# USING REAL OPTIONS DISCIPLINE FOR HIGHLY UNCERTAIN TECHNOLOGY INVESTMENTS

*Here's a methodology and investment discipline you will need for convincing a CFO that your proposal for a promising though uncertain project is prudent.*

Ian C. MacMillan, Alexander B. van Putten, Rita Gunther McGrath, and James D. Thompson

OVERVIEW: *Existing methodologies offer little help in selecting among uncertain technology investments. However, Discovery Driven Planning in conjunction with Real Options Discipline allows managers to make aggressive investments while maintaining fiduciary responsibility. Discovery Driven Planning provides an effective way to plan investments when there is true ambiguity about their prospects. Real Options Discipline yields a more effective selection method than is offered by standard net present value calculations, which tend to reject investments with high potential but uncertain outcomes. When combined, the two methodologies create an effective way of managing highly uncertain projects in order to capture their potential value while limiting costs.*

KEY CONCEPTS: *real options, uncertainty, valuation, discovery-driven planning.*

A combination of advancing technology, globalization of competition and market turbulence, is pushing firms to make technology investments with increasingly ambiguous outcomes. CFOs and senior management, besieged by requests for funds to support technology

*Ian MacMillan is co-director of the Wharton Entrepreneurial Center, and director of the Snider Entrepreneurial Research Center at The Wharton School, University of Pennsylvania in Philadelphia. He is also the Dhirubai Ambani Professor of Innovation and Entrepreneurship at Wharton. MacMillan has extensive consulting experience, having worked with such companies as Air Products, DuPont, General Electric, Hewlett-Packard, IBM, Intel, L. G. Group (Korea), Matsushita (Japan), Microsoft, and Texas Instruments. He received his B.Sc. from the University of Witwatersrand, and his M.B.A. and D.B.A. from the University of South Africa. He has published widely and with co-author Rita McGrath was awarded the Industrial Research Institute's Maurice Holland Award for the best original article published in* Research-Technology Management *in 2000 ("Assessing Technology Projects Using Real Options Reasoning").* **MacMillan@wharton.upenn.edu**

*Alexander van Putten is an adjunct faculty member of the Management Department at The Wharton School. Prior to joining the faculty in 1993, he worked for 20 years in arbitrage and real estate investment. He received a B.A. from Boston University and an M.BA. from The Wharton School. He consults with such companies as Air Products, Automatic Data Processing, DuPont, and Philips on ways to accelerate growth using options-based management.* **alexvp@wharton.upenn.edu**

*Rita Gunther McGrath is an associate professor of management at Columbia Business School, New York, N.Y. Widely published, she is the co-author (with Ian MacMillan) of* Entrepreneurial Mindset *(HBS Press, 2000) and* Market Busters, 40 Strategic Moves That Drive Exceptional Business Growth *(HBS Press, 2005). She has won several awards, including the IRI's Maurice Holland Award and the Strategic Management Society's Best Paper Award for 2001. She consults with Air Products, DuPont, Microsoft, Nokia, and other companies, and received her Ph.D. from The Wharton School.* **RDM20@columbia.edu**

*James Thompson is an associate director of Wharton Entrepreneurial Programs in Philadelphia. He teaches innovation and entrepreneurial management, and is research director of the center's technology commercialization and societal wealth creation programs. Prior to joining The Wharton School he was divisional officer of a textile and apparel corporation, responsible for business development, international market development, and business-unit turnarounds. He holds a master's degree in business administration.*
**jamestho@wharton.upenn.edu**



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investment proposals, need a selection methodology that simultaneously allows for more aggressive investments while maintaining fiduciary responsibility.

Those firms able to develop methodologies for evaluating and pursuing technology investments that are rich in opportunity, while controlling risk, will inevitably develop newer technologies than their more timid competitors. By technologically outpacing their peers, these firms will be rewarded with breakthroughs that in turn bring investor recognition in the form of higher market valuations.

In this article, we argue that by applying Discovery Driven Planning to select, and Real Options Discipline to evaluate, uncertain projects, CTOs can begin to propose more aggressive investments in uncertain, but strategically important areas, while at the same time assuring their CFOs of fiduciary responsibility.

We start by stressing that initially there is no need for, nor sense in, recommending mass implementation of our approach—the best line of attack is to apply the process to a few pilot projects with the purpose of systematically learning whether it will effectively address the issues facing your firm.

### The Problem with DCF

Real Options Discipline combined with a well-executed Discovery Driven Plan can enable a company to improve its overall commercialization success rate by making deliberate, low-cost "test investments" that demonstrate the plausibility of technology development investments with large upside potential but highly uncertain chances of success. In such cases, discounted cash flow analysis (DCF) often suggests that a project should be disallowed. To understand why this happens let's revisit the basics of DCF analysis. It begins with the prediction of the expected values of cash inflows and outflows for the life of a project. Next, it requires:

**1.** The calculation of the expected values of the net cash flow for each year.

**2.** Discounting each year's expected net cash flow back to the present, using a risk-adjusted discount rate that reflects the project's uncertainty.

**3.** Adding up the discounted cash flows and subtracting the investment to arrive at the net present value (NPV). If it is greater than zero, the investment is justified.

NPV is a perfectly appropriate methodology and should *always* be used when the investment is certain. But what if the outcome is uncertain? Then the flaw is that when doing more complex DCF calculations, there is the requirement to estimate all the different cash inflows and outflows, which are then discounted back to their present value. In doing this the DCF methodology implicitly assumes that once the project is approved, all those cash flows will automatically take place, which eliminates flexibility. By contrast, the real options view is that the best course of action may be to decide not to incur any of the cash flows along the way after approval; and this flexibility can have huge value. Let's illustrate this now with a highly simplified example.

### Investing Under High Uncertainty

In this simplified situation, NPV logic is applied to a highly uncertain technology project. A technology team thinks that they can develop a new technology that could radically change the way the firm competes. They think they can develop this new technology for a development budget of \$25, which will then cost \$200 to scale up for commercial application, for a total budget of \$225.

It has high risk—but also high upside potential: There is only a 5% chance that the new technology will work, but if it does work it will lead to a new commercial product that will yield a guaranteed DCF of net revenues of \$4000, (excluding the R&D and installation costs). According to the conventional NPV calculation:

$$\begin{aligned} \text{NPV} &= \text{Expected Total DCF Cost} + \\ &\quad \text{Expected DCF Net Revenues} \\ &= -(225) + 0.05 \times 4000 \\ &= -225 + 200 \\ &= -\$25 \end{aligned}$$

With the proposal structured in this way, where the project proponents assume that they will get the full proposed budget if approved, your CFO would be absolutely right to turn down the project.

### Real Options Discipline

However what if you used the following argument with the CFO; "We will spend only \$25 to see if the technology works out. We will apply for the \$200 for technology scale up *only* if the technology works, BUT we will drop the project if the technology doesn't work."

Now the investment can be looked at as spending \$25 on buying a technology option, which gives your CFO the right, *but not the obligation,* to spend another \$200 and thereby secure a DCF of \$4000.

This means that the \$25 investment in developing the technology has a 5% chance of precipitating a \$200 installation cost with the same 5% chance of delivering \$4000.

$$\begin{aligned} \text{NPV} &= -25 + 0.05\,(-200 + 4000) \\ &= -25 + 190 \\ &= \$165 \end{aligned}$$

This shows that even in cases where there is a high probability of failure (95%), *if* the upside is very large, and *if* the firm can capture the right to that potential at relatively low cost, and *if* the project can be ruthlessly stopped should the option investment fail, it is still a good idea to go ahead. However, what we call the Real Options Discipline (ROD) needs to be rigorously applied: in the absence of *any* of the above *ifs,* the project fails the ROD test. Any CFO who allows such a flawed project to slip by can justly be accused of sparing the ROD and spoiling the profits!

In effect, the flexibility provided by the option to discontinue the project has value that should be considered. The difference between NPV and ROD is that in conventional NPV proposals the project sponsors implicitly assume that once the project starts all investment steps will automatically be carried out. In fact, after any of many investment steps, projects can be stopped, put on hold, redirected, or postponed. The flexibility to stop, postpone, redirect, or put on hold further investment creates the *option value.*

Like the simple example above, if your project managers can promise your CFO that they have built in the flexibility to invest a small amount to discover if they are right, and stop at low cost if they are wrong, the CFO can "buy" an option on the upside of the NPV distribution while avoiding the downside. If your project managers cannot do so, they should be subjected to conventional NPV discipline.

**A More Complex Case**

Although the above simple example had discrete probabilities of revenue outcomes (95/5), and precise cost estimates, this is rarely the case in major strategic projects. Usually the revenue and cost projections each have a distribution of possible values, and so there is no way of doing the simple probability calculation we did above with any degree of accuracy. NPV analysis tries to consider this by applying a higher discount rate to adjust for the risk, giving a risk-adjusted value of the project. In fact, use of the higher risk-adjusted discount rate actually reduces the NPV, as it should.

What risk-adjusted NPV analysis does not do is recognize the value of flexibility captured by using the Real Options Discipline that allows for sustained investment only if the value of continuing to the next stage of project development exceeds the cost of doing so. It is this option value, applicable only to projects that satisfy the ROD test, that would put the overall project into an "invest" category.

How does one take into account the fact that the revenues and costs of uncertain projects have distributions of values? This calls for a different approach to planning.

**Assumption-to-Knowledge Ratio and DDP**

In the absence of hard knowledge, plans must be made on the basis of assumptions. In conventional planning, one extrapolates to the future from a well-understood and predictable platform of past experience. With a new technology, there is no such platform. In any technology development situation, the proportion of assumptions that need to be made relative to knowledge is considerable. We refer to this as the assumption-to-knowledge ratio. Managing when most decisions are based on assumptions is a completely different proposition than running an operation in which you generally know what is going on. The primary challenge is to maximize the conversion of assumptions to knowledge at the minimum possible cost. Clearly, a method of planning appropriate to uncertain situations has to acknowledge the challenge that high levels of assumptions relative to knowledge creates.

**Discovery Driven Planning obliges managers to show how key numbers will be tested and confirmed as the work progresses.**

Discovery Driven Planning is the method we have developed for planning under uncertainty. It is, in effect, a plan to learn by setting up key checkpoints for converting the assumptions that are made about the technology project into knowledge as the project unfolds.

We break the process into six disciplined planning stages: 1) framing; 2) benchmarking; 3) specification of deliverables; 4) documenting assumptions; 5) simulation and sensitivity analysis; 6) Planned assumption testing at CheckPoints™ (*1*). We illustrate this below with a simplified example from the bioscience field that we shall call the BioBarrier Project.

**Six Disciplines of Discovery Driven Planning**

**1.** *Specification of a challenging frame*

With a Discovery Driven Plan we seek to pursue an attractive upside right from the outset. What this means in practice is to specify what the desired business must look like if the technology succeeds (not what the technology will look like) and make this absolutely clear to everyone involved. Whatever new technology you elect to develop must specify a challenging commercial result that will justify all the trouble.

In our example, the firm BioBarrier has developed a new bioscience molecule that in an aqueous solution holds great promise as a barrier for infection, used for washing down surfaces and the body to prevent infection. The target market is hospitals. In setting up the frame, BioBarrier decided that it needs a meaningful increment in profits and profitability to justify the project. So, in Table 1 we construct a reverse income statement and balance sheet that starts with required performance and from there specifies allowable costs and investment, which establishes the boundaries within which the project team must operate.

Observe in Table 1 that we assign numbers to all assumptions because later we will be designing specific checkpoints where the various assumptions will be tested. Notice also that we are inserting benchmarking data. In this case, BioBarrier is looking to be more profitable than the parent's current 20% return on assets (profits divided by employed assets, a test of operating efficiency) and for BioBarrier to earn better than the parent's 15% return on sales (profits divided by sales, a test of profitability). Under the heading Source we show the origin of the assumption values; if these values result from a calculation, they are shown as a formula derived from the numbered lines in the left-hand column. Finally, with the nearest competitive product selling at $55 per gallon, Table 1 presents the firm with a competitive benchmark that supports the assumption that the firm will have to enter the market at a price below this if it is to be successful.

This quick exercise leads to the immediate determination that the project will have to sell one million gallons a year to deliver the specified operating profits. Clearly, this is going to have to be a national business.

**2.** *Benchmarking against competitive market reality*

As your technology managers formulate plans, it is very easy for the plan on paper to take on an unrealistic quality. Potential markets for the technology appear larger and more profitable than they are, and performance relative to the competition recedes into the background. What is needed is a grasp of what the project

**The MacVan method corrects a critical flaw in the typical option pricing methodology.**

must achieve against benchmarked parameters in order to succeed competitively, and what the scope of the market must be to allow that expected performance.

This discipline forces one to face up to the reality that under competitive conditions your firm will be pressed by talented, aggressive competitors to meet benchmark standards they have set. This part of the planning process forces managers to articulate exactly how they plan to achieve or exceed competitive benchmark standards.

Table 2 shows the process unfolding as we calculate the advertising required in light of the benchmarked advertising-to-sales ratio prevailing in the industry. As we calculate the size and cost of the sales force, we use the data about the number of sales calls per order, order size, sales calls per day, sales salaries, and commissions from appropriate sources in the industry. If such data are not available, we have to use our best guess. All assumptions are flagged as such by the bold type in the cell. This is because we actually enter our best guess of the range this variable will take: lowest, most likely and highest values. These ranges will later be used to simulate the business.

**3.** *Specification of organizational deliverables*

The organizational deliverables statement is a detailed specification of your assumptions about the daily operating activities that will be needed for the technology to become an operating reality. The difference again is that in a Discovery Driven Plan, the frame dictates

***Table 1.—Framing the Project***

| Line | Goal | Value | Assumption No. | Benchmark | Source |
|---|---|---|---|---|---|
| 1 | Required Operating Profits | **$10,000,000** | 1 | | Policy Decision |
| 2 | Required Return on Assets | **25.0%** | 2 | 20.0% | Policy Decision |
| 3 | Required Return on Sales | **20.0%** | 3 | 15.0% | Policy Decision |
| 4 | Allowable Assets | $40,000,000 | | | line 1/line 2 |
| 5 | Necessary Sales Revenues | $50,000,000 | | | line 1/line 3 |
| 6 | Allowable Costs | $40,000,000 | | | line 5 − line 1 |
| 7 | Selling Price per Gallon | **$50.00** | 4 | $55.00 | Current Price |
| 8 | Required Gallons of Sales | $ 1,000,000 | | | line 5/line 7 |

*Table 2.—Operational Specifications*

| Line | Operation | Value | Assumption | Benchmark | Source |
|---|---|---|---|---|---|
| 9 | Advertising as Percent of Sales | **12.0%** | 5 | 10% | Industry average |
| 10 | Total Advertising | $6,000,000 | | | |
| 11 | Gallons Per Order | **10** | 6 | 10 | Distributors |
| 12 | Sales Calls per Order | **4** | 7 | 4 | Distributors |
| 13 | Sales Calls per Day | **7** | 8 | 8 | Distributors |
| 14 | Sales Days per Year | **250** | 9 | | |
| 15 | Gallons per Salesperson per Year | 3,750 | | | lines 11 × 13/12 × 14 |
| 16 | Salesforce Required | 267 | | | line 8/line 15 |
| 17 | Sales Commissions | **15%** | 10 | | Competitors |
| 18 | Sales Salary | **$30,000** | 11 | $30,000 | Competitors |
| 19 | Total Commissions | $7,500,000 | | | line 5/line 17 |
| 20 | Total Salaries | $8,000,000 | | | line 16/line 18 |
| 21 | Total Selling Expenses | $15,500,000 | | | line 19/line 20 |
| | **Manufacturing Costs** | | | | |
| 22 | Raw Materials per Gallon | **$10** | 12 | 80 | Suppliers |
| 23 | Container Cost per Gallon | **$1** | 13 | 10 | Suppliers |
| 24 | Total Materials Costs | $11,000,000 | | | (line 24 + 23)/line 8 |
| 25 | Gallons per Day per Production Plant | **$1,000** | 14 | 1200 | Equipment suppliers |
| 26 | Production Days per Year | **$250** | 15 | 250 | Industry practice |
| 27 | Number of Plants | $4 | | | line 8/(lines 25 × 26) |
| 28 | Production Workers per Plant | **$12** | 16 | 15 | |
| 29 | Total Production Staff | $48 | | | lines 27 × 28 |
| 30 | Production Salaries | **$36,000** | 17 | $30,000 | Workers |
| 31 | Production Salary Costs | $1,728,000 | | | lines 29 × 30 |
| | **Equipment Charges** | | | | |
| 32 | Equipment Cost per Production Plant | **$3,000,000** | 18 | $3,000,000 | Equipment suppliers |
| 33 | Total Equipment | $12,000,000 | | | lines 27 × 32 |
| 34 | Depreciation Rate | **10%** | 19 | 10% | Industry practice |
| 35 | Annual Depreciation | $1,200,000 | | | lines 33 × 34 |
| | **Delivery Costs** | | | | |
| 36 | Deliveries per Year | 2142 orders | | | lines 7 × 11 |
| 37 | Delivery Charges per Delivery | **$40.00** | 20 | $ 40.00 | Delivery firm |
| 38 | Delivery Costs per Year | $85,680 | | | lines 36 × 37 |
| 39 | Overhead as Percent of Revenue | **10%** | 21 | 10% | Company Records |

*Table 3.—Reverse Financial Statements*

| Line | Operation | Value | Assumption | Benchmark | Source |
|---|---|---|---|---|---|
| 40 | Materials Costs | $11,000,000 | | | lines (22 + 23) × 8 |
| 41 | Production Salaries | $1,728,000 | | | lines 29 × 30 |
| 42 | Delivery Costs | $85,680 | | | lines 36 × 37 |
| 43 | Depreciation Charges | $1,200,000 | | | lines 33 × 34 |
| 44 | Overhead | $5,000,000 | | | lines 5 × 39 |
| 45 | Maximum Cost Allowed | $ (513,580) | | | |
| 46 | Profit | $9,486,320 | | | line 1–46 |
| 47 | Return on Sales | 19.0% | | | line 1/46 |
| 48 | **Balance Sheet Items** | | | | |
| 49 | Days Inventory | **90 days** | 22 | 90 | Bank |
| 50 | Days Receivables | **90 days** | 23 | 90 | Bank |
| 51 | Allowable Assets | $40,000,000 | | | line 1/2 |
| 52 | Receivables | $12,500,000 | | | line 5/(360/47) |
| 53 | Inventory | $2,750,000 | | | line 39/(360/46) |
| 54 | Equipment | $12,000,000 | | | line 22 × 32 |
| 55 | Buildings | $2,000,000 | | | Realtor’s Estimate |
| 56 | Other Allowable Assets | $10,750,000 | | | line 48–49–50–51 |
| 57 | Return on Assets | 32.4% | | | line 45/(48–52) |

what this translation will look like. For instance, the number of sales you need to close will dictate how big the sales staff has to be, and in turn the cost that will be consumed by the selling process. The more realistic these deliverables are, the greater the confidence you can have that the plan is feasible.

Referring again to Table 2, the operational specifications systematically build the business: they calculate what physically must be done based on benchmarked assumptions about the advertising, selling, manufacturing, plant, and delivery effort that will go into operating the business, with the degree of uncertainty about these assumptions reflected by broadness of range.

When this has been completed, the information flows into a reverse income statement and balance sheet shown in Table 3.

Here we see in line 45 that the business as planned will overshoot allowable costs, but the balance sheet will have plenty of cushion and deliver 30+% return on assets if things go well. However, it would be foolish to launch the project assuming all will go well! We need a way of testing assumptions, particularly critical ones, ahead of investment.

**4.** *Document assumptions*

This is the biggest single difference between Discovery Driven Plans and conventional ones. In Discovery Driven Plans, the entire plan is organized around converting the maximum number of assumptions to knowledge at minimum cost. All the assumptions are entered into the columns of an assumption/CheckPoint list as shown in Table 4 (which is purely illustrative and has nothing to do with the example).

**5.** *Simulate and identify sensitivities*

The next step in the process is to simulate the business with a simulation software package. Crystal Ball™ is a popular, user-friendly one that we use; it works with Excel to generate a Monte Carlo simulation of the project outcomes (*1*).

***Table 4.—Illustrative Assumption/Checkpoint List***

| | Assumption | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Checkpoint** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | etc |
| Lab bench | × | × | | | | | | |
| Pilot plant | | × | | | | | | |
| Market analysis | | × | × | | | | | |
| Feasibility analysis | | | × | × | × | | | |
| Focus group tests | | | | | × | | | |
| Field trials | | | | | × | | | |
| First production plant | | | | | | × | × | |
| Sales force selection and training | | | × | | | × | | |
| First major orders | | | × | | | | | |
| etc. | | | | | | | | |

A Monte Carlo simulation varies each assumption within its range at random and simultaneously with all the other assumption ranges to produce a distribution of possible outcomes. By running the simulation and a sensitivity analysis, it is possible to uncover the small number of truly critical assumptions and to find ways to design check points where the assumptions can be tested ahead of significant investment. The value of the simulation also lies in that it yields a useful estimate of the volatility of profits, which is needed for the application of the Black-Scholes formula to value the option value of the investment.

The Black-Scholes formula provides the basis for option pricing. The authors of the model were awarded the Nobel prize in 1993 for having developed an effective and simple way to price financial options using only five parameters: the price of the underlying asset, the price at which the option can be exercised profitably, the length of time before the option expires, the risk-free rate of interest, and the volatility of the underlying asset. It is easily calculated by using any number of free websites that provide further background on its use.

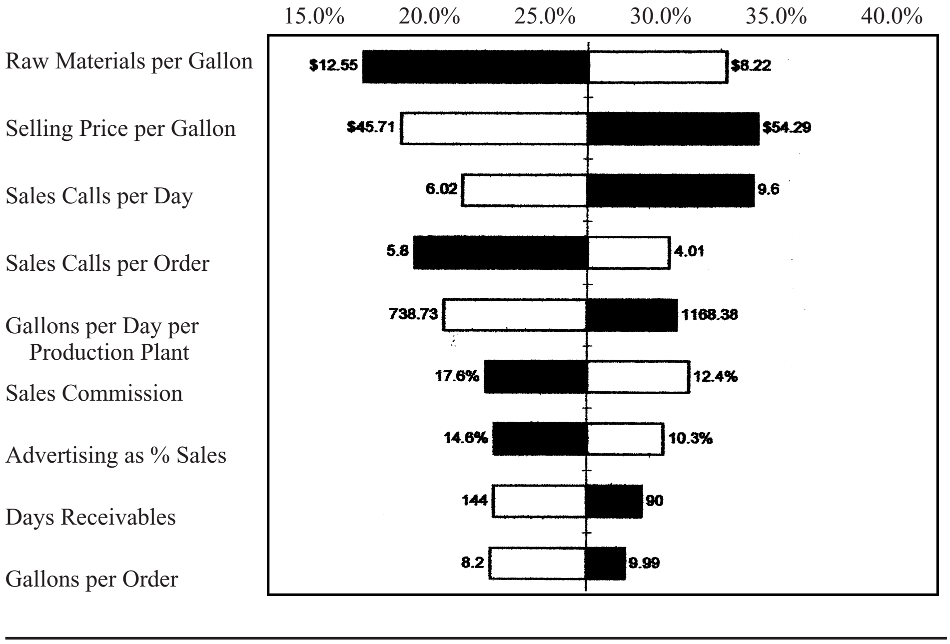
While the Black-Scholes formula is very useful in providing the correct value of financial options, it does have limitations when applied to valuing the option value of real assets. If revenues and costs are simulated separately, their coefficients of variation provide the basis for the volatility calculations of the Black-Scholes equation as modified by what we call the MacVan Adjusted Option Value method. This method corrects a critical flaw in the typical option pricing methodology as applied to real assets such as R&D projects in that it adjusts the option value up or down in accordance with the source of the uncertainty found in a project investment (*2*). A full discussion of real option pricing and the MacVan method is beyond the scope of this article, but we did want to make the link between the information developed by using Discovery Driven Planning and the use of real options valuation for highly uncertain project investments.

Referring back to the sensitivity analysis, Table 5 shows that only four variables explain about 90% of the variance in forecast profits. These are the critical variables. It is common to have no more than 10 variables explain about 90% of the variance in profits. The usefulness of this information is that it directs project teams to focus on those assumptions that are responsible for the bulk of the variability in the projected outcomes.

**6.** *Plan to learn at key CheckPoints*

The concept of CheckPoints is that you plan to test your assumptions ahead of major investments; then, as you reach a CheckPoint, you re-plan using knowledge you have created. As the plan unfolds, your assumption ranges should narrow or the project should be shut down. This leads to disappointment perhaps, but at low cost. In

*Table 5.—Sensitivity Analysis: Return on Assets*




assembling the assumption/CheckPoint matrix, no assumption should go untested and the critical assumptions should be revisited several times, in order to narrow the range of potential values the assumption could have by the infusion of new knowledge gained at that CheckPoint.

In situations of high uncertainty, the only way to plan is to plan to learn, and the only way to accomplish the objectives is to learn the way to achieve them. To identify CheckPoints, start with the major events that are likely to occur as the project unfolds. Common events for manufacturing projects include concept test, model development, focus group test, prototype, market test, pilot plant, full-scale plant initial run, initial sales, initial returns, redesign, and so on. As with assumptions, just because you aren't in control of a CheckPoint, it is still a point at which major assumptions will be revealed to be correct or not. Therefore, that first competitive response should be put in as a CheckPoint, even though it is not possible to know when or who will cause it to occur.

This approach to planning is not only realistic but is also much more motivating than the conventional approach for new technologies. It gives people permission to learn instead of having them feel obliged to justify differences between what was planned and what the reality is.

### Valuing Real Options

How does one calculate the value of a real option? In real-life cases, where there are continuous probability distributions, some theorists and consultants have argued that valuing uncertain investments with flexibility to stop is much the same as calculating the value of a financial option. They go on to say that this can be done by simply applying the traditional Black-Scholes equation used in financial options valuation (see "Black-Scholes Estimate of Real Options Value," next page). Along with many CFOs, *we totally disagree,* particularly in cases where there is high cost uncertainty, which would add to the valuation instead of penalizing it (*3*). We developed the Adjusted Option Value methodology to deal with this, as explained in "Black-Scholes Estimate of Real Options Value."

The mindless use of Black-Scholes is also questionable for several fiduciary reasons. Three concerns that we have heard from CFOs are presented in Table 6. Beside each one we have shown how the Discovery Driven Planning process responds. Without DDP (or its equivalent) the concerns remain valid.

### Combining DDP and Adjusted Option Value

The method we use and recommend combines Discovery Driven Planning and Adjusted Option Value, as follows.

**1.** Develop a Discovery Driven Plan in which all key assumptions are input as ranges, the uncertainty being reflected by the width of the range. All ranges should be constructed with a 90% confidence interval.

**2.** Run a Monte Carlo simulation of the plan to get the expected values and standard deviations of costs and revenues.

**3.** Use the expected values and suitable discount rates to calculate the NPV of the project.

**4.** Use the standard deviations of revenues and costs as a proxy for volatility in a modified Black-Scholes equation

**Black-Scholes Estimate of Real Options Value**

The Black-Scholes equation does an effective job of providing an estimate of the option value provided by project investments, with several caveats. The equation requires only six inputs: the stock price, the time before option expiration, the volatility of the stock, the risk-free rate of interest, and any dividends that might be paid during the life of the option, and of course the price at which the option can be exercised and converted into the underlying stock—the strike price. These inputs track roughly into the output provided by the Monte Carlo simulation as shown below.

| Financial Option Input | Real Option Input |
|---|---|
| Stock price. | The present value of the mean of the projected cash flow distribution generated by the Monte Carlo simulation discounted at an appropriate interest rate that reflects the risk inherent to the project. |
| The time before option expiration. | The time before an irrevocable investment must be made to commercialize the project. |
| The volatility of the stock. | The annualized standard deviation of the cash flow standard deviation divided by the mean of that same distribution derived from the simulation. |
| The risk-free rate of interest. | The U.S. Treasury note rate with a maturity commensurate with the length of time that the option may remain extant. |
| The strike price at which the option can be converted into the underlying stock. | The cost to develop the project to the point of commercialization. |
| Any dividends that might be paid during the life of the option. | Any cash flows that might be generated during development. |

We observed that there are caveats associated with the use of the Black-Scholes model to price the optionality of real assets. The caveats surround the following issues. First and foremost, Black-Scholes must be used carefully to arrive at the value of sequential options such as R&D projects because the value of a sequence of options is not strictly additive. There are better methods that are beyond the scope of this article.

Consider a sequence of three options that can only be exercised in consecutive order. The third option cannot be exercised, meaning that the project development would not continue to be funded unless the second option had been exercised before it and that option could not have been exercised unless the first option had been exercised. Therefore, adding the options together would overstate the value of the project because the third option is comprised in part of the first and second options.

Another objection relates to the way in which all options are calculated, regardless of the method, in that the volatility estimates are based on the uncertainty found in the entire project regardless of its source. This means that there are differing levels of uncertainty surrounding the values of projected revenues and cost estimates. Under current valuation methodology, all uncertainties boost project volatility, regardless of their source, which in turn increases the option value of the project. We do not agree that projects that have greater uncertainty surrounding costs are more valuable than projects that have less cost uncertainty. Costs are very real whereas revenues are often ephemeral.

The MacVan Adjusted Option Value method corrects this bias by adjusting the project volatility downward when there is greater uncertainty surrounding costs than revenues (*2*). This is done by calculating the volatility of revenues and costs separately through the Monte Carlo simulation; if costs have a greater volatility than the revenues have, dividing revenue volatility by the cost volatility and multiplying that ratio by the project volatility will simply adjust the project volatility downward and penalize the option value offered by the project.

To see how this works in practice, consider a project that has the following characteristics derived from a Monte Carlo simulation.

| | |
|---|---|
| • Mean of the distribution of projected annual cash flows | $7,000,000 |
| • Volatility estimate of revenues | 55% |
| • Volatility estimate of costs | 70% |
| • Overall project volatility as traditionally calculated | 60% |
| • Length of time the option will remain in effect | 3 years |
| • Development cost | $20 million |
| • Risk-free rate of interest | 5% |
| • Dividends | 0 |

Given these characteristics, including overall project volatility of 60%, the option value of the project using Black-Scholes is approximately $986,000. By comparison, the MacVan method adjusts for the greater risk that the project holds for the company resulting from having higher uncertainty surrounding the cost estimates than the revenue estimates. MacVan adjusts overall volatility downward in the following way:

Revenue volatility of 55% divided by cost volatility of 70% = 0.7 times overall volatility of 55% = adjusted volatility of 42%.

With this new adjusted project volatility estimate, the option value falls to approximately $326,000. This reduced option value correctly reflects the fact that this project's value should be penalized because of the very real risks inherent with a very uncertain cost structure.—**The Authors**

*Table 6.—Concerns About Black-Scholes*

| Concern | Response |
|---|---|
| Real Options Discipline will be encouraging people to package any and every risky project as a real option play. | This is why a technique like Discovery Driven Planning (DDP) is so important. Unless a real options investment is accompanied by a DDP checkpoint-based plan where the CFO will only release increments of funding as uncertainty is *demonstrably* reduced, there is a real danger of a proliferation of high-risk, high cost-of-failure projects. |
| Real Options Discipline, in acknowledging a high probability of failure, could encourage people to try to package every project as an option play, so that if it failed it would be treated as an inevitable consequence of option-based investing. | First, we need to differentiate highly uncertain projects from those that are more certain. For projects with moderate uncertainty, there is no reason for managers not to "make their numbers" and for the project to be subjected to risk-adjusted NPV criteria. For those projects characterized by high uncertainty, the managerial obligation is to drive down the cost of failure. No manager who could have found ways to reduce the cost of failing to an acceptable minimum should feel that they are immune from censure. So, for uncertain projects there comes a responsibility to do the hard work necessary to identify, document and plan to test assumptions at key CheckPoints™ that have been designed for the purpose of testing these key assumptions ahead of major investment. Over time, this discovery-driven process should either reduce the uncertainty, thus justifying more aggressive investment increments, or the project should have been demonstrated as infeasible and terminated inexpensively. |
| People already "game" with NPV, but if we let them loose with real options they will just keep changing the numbers until their pet project is justified. | The options investment process must be accompanied by the requirement that key assumptions be articulated, challenged, documented, and tested, and the plan redirected in the light of emerging knowledge. This knowledge is deliberately gleaned from the planned, unfolding checkpoints. Over time uncertainty is either reduced, so that NPV begins to dominate, or, the process is terminated at low cost. Discovery Driven Planning obliges project managers to articulate how key numbers are arrived at, and how they will be tested and confirmed, as the project progresses. This actually exposes attempts to game. |

using the MacVan method to calculate an Adjusted Option Value (AOV) of the project.

**5.** This yields the Total Project Value (TPV) = NPV + AOV.

**6.** Run a sensitivity analysis to find the most critical assumptions.

**7.** Define how the most critical assumptions can be tested.

**8.** Develop a CheckPoint plan that specifies when these assumptions will be tested (as early as possible), along with cost estimates to do so.

**9.** At each CheckPoint, estimate the minimum investment required to get to the next CheckPoint, and what the current TPV is.

**10.** If the current TPV is greater than the cost to get to the next CheckPoint, fund the next step. If not, discontinue. Remember to live by the venture capitalist dictum, "Fail fast, fail cheap, move on."

We argue that for a firm that has more projects under consideration than it can fund or staff, the issue is not what the precise value of a specific project is, but rather whether this project is preferable to other projects competing for the limited pool of funds and talent. As long as we are comfortable that all the projects applying for funds are being valued the same way, the problem is not to quibble about exact value, but to select, and assign resources to the best projects using relative values.

Additionally, if a project has too high an option value in relation to its TPV, we suggest that it may not be the best choice because of the high level of uncertainty surrounding it—there are surely other projects that don't depend so heavily on the option portion of their Total Project Value.

### Recommended Actions

We repeat: we do not recommend immediate firm-wide implementation of the combined DDP/AOV. We suggest that you start by selecting three pilot projects, where your CTO's gut-feel suggests they deserve funding but conventional decision making tools lead to an NPV that says otherwise.

Working up and executing a well-configured Discovery Driven Plan and Adjusted Option Value for each will begin to flesh out which specific approach will work for your firm and convince your CFO that you can both invest to win in the highly uncertain technology race while preserving fiduciary responsibility.

**References and Notes**

**1.** CheckPoint is a trademark of Triad Consultants, Ltd. Crystal Ball is a trademark of Decisioneering, Inc.
**2.** A. van Putten and I. MacMillan. "Making Real Options Really Work. *Harvard Business Review* December 2004, pp. 134–141.
**3.** An alternative approach would be to use a Binomial Lattice, but this too does not penalize high cost uncertainty.