The concept of options and real options in investment appraisal

A net present value (NPV) calculation within an investment appraisal evaluation normally assumes that a project commences immediately and proceeds until it finishes. It is treating the investment as a one-off decision. Many investment decisions, however, are flexible and managers are faced with several possible actions that could be taken. NPV calculations also largely ignore the strategic value of the projects, such as the opportunity to expand into a new market; develop natural resources such as shale gas, oil, gold, and other minerals; exploiting new technology; or entering into an agreement to acquire or merge with another company.

Risks and uncertainties can be dealt with in NPV evaluations by adjusting the cost of capital, attaching probabilities to outcomes, or conducting sensitivity analysis (which is always recommended). This article reviews the basic concept of evaluating options within investment decisions, firstly, by introducing the concept of options via a simple example; then moving on to look at how we might value an option to aid decision making, and finally we look at the use of the Black-Scholes option pricing model to attach a fair value to an option within an investment decision.

Different types of options include:

Options to delay/defer without losing the opportunity. For example, should we begin mining silver now or wait until the price goes up, or wait until market conditions are more favourable before opening a new store, or wait until the political environment is known with more certainty, for example, when an election is on the horizon, or new legislation is being debated and the outcome is uncertain.

Options to switch/redeploy assets if market conditions change. For example, investing in a flexible manufacturing system that is capable of producing more than one product without any additional switching cost to change, or changing the use of a building, such as an option for a college to change office space into additional teaching space should the capacity be required.

Options to expand/contract operations depending on market conditions. For example, designing projects in a way that is easily scalable may cost more up front but saves money later. Similarly construction projects such as a sports stadium could be designed to incorporate a single tier stand with much stronger foundations than initially required so that if the team (or venue) was successful, and required additional space to accommodate increased attendance in the future, a second tier could easily be added. These are sometimes described as follow-on projects where additional investment is made if phase one is successful. As in the example of the sports stadium, projects such as this often require more expenditure in phase 1 than would be required if there was no follow-on option, thus there is a cost to building in the flexibility (akin to a premium paid for a financial option as we will see later).

Options to abandon/exit a project at various stages during its lifetime. For example, a phased project to expand the market into overseas locations by first establishing an export facility, then later establishing overseas sales offices in key locations, then adding production facilities in key markets, provides opportunities to abandon part or all of the project at various stages within its lifetime. Similarly, projects that involve equipment or facilities that would have a re-sale value at various points within a project lend themselves to reviewing an abandonment option.

Viewing options within investment decisions is therefore useful in situations where there is:

Flexibility: the ability to change the business route over time.

Uncertainty: the value of a project cannot be fully predicted.

Irreversibility: most decisions have no turning back, and as a result imply sunk costs.

Viewing options as real options

An option definition when referring to financial options gives the holder the right, but not the obligation, to buy or sell an underlying asset, such as a share. The option helps to place a value on the flexibility in the decision. For example, a call option (right to buy in the future) on a share allows an investor to wait and see what happens to the price of a share before deciding whether to exercise the option. It is possible, for the price of the option, known as the premium, to benefit from favourable movements without being affected by adverse movements in the price of the underlying asset (the share). Real options, however, refer to the choices or opportunities that a business may or may not take advantage of, or realise. Real options involve decisions that managers make that involve tangible assets. As with financial options real options can involve spending some money up front (like the premium paid for a financial option) which provides the flexibility later.

The concept of real options provides a means of placing a value on the flexibility that is present in many real investment decisions. As with any numerical technique it does not provide the definitive answer to an investment decision, but provides managers with some additional information that facilitates a more informed decision.

Let's begin with a very simple example of dealing with options in investment appraisal.

Option to wait (example 1)

Suppose a company has the opportunity to launch a new product. The initial investment in machinery to produce the product will cost $27,500. There is, however, some uncertainty over the demand conditions for this year due to the impact of a virus that is potentially spreading around the globe and could reduce demand.

If demand for the product proves to be unaffected the net cash inflow could be $10,000 per annum, but if the outbreak adversely affects demand the net cash inflow may only reach $5,000 per annum. The marketing department suggest that there is a 50% chance of the demand being affected.

We could use the concept of probabilities and calculate that the likely cash inflow is:

($10,000 x 50%) + ($5,000 x 50%) = $7,500

Assuming a cost of capital of 10% and a time horizon of 5 years, a net present value calculation would provide the following result.

Year	0	1	2	3	4	5
	$	$	$	$	$	$
Initial investment	(27,500)					
Cash flow		7,500	7,500	7,500	7,500	7,500
Net cash flow	(27,500)	7,500	7,500	7,500	7,500	7,500
Discount factor	1.000	0.909	0.826	0.751	0.683	0.621
Discounted Cash Flow	(27,500)	6,818	6,195	5,633	5,123	4,658
Net Present Value						925

This provides a positive present value but is relatively low.

However, the product development team do not believe that any of their competitors are in a position to launch a similar product and steal the market, so they suggest that it would be a possibility to wait and launch the product next year once the potential demand is more certain.

We could undertake another NPV calculation to illustrate what might happen if the company waited and launched the product next year. As with the normal convention we will assume that all cash flows occur at the end of the year.

If demand is good:

Best case scenario

Year	0	1	2	3	4	5	6
	$	$	$	$	$	$	$
Investment		(27,500)					
Cash flow			10,000	10,000	10,000	10,000	10,000
Net cash flow	0	(27,500)	10,000	10,000	10,000	10,000	10,000
Discount factor	1.000	0.909	0.826	0.751	0.683	0.621	0.564
Discounted Cash Flow	0	(24,998)	8,260	7,510	6,830	6,210	5,640
Net Present Value							9,453
Expected value 50% probability							4,726

This provides a larger positive NPV.

Worst case scenario

NPV calculation	0	1	2	3	4	5	6
	$	$	$	$	$	$	$
Initial investment		(27,500)					
Cash flow			5,000	2,000	5,000	5,000	5,000
Net cash flow	0	(27,500)	5,000	5,000	5,000	5,000	5,000
Discount factor	1.000	0.909	0.826	0.751	0.683	0.621	0.564
Discounted Cash Flow	0	(24,998)	4,130	3,755	3,415	3,105	2,820
Net Present Value							(7,773)
Expected value 50% probability							(3,886)

This returns a negative NPV.

We can see from this basic analysis that there is a benefit with the option to wait and see what the demand conditions are like in one year's time. If demand is high the company would launch the product, but if demand is low the decision not to launch would be more appropriate. This would mitigate the risk of launching the product now and demand being low.

Option to abandon (example 1)

We could also use the same basic approach to evaluate an option to abandon.

Let's assume that the company launched the product and at the end of the first year has the option to sell the plant and equipment for $22,500 and abandon the product. We can treat this as a separate decision, as the initial cost and the first year of trading are effectively sunk costs, and we can use the concept of the opportunity cost to determine that the lost future cash inflows constitute the cost of abandoning the product.

Best case scenario – good trading conditions

Year	0	1	2	3	4	5
	$	$	$	$	$	$
Cash flow (Lost income)			(10,000)	(10,000)	(10,000)	(10,000)
Sale of plant and machinery		22,500				
Net cash flow	0	22,500	(10,000)	(10,000)	(10,000)	(10,000)
Discount factor	1.000	0.909	0.826	0.751	0.683	0.621
Discounted Cash Flow	0	20,453	(8,260)	(7,510)	(6,830)	(6,210)
Net Present Value						(8,358)
Expected value 50% probability						(4,179)

Worst case scenario – bad trading conditions

Year	0	1	2	3	4	5
	$	$	$	$	$	$
Cash flow (Lost income)			(5,000)	(5,000)	(5,000)	(5,000)
Sale of plant and machinery		22,500				
Net cash flow	0	22,500	(5,000)	(5,000)	(5,000)	(5,000)
Discount factor	1.000	0.909	0.826	0.751	0.683	0.621
Discounted Cash Flow	0	20,453	(4,130)	(3,755)	(3,415)	(3,105)
Net Present Value						6,048
Expected value 50% probability						3,024

It may not seem that surprising, but this example illustrates that if demand turns out to be good then it is better to continue with the project, but if demand proves to poor, then it is better to abandon the project.

We have evaluated the various options but so far all we have done is to undertake a NPV calculation for each option available to the company.

Let’s continue with a slightly more complex example, but using the same principle before we move on to looking at how we can use the concept of financial options and the Black-Scholes option pricing model to place a ‘fair value’ on an option.

Option to wait (example 2)

Let’s assume that a company has a choice of investing in a new facility this year, wait until next year, or not at all. The plant and equipment can only be used for this investment and once the decision is made it cannot be reversed.

The cost of the plant and equipment is $50m and the net cash flows arising from the investment are estimated with some degree of certainty at $75M. The cash flows for the next year, however, are less certain and if trading conditions are favourable net cash flow generated could be $100m, but if conditions are bad net cash flow could be $50M. The marketing department predict that there is a 66.66% chance of good conditions and a 33.34% chance of poor conditions.

If the investment is made this year it provides a net present value of:

Invest in this year

Year	0	1
	$m	$m
Investment now cash flow	(50)	75
Discount factor	1	0.909
Discounted Cash Flow	(50)	68.175
Net Present Value		18.175

If the investment is made next year it provides the following net present values:

Good conditions

Year	0	1	2
	$m	$m	$m
Investment next year – Good year cash flow		(50)	100
Discount factor	1	0.909	0.826
DCF		(45.45)	82.6
NPV			37.15

Bad conditions

Year	0	1	2
	$m	$m	$m
Investment next year - Bad year cash flow		(50)	50
Discount factor	1	0.909	0.826
DCF		(45.45)	41.3
NPV			(4.15)

This shows that investing next year if conditions are favourable provides a higher NPV than investing this year, and if conditions are bad the company would not invest.

If we take the expected value of the good scenario 66.66% of $37.15m = $24.76m and deduct the NPV from investing this year of $18.157m we could say that the option to wait has a value of $6.603m.

This is by no means precise, but it provides the management team with more information on which to base a decision. If the decision is made to invest without this knowledge there is a 33% chance the management finds themselves in a situation with reduced net cash flows and regretting having made the decision to invest. With this knowledge, management have a better idea of the value of waiting and having the benefit of additional information on the likely trading conditions.

Wait/abandon phase 2 (example 3)

Supermarkets often have a similar dilemma when entering a new market. Let's assume that a supermarket is planning to enter a new market and the operations team and marketing team have combined to identify the following information.

Open 1 store, 2 stores, or not invest

	$m		$m
Cash flow if high demand	14	50%	7
Cash flow if low demand	8	50%	4
Expected value of cash inflow			11
Investment per store	(10)		

We can undertake suitable analysis as follows:

Invest in opening one store now and operating for 1 year. Let's use the expected value of cash flows generated.

Year	0	1
	$m	$m
Investment per store	(10)	
Cash flow		11
Net cash flow	(10)	11
Discount factor	1	0.909
Discounted Cash Flow	(10)	9.999
Net Present Value		(0.001)

This produces a very low NPV and therefore the company may be uncertain as to whether to proceed. However, let's assume that they have made the strategic decision that there are significant benefits to entering the new market. They take the decision to proceed with the risk that if demand is low the store may lose money.

The cautious approach is to open one store now and then see how demand develops before making the decision to invest in a second and potential future stores.

If demand conditions are good or bad it generates the following NPV's under each scenario for the investment in the second store.

Best case scenario

Year	0	1	2
	$m	$m	$m
Investment per store		(10)	
Cash flow good conditions			14
Net cash flow		(10)	14
Discount factor		0.909	0.826
DCF		(9.09)	11.564
NPV			2.473
Expected value 50%			1.2365

Worst case scenario

Year	0	1	2
	$m	$m	$m
Investment per store		(10)	
Cash flow bad conditions			8
Net cash flow			8
Discount factor		0.909	0.826
DCF		(9.09)	6.608
NPV			(2.482)
Expected value			(1.241)

If demand conditions are bad, then the decision would be not to open the second store. A decision must then be made as to whether to close the first store and cut its losses.

However, we could take the expected value of the good outcome of $1.2365, add it to the NPV of opening one store in year 1 which was $(0.001)m, which would give us an indication that the value of the option to wait is $1.2355m.

This is a fairly crude way of putting a value on the option to wait and various authors suggest that we treat the options in the same way as financial options, and use the Black-Scholes option pricing model that was developed to place a 'fair value' on the options.

Black-Scholes Option Pricing model

The Black-Scholes formula is given as follows:

$$c = S_0\ N(d_1) - K\ e^{-rT} N(d_2)$$

$$p = K\ e^{-rT}\ N(-d_2) - S_0\ N(-d_1)$$

$$\text{where} \quad d_1 = \frac{\ln(S_0 / K) + (r + \sigma^2 / 2)T}{\sigma\sqrt{T}}$$

$$d_2 = \frac{\ln(S_0 / K) + (r - \sigma^2 / 2)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

c = a call option – this is the right, but not the obligation, to buy a share by, or at, a specified date and price, in the future

p = a put option – this is the right, but not the obligation, to sell a share by, or at, a specified date and price, in the future.

There are five variables that we need before we can calculate a value of a real option. The table below illustrates how these relate to the financial option calculation.

Symbol	Financial Option	Real Option
S	Stock price	The underlying asset value, which is the present value of future cash flows arising from the project.
K	Strike price	The exercise price, which is the amount paid when the call option is exercise or amount received if the put option is exercised.
T	Time to maturity	Time before the opportunity expires
σ	Volatility	Riskiness of asset/project. This is measured by the standard deviation and can be derived from past projects or estimated using statistical techniques.
r	Risk-free rate	The risk-free rate which is normally taken as the return offered by a short-dated government bill.

[For the mathematicians among the readers, the e in the formula indicates an exponential term and IN signifies the natural logarithm. N is the cumulative probability distribution function for a standardised normal variable]

The formula can look quite daunting, but it is relatively easy to undertake using Excel and there are excellent free resources that can be downloaded to help. In this article a free resource is used from the Corporate Finance Institute web site that can be found at:

https://corporatefinanceinstitute.com/resources/templates/excel-modeling/black-scholes-calculator/

This is free to use for educational purposes but there are other sites that provide access to a calculator.

Option to wait (example 4)

Let's take an example valuing an option to wait.

A company has the opportunity to bid for a contract that will give it exclusive rights to manufacture and market a new product in its home country. The initial set up costs would be $50m and the cash flows generated over a four-year period are estimated as follows:

			1	2	3	4
Cash flow $m			20	25	15	10

However, there is considerable volatility attached to the cash flows. The rights are such that the company does not have to commence manufacturing straight away but could wait 2 years to see how the market conditions develop before deciding to go ahead and manufacture.

If the company manufactures immediately the NPV, assuming a cost of capital of 11%, is as follows:

Year	0	1	2	3	4
	$m	$m	$m	$m	$m
Initial investment	(50)				
Cash flow		20	25	15	10
Net cash flow	(50)	20	25	15	10
Discount factor 11%	1	0.901	0.812	0.731	0.659
DCF	(50)	18.02	20.3	10.965	6.59
NPV					5.875

The difficulty is the high degree of volatility over the cash flows, which means that the future, if a decision to wait is taken, could be quite different. The difficulty is how much to bid for the contract. Logic might suggest that the company could bid up to $5.875m as this is the estimated NPV of the project.

However, what is the value of the option to wait. This is like a call option where we can pay a cost (the premium) to provide the opportunity to buy a share in the future. We can use the Black-Scholes option pricing formula to calculate a value for this option.

S – the asset value would be the NPV of the cash flows generated if we waited. Let's assume a cost of capital of 11% This would be:

Year	0	1	2	3	4	5	6
	$m	$m	$m	$m	$m	$m	$m
Cash flow				20	25	15	10
Net cash flow	0	0	0	20	25	15	10
Discount factor 11%	1	0.901	0.812	0.731	0.659	0.593	0.535
DCF	0	0	0	14.62	16.475	8.895	5.35
NPV							45.34

S = $45.34m

K = $50m

T = 2 years

r = 4.5% (assumed)

ợ = 50%

If we plug these values into the Black-Scholes formula it provides the following value of the option.

Type of Option		Call Option
Stock Price (S_0)	$	45.34
Exercise (Strike) Price (K)	$	50.00
Time to Maturity (in years) (t)		2.00
Annual Risk Free Rate (r)		4.50%
Annualized Volatility (σ)		50.00%
Option Price	$	12.40

Additional Calculation Parameters	
$\ln(S_0/K)$	(0.098)
$(r+\sigma^2/2)t$	0.340
$\sigma\sqrt{t}$	0.707
d_1	0.342
d_2	(0.365)
$N(d_1)$	0.634
$N(d_2)$	0.358
$N(-d_1)$	0.366
$N(-d_2)$	0.642
e^{-rt}	0.91393

The call option has a value of $12.4m. The company could therefore bid up to $12.4m for the exclusive rights rather than the $5.875m. The increase in value reflects the fact that there is a period before the decision needs to be made and the volatility of the cash flows. The benefit of the model is that it is able to take some account of the degree of volatility in the outcomes (future cash flows) without having to undertake numerous NPV calculations. However, as highlighted later under the limitations of Black-Scholes, the model makes some assumptions about the behaviour of the stock market, and therefore it is always advisable to undertake some sensitivity analysis by adjusting the input values to take account of differing cash flows and different degrees of volatility. As with any model it is an aid to decision making, not the decision maker itself.

Follow-on option (example 1)

Let's look at another example where a company has the option to undertake a follow-on project at some point in the future.

Let's assume the following data

Cost of capital	10%
	$000
Initial investment	(750)
Additional investment in year 2	(600)

Year	1	2	3	4	5	6	7	8	9	10
	$000	$000	$000	$000	$000	$000	$000	$000	$000	$000
Net cash flow from first project	150	150	150	150	150	150	150	150	150	150
Net cash flow from additional investment			75	75	75	75	75	75	75	75
	150	150	225	225	225	225	225	225	225	225

If we calculate the NPV for the project overall as one project, it provides the following NPV.

Year	0	1	2	3
	$000	$000	$000	$000
Initial investment	(750)			
Additional investment			(600)	
Cash flow		150	150	225
Net cash flow	(750)	150	(450)	225
Discount factor	1	0.909	0.826	4.409*
Discounted Cash Flow	(750)	136.35	(371.7)	992.025
Net Present Value				6.675

* using the annuity value for years 3 – 10

Management are worried that this is quite low.

So, lets split out the two phases.

Phase 1

Year	0	1	2	3
	$000	$000	$000	$000
Initial investment	(750)			
Cash flow		150	150	150
Net cash flow	(750)	150	150	150
Discount factor	1	0.909	0.826	4.409
DCF	(750)	136.35	123.9	661.35
NPV				171.6

Phase 2

Year	0	1	2	3
	$000	$000	$000	$000
Initial investment	0		(600)	
Cash flow				75
Net cash flow	0	0	(600)	75
Discount factor	1	0.909	0.826	4.409
DCF	0	0	(495.6)	330.675
NPV				(164.925)

Phase 1 is positive but phase 2 is negative, which gives us the low overall NPV for the project. But what if phase 2 is optional? Plugging the values into the Black-Scholes formula we could calculate a value for the follow-on option.

Note we use the $600m as the investment required in year 2 for phase 2, but the NPV of the future cash flows of $330.675m

Type of Option		Call Option
Stock Price (S_0)	$	330.67
Exercise (Strike) Price (K)	$	600.00
Time to Maturity (in years) (t)		2.00
Annual Risk Free Rate (r)		5.00%
Annualized Volatility (σ)		50.00%
Option Price	$	41.24

Additional Calculation Parameters	
$\ln(S_0/K)$	(0.596)
$(r+\sigma^2/2)t$	0.350
$\sigma\sqrt{t}$	0.707
d_1	(0.348)
d_2	(1.055)
$N(d_1)$	0.364
$N(d_2)$	0.146
$N(-d_1)$	0.636
$N(-d_2)$	0.854
e^{-rt}	0.90484

This gives us an option value of \$41.24m. The total NPV could be given as Phase 1 plus the option value. \$171.6m + \$41.24m = \$212.84.

Phase 1 is clearly beneficial, and the company then has the option to undertake phase 2, if it finally becomes worthwhile. Note, again that the benefit of the Black-Scholes model is that it takes account of the volatility of future cash flows.

Option to abandon (example 1)

Let's look at an example of a put option. The option to abandon can be viewed like a put option (the right to sell).

XYZ is part of group of companies that operates world-wide. XYZ is known for its innovative approach to developing new technology projects, but often lacks the marketing expertise to fully exploit their potential. To date XYZ has developed new products which it has effectively sold to the parent company, which then organises one of the operating subsidiaries to manufacture and distribute the product.

XYZ has developed a new product which is ready for launch but the senior management team are uncertain about future demand, however, the marketing department are confident that once consumers use the product and word of the benefits gain momentum the product will do well. The marketing department are so bullish about the product that they want XYZ to manufacture and distribute the product. The NPV for the product was calculated by the finance department as follows:

Year	0	1	2	3	4	5
	$000	$000	$000	$000	$000	$000
Initial investment	(40,000)					
Cash flow		1,750	5,500	12,500	15,000	20,000
Net cash flow	(40,000)	1,750	5,500	12,500	15,000	20,000
Discount rate 10%	1.000	0.909	0.826	0.751	0.683	0.621
DCF	(40,000)	1,591	4,543	9,388	10,245	12,420
NPV						(1,814)

Despite the negative NPV the marketing department is still extremely keen to launch the product. The chief executive was not fully convinced and sought advice from their parent company. The proposal was sent to the parent company for review and the result was that they liked the idea. However, their operations team were unsure about the reliability of the new technology so they have agreed that if XYZ want to take the risk and launch the product they can do so, and once any teething problems have been sorted out, after 2 years the parent company would buy the project for $30,000,000 and manage the project thereafter.

The marketing department of XYZ insisted that there was a strong possibility that cash flows could improve in the future. The finance department suggested using the Black-Scholes option pricing model to calculate the value of the abandonment option at the end of year 2.

The benefit foregone in this case would be the NPV of the cash flows in years 3 – 5 of ($9,388 + $10,245 + $12,420) $32,053. The finance department suggested using a volatility of 50% and a risk free rate of 5%.

Type of Option	Put Option
Stock Price (S_0)	$ 32,052.00
Exercise (Strike) Price (K)	$ 30,000.00
Time to Maturity (in years) (t)	2.00
Annual Risk Free Rate (r)	5.00%
Annualized Volatility (σ)	50.00%
Option Price	$ 5,940.38

Additional Calculation Parameters	
$\ln(S_0/K)$	0.066
$(r+\sigma^2/2)t$	0.350
$\sigma\sqrt{t}$	0.707
d_1	0.589
d_2	(0.119)
$N(d_1)$	0.722
$N(d_2)$	0.453
$N(-d_1)$	0.278
$N(-d_2)$	0.547
e^{-rt}	0.90484

The put option value – the right to sell the project to the parent company has a value of $5,940.

The NPV with the put option is therefore $5,940 - $1,814 = $4,126.

It suggests that it would be worth undertaking the project with the put option in place.

Limitations of Black-Scholes options pricing model

There are some limitations of using the Black-Scholes model of option pricing.

It is useful for valuing European style options where the option has a specific time that it can be exercised. However, many real business decisions are akin to American style options that can be exercised at any time up to the exercise date. The use of the Black-Scholes model therefore provides an indication of the likely value. The model also makes some general assumptions about the performance of the stock market which may not apply directly to real business decisions.

It is also not able to take account of the behavioural aspects of many decisions. As with any business decision the strategic aspects should always be considered, and a decision should never be made based purely on the numbers. The numbers are only part of the information that is used to make strategic decisions.