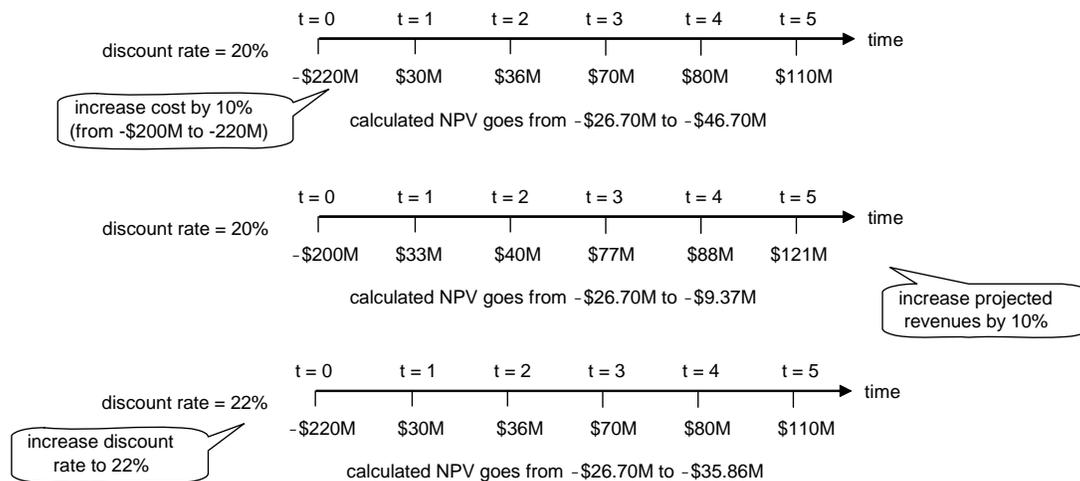
The extended example below shows the importance of waiting. That is, suppose a firm needs to make a rather large capital investment decision but at the same time has the Option to Wait and Defer on making the decision until later. The firm may be involved in pharmaceutical research and development activities, IT investment activities, or simply in marketing a new product that is yet untested in the market.

Suppose the analyst charged with performing a financial analysis on the project estimates that the most probable level of net revenues generated through the implementation of the project with an economic life of 5 years is presented in the time line below. Further, s/he assumes that the implementation cost is \$200 million and the project's risk-adjusted discount rate is 20%, which also happens to be the firm's weighted average cost of capital. The calculated net present value (NPV) is found to be at a loss of -\$26.70M.



B. Sensitivity Analysis on Discounted Cash Flow

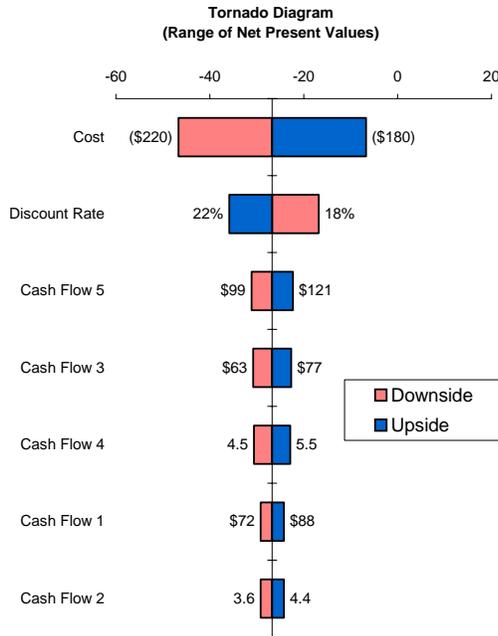
Even though the NPV shows a significant negative amount, the analyst feels that the investment decision can be better improved through more rigor. Hence, s/he decides to perform a sensitivity analysis. Because in this simplified example, we only have three variables (discount rate, cost, and future net revenue cash flows), the analyst increases each of these variables by 10% to note the sensitivity of calculated NPV to these changes.



The entire set of possible sensitivities are presented in the table below, arranged in descending order based on the range of potential outcomes (indication of the variable's sensitivity). A Tornado Diagram is also created based on this sensitivity table.

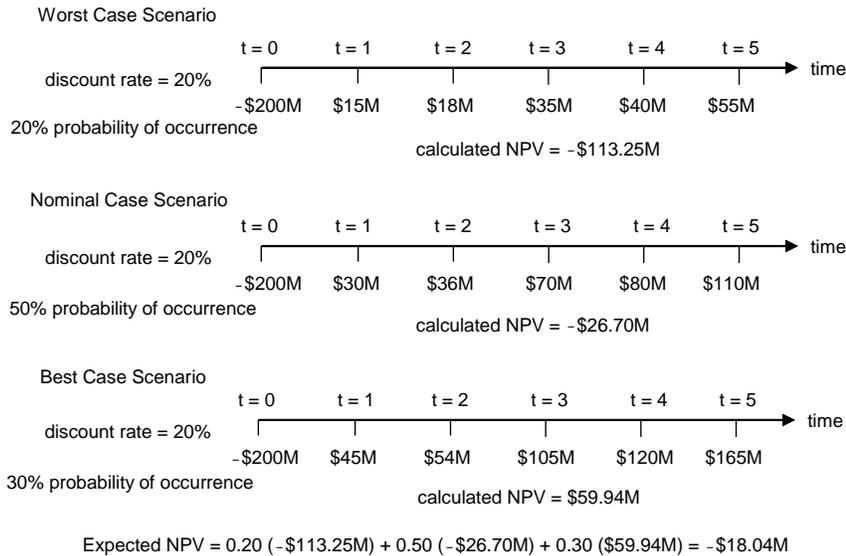
Variable	Expected NPV			Input		
	Downside	Upside	Range	Downside	Upside	Base Case
Cost	(\$46.70)	(\$6.70)	\$40.00	(\$220)	(\$180)	(\$200)
Discount Rate	(\$16.77)	(\$35.86)	\$19.09	18%	22%	20%
Cash Flow 5	(\$31.12)	(\$22.28)	\$8.84	\$99	\$121	\$110
Cash Flow 3	(\$30.75)	(\$22.65)	\$8.10	\$63	\$77	\$70
Cash Flow 4	(\$30.56)	(\$22.85)	\$7.72	\$72	\$88	\$80
Cash Flow 1	(\$29.20)	(\$24.20)	\$5.00	\$27	\$33	\$30
Cash Flow 2	(\$29.20)	(\$24.20)	\$5.00	\$32	\$40	\$36

Figure 5 – Discounted Cash Flow Model and Sensitivity Analysis



C. Scenario Analysis

Next, scenarios were generated. The analyst creates three possible scenarios and provides a subjective estimate of the probabilities each scenario will occur. For instance, the worst case scenario is 50% of the nominal scenario's projected revenues, while the best case scenario is 150% of the nominal scenario's projected revenues.



NPVs for each of the scenarios are calculated, and an Expected NPV is calculated to be -\$18.04M based on the probability assumptions. The problem here is obvious. The range of possibilities is too large to make any inferences. That is, which figure should be believed? The -\$18.04 or perhaps the nominal case of -\$26.70? In addition, the upside potential and downside risks are fairly significantly different from the nominal or expected cases. What are the chances that any of these will actually come true? What odds or bets or faith can one place in the results? The analyst then decides to perform some Monte Carlo simulations to answer these questions.

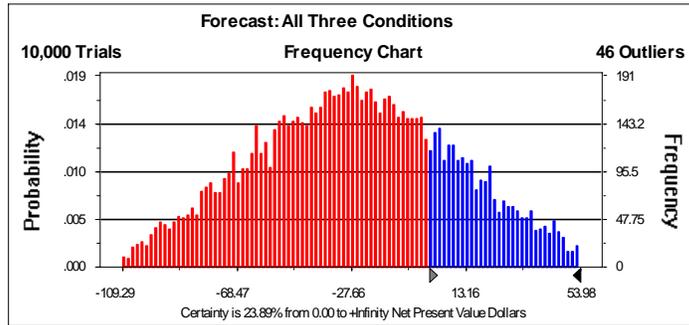
Figure 6 – Tornado Diagram and Scenario Analysis

D. Simulation

There are two ways to perform a Monte Carlo simulation in this example. The first is to take the scenario analysis above and simulate around the calculated NPVs. This assumes that the analyst is highly confident of his/her future cash flow projections and that the worst-case scenario is indeed the absolute minimum the firm can attain and the best case scenario is exactly at the top of the range of possibilities. The second approach is to use the most likely or nominal scenario and simulate its inputs based on some management-defined ranges of possible cost and revenue structures.

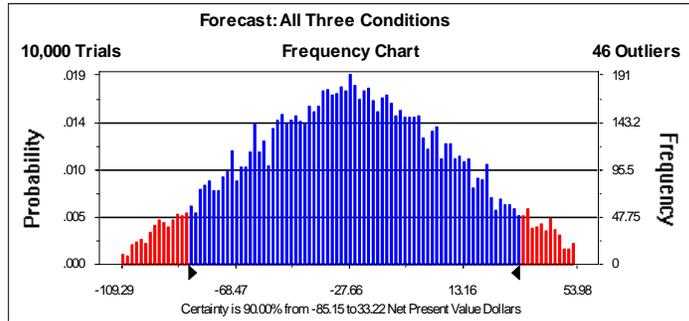
(i) Simulating around scenarios

The analyst simulates around the three scenarios using a Triangular Distribution with the worst-case, nominal-case and best-case scenarios as input parameters into the simulation model.



Mean	-27.06
Standard Deviation	35.31
Range Minimum	-112.21
Range Maximum	57.43
Range Width	169.64

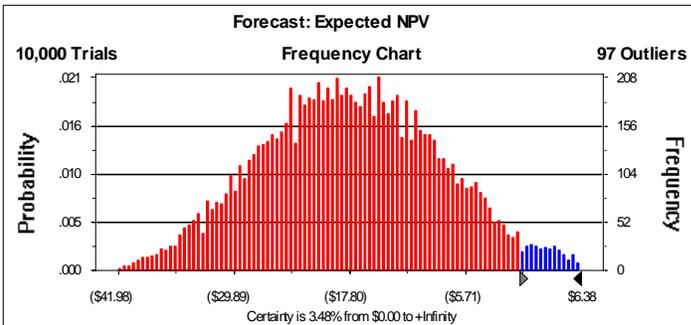
We see that the range is fairly large as the scenarios were rather extreme. In addition, there is only a 23.89% chance that the project will break even or have an NPV > 0.



The 90% statistical confidence interval is between -\$85.15M and \$33.22M, which is also rather wide. Given such a huge swing in possibilities, we are much better off with performing a simulation using the second method, that is, to look at the nominal case and simulate around that case's input parameters.

(ii) Simulating around the nominal scenario

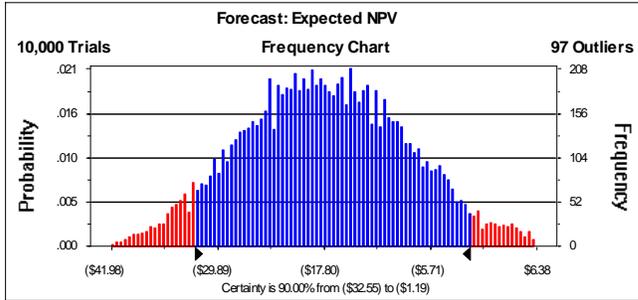
In the scenario analysis, the analyst created two different scenarios (worst case and best case) based on a 50% fluctuation in projected revenues from the base case, here we simply look at the base case and by simulation, generate 10,000 scenarios. Looking back at the Tornado diagram, we noticed that discount rate and cost were the two key determining factors in the analysis; the second approach can take the form of simulating these two key factors. The analyst simulates around the nominal scenario assuming a normal distribution for the discount rate with a mean of 20% and a standard deviation of 2% based on historical data on discount rates used in the firm. The cost structure is simulated assuming a uniform distribution with a minimum of -\$180M and a maximum of -\$220M based on input by management. This cost range is based on management intuition and substantiated by similar projects in the past. The results of the simulation are shown below.



Mean	-25.06
Standard Deviation	14.3
Range Minimum	-69.54
Range Maximum	38.52
Range Width	108.06

Here we see that the range is somewhat more manageable and we can make more meaningful inferences. Based on the simulation results, there is only a 3.48% chance that the project will break even.

Figure 7 – Monte Carlo Simulation



The 90% statistical confidence interval is between -\$32.55M and -\$1.19M.

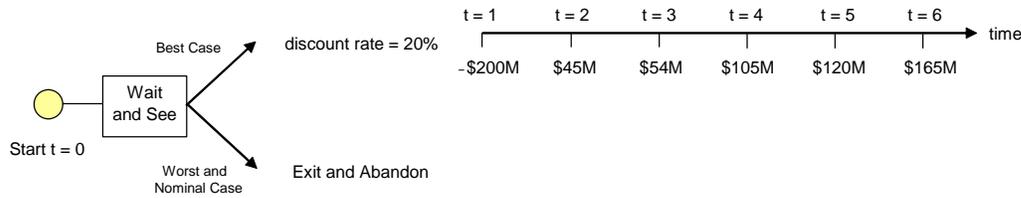
Most of the time, the project is in negative NPV territory, suggesting a rather grim outlook for the project. However, the project is rather important to senior management and they wish to know if there is some way to add value to this project or make it financially justifiable to invest in. The answer lies in using Real Options.

E. Real Options

We have the option to wait or defer investing until a later date. That is, wait until uncertainty becomes resolved and then decide on the next course of action afterwards. Invest in the project only if market conditions indicate a good scenario and decide to abandon the project if the market condition is akin to the nominal or worst-case scenarios because they both bear negative NPVs.

(i) Option to Wait I (Passive Wait and See Strategy)

Say we decide to wait one year and assuming that we will gather more valuable information within this time frame, we can then decide whether to execute the project or not at that time. Below is a decision tree indicating our decision path.

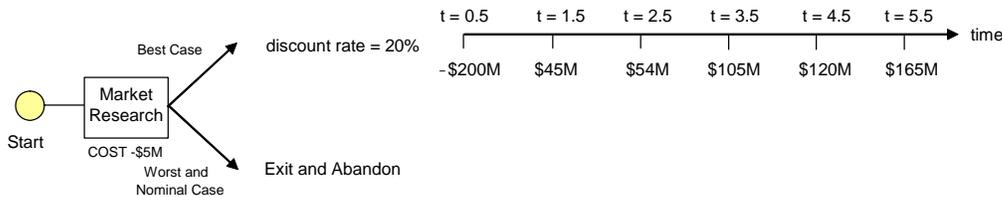


Calculated NPV after waiting for one year on new information = \$49.95M

We see here that the NPV is positive because if after waiting for a year, the market demand is nominal or sluggish, then management has the right to pull the plug on the project. Otherwise, if it is a great market which meets or exceeds the best-case scenario, management has the option to execute the project, thereby guaranteeing a positive NPV. The calculated NPV is based on the forecast revenue stream and is valued at \$49.95M.

(ii) Option to Wait II (Active Market Research Strategy)

Instead of waiting passively for the market to reveal itself over the one-year period as expected previously, management can decide on an active strategy of pursuing a market research strategy. If the market research costs \$5M to initiate and takes 6 months to obtain reliable information, the firm saves additional time without waiting for the market to reveal itself. Here, if the market research indicates a highly favorable condition where the best-case scenario revenue stream is to be expected, then the project will be executed after 6 months. The strategy path and time lines are shown below.

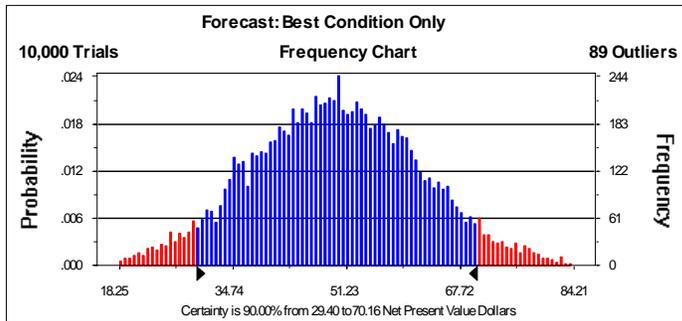


Calculated NPV after active market research = \$49.72M (after accounting for the -\$5M in market research costs)

The calculated NPV here is \$49.72M, relatively close to the passive waiting strategy. However, the downside is the \$5M which also represents the greatest possible loss, which is also the premium paid to obtain the option to execute given the right market conditions.

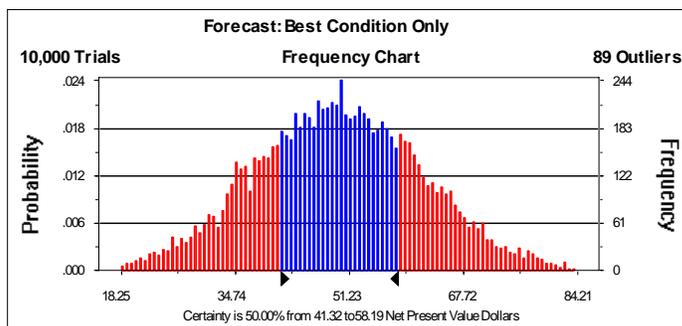
Figure 8 – Real Options Analysis

In retrospect, management could find out the maximum it is willing to pay for the market research in order to cut down the time it has to wait before making an informed decision. That is, at what market research price would the first option to wait be the same as the second option to wait? Setting the difference between \$49.95M and \$49.72M as the reduction in market research cost brings down the initial \$5M to \$4.77M. In other words, the maximum amount the firm should pay for the market research should be no more than \$4.77M; otherwise, it is simply wise to follow the passive strategy and wait for a year.



Mean	49.73
Standard Deviation	49.73
Range Minimum	12.43
Range Maximum	-0.25
Range Width	94.57
	94.82

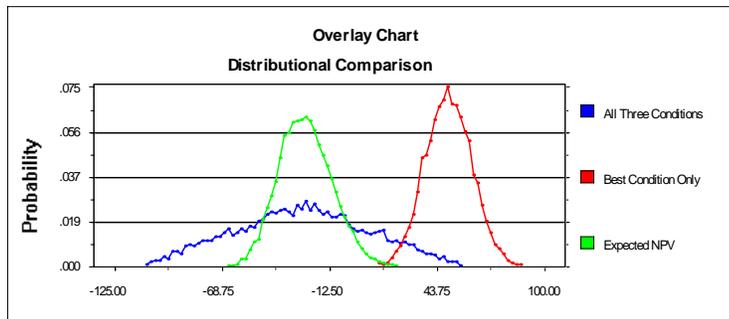
The resulting distribution range is less wide, providing a more meaningful inference. Based on the simulation results, the 90% confidence interval has the NPV between \$29.40M and \$70.16M. The range, which means almost 100% of the time, the NPV takes on a positive value.



The 50% confidence interval has the NPV between \$41.32M and \$58.19M. We can interpret this range as the expected value range because 50% of the time, the real NPV will fall within this range, with a mean of \$49.73M.

F. Observations

We clearly see that by using the three Scenarios versus an Expected Value approach, we obtain rather similar results in terms of NPV but through simulation, the Expected Value approach provides a much tighter distribution and the results are more robust as well as easier to interpret. Once we added in the Real Options approach, the risk has been significantly reduced and the return dramatically increased. The overlay chart below compares the simulated distributions of the three approaches. The blue series is the Scenario approach incorporating all three scenarios and simulating around them. The green series is the Expected Value approach, simulating around the nominal revenue projections, and the red series is the Real Options approach where we only execute if the best condition is obtained.



The example here holds true in most cases when we compare the approach used in a traditional Discounted Cash Flow (DCF) method to Real Options. As we can define risk as uncertain fluctuations in revenues and the NPV level, all downside risks are mitigated in Real Options as you do not execute the project if the nominal or worst-case scenario occurs in time. In retrospect, the upside risks are maximized such that the returns are increased because the project will only be executed when the best-case scenario occurs. This creates a win-win situation where risks are mitigated and returns are enhanced, simply by having the right strategic optionalities available, acting appropriately, and valuing the project in terms of its "real" or intrinsic value, which includes this opportunity to make midcourse corrections when new information becomes available.

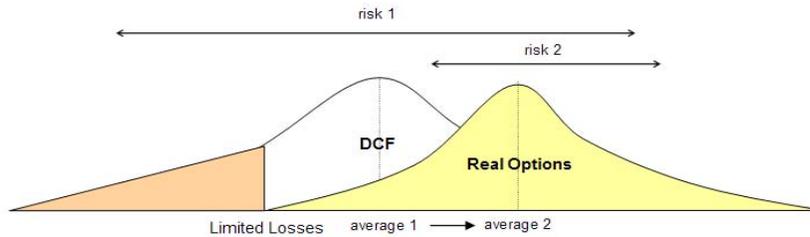
Figure 9 – Combining Real Options Analysis with Monte Carlo Simulation

$$NPV = Benefits - Cost$$

$$Option = Benefits \Phi(d_1) - Cost \Phi(d_2)$$

$$eNPV = NPV + Options Value$$

Where Φ is a probability distribution of outcomes. If there is 0% uncertainty, the probability of an outcome is 100%, hence, the option value reverts back to the NPV



Real Options provides total risk reduction, expected value enhancement, and limited downside losses

In addition, what seems on the outset as an unprofitable project yielding an NPV of -\$26.70M can be justified and made profitable because the project has in reality an Option to Wait or Defer until a later date. Once uncertainty becomes resolved and we have more available information, management can then decide whether to go forward based on market conditions. This call option could be bought through the use of active market research. By having this delay tactic, the firm has indeed truncated any downside risks but still protected its upside potential.

Next, if we look at the Minimax Approach, where we attempt to Minimize the Maximum regret of making a decision, the maximum level of regret for pursuing the project blindly using a DCF approach may yield the worst-case scenario of -\$113.25M while using an Option to Wait but simultaneously pursuing an active marketing research strategy will yield a maximum regret of -\$4.77M. This is because the levels of maximum regret occur under the worst possible scenario. If this occurs, investing in the project blindly will yield the worst case of -\$113.25, but the maximum loss in the real options world is the limited liability of the premium paid to run the market research, adding up to only -\$4.77M because the firm would never execute the project when the market is highly unfavorable.

In addition, the Value of Perfect Information can be calculated as the increase in value created through the Option to Wait as compared to the naïve Expected NPV approach. That is, the Value of having Perfect Information is \$68M. We obtain this level of perfect information through the initiation of a marketing research strategy which costs an additional \$4.77M. This means that the strategic Real Options thinking and decision-making process has created a leverage of 14.25 times. This view is analogous to a financial option where we can purchase a call option for, say, \$5 with a specified exercise price for a specified time of an underlying common equity with a current market price of \$100. With \$5, the call purchaser has leveraged his purchasing power into \$100, or 20 times. In addition, if the equity price rises to \$150 (50% increase akin to our example above), the call holder will execute the option, purchase the stock at \$100, turn around and sell it for \$150, less the \$5 cost and yield a net \$45. The option holder has, under this execution condition, leveraged the initial \$5 into a \$45 profit, or 9 times the original investment.

Finally and more importantly is that we see by adding in a strategic option, we have increased the value of the project immensely. It is therefore wise for management to consider an optionality framework in the decision-making process. That is, to find the strategic options that exist in different projects or to create strategic options in order to increase the project's value.

Figure 10 – Comparing DCF and Real Options Results

Critical Steps in Performing Real Options

Figure 11 shows the real options process up close. We can segregate the real options process into the following eight simple steps. These steps include

- Qualitative management screening
- Base case net present value analysis
- Monte Carlo simulation
- Real options problem framing
- Real options modeling and analysis
- Portfolio and resource optimization
- Reporting
- Update analysis

Qualitative Management Screening

Qualitative management screening is the first step in any real options analysis (Figure 11). Management has to decide which projects, assets, initiatives, or strategies are viable for further analysis, in accordance with the firm's mission, vision, goal, or overall business strategy. The firm's mission, vision, goal, or overall business strategy may include market penetration strategies, competitive advantage, technical, acquisition, growth, synergistic, or globalization issues. That is, the initial list of projects should be qualified in terms of meeting management's agenda. Often this is where the most valuable insight is created as management frames the complete problem to be resolved.

Base Case Net Present Value Analysis

For each project that passes the initial qualitative screens, a discounted cash flow model is created (Figure 11). This serves as the base case analysis where a net present value is calculated for each project. This also applies if only a single project is under evaluation. This net present value is calculated using the traditional approach of forecasting revenues and costs, and discounting the net of these revenues and costs at an appropriate risk-adjusted rate.

The use of time-series forecasting may be appropriate here if historical data exist and the future is assumed to be somewhat predictable using past experiences. Otherwise, management assumptions may have to be used.

Monte Carlo Simulation

Because the static discounted cash flow produces only a single-point estimate result, there is often little confidence in its accuracy given that future events that affect forecast cash flows are highly uncertain. To better estimate the actual value of a particular project, Monte Carlo simulation may be employed (Figure 11).

Usually, a sensitivity analysis is first performed on the discounted cash flow model. That is, setting the net present value as the resulting variable, we can change each of its precedent variables and note the change in the resulting variable. Precedent variables include revenues, costs, tax rates, discount rates, capital expenditures, depreciation, and so forth, which ultimately flow through the model to affect the net present value figure. By tracing back all these precedent variables, we can change each one by a preset amount and see the effect on the resulting net present value. A graphical representation can then be created, which is often called a Tornado Diagram because of its shape, where the most sensitive precedent variables are listed first, in descending order of magnitude. Armed with this information, the analyst can then decide which key variables are highly uncertain in the future and which are

deterministic. The uncertain key variables that drive the net present value and hence the decision are called critical success drivers. These critical success drivers are prime candidates for Monte Carlo simulation. Because some of these critical success drivers may be correlated – for example, operating costs may increase in proportion to quantity sold of a particular product, or prices may be inversely correlated to quantity sold – a correlated Monte Carlo simulation may be required. Typically, these correlations can be obtained through historical data. Running correlated simulations provides a much closer approximation to the variables' real-life behaviors.

Real Options Problem Framing

Framing the problem within the context of a real options paradigm is the next critical step (Figure 11). Based on the overall problem identification occurring during the initial qualitative management screening process, certain strategic optionalities would have become apparent for each particular project. The strategic optionalities may include among other things, the option to expand, contract, abandon, switch, choose, and so forth. Based on the identification of strategic optionalities that exist for each project or at each stage of the project, the analyst can then choose from a list of options to analyze in more detail.

Real Options Modeling and Analysis

Through the use of Monte Carlo simulation, the resulting stochastic discounted cash flow model will have a distribution of values. In real options, we assume that the underlying variable is the future profitability of the project, which is the future cash flow series. An implied volatility of the future free cash flow or underlying variable can be calculated through the results of a Monte Carlo simulation previously performed. Usually, the volatility is measured as the standard deviation of the logarithmic returns on the free cash flows stream. In addition, the present value of future cash flows for the base case discounted cash flow model is used as the initial underlying asset value in real options modeling (Figure 11).

Portfolio and Resource Optimization

Portfolio optimization is an optional step in the analysis (Figure 11). If the analysis is done on multiple projects, management should view the results as a portfolio of rolled-up projects. This is because the projects are, in most cases, correlated with one another, and viewing them individually will not present the true picture. As firms do not only have single projects, portfolio optimization is crucial. Given that certain projects are related to others, there are opportunities for hedging and diversifying risks through a portfolio. Because firms have limited budgets, have time and resource constraints, while at the same time have requirements for certain overall levels of returns, risk tolerances, and so forth, portfolio optimization takes into account all these to create an optimal portfolio mix. The analysis will provide the optimal allocation of investments across multiple projects.

Reporting

The analysis is not complete until reports can be generated (Figure 11). Not only are results presented, but also the process should be shown. Clear, concise, and precise explanations transform a difficult black-box set of analytics into transparent steps. Management will never accept results coming from black boxes if they do not understand where the assumptions or data originate and what types of mathematical or financial massaging takes place.

Update Analysis

Real options analysis assumes that the future is uncertain and that management has the right to make midcourse corrections when these uncertainties become resolved or risks become known; the analysis is usually done ahead of time and thus, ahead of such uncertainty and risks. Therefore, when these risks become known, the analysis should be revisited to incorporate the decisions made or revising any input assumptions. Sometimes, for long-horizon projects, several iterations of the real options analysis should be performed, where future iterations are updated with the latest data and assumptions.

Integrated Risk Management Process

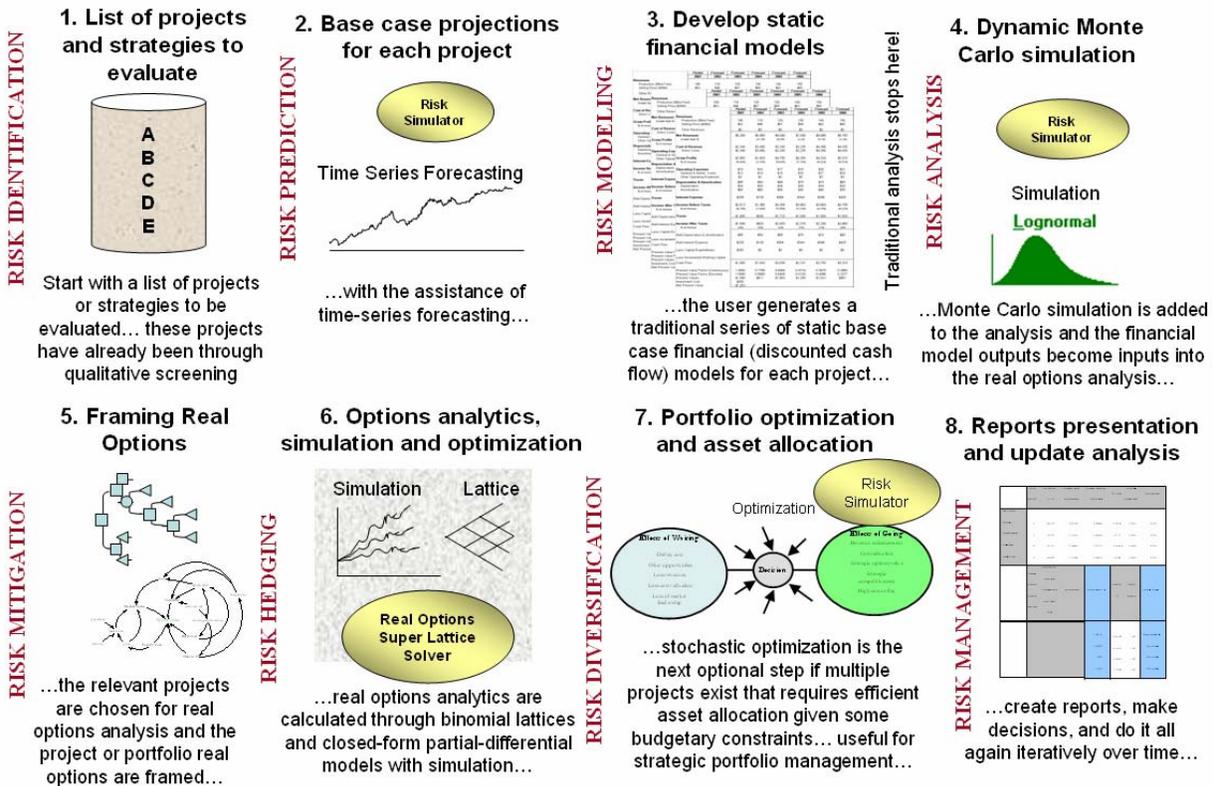


Figure 11 – Real Options Integrated Process

Conclusion

So, how do you get real options implemented in your organization? First of all, it is vital to truly understand that real options analysis is *not* a simple set of equations or models. It is an *entire decision-making process* that enhances and complements the traditional decision analysis approaches. It takes what has been tried and true financial analytics and evolves them to the next step by pushing the envelope of analytical techniques. Several issues should be considered when attempting to implement real options analysis:

- **Tools**—The correct tools are important. These tools must be more comprehensive than initially required because analysts will grow into them over time. Do not be restrictive in choosing the relevant tools. Always provide room for expansion. Advanced software tools will relieve the analyst of detailed model building and let him or her focus instead on 75 percent of the value—thinking about the problem and interpreting the results.

- **Resources**—The best tools in the world are useless without the relevant human resources to back them up. Tools do not eliminate the analyst, but enhance the analyst’s ability to effectively and efficiently execute the analysis. The right people with the right tools will go a long way. Because there are only a few true real options experts in the world who truly understand the theoretical underpinnings of the models as well the practical applications, care should be taken in choosing the correct team. A team of real options experts is vital in the success of the initiative. A company should consider building a team of in-house experts to implement real options analysis and to maintain the ability for continuity, training, and knowledge transfer over time. Knowledge and experience in the theories, implementation, training, and consulting are the core requirements of this team of individuals. Training plays a vital part in developing this in-house expertise. Nothing will kill a real options analysis project faster than over-promising and under-delivering due to insufficient training. A typical in-house real options expert needs to have the following theoretical knowledge and applied expertise: econometrics, statistics, simulation, financial modeling, and experience in participating in at least two to three real options analysis projects.
- **Senior Management Buy-in**—The analysis buy-in has to be top-down where senior management drives the real options analysis initiative. A bottom-up approach where a few inexperienced junior analysts try to impress the powers that be will fail miserably.

The author’s *Real Options Super Lattice Software (SLS)* and Risk Simulator software comprises several modules, including the *Single Super Lattice Solver (SSLS)*, *Multiple Super Lattice Solver (MSLS)*, *Multinomial Lattice Solver (MNLS)*, *SLS Excel Solution*, and *SLS Functions*. These modules are highly powerful and customizable binomial and multinomial lattice solvers and can be used to solve many types of options (including the three main families of options: *real options*, which deals with physical and intangible assets; *financial options*, which deals with financial assets and the investments of such assets; and *employee stock options*, which deals with financial assets provided to employees within a corporation).

- The **SSLS** is used primarily for solving options with a *single underlying asset* using binomial lattices. Even highly complex options with a single underlying asset can be solved using the SSLS. Example options solved include options to abandon, choose, contract, defer, expand, wait, and so forth.
- The **MSLS** is used for solving options with *multiple underlying assets* and sequential compound options with *multiple phases* using binomial lattices. Highly complex options with multiple underlying assets and phases can be solved using the MSLS. Example options solved include sequential compound options, phased stage-gate options, switching options, and multiple asset options.
- The **MNLS** uses *multinomial lattices* (trinomial, quadrinomial, pentanomial) to solve specific options that cannot be solved using binomial lattices. Example options solved include rainbow options, jump-diffusion options, mean-reverting options, and so forth.
- The **SLS Excel Solution** implements the SSLS and MSLS computations within the Excel environment, allowing users to access the SSLS and MSLS functions directly in Excel. This feature facilitates model building, formula and value linking and embedding, as well as allows the running of simulations, and provides the user sample templates to create such models.
- The **SLS Functions** are additional real options and financial options models accessible directly through Excel. This facilitates model building, linking and embedding, and running simulations. These functions are able to replicate the results from all the other modules directly in Excel.

There are however several pitfalls in using real options. It is by no means the silver bullet or the end-all and be-all methodology that will solve all your problems. Some of the same problems found in

DCF modeling is also captured in real options (the accuracy of cash flow forecasting, for instance), and in the end, when uncertainty is zero, the options analysis results revert back to the DCF value. If care is taken in the modeling and the relevant projects have been chosen, real options analysis will provide a wealth of information that cannot be obtained otherwise. The following criteria should be used in selecting the relevant projects for implementation: *The project has to be faced with or operates under uncertainty; management must have the strategic and operational flexibility (i.e., options exist) to make mid-course corrections when uncertainty becomes resolved over time; and management must be credible enough to execute the profit-maximizing behavior at the appropriate time, otherwise all the options in the world are useless.*

The idea of this paper is to demystify the black-box analytics in real options and to make transparent its concepts and applications. Rather than relying on stochastic Ito calculus, variance reduction, differential equations or stochastic path-dependent simulations to solve real options problems, I have found that by my relying heavily on binomial lattices (which I have shown time and again to be reliable and produce identical results, at the limit, to the former approaches)³ complex concepts can be explained very easily to senior management. While it is extremely easy to modify binomial lattices depending on the real options or to more accurately mirror the intricacies of actual business cases, it is extremely difficult to do so using the more advanced techniques. In the end, the more flexible and mathematically manageable approach becomes the pragmatic approach. The flexibility in the modeling approach flows well: “if you can think it, you can solve it!” Finally, my intention is to briefly reveal the applications of real options. A black box will remain a black box if no one can understand the concepts despite its power and applicability. It is only when the black box becomes transparent that analysts can understand, apply, and convince others of its results and applicability, that the approach will receive wide-spread influence. So, buy yourself an option and learn more about the subject before attacking it head first and biting off more than you can chew. Test the applications on a smaller scale pilot project but with significant visibility, attack problems that have clear optionalities, choose projects with cross-functional and interdepartmental implications, obtain management buy-in and sponsorship, and perform some back-casting (as opposed to forecasting where you look to the future, back-casting uses data from a project in the past—you get the results instantly, as opposed to having to wait for years before the accuracy of the results can be verified).

³ For the technical details, please see my books on real options and simulation: “*Real Options Analysis: Tools and Techniques, 2nd Edition*,” (Wiley 2005), “*Real Options Analysis Course*,” (Wiley 2003), and “*Applied Risk Analysis: Moving Beyond Uncertainty*,” (Wiley 2003).

Author's Vita



Dr. Johnathan C. Mun is the founder and CEO of Real Options Valuation, Inc., a consulting, training, and software development firm specializing in strategic real options, financial valuation, Monte Carlo simulation, stochastic forecasting, optimization, and risk analysis located in northern California. He is the creator of the *Real Options Super Lattice Solver* software, *Risk Simulator* software, and *Employee Stock Options Valuation* software at the firm, as well as the risk analysis Training DVD and he holds public seminars on risk analysis and Certified Risk Analyst (CRA) programs. He has authored eight books including *Modeling Risk: Applying Monte Carlo Simulation, Real Options, Optimization, and Forecasting*, (Wiley 2006), *Real Options Analysis: Tools and Techniques*, First and Second Editions (Wiley 2003 and 2005), *Real Options Analysis Course: Business Cases* (Wiley 2003), *Applied Risk Analysis: Moving Beyond Uncertainty* (Wiley 2003), *Valuing Employee Stock Options* (Wiley 2004), and others. His books and software are being used at top universities around the world (including the Bern Institute in Germany, Chung-Ang University in South Korea, Georgetown University, ITESM in Mexico, Massachusetts Institute of Technology, Naval Postgraduate School, New York University, Stockholm University in Sweden, University of the Andes in Chile, University of Chile, University of Pennsylvania Wharton School, University of York in the United Kingdom, and Edinburgh University in Scotland, among others).

Dr. Mun is also currently a finance and economics professor and has taught courses in financial management, investments, real options, economics, and statistics at the undergraduate and the graduate M.B.A. levels. He is teaching and has taught at universities all over the world, from the U.S. Naval Postgraduate School (Monterey, California) and University of Applied Sciences (Switzerland and Germany) as full professor, to Golden Gate University (California) and St. Mary's College (California), and has chaired many graduate research thesis committees. He also teaches risk analysis, real options analysis, and risk analysis for managers' public courses where participants can obtain the Certified Risk Analyst (CRA) designation upon completion of the week-long program. He was formerly the Vice President of Analytics at Decisioneering, Inc. where he headed up the development of options and financial analytics software products, analytical consulting, training, and technical support, and where he was the creator of the Real Options Analysis Toolkit software, the older predecessor of the Real Options Super Lattice software. Prior to joining Decisioneering, he was a Consulting Manager and Financial Economist in the Valuation Services and Global Financial Services practice of KPMG Consulting and a Manager with the Economic Consulting Services practice at KPMG LLP. He has extensive experience in econometric modeling, financial analysis, real options, economic analysis, and statistics. During his tenure at Real Options Valuation, Inc., Decisioneering, and at KPMG Consulting, he had taught and consulted on a variety of real options, risk analysis, financial forecasting, project management, and financial valuation issues for over 100 multinational firms (former clients include 3M, Airbus, Boeing, BP, Chevron Texaco, Financial Accounting Standards Board, Fujitsu, GE, Microsoft, Motorola, Pfizer, Timken, U.S. Department of Defense, U.S. Navy, Veritas, and many others). His experience prior to joining KPMG included being Department Head of financial planning and analysis at Viking Inc. of FedEx, performing financial forecasting, economic analysis, and market research. Prior to that, he did financial planning and freelance financial consulting work.

Dr. Mun received his Ph.D. in Finance and Economics from Lehigh University, where his research and academic interests were in the areas of Investment Finance, Econometric Modeling, Financial Options, Corporate Finance, and Microeconomic Theory. He also has an M.B.A. in business administration, an M.S. in management science, and a B.S. in Biology and Physics. He is Certified in Financial Risk Management (FRM), Certified in Financial Consulting (CFC), and is Certified in Risk Analysis (CRA). He is a member of the American Mensa, Phi Beta Kappa Honor Society, and Golden Key Honor Society as well as several other professional organizations, including the Eastern and Southern Finance Associations, American Economic Association, and Global Association of Risk Professionals. Finally, he has written many academic articles published in the *Journal of the Advances in Quantitative Accounting and Finance*, the *Global Finance Journal*, the *International Financial Review*, the *Journal of Financial Analysis*, the *Journal of Applied Financial Economics*, the *Journal of International Financial Markets, Institutions and Money*, the *Financial Engineering News*, and the *Journal of the Society of Petroleum Engineers*.