



Real Options: Valuing Managerial Flexibility

Does the net present value (NPV) approach to investment decision analysis help managers add value? Why do decision makers often overrule NPV-based recommendations on “strategic” grounds? Perhaps the numerical approach misses important considerations that are deemed valuable by managers with “good business sense.”

This note addresses one of these important considerations—the value of managerial flexibility. Managers have many options to respond to changing situations over time; effective valuation techniques should incorporate this option value.

Cash Flows, Risk, Timing, and Discounting

One of the key financial tasks facing managers in their quest to enhance value in an uncertain world is the allocation of resources over their many potential uses. This is as much a strategic task as a financial one; but financial practice includes several tools for allocating capital to investments that will add value. These tools deal with the business realities of cash flows, time and risk, providing managers with numerical techniques to “keep score” and assist in the decision-making process.

Discounted Cash Flow (DCF) Analysis

Discounted cash flow (DCF) analysis is a popular financial technique, integrating many of the basic concepts of finance theory. Unknown risky future cash flows are summarized by their expected (mean) values, and are discounted to the present at a risk-adjusted discount rate, and compared with current costs, yielding a net present value (NPV), a single, simple measure for decision making. This recipe calls for boiling the future prospects until they are sterilized of all problems of timing and risk, leaving behind only a solid measure of value. Before salting to taste (with qualitative issues that “don’t fit in the numbers”), it is good to know what the recipe leaves out.

Take a simple risky courtyard motel project that provides a single payoff in one year (after construction and syndication). You are looking at a new market where the next year will determine whether small courtyard motels are popular or unpopular in that market. That risky cash flow will be \$13 million in the “popular” outcome, or \$9 million in the “unpopular” outcome; the outcomes appear equally likely at this time. A project of this risk calls for a discount rate of 10%. The DCF technique summarizes the risky cash flow by its *expected value*, or probability-weighted average.

Professor Michael E. Edleson prepared this note as the basis for class discussion.

Copyright © 1994 by the President and Fellows of Harvard College. To order copies or request permission to reproduce materials, call 1-800-545-7685, write Harvard Business School Publishing, Boston, MA 02163, or go to <http://www.hbsp.harvard.edu>. No part of this publication may be reproduced, stored in a retrieval system, used in a spreadsheet, or transmitted in any form or by any means—electronic, mechanical, photocopying, recording, or otherwise—without the permission of Harvard Business School.

Here, the expected value is \$11 million, so the present value of the project, discounted at 10%, is \$10 million. If the current construction cost is \$9.7 million, then the NPV of the project is +\$300,000 (NPV>0); the project adds value, and you begin construction.

What is wrong with this approach? It deals with the risk and timing of the cash flows appropriately. But it does not deal with management's ability to time its *decisions* to take maximum advantage of the riskiness in the cash flows. In this case, does management have an option that we have ignored?

A Simple Option

Management has an option to wait a year (or more) before deciding on construction. They can wait out the primary uncertainty in the market during this next year, and then decide on the investment at that time. If these types of motels turn out to be unpopular, then it would make little sense to invest \$9.7 million to make \$9 million a year later. If, however, the market reveals itself to be attractive, then an investment of \$9.7 million in Year 1 would assure a \$13 million payoff in Year 2, giving a NPV of \$2.12 million in that future outcome. Since you have a 50-50 chance of a good outcome (build; \$2.12 at Year 1) and a bad outcome (don't build; \$0 at Year 1), your expected value at Year 1 is \$1.06 million. Discounted back to the present, your NPV is \$960,810 now, if you wait and decide next year. The cash flows and project values are summarized here:

	<u>Uncertainty</u>		<u>Invest Now</u>		<u>Wait</u>	
Now	? PROB=1/2 ^		-\$9.7 ^		0 ^	
Year 1	Unpop	Popular	\$9	\$13	0	-\$9.7
Year 2	Unpop	Popular	—	—	—	\$13
			(NPV = \$300,000)		(NPV = \$962,810)	

Here, the value of management's option to wait was quite high, even higher than the positive-NPV project. By ignoring this valuable option, we could have invested too early and missed a chance to add considerable value.

Management can essentially make risk work for them, rather than against them, in this case. When managers can *choose*, rather than being *locked into*, investment opportunities, one-sided payoffs may emerge (with the bad outcomes left on the table). DCF techniques give a NPV that is basically a probability-weighting of a collection of potential NPVs (some negative, some positive) for *all* the possible future outcomes. It inherently assumes management's future role is *passive* (even in the most extreme outcomes) once the original investment decision has been made. If management can actively respond to surprises and somehow *avoid* the NPV<0 outcomes, the true value of its opportunities will be *higher* than the standard NPV calculated.

OPTIONS

What is an option? An option gives its holder the *right*, but not the obligation, to buy (*call* option) or sell (*put* option) a designated asset at a predetermined price (*exercise* price). Options have value because their terms allow the holder to profit from price moves in one direction without bearing (or, limiting) risk in the other direction.

An *American*-style option gives the right to exercise the option at any time before maturity; *European*-style options may be exercised only at maturity. A table to help with pricing European options is provided in **Exhibit 1**.

Example: As this is written, the price of gold is \$390/oz. 5-month options on an ounce of gold traded at these prices:

Exercise Price	Option Price	
	Call	Put
380	\$21.80	\$5.40
400	\$11.30	\$14.30

The 380 call is “in the money,” since it allows you to buy \$390 worth of gold for only \$380. But if you exercised it now, it would only net you \$10; holding the option has more value. The 400 call is “out of the money,” as you would not pay \$400 now for \$390 worth of gold; yet, it still has value, since volatile gold prices may easily exceed \$400 before maturity.

What affects option values? Characteristics of the underlying asset and the terms of the option themselves have an impact on option value, in the direction shown below. These impacts are unambiguous, except in cases marked by a (*).

As ____ increases,	Option Value	
	Call	Put
Asset Price	↑	↓
Exercise Price	↓	↑
Maturity	↑	↑*
Volatility	↑	↑
Interest Rate	↑	↓
Dividends	↓	↑

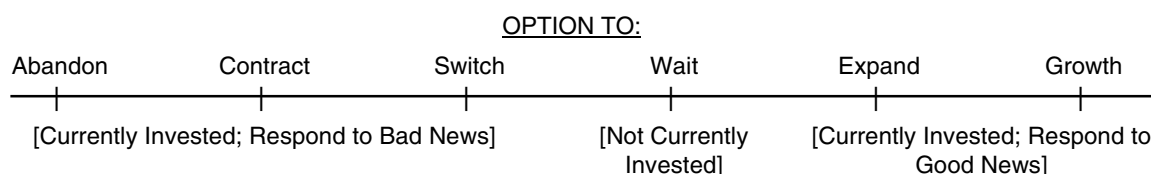
Real Options

Options in general, and their standard terminology, have been described in the box above. Most students of finance have at least a passing familiarity with *financial* options (on *financial* assets), such as a call option on shares of IBM, or a put option on a stock index.

Real options—where the underlying assets are *real* assets—are implicitly held by companies who manage their business and investment opportunities. The motel magnate above, faced with the construction/investment decision, holds a valuable option (to defer), hinting at the importance of real options in evaluating investments.

Types of Real Options

Real options are as pervasive in real life as management’s flexibility and ability to respond to developments over time. Six general categories of these real options are (1) growth options, (2) the option to expand scale, (3) timing (the option to wait), (4) the option to switch (inputs, outputs, or processes), (5) the option to contract scale, and (6) abandonment options. These options are arrayed below on a rough spectrum of the type of “news” that might cause the managerial response behind each option (and its inherent value):



Abandonment options are important in capital intensive industries where management would like to have the flexibility to capture some (resale) value for assets if their in-use value to the company falls. Also, in high variable-cost industries, the option to shut down is quite valuable. The option to either contract or expand scale is a flexible means of dealing with changing demand; simple examples are the ability to slow the rate of mineral extraction from a mine, or to easily add a temporary third shift at a factory. The option to switch encompasses the ability to change product mix, the value of cross-trained workers, land use flexibility (e.g., switching crops), and the ability of a plant to switch between coal and natural gas, in response to changing input and output prices. Timing options (to wait/defer) are valuable in natural resource industries and many capital investments—anyplace where the investment (to begin operations) is irreversible. Growth options are discussed immediately below.¹

Here are a few examples of some of these real options:

Growth Options

A Japanese recording label is considering producing a debut album for the Kyoto-grunge band Crashed Pumpkins (it has signed them to a 0-2 album contract). It has two alternative marketing plans for albums; it can do either, neither, or both (over two years). Plan A cost ¥250 million up-front; Plan B costs ¥400 million but has 50% higher revenues. Its arrangements with the group and distributors are such that its own revenues are an all-or-nothing proposition: Plan A returns ¥440 million in a year if the Pumpkins are a “hit”; but ¥0 in the equally likely outcome that the album “bombs.” The record label uses a 10% cost of capital in evaluating such investments.

Using standard DCF techniques to value this investment, the Crashed Pumpkins may never make it to the studio. Plan A has an expected cash flow (all in millions) of ¥220 in a year, worth ¥200 now, giving a -¥50 million NPV. The bigger deal looks even worse; Plan B has a hugely negative NPV of -¥100 million.

The recording label wisely (?) goes ahead with Plan A. It decides to pursue the smaller marketing plan for the debut album to “test the waters,” holding a growth option in reserve. The growth option is their ability to release a second album next year, if the first album proves a hit. Each project looks awful independently, but the information gained in one outing helps to either avoid disaster or ensure success the next time out. Here, the company invests ¥250 now, and has an equal chance of getting nothing (and doing nothing further), and getting both ¥440 plus a successful investment in a second, bigger album, in a year. In this simple example, the second album will be a hit (¥660 in year two), as it will be released only if the first album proves a “smashing success.” Thus, in the 50% “good” probability, the ¥660 in year two is worth ¥600 in year one, less the ¥400 cost (of Plan B), plus the ¥440 payoff from the first album; this is equivalent to a ¥640 cash flow in year one. Combined with the 50% “bad” probability cash flow of ¥0, the expected (mean) cash flow in year one is ¥320; discount this to the present at 10%, and the present value of first album (plus potential follow-on opportunities) is ¥291. Comparing this to the ¥250 cost, we get a “true” NPV for the entire

¹For a more thorough taxonomy and overview of real options and their interactions, see L. Trigeorgis, “Real Options and Interactions with Financial Flexibility,” *Financial Management*, Autumn 1993.

Crashed Pumpkins venture, of +¥41 million. Here, the option value that we might have ignored is ¥91 million (+41 - -50).

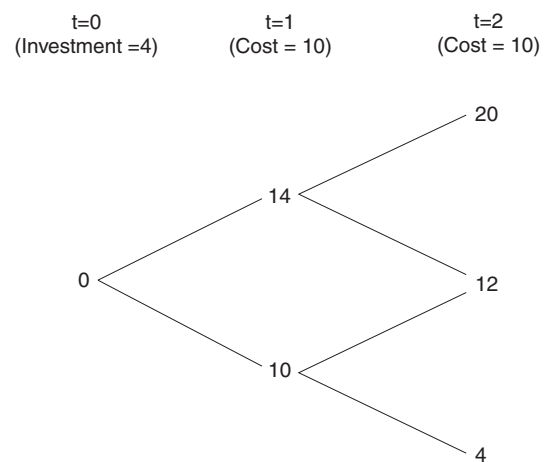
Growth options can be quite valuable, especially in industries with heavy research and development, “venture” companies, and long-lived projects and businesses with several phases. Establishing a “brand name” is a typical application of the concept of valuable growth options. Some researchers² have found upwards of half of the market value of some industries to be due not to currently planned activities, but instead due to growth options.

Abandonment Options

Quickclaims, Inc., a mining concern, is considering opening up a new short-life gold mine with an initial investment of \$4 million for a two-year claim. The expected cash flows from the mine are +\$2 million in a year, and another +\$2 million in two years. Based on the calculated NPV of -\$0.53 million (@ discount rate of 10%), you would probably advise Quickclaims to leave this opportunity buried.

Quickclaims proceeds to buy into this and other similar investments, and its stock price goes up as this becomes known. Let’s look at where the expected cash flows “came from,” and see if we can figure out what is really going on.

Gold prices are highly volatile, and Quickclaims’ potential revenue is based directly on these risky prices. The figure here shows the projected future revenue in each of the next two years, depending on the outcome of (equally likely) gold price movements. If gold prices go up in both years, the mine will see revenue of \$14 million in the first year, and \$20 million in the second year. If prices go down for two years, revenue will be \$10 million, followed by \$4 million in the year two. These are just the revenues; *costs* will be \$10 million in each year that the mine is operated. Now, note that the expected value of the future revenue in each year is \$12 million; after costs, the expected cash flow in each year is indeed \$2 million.

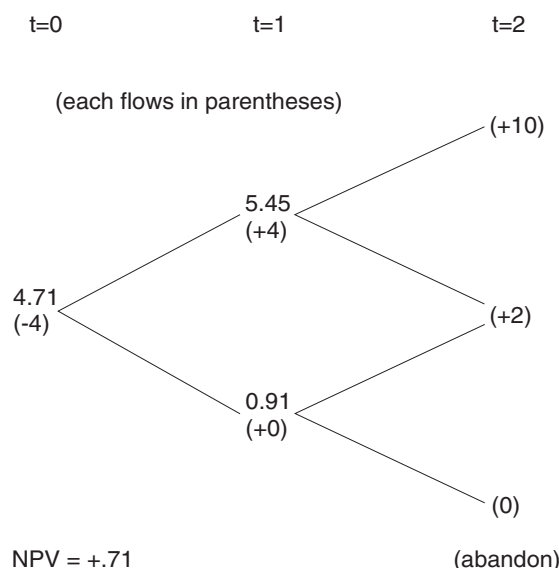


The problem with this analysis is in the bottom “node” of the second year. With only \$4 million of revenue, it makes little sense for the mine to run at a \$6 million loss (and yet, this number is “rolled into” the DCF calculation with a $1/4$ probability). The company would likely *abandon* mining operations in such a poor market, giving a net cash flow of \$0 at that node (instead of -\$6). The figure below gives the net cash flows, assuming the mine is operated in year one, and at all but the very worst outcome in year two:

² For example, see Carl Kester, “Today’s Options for Tomorrow’s Growth,” *Harvard Business Review*, March-April 1984.

The 5.45 value represents the probability-weighted discounting of the \$10 and \$2 profits (year 2) back to year 1, if the first year's price is high. The 0.91 value discounts the \$2 profit and abandonment (\$0) outcomes of year 2 back to year 1, if the first year's price is low. Allowing also for the first year's profits of either \$4 or \$0, all of the potential cash flows discount³ back to the present value of \$4.71 million. This exceeds the \$4 million investment cost, for a NPV of +\$.71 million, including the managerial option to abandon.

Abandonment options exist in most businesses, and are most valuable when uncertainty is high, and/or when operating margins are low. In general, abandonment options are not as significant as their growth option counterparts.



Timing Options

We have already seen the potential value of the option to wait, in the case of the motel investment. An $NPV > 0$ may indicate that an investment is in order; but not necessarily optimal to invest *now*. Here's another example that is more realistic, and does not require information about future prices and probabilities.

A Bubblin' Crude (ABC) is an oil company faced with a great investment opportunity to develop some large reserves under government land. Based on oil prices, they calculate the present value of the future cash flows from the reserves to be currently \$100 million. They can "buy in" now with an investment of \$80 million, all told.

Alternatively, they may pay a \$6 million up-front lease fee to reserve the right to wait two additional years, and then pay an even higher investment of \$90 million at that time to develop the reserves. That is, they have (or can buy) an *option to wait* for two years before investing. Interest rates are 8%, and based on the volatility of the price of oil, you calculate that the oilfield value (currently \$100 million) has an annual standard deviation of 35%.

You can use the table in **Exhibit 1** to solve for the value of this lease-wait alternative. You have a two-year European-type call option on an asset worth \$100, with an exercise price of \$90. By calculating two numbers, you can get the value of the option⁴ (as a % of the \$100 million asset).

³Even this analysis isn't exactly right; the problem has to do with the discount rate. When discounting the expected values, we used a 10% discount rate that reflected the riskiness of the outcomes (spread from -\$6 to +\$10). But the option to shut down avoids the -\$6 outcome in year 2, giving us a "tighter" spread of possible outcomes. Thus, a lower discount rate is in order to reflect the lower risk; we have slightly undervalued this option to abandon. The converse is true for growth options (any option that increases the spread on the upside).

⁴Note that this approach (option valuation, instead of "discounting decision trees") avoids the problem of the proper discount rate, discussed in the previous footnote. The option pricing technique does not require the risk-adjusted discount rate as an input; only the risk-free interest rate is required. Option pricing theory is based on relative valuation of the option and its underlying asset; the risk-adjusted discount rate used in valuing the asset adds no helpful information (beyond the asset price itself) to the valuation of the option.

The present value of the exercise price is $90 \div (1.08)^2 = \$77.16$

The share price $\div$ PV{exercise price} is $100 \div 77.16 = 1.30$ (so, look in that row)

The annual $\sigma \times$ square root of time = $.35 \times \sqrt{2} = 0.50$ (so, look in that column)

The table gives us an option value of 31%.

The option value is 31% of asset value = $31\% \times \$100 = \$31$ million.

Now we can decide on the best course of action for ABC. The NPV of the oil investment appears to be +\$20 million ($=100-80$), based on doing it now. The option value of the oil field as a future opportunity is considerably higher—\$31 million in present value.⁵ Of course, since we would have to pay \$6 million now to secure that value, the NPV of the “lease-wait” alternative comes down to +\$25 million ($=31-6$). ABC’s executives might have jumped at the highly profitable “drill now” decision, leaving considerable value on the table. A bit of patience in this case is worth an extra \$5 million.

Summary

Real options are practically everywhere around us. They can be quite valuable, and are an important factor in the resource allocation process. Even managers who adhere strictly to non-option DCF techniques will generally assign some qualitative value to flexibility where it seems important. The value of managerial flexibility can also be dealt with directly, so that they can be considered in conjunction with standard NPV decision rules.

This is not to say that real options are easy to deal with. They are often hard to identify, and usually multiple species of options can get tangled together in complex fashion (there may be an option to wait on a project with an option to grow, to abandon, and also to switch fuels). The valuation of even the simplest real-life real options can be fraught with a magnitude of complexities, making the approach more difficult to apply than more traditional techniques. Still, a failure to consider these valuable options, at least at a conceptual level, will usually result in suboptimal decisions that pass up considerable value. Important corporate concerns that are often termed as strategy issues or strategic value, turn out to be reflections of managerial flexibility that have real option value. Managing this value may be a critical component of the important job of resource allocation in an uncertain environment.

⁵Where does this option value come from? In this case, it is the bad outcomes (low oil prices) that one might avoid with the flexibility built into the two-year lease. If oil prices sink, and the value of the oilfield in two years is less than \$90 million, we can walk away. We avoid owning the oilfield, when owning it is least attractive (but get to keep the entire upside). With the immediate purchase, we are committing to the oilfield for better or worse, for higher or lower (oil prices); the option gives us the good without the bad.

Exhibit 1 Calculating the Value of Call Options

OPTION VALUES								
Multiply the percentage in the table, times the share price, to get the approximate value of the call option.								
Share Price ÷ PV of Exercise Price	Annual σ x Square Root of Time							
	0.25	0.50	0.75	1.00	1.25	1.50	1.75	2.00
0.5	0%	3%	10%	19%	29%	39%	48%	56%
0.6	0%	5%	14%	24%	34%	43%	52%	60%
0.7	1%	8%	18%	28%	37%	46%	55%	62%
0.8	3%	12%	22%	32%	41%	50%	58%	65%
0.9	6%	16%	26%	35%	44%	52%	60%	67%
1.0	10%	20%	29%	38%	47%	55%	62%	68%
1.1	15%	24%	33%	41%	49%	57%	64%	70%
1.2	20%	28%	36%	44%	52%	59%	65%	71%
1.3	25%	31%	39%	47%	54%	61%	67%	72%
1.4	29%	35%	42%	49%	56%	62%	68%	73%
1.5	34%	38%	44%	51%	57%	64%	69%	74%
2.0	50%	51%	55%	60%	65%	69%	74%	78%

SOURCE: Calculations using the Black-Scholes option pricing formula.

NOTE: For options on non-dividend-paying stocks.

NOTE: For European *put* values, add PV{Exercise Price} to call option value, then subtract Share Price.

Example: The price of a share of stock is \$50; the stock pays no dividends, and has an annual volatility of 25%. Interest rates are 5%. Price a 4-year call option on the stock, exercisable at \$60/share only at maturity.

Calculation: The option value is approximately **\$10**:

The PV{Exercise Price} is $60 \div (1.05)^4 = \$49.36$

Share Price ÷ PV{Exercise Price} is $50 \div 49.36 = 1.013$

The Annual σ x Time is $25\% \times 4 = 50\%$

Row 1.0, Column 0.50, Table gives **20%**

Option Value is 20% of Stock Price = $20\% \times \$50 = \$10$