Topic 7 - Real Options

BMAE Ch. 23

Topics Covered

- Real Options vs. Financial Options
- The Option to Wait: Investment as a Call Option
- Growth and Abandonment Options
- Real Options Theory Applied to “Real World” Situations: Rules of Thumb, Key Insights & Challenges

Real Options: Overview

Real Options: what are they?

The right to make a particular business decision in future, e.g. a capital investment or the sale of assets, after more information has emerged.

A distinction between real options and financial options is that real options (and the underlying assets on which they are based) are not traded in competitive markets.

Real Options: four major categories

1. The *option to wait* and learn before investing (a.k.a. “timing options”).
2. The *option to expand* if the immediate investment project succeeds (a.k.a. “growth options”).
3. The *option to shrink or abandon a project* (a.k.a. the “abandonment option”).
4. The *option to vary the mix of output or the firm’s production methods*.

Decision Trees

- Many corporate investment decisions contain real options.
- They can be analysed by creating a decision tree that identifies the following:
  - **Decision nodes** showing the choices available at each stage
  - **Information nodes** showing the payoff relevant information to be learned
  - **Investments made & payoffs earned** over time
- Once the decision tree is created, we can value the investment opportunity.

Timing Options / a.k.a. the Option to Wait:

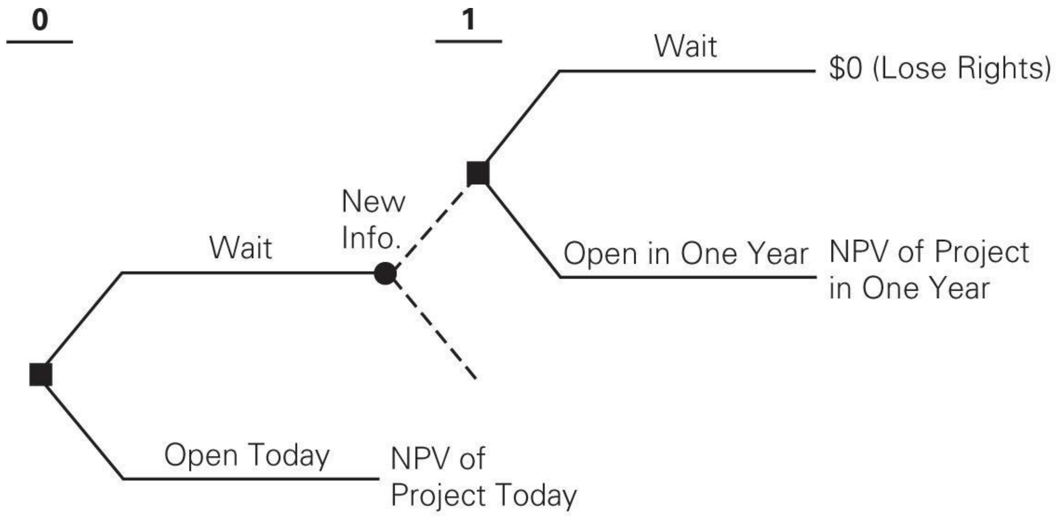
Investment as a Call Option

An Investment (Timing) Option

Assume you have negotiated a deal with an electric car manufacturer to open one of its dealerships in your hometown.

- The terms of the contract specify that you must open the dealership either immediately or in exactly one year.
  - If you do neither, you lose the right to open the dealership at all.

An Investment (Timing) Option



An Investment (Timing) Option

How much you should pay for this opportunity?

- It will cost $5 million to open the dealership, whether you open it now or in one year.
- If you open the dealership immediately, you expect it to generate $600,000 in free cash flow the first year.
  - Future cash flows are expected to grow at a rate of 2% per year.
- The cost of capital for this investment is 12%.

An Investment (Timing) Option

If the dealership were to open today, its value would be

$$V = \frac{\$600{,}000}{12\% - 2\%} = \$6 \text{ million}$$

- This would give an NPV of $1 million.
  - $6 million – $5 million cost to open the dealership = $1 million (net)

Given the flexibility you have to delay opening for one year, what should you be willing to pay?

When should you open the dealership?

An Investment (Timing) Option: applying the Black-Scholes method

The payoff if you delay is equivalent to the payoff of a one-year European call option on the dealership with a strike price of $5 million.

Assume:

- The risk-free interest rate is 5% continuously compounded.
- The volatility is 40%.
- If you wait to open the dealership you have an opportunity cost of $600,000 (the free cash flow in the first year).
  - Comparing this real option to a financial option, the free cash flow here is equivalent to a dividend paid by a stock.
  - The holder of a call option does not receive the dividend until the option is exercised.

An Investment (Timing) Option: applying the Black-Scholes method

Financial Option		Real Option	Example
Stock Price	S	Current Market Value of Asset	\$6 million
Strike Price	K	Upfront Investment Required	\$5 million
Expiration Date	T	Final Decision Date	1 year
Risk-Free Rate	r_f	Risk-Free Rate	5%
Volatility of Stock	σ	Volatility of Asset Value	40%
Dividend	Div	FCF Lost from Delay	\$0.6 million

An Investment (Timing) Option: applying the Black-Scholes method

Let "C" be the value (as of today) of the call option to open the dealership:

$$d_1 = \frac{\ln[S^x / PV(K)]}{\sigma\sqrt{T}} + \frac{\sigma\sqrt{T}}{2} = \frac{\ln(5.43/\ 4.76)}{0.40} + 0.20 = 0.5276$$

$$d_2 = d_1 - \sigma\sqrt{T} = 0.5276 - 0.40 = 0.1276$$

S^x = *Current Market Value of Asset - PV(FCF Lost from Delay) = 6m – (600,000/1.05) = \$5.43m*

$$\boldsymbol{C = S^x N(d_1) - PV(K) N(d_2)}$$

$$= (\$5.43 \text{ million}) \times (0.701) - (\$4.76 \text{ million}) \times (0.551)$$

$$= \mathbf{\$1.2\ million}$$

An Investment (Timing) Option

The **value today of waiting to invest** in the dealership next year, and only opening it if it is profitable to do so, is **$1.2 million.**

- **This exceeds the NPV of $1 million from opening the dealership today...**which would have destroyed the (more valuable!) option of waiting.
- Thus, in net terms you are $200,000 better off simply by holding your real option to wait

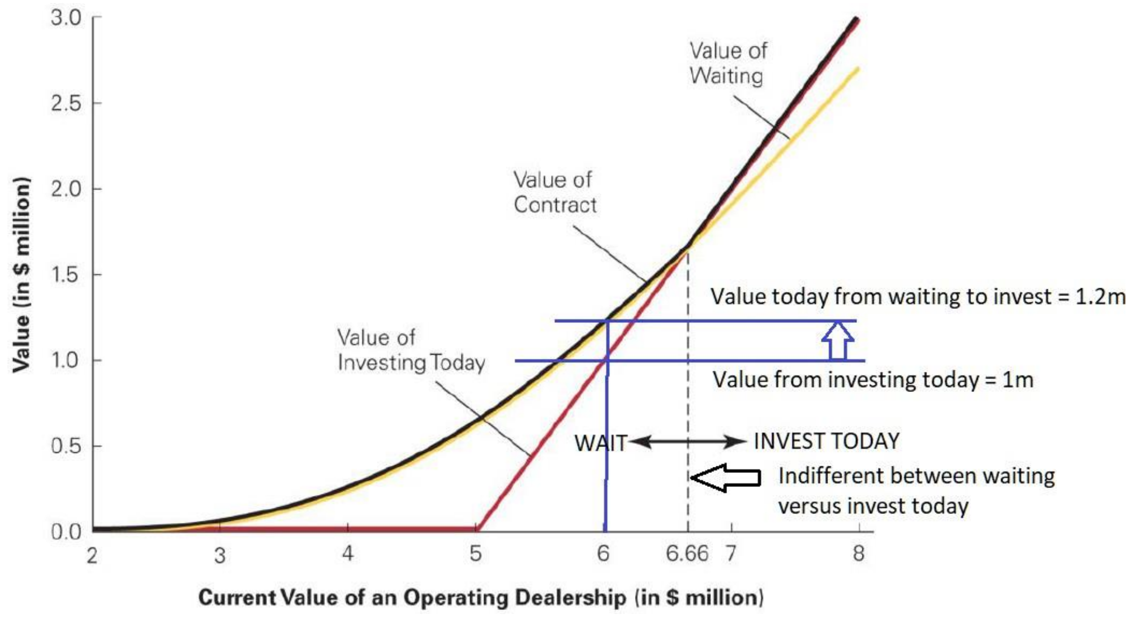
An Investment (Timing) Option

What is the advantage of waiting in this case?

- If you wait, you will learn more about the likely success of the business.
- Because the investment in the dealership is not yet committed, you can cancel your plans if the popularity of the dealership should decline. By opening the dealership today, you give up this option to “walk away.”

An Investment (Timing) Option

Whether it is optimal to invest today or in one year will depend on the magnitude of any lost profits from the first year compared to the benefit of preserving your right to change your decision.



An Investment (Timing) Option

When you have the option of deciding when to invest, it is usually optimal to invest only when the NPV is substantially greater than zero.

You should invest today only if the NPV of investing today exceeds the value of the real option to wait.

Given the real option to wait, an investment that currently has a negative NPV can end up having a positive one at a future date.

An Investment (Timing) Option

Other factors affecting the decision to wait:

- Volatility
  - The option to wait is most valuable when there is a high level of uncertainty.

- Dividends
  - Absent dividends, it is not optimal to exercise a call option early.
  - In the real option context, it is always better to wait unless there is a cost to doing so.
    The greater the opportunity cost (of more dividends paid / more free cash flow generated from operations), the less attractive the option to delay becomes.

Growth & Abandonment Options

Growth and Abandonment Options

Growth Options

- The option to invest/expand in the future
- A “call” option

Abandonment Options

- The option to divest – e.g. to sell all the assets linked to a particular project, if the salvage value exceeds the value of continuing operations
- A “put” option

Because these options have value, they contribute to the value of any firm that has future possible investment opportunities.

Future growth opportunities can be thought of as a collection of real call options on potential projects.

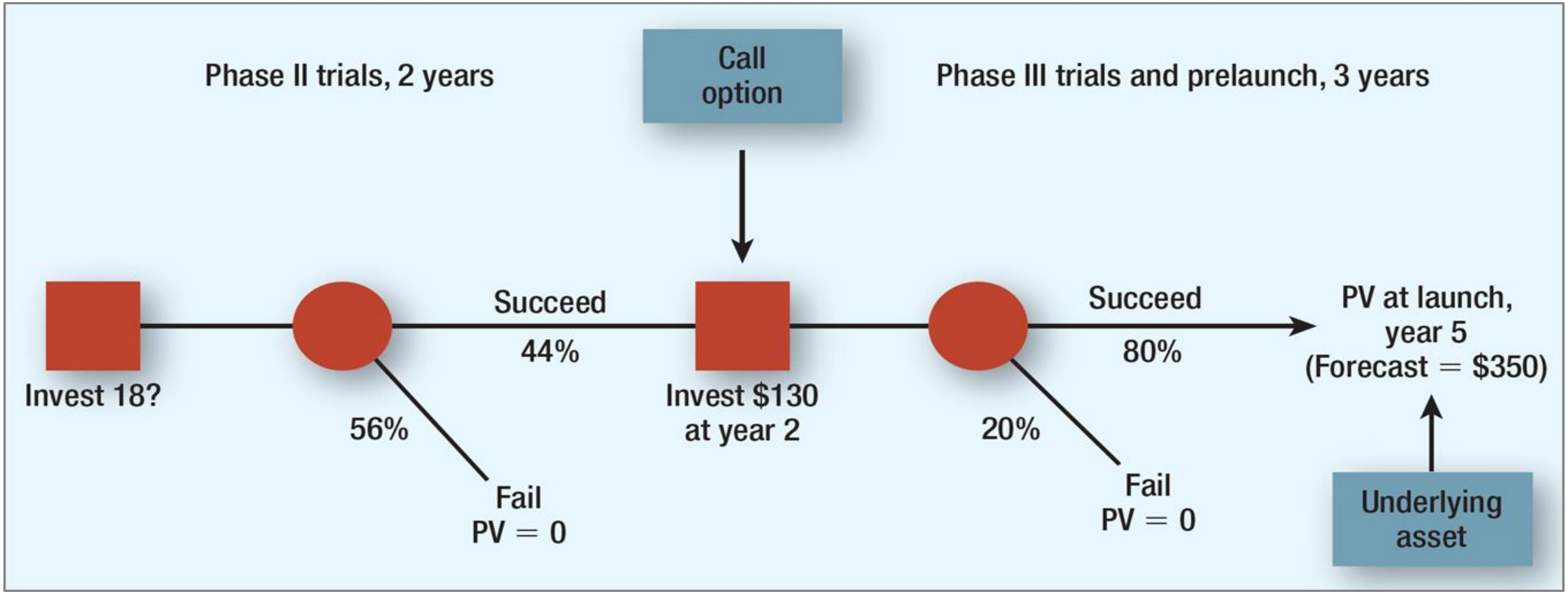
Growth and Abandonment Options: A framework for valuation?

Growth and abandonment options are a good fit for this simple valuation relationship:

$$\text{Value "real option"} = \text{NPV}_{\text{with option}} - \text{NPV}_{\text{without option}}$$

Of course, calculating a project's NPV *with the real option attached* can be tricky. Today's worked examples should help you with this.

Growth Options: an R&D example



- If Phase II trials are successful, there is an option to invest $130 million at Year 2.
- If exercised, there is an 80% chance of launching the approved drug.
- The PV of the drug, forecast at $350 million by Year 5, is the underlying asset of the call option.

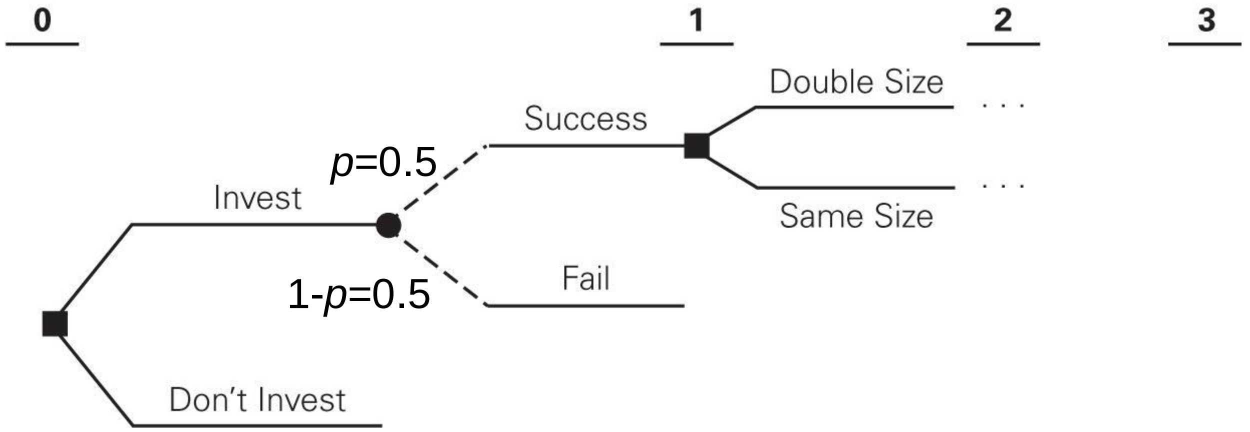
Growth Option: applying the risk-neutral method

Consider an investment opportunity with an option to grow that requires a $10 million investment today.

Assume:

- In one year you will find out whether the project is successful.
- The risk-neutral probability that the project will generate $1 million per year in perpetuity is 50%; otherwise, the project will generate nothing.
- At any time we can double the size of the project on the original terms.
- The risk-free rate is 6%.

Growth Option: risk-neutral method



- Risk-neutral probabilities: risk-adjusted probabilities of future cash flow outcomes
- *p* and *(1-p)* given an up % movement "*u*" and a down % movement "*d*" respectively can be discounted at the risk-free rate (*Rf*).

$$p*u + (1-p)*d = Rf$$

$$p = (Rf-d) / (u-d)$$

Growth Option: risk-neutral method

The **value of a real option today** can be thought of as the *probability-weighted cash flows* it is expected to generate in the future, *discounted back to today* (usually at the risk-free rate of return). In other words:

$$\mathbf{PV_{option}} = \frac{\boldsymbol{p * (Option\,payoff\ for\ \text{“}up\text{”})\ +\ (1 - p) * (Option\,payoff\ for\ \text{“}down\text{”})}}{\boldsymbol{(1 + Rf)^{t}}}$$

- Some questions require you to first find “p” and “(1-p)” using the relationship on the previous slide.
  - In this problem, you are already given the value of p (50% chance of up or down).
- *Usually*, one of the two option payoffs is $0 (e.g. when “down” for a call, or “up” for a put). *This makes the calculation faster than it looks…*

Growth Option: risk-neutral method

By investing today, the **expected value (i.e. on-average)** of future annual cash flows are $500,000 if we ignore the option to double the project's size.

$$E[FCF_{\text{without option}}] = (\$1 \text{ million} \times 50\%) + (\$0 \times 50\%) = \$500{,}000$$

Growth Option: risk-neutral method

Computing the NPV *without the option* gives:

$$NPV_{\text{without growth option}} = \frac{500{,}000}{0.06} - 10{,}000{,}000 = -\$1.667\text{ million}$$

- The negative NPV suggests that you should not take on the project today.
- However, this means you would never find out whether the project could be successful…

Growth Option: risk-neutral method

Now consider undertaking the project and exercising the growth option to double the size in a year if the product takes off.

- The NPV of doubling the size of the project in a year in this state is:

$$NPV_{\text{doubling after a year}} = \frac{1{,}000{,}000}{0.06} - 10{,}000{,}000 = \$6.667 \text{ million}$$

Growth Option: risk-neutral method

The risk-neutral probability that this state will occur is 50%, so the expected (future) value of the growth option is $3.333m:

FV of growth option = (50% x $6.667m) + (50% x $0m)
FV of growth option = $3.333 m

Applying our risk-free rate of 6%, the PV today of that FV is:

$$\boldsymbol{PV_{\text{growth option}}} = \frac{\$3.333\text{m}}{1.06} = \mathbf{\$3.145\ million}$$

Growth Option: risk-neutral method

You have this option only if you choose to invest today, so the total $NPV_{\text{with option}}$ of undertaking the project is the $NPV_{\text{without option}}$ that we calculated before plus the PV of the growth option we obtain by undertaking the project:

$$\boldsymbol{NPV_{\textit{with growth option}} = NPV_{\text{without growth option}} + PV_{\text{growth option}}}$$

$$\boldsymbol{NPV_{\textit{with growth option}}} = -\$1.667\text{m} + \$3.145\text{m} = \mathbf{\$1.478\ million}$$

Growth Option: risk-neutral method

This analysis shows that the NPV of the investment opportunity is positive and the firm should undertake it.

- It is optimal to undertake the investment today only because of the existence of the future growth option.

Abandonment Option

Assume you are the CFO of a chain of gourmet food stores and are considering opening a new store in the recently renovated Ferry Building in Boston.

- If you do not sign the lease on the store today, someone else will, so you will not have the opportunity to open a store later.
- There is a clause in the lease that allows you to break the lease at no cost in two years.
- Including the lease payments, the new store will cost $10,000 per month to operate.

Abandonment Option

Because the building has just reopened, you do not know what the pedestrian traffic will be.

- If your customers are mainly limited to morning and evening commuters, you expect to generate $8,000 per month in revenue in perpetuity.
- If, however, the building becomes a tourist attraction, you expect to generate $16,000 per month in revenue in perpetuity.

Abandonment Option

There is a 50% chance that the Ferry Building will become a tourist attraction…and a 50% chance that it won't.

The cost to open the store will be $400,000.

The risk-free interest rate is constant at 7% per year, which is equal to = $1.07^{\wedge(1/12)} - 1$ = **0.565% *per month***.

We will use the monthly risk-free rate to match the monthly cash flows.

Abandonment Option

The number of tourists visiting the Boston Ferry Building represents idiosyncratic uncertainty (i.e. not a form of systematic risk).

Because this is the kind of uncertainty investors in your company can costlessly diversify away, the appropriate cost of capital is the risk-free rate.

Abandonment Option

If you were forced to operate the store under all circumstances, the *expected revenue* (i.e. *on-average*) would be $12,000:

E[Revenue] = (50% x $8000) + (50% x $16,000) = $12,000

The NPV of opening the store WITHOUT an abandonment option is:

$$\boldsymbol{NPV_{without\ option}} = \frac{12{,}000}{0.00565} - \frac{10{,}000}{0.00565} - 400{,}000 = \mathbf{-\$46{,}018}$$

Given this negative NPV, it does NOT make sense to open this store WITHOUT an option to abandon included.

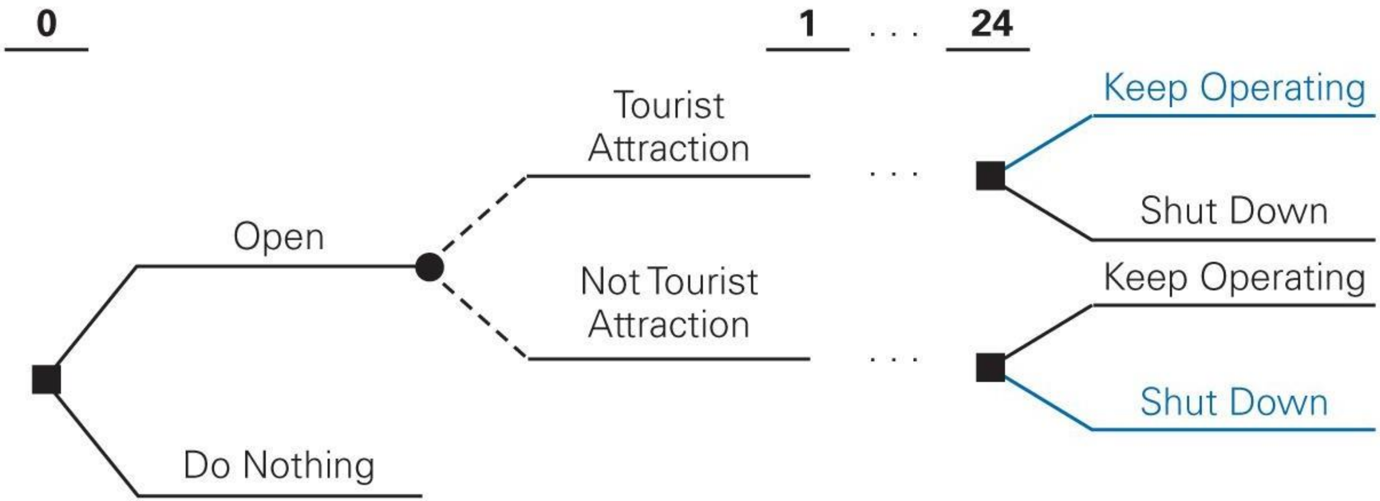
Abandonment Option

In reality, you would not have to keep operating an unsuccessful store forever.

You have an option to get out of the lease after two years at no cost.

- After the store is open, it will be immediately obvious whether the Ferry Building is a tourist attraction.
- The decision tree is shown on the next slide.

Abandonment Option



Abandonment Option

If the Ferry Building DOES become a tourist attraction (a 50% probability), the NPV of the investment opportunity is:

$$NPV = \frac{16{,}000}{0.00565} - \frac{10{,}000}{0.00565} - 400{,}000 = \mathbf{\$661{,}947}$$

Option to Abandon

If the Ferry Building did NOT become a tourist attraction (50% probability), you would close the store after two years, and the NPV of opening would have been negative:

$$
\begin{aligned}
NPV &= \frac{8000}{0.00565}\left(1 - \frac{1}{1.00565^{24}}\right) - \frac{10,000}{0.00565}\left(1 - \frac{1}{1.00565^{24}}\right) - 400,000 \\
&= \mathbf{-\$444,770}
\end{aligned}
$$

Or, you can input these numbers using the Excel "PV" formula:

NPV = **PV(0.00565,24,-8000)** - **PV(0.00565,24,-10000)** – 400000

NPV = –**$444,770**

Option to Abandon

There is an equal probability (50% / 50%) of either state. The NPV of opening the store WITH the option to abandon after 2 years is:

$$NPV_{\text{with option}} = 50\% \times \mathbf{\$661{,}947} + 50\% \times \mathbf{\${-}444{,}770} = \mathbf{\$108{,}589}$$

- By exercising the option to abandon the venture, you limit your losses and the NPV of undertaking the investment becomes positive.

- The value of the option to abandon is $154,607 – i.e. the difference between NPV *with option* vs. NPV *without the option* attached:

$$\mathbf{PV_{\text{abandonment option}} = NPV_{\textit{with option}} - NPV_{\textit{without option}}}$$

$$\mathbf{Pv_{\text{abandonment option}}} = \$108{,}589 - (\${-}46{,}018) = \mathbf{\$154{,}607}$$

Option to Abandon

It is easy to ignore or understate the importance of the option to abandon.

- Many times, abandoning an economically unsuccessful venture to derive salvage value can *add more value* than starting a new one.
- Managers often de-emphasize this alternative.

Flexible Production Options: a qualitative example

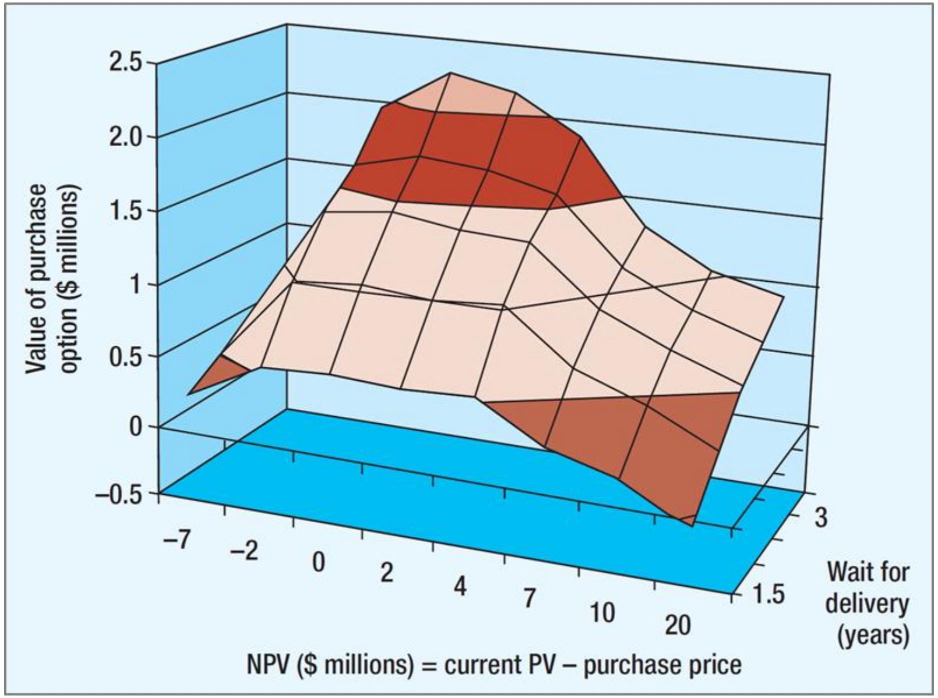
Flexible Production: Aircraft example

If exercised in Year 3, option guarantees fixed price & delivery at Year 4. Without option, plane can still be ordered in Year 3 but with uncertain price & delivery.

	Year 0	Year 3	Year 4	Year 5 or later
Buy option	Airline and manufacturer set price and delivery date	Exercise? (Yes or no)	Aircraft delivered if option exercised	
Wait	Wait and decide later	Buy now? If yes, negotiate price and wait for delivery.		Aircraft delivered if purchased at Year 3.

Flexible Production: Aircraft example (illustrated)

Value of aircraft purchase option—the extra value of the option vs. waiting and possibly negotiating a purchase later. Purchase option is worth most when NPV of purchase now is about zero and the forecasted wait for delivery is long.



Applying real options theory to real world situations:

Rules of thumb, insights, & challenges

Rules of Thumb?

One of the major drawbacks of using the real option analysis is that it can be difficult to implement.

Consequently, many firms resort to following rules of thumb to compare against the NPV ranking.

Profitability Index Rule:

- Recommends investment whenever the profitability index exceeds some predetermined number

- The profitability index is defined as follows:

$$\text{Profitability Index} = \frac{\text{NPV}}{\text{Initial Investment}}$$

- When there is an option to delay, **a good rule of thumb is to invest only when the index is at least 1.**

Rules of Thumb?

Hurdle Rate Rule

- Raises the discount rate by using a higher discount rate than the cost of capital to compute the NPV, but then apply the regular NPV rule
- A higher discount rate created by the **hurdle rate rule**:

Hurdle rate = (actual) cost of capital + extra risk premium

- IRR is the rate at which the project breaks even. If a project has an IRR > Hurdle rate, then it should be undertaken.

Using a hurdle rate rule is cost-effective but it does not provide an accurate measure of value. NPV using the appropriate (actual) cost of capital is the more accurate measure of value.

Insights from Real Options

Out-of-the-money real options have value.

- Even if an investment has a negative NPV, if there is a chance it could be positive in the future, the opportunity is worth something today.

In-the-money real options need not be exercised immediately.

- The option to delay may be worth more than the NPV of undertaking the investment immediately.

Waiting is valuable.

- By waiting for uncertainty to resolve, you can make better decisions.

Insights from Real Options

Delay investment expenses as much as possible.

- Committing capital before it is absolutely necessary gives up the option to make a better decision once uncertainty is resolved.

Create value by exploiting real options.

- The firm must continually revaluate its investment opportunities, including the options to delay or abandon projects, as well as to create or grow them.

Challenges

Practical reasons why real options are not always feasible to use:

- Valuation of real options can be complex, and sometimes it is impossible to arrive at the “perfect” answer.
- Real options do not always have a clear structure for their path and cash flows.
- Competitors also have real options that can alter the value of your options by altering the underlying assumptions and environment that serve as the basis of your valuation (gaming of real options).

Given these limitations, real options are not always the best approach when valuing projects.