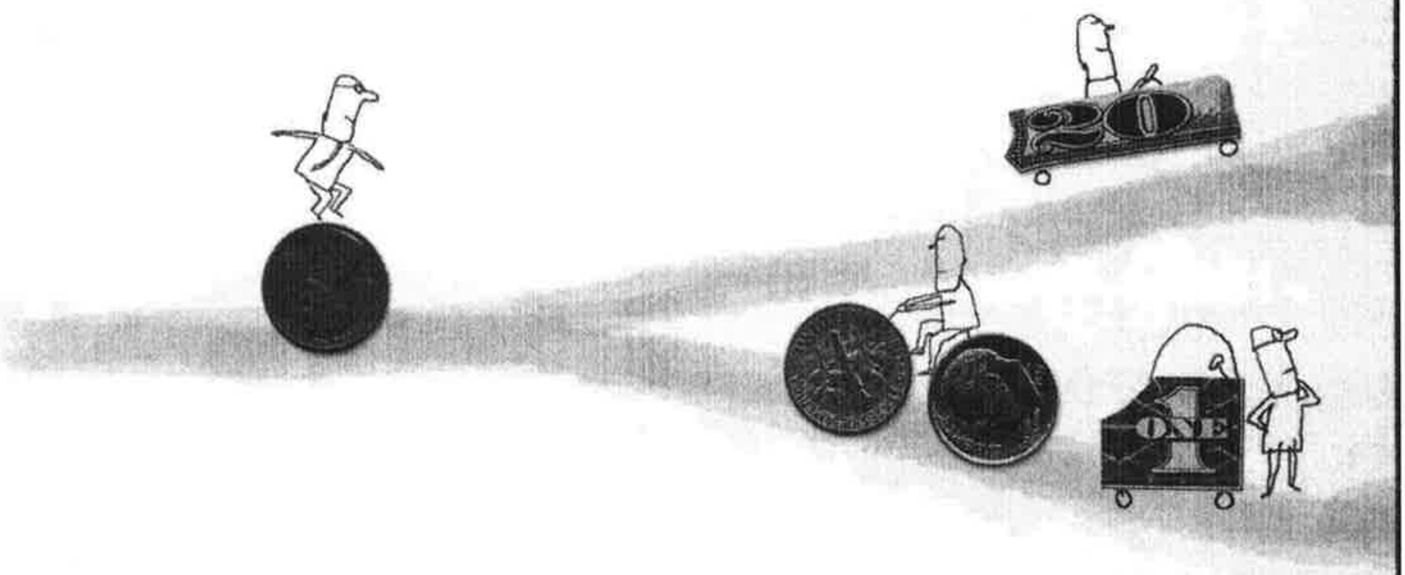


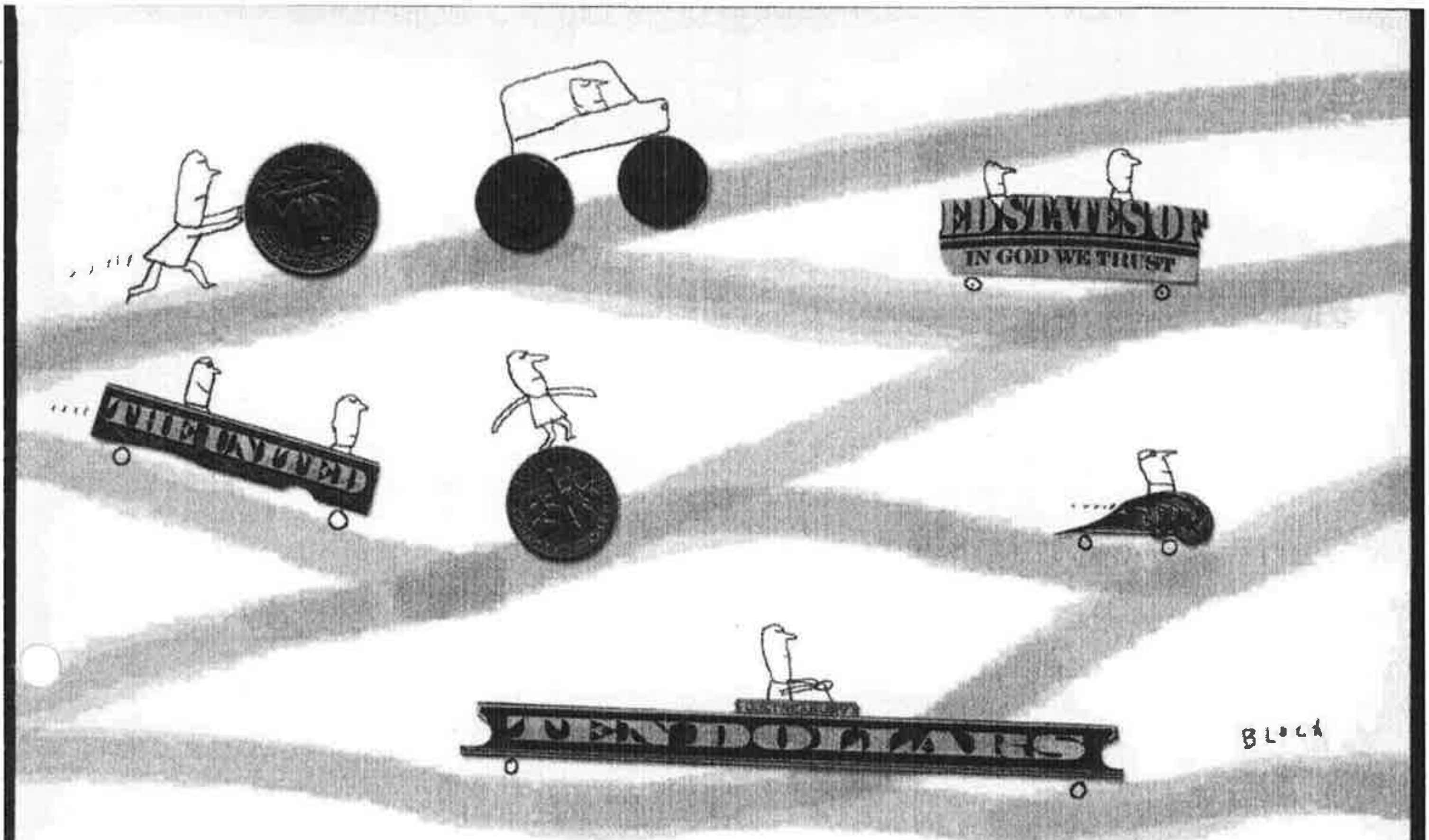
A Real-World Way to

by Tom Copeland and Peter Tufano

THE MARKET VALUES a growth company largely by estimating the prospects of its portfolio of growth projects. These projects – research and development, investments in new capacity, geographical expansion, and other initiatives – are seldom simple onetime decisions; in most cases, a company's investments are multistaged, and at each step the company may push ahead or pull out after gaining new information. These projects are thus options – "real" options, as opposed to financial options – in which managers have the right but not the obligation to invest. It's therefore appropriate that managers have begun to apply option theory to help them make decisions about these projects. Indeed, a survey of 4,000 CFOs published in 2001 by John Graham and Campbell Harvey found that 27% of the respondents claimed they "always or almost always" used some sort of options approach to evaluating and deciding upon growth opportunities.

But there are, it seems, at least as many customers who are dissatisfied with this tool. Also in 2001, a "Management Tools and Techniques" survey by Bain & Company of 451 senior executives who had tried the real-options approach showed that fully a third of them had given up using it that same year. The reasons for this high defection rate seem just as sensible as the reasons for using the tool and are usually based on technical grounds. As many executives point out, options embedded in management decisions are far more complex and ambiguous than financial options. Their concern is that it would be dangerous to try to reduce those complexities into standard option models, such as the Black-Scholes-Merton model, which have only five or six variables. What's more, in the wake of the high-tech collapse, it's easy to see why people might be skeptical of a valuation tool that arguably exaggerated those companies' growth potential.

Critics are right to point out problems with the most widely used option-based methodologies for valuing a company's growth choices. Yet the technical difficulties of real options are easy to address: There are valuation methodologies that effectively capture the complexities and the iterative nature of managerial decisions, and the Black-Scholes-Merton model is not the only, or even the most appropriate, way to value real options. The valuation model we present here is a binomial model, so called because in each time period the value can only go up to one particular value or down to another. It captures the contingencies of real options and addresses nearly all of



Manage Real Options

Real options don't have to be a black box. Here's an approach that not only makes the math of options easier but also helps you make better decisions about exercising them.

the most commonly voiced criticisms of using option theory to manage those contingencies.

We do not maintain, however, that simply switching to a binomial model will put everything right, for the biggest problem with real options (though it is seldom voiced) is more managerial than technical. Much of the gap between the theoretical and realized values of companies' growth projects may be the result of a disconnect between the way managers value options and the way they manage them – a problem that, incidentally, applies to both real and financial options.

In calculating real-option values, most managers, academics, and consultants assume that option holders will always make optimal exercise decisions – timely choices based on rational analyses of all the available information. But if an option holder fails to make exercise decisions optimally, the options become far less valuable. If you buy auto insurance, for example, but do not file a claim when you have an accident, you will have overpaid for the insurance. In the same way, if you purchase a call option on a stock that appreciates wildly, but exercise it at the wrong time, you will have overpaid for the option. There is a longstanding and mounting body of evidence showing that even financial options are exercised suboptimally. At times, holders are trigger-happy, exercising too soon; at other times, they fall asleep at the switch. If holders of financial options don't always behave optimally, we can scarcely expect holders of far more complex real options to behave any better.

What can managers do about the danger that real options will be exercised at the wrong time? They could give up on real options, throwing away a tool that ideally captures the contingencies in managing growth opportunities. Or they could adjust the model by assuming that their behavior will be suboptimal. That would give a more accurate value for the options – but at the expense of institutionalizing and perhaps perpetuating inferior decision making. Our preferred solution is to change the processes

SERGE BLOCH

of corporate planning and budgeting to help improve the timeliness of managerial decisions; after all, good management is as much about making decisions at the right time as about making the right decisions. But before we review the managerial aspects of real options and present our suggestions for how companies can make their decisions more timely, we'll explore the technical issues and present our preferred valuation methodology.

Choosing the Right Model

Critics of options-based approaches to valuing and managing growth opportunities often point out that there is a world of difference between relatively simple financial options and highly complex real options. These differences, they argue, make it practically impossible to apply financial-option models to real-option decisions. They are right about the differences but wrong to assume that they are insurmountable. Valuation models can accurately capture even the most complex real options.

There are two main differences between financial and real options. First, the information necessary to value financial options and make decisions about exercising them is typically much more readily available than for real options. Holders of options on IBM shares can base their exercise decisions on the current price of IBM stock (the option's underlying asset). In some cases, the values of the assets underlying real options are similarly observable. An oil company can estimate the value of its proven reserves if there is an active market for oil properties, or it can estimate a reserve's value by looking at expected extraction costs and the readily observable price of oil.

But in most cases, the value of the underlying asset is not so clear. For instance, the value of an unmade movie sequel or an untested drug cannot be read off a Bloomberg screen. Sometimes the value of comparable assets can be observed – or guessed at. For instance, it might be possible to estimate the evolving value of a new drug based on the past performance of other drugs that treat the same disease. Some critics of the real-options tool feel that these kinds of assumptions render option-based valuation models useless.

Option models are not alone in requiring assumptions, however. Net-present-value analysis of expected cash flows – the main alternative to real-options analysis and the method most firms use to value investment projects – requires making simplifying assumptions that are at least as heroic as any made in an options-based calculation. For example, people applying cash-flow valuation models implicitly assume that all future investments are precommitted – in other words, that the company has already decided to make those investments. That, of course, is never the case. Companies can always choose not to make investments in a project. Furthermore, the common technique of using weighted average cost of capital (WACC) to discount those cash flows assumes that firms adjust their levels of debt to maintain a relatively constant market-value leverage ratio, though firms don't really do this. It is surely no less acceptable to make educated assumptions about the value of the asset underlying a real option. The truth is, all models are simplified representations of reality, and all involve assumptions.

The second important difference between real and financial options relates to the clarity of the options' terms. The right to exercise financial options is unambiguous. For instance, the holder of a particular financial option on IBM might have the right to buy 100 shares at a fixed price (say $85) at any time before a specified maturity date. But it is often unclear what the holder of a real option has the right to buy or how long that right will last. Many real options are sequential, or "compound" – exercising uncovers not an underlying asset but another option. A pharmaceutical company's decision to invest in phase-three testing of a new drug, for example, depends on the outcomes of earlier tests. Indeed, this feature is characteristic of most R&D and product-development projects, in which companies make additional investments at critical points. Even if it is relatively clear what the underlying asset is – a new plant, for instance – the maturity of an option can be indeterminate: Does the opportunity to expand a business last forever or until a competitor takes away the opportunity by expanding first? And whereas the owner of a financial option typically has exclusive rights – for those 100 shares of IBM, say – the same may not be true for a real option: Your company might have the option of building a plant in Brazil, but so do many others.

Many of the problems with real-options analysis stem from the use of a valuation model that demands more simplicity and clarity than the real-options world presents.

> A lot has happened in the world of option value since the publication of the Black-Scholes-Merton model, and the range of options that are amenable to valuation has greatly expanded.

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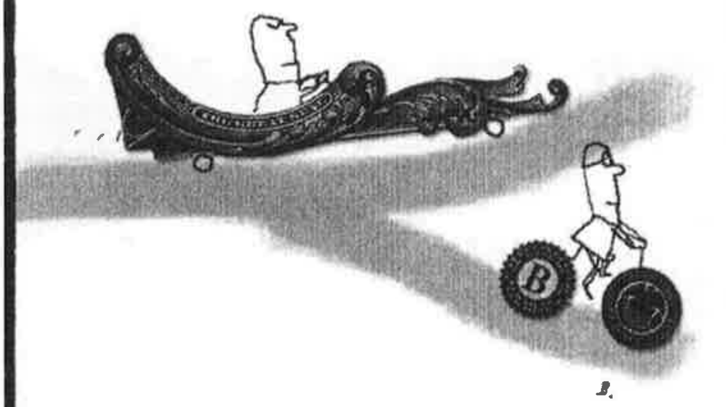


The elegant, Nobel Prize–winning Black-Scholes-Merton model, published in 1973, was designed to value an option that was exercisable only at the end of its life and whose underlying share paid no dividends. It was a breakthrough in economics, because it represented the first complete formula for pricing so-called European-style options. But it was never intended for use with more complicated derivatives, such as compound options, and attempts to use it for real-option valuation are misguided and inappropriate. Fortunately, a lot has happened in the world of option value since the publication of the Black-Scholes-Merton model, much of it inspired by those researchers' groundbreaking insights, and the range of options that are amenable to valuation has greatly expanded. In particular, work by John Cox, Steve Ross, and Mark Rubinstein has led to the creation of binomial, or lattice, models that are built around decision trees and are ideally suited to real-option valuation.

What distinguishes binomial models is that they use algebra. That's a practical advantage over the calculus-based Black-Scholes-Merton model, because it means binomial models can be built using standard spreadsheet software. The math, in other words, is much less formidable, although there may be more of it. Binomial models can also be more easily customized to reflect changing volatility, early decision points, and multiple decisions. Their relative transparency and flexibility mean that you can tinker with a binomial model you've created until it closely reflects the project you wish to value. It is true that building a customized binomial model for each real option involves more work than plugging numbers into a Black-Scholes-Merton box, but most managers evaluating major projects using NPV analysis prefer to create their own spreadsheets anyway rather than rely on generic models. Another advantage is that because the models are more transparent and can be spreadsheet based, even managers whose math skills are long forgotten can understand and thus provide insight into the assumptions. Instead of having to make guesses about the "volatility" of a project's returns, for example, managers can think about the probability that a company's revenues will rise or fall by a particular percentage.

The Binomial Model in Action

Let's illustrate how the binomial model works. Suppose that a commodity chemical company – we'll call it Copano – is considering investing in a new plant. The project will cost \$60 million immediately for permits and preparation, which will take a year. At the end of that year, the firm could invest \$400 million to complete the design phase. Managers believe that once the design phase is over, the firm has a two-year window during which it can invest the \$800 million needed to build the plant. Since the project involves a phased investment, it can be treated as a compound option: A \$60 million investment creates the right to invest \$400 million in one year, and exercise of that choice creates the right to invest \$800 million to purchase a new asset, namely the plant.

Using the binomial model to value this investment project as a compound option is a two-step process. First, you must figure out the full range of possible values for the underlying asset – in this case, the plant – during the project's lifetime. This involves estimating what the asset's value would be if it existed today and forecasting to see the full set of possible future values of the plant. Once you know that, you work back from the plant's value at completion, factoring in the various later investments, to determine the value of the plant-development project today. These second-step calculations provide you with numbers for all the possible future values of the option at the various points where a decision is needed on whether to continue with the project.

Modeling the Value of the Underlying Asset. Modeling the asset's value involves drawing what we call an event tree, which shows the possible future values of the plant under plausible market scenarios. The first step in drawing a tree for Copano is estimating what the value of the plant would be if it existed today, a figure that may be derived from traditional nonoption valuation techniques, such as discounted cash flow. The second step is estimating how much this value is likely to move up or down during the period in question. If we assume that the distribution of possible plant values is fairly standard (what statisticians refer to as lognormal), the factor to apply for an up movement is given by the formula *e* to the power of (sigma multiplied by the square root of the time elapsed), where *e* is the base of the natural logarithm (2.718), sigma is the volatility of the asset (the likely change in the plant's value), and the time, *t*, is measured in years. The factor for a down movement is the inverse of the up factor – that is, $1/e^{\sigma\sqrt{t}}$. Other formulas can be used in cases where the distribution of the possible underlying asset values is not lognormal.

The challenge, clearly, is to calculate sigma. How do you estimate the volatility of a chemical plant's value? The answer is to look at the plant's value drivers. For a commodity chemical company like Copano, plant value is often driven by changes in a single key variable, such as the spread between the price of the output commodity chemical (polyethylene terephthalic acid, or PTA, for example) and the cost of a key input commodity chemical (p-xylene, say). The volatility of such a spread can be easily estimated. By looking at how this volatility feeds into the plant value, which you can do by performing sensitivity analyses on the original discounted-cash-flow model of the plant value today, you can estimate the volatility of the plant's value.

In this instance, we estimate that if the plant existed today, its value would be $1 billion (without optionality), and the sigma, or volatility, of the value is 18.23%. This means that about two-thirds of the time over the course of the next year, the value would be expected to go up or down by less than 18.23% – one standard deviation, or sigma – and that about 95% of the time, its value would go up or down by less than 36.46% – twice 18.23%, or two standard deviations. With a sigma of 18.23%, the up and down factors are 1.20 and 0.833, respectively. In a year, therefore, the plant will be worth either $1.2 billion or $833 million. If the plant's value goes up to $1.2 billion, then the potential year-two values are $1.44 billion and $1 billion. If the plant's value falls to $833 million, the year-two potential values are $1 billion and $694 million. The potential plant values at the end of the third year range from $1.728 billion to $579 million, as shown in the exhibit "Copano's Event Tree." Mapped out on the tree, these numbers show how much the plant could be worth at each stage of the project's life. The tree shows you something else, too: At every point where the tree branches, there is a chance to make a go/no-go decision on whether to build the plant. The next step is to put a value on each of those intermediate real options, as well as on the total compound option of which they are a part, so that you will know whether to hold on to the option or abandon it. If the event tree looks a little crude, don't worry. You can easily make it more complicated by, for example, breaking it down into smaller time periods, thereby capturing more of the intermediate values.

Valuing Your Options. To calculate the possible values of the project as an option at each stage in the decision tree, you have to begin from the end, the point furthest in the future. If you abandon the project, its value is zero. Otherwise, the value at the end of year three is the difference between the value of the plant at the end of year three and the cost of building it. If the plant's value at the end of year three is $1.728 billion, then the project's incremental value at that point is $1.728 billion minus the remaining cost of $800 million needed to build the plant, or $928 million. But if the value of the completed plant turns out to be $579 million – that is, less than the construction cost – the project's incremental value is zero, because you would not invest the $800 million to build the plant. Looking down the right hand side of the exhibit "Copano's Decision Tree," we see three potential scenarios in which the project's incremental value at the end of year three is positive and one in which the costs of the project exceed the plant's value, so the project value is zero.

We now work back from the end of year three to determine the project's potential values at the end of year two. In each scenario, the value will be the larger of the

From Events...

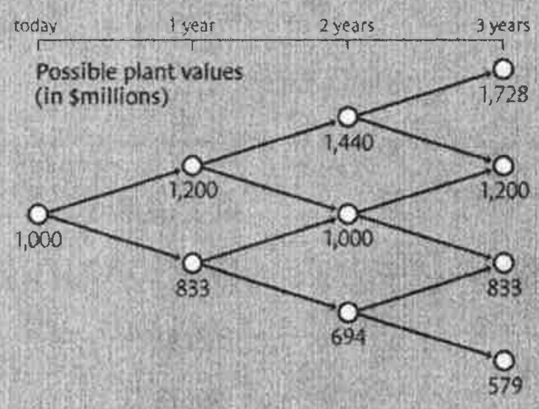
At each decision point in the life of a new chemical plant, Copano's managers need to know what action to take. Should they commit to investing the full amount needed? Keep the project alive by spending a lesser amount? Or simply pull the plug?

So they create a *decision tree*, which shows how the project's value can change over time and lets them decide what action will be best at points along the way.

To build that decision tree, they calculate how much the plant would be worth if it existed today and what its value could be at points in the future. That involves creating another type of tree, called an *event tree*. It reflects how the plant's likely values are determined by fluctuations in the spread between the prices of the input and output chemicals. The calculation of the plant's likely values takes into account the volatility of the spread (see the text of the main article for details).

We'll assume that if it existed today, the plant would be worth $1 billion and that a widening of the price spread would increase plant value by a factor of 1.20 and a narrowing of the spread would decrease the value by a factor of 0.833. The values the plant could have a year hence, two years hence, and three years hence are as shown:

Copano's Event Tree



value of exercising the option by building the plant at that point for a cost of $800 million and the value of keeping the option alive – deferring the decision on whether to spend the $800 million on building the plant until the next period. If the plant is to be built at the end of year two and its value turns out to be $1.44 billion (the highest of the potential values at that period as shown on the event tree), then the value of the project if the firm chooses to build immediately is $1.44 billion less the $800 million exercise cost, or $640 million. If it decides to defer building the plant, however, the company still has a valuable option. To calculate the value of that option, we in principle discount the average of the two payoffs the plant could have at the end of year three (if it is worth $1.44 billion at the end of year two, then it will be worth $1.728 billion or $1.2 billion at the end of year three, as shown on the event tree). Unfortunately, we cannot determine, a priori, what that discount rate should be, because the risk of the option on the project is different from the risk of the project itself. Instead, we have to employ a different approach – one that involves identifying a portfolio that exactly replicates the two payoffs to the option (see the sidebar "The Replicating Portfolio Technique"). Using this technique, we can determine that the

...to Decisions

Copano's managers use the values from the event tree to begin their calculation of the values on the decision tree. We've put a check mark on the choices that would realize the project's maximum value.

Copano's Decision Tree

How did Copano's managers derive the numbers on the decision tree? They worked *backward* from the end of year three, using the values from the event tree, and they relied on the replicating portfolio technique, which is explained in the sidebar with that title. See steps 1 through 4 above the decision tree.

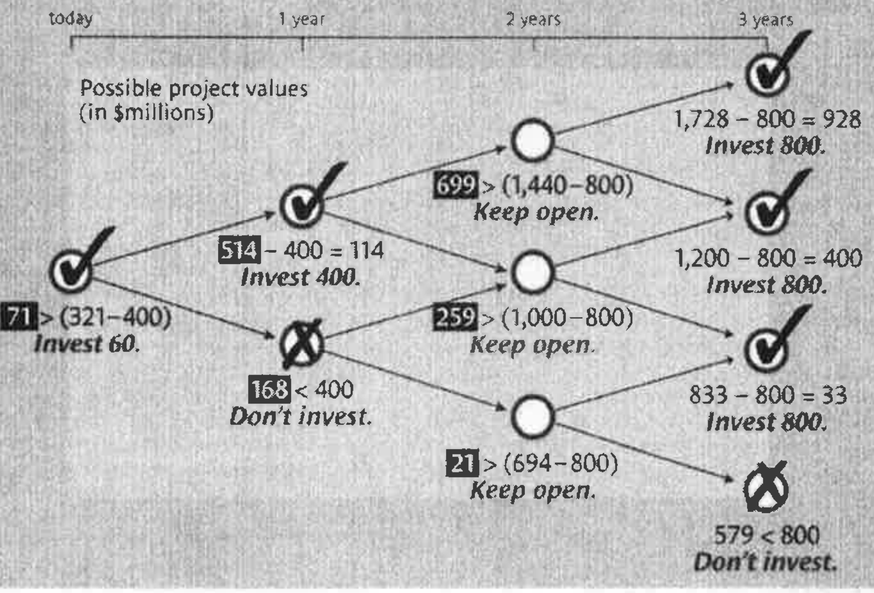
The figures in black boxes are derived using the replicating portfolio technique.

Step 4: They used the replicating portfolio technique to get a starting project value of $71 million. Since the initial required investment is only $60 million, the project is worth the investment.

Step 3: The managers again used the replicating portfolio technique to estimate the value of the project if it were kept alive. But at this point in the project's time line, immediate exercise isn't possible – the most that can be done is to keep the option alive by investing $400 million. If the value of the kept-alive option is less than the $400 million cost of keeping the option alive, they terminate the project; otherwise, the difference – the value of the kept-alive option minus $400 million – becomes the project value at that point in the decision tree.

Step 2: The managers calculated potential end-of-year-two project values by doing two things – they did the same kind of subtraction as in Step 1 (using figures from Copano's Event Tree) to get the value of exercising the option immediately, and they used the replicating portfolio technique to estimate the value of the project if it were merely kept alive; thus they could see which course of action would be better.

Step 1: Copano's managers first calculated potential final project values by subtracting the $800 million cost of exercising the ultimate option – constructing the plant – from the possible final plant values (from Copano's Event Tree on the previous page); for the $579 million scenario at the bottom right of the event tree, the construction cost is greater than the plant value, so the project's value in that case is considered to be zero – the managers would not go ahead.



value of keeping the option alive is $699 million. In this case, that number is greater than the value of exercising the option by building the plant. The right choice for managers, therefore, is to defer building and to keep the option alive; that choice gives them a project value of $699 million. Note that in this simplified model, the numbers show that delaying exercise of the option until maturity is always optimal. In more complex situations, early exercise may sometimes be better, and the model would bring that out very clearly.

What about at the end of the first year, when the company must decide whether to spend $400 million on the design phase? At that point, the project's incremental value is the value of the right to invest $800 million in building the plant over the following two years less the $400 million the firm must invest in order to have that option – but if the result of that subtraction is negative, the project's value is zero. To determine the value of that right to invest, we simply work backward from the possible values at the end of year two that we have already calculated using the replicating portfolio technique, just as we worked back from year three to get the potential values at the end of year two. In one case, a case that matches the scenario on the event tree in which the underlying asset is worth $1.2 billion, we find that the value of having the right to invest is $514 million. Since the cost of acquiring that option is $400 million, the rational course is to invest in design, giving us a project value of $114 million. In the event that the plant value falls by the end of year two to $833 million, the calculation shows that the value of the right to build the plant is only $168 million, which is less than the cost to buy that right, so the company would rationally not invest and would abandon the plant project as having zero value.

The final step is calculating the value of the compound option at the beginning of the first year – in other words, the project's current value – in order to determine whether it merits the up-front investment. This value is determined by the two payoffs of either zero or $114 million. Working back from these using the replicating portfolio technique, we find that the right to invest $400 million in a year's time is worth $71 million, $11 million more than the $60 million cost of permits and preparation. This contrasts with the net present value of minus $9 million, which a conventional NPV analysis would give ($1 billion less the present value of the three capital outlays, which come to $1.009 billion if we assume a discount rate of 10.83% for the industry).

Obviously, to build the tree, managers must make some fairly bold assumptions – about the value of the plant today (supposing it were immediately operational) and how that value might change over time. But we would argue that savvy managers should be thinking not only about today's value (the average of all future values) but also the range of future outcomes. Using our real-option model would force them to do this, and by looking at how the values of their previous chemical plants – and those of competitors – have evolved in the past, they can construct plausible scenarios for those different possible futures.

The Problem of Poor Exercise

Using the right valuation model will make real-options-based management work a lot better. But it doesn't, we regret, go to the heart of the problem many managers have with real options: Managers suspect that the options approach routinely overvalues a company's growth opportunities. These critics are correct to suspect that some kind of valuation error is occurring, but we believe that they are wrong in ascribing the problem to the options approach itself. In our opinion, the real reason that real options sometimes turn out to be less valuable than predicted by models is that managers don't exercise their option rights in a timely and rational manner.

The Replicating Portfolio Technique

As MBA graduates may remember from their finance courses, any option on a share can be expressed as a portfolio consisting of a certain number of shares and a certain number of bonds. For instance, a call option more or less amounts to the same thing as selling a number of risk-free par-value bonds and buying shares with the proceeds. To see how the technique applies here, let's assume we are trying to estimate the value of the option at the end of year two under a scenario in which the plant has a current value of $1.44 billion (the highest-value end-of-year-two scenario).

An option that is kept alive will have two possible payoffs: $928 million or $400 million. This means that a certain proportion of plant value (the equivalent of equity) less a certain amount of bonds with interest (we'll assume a risk-free rate of 8%) will also produce either $928 million or $400 million after a year, depending on whether the plant is worth $1.728 billion or $1.2 billion at the end of the year. Mathematically, we could express this as two formulae: $m(1{,}728) - (1{+}.08)(B){=}928$ and $m(1{,}200) - (1{+}.08)(B){=}400$, where m is the proportion of plant value and B is the number of par-value million-dollar bonds. We have, of course, two unknowns – the proportion of plant value and the number of bonds in the portfolio – but since we also have two equations, we can solve for both unknowns. In this case, the replicating portfolio for an option in the top node in year two calls for one plant worth $1.44 billion and minus 741 par-value million-dollar bonds. Thus the option is worth $699 million.

This is not by any means a new problem, and it is one that financial-option holders suffer from, too. American-style call options give holders the right to buy the stock at any time through the maturity date, and sometimes it is best to exercise an option early rather than sell it to someone else. For instance, before the 1920s, options were not "split protected," so if a company split its stock two for one, cutting its stock price in half, holders of call options could have been wiped out in a day. Early financial magazines carried articles advising investors to be alert to impending splits. While current-day options are protected against stock splits – the exercise prices and number of options are adjusted in response to splits – investors still have to vigilantly keep track of stock dividends, because most options are not dividend protected. Their exercise prices are not adjusted downward when the stock goes ex dividend. It is therefore sometimes best to exercise call options just before the stock loses its right to the dividend.

Recent research shows that individual holders of traded options sometimes exercise their options far too early. A study by Allen M. Poteshman and Vitaly Serbin of outstanding call options on the Chicago Board of Exchange found that brokerage customers exercise 2% to 3% of outstanding calls too early. A 1999 study by Chip Heath, Steven Huddart, and Mark Lang revealed that corporate officers who hold executive stock options also have a tendency to exercise their options too early if there has been a recent run-up in the stock price. (Professional investors are much savvier – the former study showed that proprietary traders never exercise early.)

If investors in traded options suffer from an itchy trigger finger, holders of nontraded financial options may suffer the opposite problem; to mix our metaphors, they fall asleep at the switch. If you hold a fixed-rate mortgage and you have the option to refinance, it is possible to work out the exact amount of interest-rate decline that should cause you to exercise your option to refinance. But some evidence suggests that home owners routinely exercise that option too late, even if they know that the arithmetic works out in favor of refinancing. Corporate financial officers may have the same problem in managing their companies' debt portfolios. Many corporate bonds are callable, so that the company has the flexibility to refinance at a lower rate. Some research suggests that CFOs occasionally exercise those options too late, although this is a debated issue.

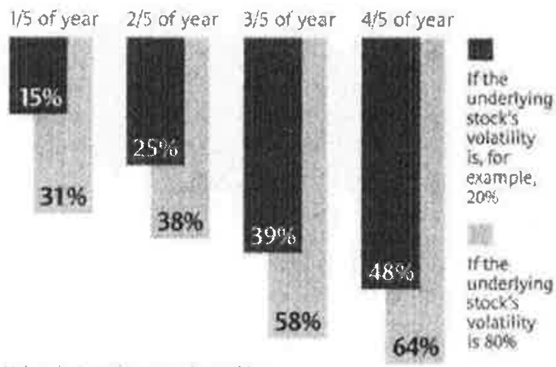
Falling asleep seems to be a particular problem for the issuers of nontraded options, who either forget them or are simply unaware that they have issued them. The insurance industry provides a particularly egregious example. During the 1960s, a standard clause in whole life contracts allowed policy owners to borrow against the cash value of the insurance contract at a fixed interest rate (9%, say) for

The Cost of Falling Asleep

The biggest problem with real options is that managers don't always exercise them at the right time. This graph shows the extent to which value is destroyed when option holders are asleep at the switch – and how the volatility of the underlying asset affects that value destruction.

For simplicity, the exhibit models not a real option but a stock option – a put option with a year to maturity. The underlying asset, the stock, has a value of $100, and the at-the-money option has an exercise price of $100. It is often optimal to exercise a put option early, so the slower an option holder is to "wake up" and make decisions, the greater the gap between the value he realizes and the value realized by a very alert option holder who had been making decisions throughout the year. The four sets of bars represent four hypothetical option holders, ranging from fairly alert on the left to very sleepy on the right. The shaded bars represent the value gap for an option on a stock whose price volatility is 20%; the unshaded bars represent the gap for an option on a stock with much higher volatility – 80%, for illustration. As you can see, the members of the late risers club, at the far right, destroy 48% or 64% of the option's value (depending on the volatility) relative to the very alert holder.

The option holder makes no decisions until after...



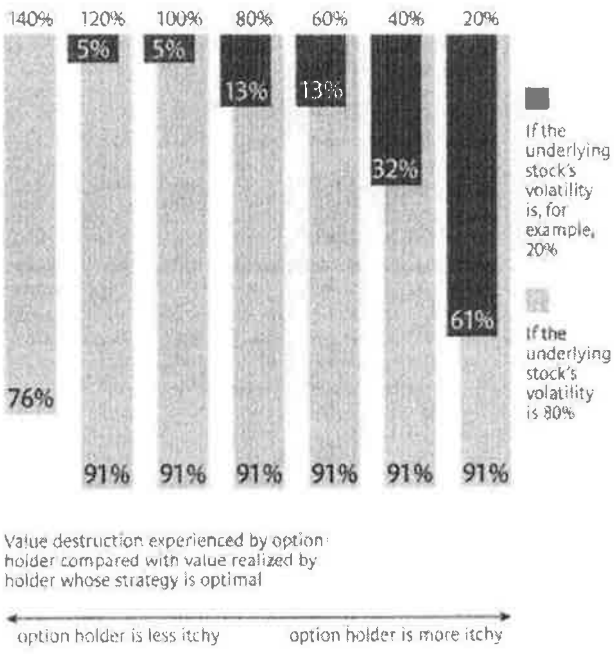
Value destruction experienced by option holder compared with value realized by very alert holder who makes decisions all year long

option holder is more alert ← → option holder is more sleepy

The Cost of an Itchy Trigger Finger

This graph shows what happens when option holders are too quick to pull the trigger and cash in. For simplicity, it models the value of a call option with a year to maturity, where the underlying asset has a value of $100 and the at-the-money option has an exercise price of $100. The underlying stock does not pay dividends, so early exercise is not optimal. The itchier the option holder's trigger finger – as evidenced by her willingness to exercise early – the greater the gap between that holder's realized value and the value captured by an option holder who has the patience to extract the maximum value from the option. The seven sets of bars represent seven hypothetical option holders, ranging from fairly patient on the left to very itchy on the right. The option holder at the extreme left is assumed to apply a rule that leads to exercise the first time the market price of the option is 140% above the exercise price; the itchiest holder exercises as soon as the option is only 20% in the money. The shaded bars represent the value gap for an option on a stock whose price volatility is 20%; the unshaded bars represent the gap for an option on a stock with much higher volatility – 80%. For highly volatile underlying assets, 91% of the value of the option could be destroyed by early exercise.

The option holder's strategy is to exercise if the market price exceeds the exercise price by...



the life of the policy. In 1969, when he was 23, one of the authors of this article purchased one of these policies, which had an expected life in excess of 60 years. Although interest rates were quite low in 1969, by 1981 it was possible to invest in government debt, risk free, at over 20%. It was also possible to borrow from the insurance company at 9% and buy government bonds – a risk-free, self-financing arbitrage, constrained only by the cash value of the policy. As millions of customers woke up to the value of exercising their option to borrow, the insurance companies began to lose money, and several went bankrupt.

The question of whether companies exercise their real options optimally has been much less comprehensively researched. Much of the relevant academic work has taken place in the context of the mining industry, where mine openings and closings can be modeled as options (as indeed they sometimes are by firms in the industry). One study by Alberto Moel and Peter Tufano shows that profitable firms were slower than less profitable companies to close similar mines. This suggests that exercise policy in corporate settings might not be as optimal as one might expect; if the companies were routinely exercising optimally, there would be no differences among them in the timing of closures. All in all, considering that executives may mismanage certain financial options they create or hold, it seems unlikely that managers will always exercise their real options in a timely and rational manner.

The costs of mismanaging an option vary, depending on the volatility of the underlying asset, but they can be substantial, as illustrated in the exhibit "The Cost of Falling Asleep." The exhibit takes the value of an American-style put option (one that can be exercised early) when it is optimally exercised and compares it to the value of such an option in a situation where the investor "wakes up" late and only begins to consider exercising at some point beyond the optimal moment. As the chart shows, suboptimal exercise by the sleepy investor can destroy much of an option's value. The exhibit "The Cost of an Itchy Trigger Finger" shows the difference between the value of an American-style call option held by a careful investor and the value of one held by an investor who chooses to exercise his options in an ad hoc manner, whenever the stock price is some percentage above the exercise price. For high levels of share price volatility, the itchy owner squanders as much as 91% of the option's value. A number of high-tech companies, whose stock-options values depended largely on their perceived growth opportunities, experienced share price declines of these magnitudes.

Managing Binomially

So what can a company do to improve the way it manages its real options? We believe the solution to the suboptimal exercise problem is to make the company's planning and budgeting reflect the decision trees that managers would construct in using the binomial model to value their projects. In practice, this means explicitly looking out for the decision trigger points that correspond to the nodes on a binomial decision tree. If companies are to duck the exercise decisions they must make to maximize option value, this should at least be the result of a conscious choice.

To be useful, the trigger points should not only tell managers when they need to decide on exercise, they should also specify rules governing the exercise decisions. In other words, they should set what academics would call optimal exercise boundaries for an option, like the instructions you might give your broker about exercising your stock options if you're planning to be away on vacation and out of touch. In the case of the Copano project, for example, the timing of exercise decisions was determined by discrete events – the completion of the first two phases of the project. The rule for what decision to make, however, was determined by the spread between the two commodity-chemicals prices that drove the new plant's value. Similarly, Jane McCarthy and Peter Monkhouse of BHP Billiton have written about that company's approach to finding the "critical price envelope" that determines when various mines should be opened or closed. In other cases, however, a company might find that exercise timing is determined by the passage of a particular time period or by a discrete event such as whether or not a competitor has come out with a new product.

Having identified the triggers for option exercise, companies need to clearly designate who has responsibility for the exercising. Decisions don't materialize on their own – people make them. So it is important for companies to identify clearly and in advance who will have responsibility for acting on the trigger. For some kinds of real options, companies already do this. Shell, for example, doesn't have a head of mergers and acquisitions, it has a head of *divestitures* and acquisitions – D&A. The title signals that the person is responsible for the option of divesting as well as acquiring businesses.

Once the managers responsible for the exercise decisions have been assigned, the company needs to make sure those people are properly motivated. Although the decision to exercise an option can be visible and exciting (ground-breaking ceremonies, banners, press releases), some of the best option-exercise decisions aren't flashy. They are decisions like shutting down unprofitable operations or waiting until conditions improve. They can create massive amounts of value, but they don't lend themselves to stories in the company newsletter. Companies need to find ways to reward the people who make these decisions, using means such as combinations of compensation, increased responsibility, and public acknowledgement.

As is the case with any managerial process, companies need to develop ways to track exercise-decision performance. One large South American conglomerate we know of measures its exercise performance by tracking the time lag between the resolution of uncertainty (for example, when the price of a particular commodity hits a trigger point for opening or closing a mine) and an appropriate action by the company. For this kind of analysis to be helpful, however, the trigger points must be unambiguously specified in advance; otherwise, it would be too easy to reinterpret the triggers to favor decisions that have already been made.

Obviously, triggers should not be precise dates or numbers but rather ranges around which there can be some flexibility and debate. Anyone proposing that an option be exercised before the relevant trigger flips would need to present a compelling case. Similarly, anyone suggesting that the company hold on to an option that the trigger rules say should be exercised would have to show how the basic assumptions underlying the project's valuation had changed. In a sense, therefore, the trigger points are like the warning lights on an aircraft's control panel – to be ignored only if the pilot really knows better.

In some cases, companies may find it useful to share their trigger points with investors and analysts, as the information will enable these stakeholders to assess the quality of the company's decision making. Of course, that benefit must be weighed against the risk that the information will also prove enlightening to competitors. But in most cases, companies can find a compromise solution that reveals the quality of their processes without divulging strategically sensitive performance goals. Commercial banks, for example, in communicating their asset–liability management (ALM) policies, explain the general approach they take to hedge their risk, but not extraordinary details about their strategies.

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We believe that the solution to the real-options problem is twofold. First, many companies will find real options much more user-friendly if they move away from the Black-Scholes-Merton model – essentially a cookie-cutter approach to option valuation – and invest the time to build their own binomial spreadsheets. Second, managers who employ flexibility as a strategy must improve their reaction times; by modifying their planning and budgeting systems, they must develop their ability to monitor the conditions for exercise defined in their models. This is particularly urgent as companies grow, because experience suggests that managers' instinctive nimbleness and alertness diminish as their decisions grow in scale and impact. The pilot of a 747 relies a lot more on instruments than does the pilot of a twin-engine Cessna.

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