Real Options
More resources:  http://www.real-options.com/
Look over the presentation:  “Real Options Results are In: Executives, Beware the Hype”
What’s the problem we’re trying to address?

- The underlying objective: make investments and manage those investments over time in order to maximize shareholder value.

- Recognize the ability to learn over time and adjust future decisions (“managerial flexibility”)
  - Don’t focus on most likely scenario, but on range of possible scenarios
  - Decisions between alternatives are made after (some) uncertainty is resolved (one alternative is “don’t invest”)
  - Uncover significant value when uncertainty is large by seizing upside potential and limiting downside risk
What are real options?

- Flexibility analogous to financial options, but on *real* assets
  - growth options
    - R&D
    - Land
    - Oil Exploration
    - Staged investments; expansion options
    - Follow-on or sequential investments (M&A program, brands)
  - contraction options
    - Abandonment
    - Contract scale; temporarily shut down (compound option)
  - other flexibility options
    - Input or output mix flexibility (option to switch)
    - Global production flexibility
Sources of real option value

• Real options may arise “naturally” in a firm due to competencies already existing in the firm:
  – early capture of market share, high entry costs, technical expertise, advertising, brand names…

• Real options may also be created or purchased.
  – Patents, production flexibility, rights to develop land or natural resources, and various *contractual real options* such as warranties, leases, or options to purchase equipment or capacity in the future.
## Options can be found in all industries

<table>
<thead>
<tr>
<th>Industry</th>
<th>Key Options Developed or Exercised</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automobile</td>
<td>• Recently GM delayed its investment in a new Cavalier and switched its resources into producing more SUVs.</td>
</tr>
<tr>
<td>Computers</td>
<td>• HP moved to delay final assembly of its printers for overseas markets till an actual order was received -- this increased costs but created the option to tailor production to demand.</td>
</tr>
<tr>
<td>Aircraft Manufacturers</td>
<td>• Parallel development of cargo plane designs created the option to choose the more profitable design at a later date.</td>
</tr>
</tbody>
</table>
| Oil & Gas              | • Oil leases, exploration, and development are options on future production  
                         | • Refineries have the option to change their mix of outputs among heating oil, diesel, unleaded gasoline and petrochemicals depending on their individual sale prices. |
| Pharma                 | • R&D has several stages - a sequential growth option.                                                                                                           |
| Telecom                | • Lay down extra fiber as option on future bandwidth needs  
                         | • Existing customer base, products and service agreements serve as a platform for future investments                                                             |
Options can be found in all industries, cont.

<table>
<thead>
<tr>
<th>Industry</th>
<th>Key Options Exercised or Nurtured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utilities</td>
<td>• Developing generating plants fired by oil &amp; coal creates the option to reduce input costs by switching to lower cost inputs.</td>
</tr>
<tr>
<td></td>
<td>• Delay the decommissioning of nuclear plants in the event that decommission costs come down.</td>
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<tr>
<td></td>
<td>• Peaking plants produce energy at a cost higher than the average price of energy. The owners have the option to operate the plant only when the price of energy spikes and shutdown if the production of energy is not profitable.</td>
</tr>
<tr>
<td>Real Estate</td>
<td>• Land is often left undeveloped so that developers retain their option to develop the land for a more profitable use than exists today.</td>
</tr>
<tr>
<td></td>
<td>• Multipurpose buildings (hotels, apartments, etc.) that can be easily reconfigured create the option to benefit from changes in real estate trends.</td>
</tr>
<tr>
<td>Airlines</td>
<td>• Airlines can delay committing to firm orders until sufficient uncertainty has been resolved. This can help to mitigate overcapacity problems.</td>
</tr>
<tr>
<td></td>
<td>• Alternatively, aircraft manufacturers may grant the airlines contractual options to deliver aircraft. These contracts specify short lead times for delivery (once the option is exercised) and fixed purchase prices.</td>
</tr>
<tr>
<td></td>
<td>• Airlines may also be offered “contingency rights” that give the airline the option to choose type of aircraft delivered within a family of aircraft types.</td>
</tr>
</tbody>
</table>
What companies are using real options analysis?

- Oil & Gas: Chevron, Texaco, Anadarko, BP Amoco, Petrobras
- Power: TVA, Enron, U.S. DOE
- Pharma: Merck, Eli Lilly, Amgen, Endo, Schering-Plough, Pfizer
- Technology: Cadence Design Systems, Philips
- Telecom: Cable & Wireless, Sprint
- Manufacturing: HP, Airbus, Boeing, GM
- Other: Dupont, Rhone-Poulenc Rorer
Real Options Analysis: A Strategic Planning Tool ...

• A **framing** tool for decision making and strategic planning.
  – Understand the key uncertainties that affect project/firm value
  – How will uncertainty be resolved? (the value of information)
  – Recognize, create, and optimally manage flexibility

• Key insights (build on options intuition)
  – Don’t necessarily invest in a project with NPV>0
  – Invest in stages - each step provides information
  – Pursue several paths at once (and expect failure…)
  – Think explicitly about “downstream decisions”; remain flexible
  – Volatility can enhance value if you keep your options open
A valuation tool that properly measures the risk of complex projects, and uses the appropriate risk-return relationships from financial markets.

- Line up strategy with shareholder value creation
- Avoid short-term metrics
- NPV/DCF are theoretically correct, but one must recognize that options are difficult to value properly
  - Cash flows altered by downstream decisions
  - Discount rates extremely difficult to estimate accurately
- Most projects not “average” projects - be careful using WACC!
  - Consider risk of R&D, exploration, test marketing projects:
    - .90 probability of -100% return, .10 probability of 1000%
The Roots of Real Options Analysis

Decision Analysis
- Decision Trees (using Utilities)
- Decision Trees using WACC

Valuation
- DCF Analysis (NPV, SVA)
- Scenario Analysis
- Financial Option Pricing

REAL OPTIONS ANALYSIS
The real options analysis process

- Framing
- Analysis
- Interpret & Communicate
- Execute
Framing the decision problem

• To understand what options currently exist in a project, or how additional options could be created, it is important to frame the decision problem carefully.

• At this first stage of the analysis, questions such as the following should be asked:
  – What are the uncertainties underlying the problem and how are these uncertainties resolved?
  – What flexibility exists - or can be introduced - to react to resolution of uncertainty over time?
What are the underlying uncertainties?

<table>
<thead>
<tr>
<th>RISK CATEGORY</th>
<th>EXAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technological</td>
<td>New technology/process risk</td>
</tr>
<tr>
<td>Economic</td>
<td>Product demand uncertainty</td>
</tr>
<tr>
<td>Financial</td>
<td>FX / commodity price risk</td>
</tr>
<tr>
<td>Performance</td>
<td>Subcontractor risk</td>
</tr>
<tr>
<td>Legal / Regulatory</td>
<td>Political risk</td>
</tr>
</tbody>
</table>
How will uncertainty be resolved?

• Volatility is one of the key value drivers for options. In the case of financial options, volatility, together with time, measure the amount of uncertainty that will be resolved over the life of the option.

• In the case of real options, some uncertainty may be resolved through the natural course of time (e.g. for commodity prices like oil), but many uncertainties are resolved only by investing in information acquisition (e.g., feasibility studies).
  – So, we need to be able to compare the relative values (and costs) of different information acquisition alternatives, e.g. differing in terms of speed and accuracy.
What flexibility exists or can be designed into the project?

- Wait to invest in project
- Invest in project in stages
- Scale up or down level of production/use
- Expand to larger area
- Switch to new production technology
- Adjust input mix
- Invest in early stages of competing projects
- Enter into flexible contracts (options)
Framing - Uncertainties and Strategic Alternatives

- Invest in single product platform
- Invest in several product lines
- Invest at smaller scale
- Delay and run test marketing
- Partner with or acquire .com

Decision Node: (Basic DCF if no expansion)
Uncertainty Node: Infographic showing various outcomes and strategic decisions:
- Successful
  - Defer expansion
  - Reconfigure
- Low demand
- Failed
- Global expansion
- Expand to other lines
- Invest
  - Positive response
  - Lukewarm response
- Delay
Valuation when decisions are contingent on future events

**One-dimensional valuation approach:**
Find the appropriate discount rate, and discount expected future cash flows back to current date.

**Multi-dimensional valuation approach:**
Decide on optimal action at each node over time. The decisions will affect the risk of the resulting cash flows. Thus, the discount rate would need to be different at each node in the tree.
### Binomial Option Pricing Model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project value</td>
<td>100</td>
</tr>
<tr>
<td>Exercise Price</td>
<td>100</td>
</tr>
<tr>
<td>Maturity (years)</td>
<td>2</td>
</tr>
<tr>
<td>Annual Volatility</td>
<td>0.3</td>
</tr>
<tr>
<td>Annual interest rate</td>
<td>0.07</td>
</tr>
<tr>
<td>Number of Periods</td>
<td>4</td>
</tr>
<tr>
<td>Step Size (T/N)</td>
<td>0.5</td>
</tr>
<tr>
<td>Annual lost revenues</td>
<td>0.04</td>
</tr>
<tr>
<td>Date</td>
<td></td>
</tr>
<tr>
<td>Jun-97</td>
<td></td>
</tr>
<tr>
<td>Jun-98</td>
<td></td>
</tr>
<tr>
<td>Jun-99</td>
<td></td>
</tr>
</tbody>
</table>

#### Tree for the underlying project value

<table>
<thead>
<tr>
<th>Number of Downs</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Step</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>100.00</td>
<td>123.63</td>
<td>152.85</td>
<td>188.97</td>
<td>233.62</td>
</tr>
<tr>
<td></td>
<td>80.89</td>
<td>100.00</td>
<td>123.63</td>
<td>152.85</td>
<td></td>
</tr>
<tr>
<td></td>
<td>65.43</td>
<td>80.89</td>
<td>100.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>52.92</td>
<td></td>
<td>65.43</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>42.80</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A correct valuation foundation

- It is very difficult to estimate the risk at each node (i.e. at each combination of time and values of underlying uncertainties), and to come up with a corresponding discount rate.

- Fortunately, a simpler approach to this problem has been developed. Instead of adjusting the discount rates for risk, we can risk-adjust the expected cash flows (downward) and then simply use a risk-free discount rate!
A growth option example

Period:

0                1                2           3                4                 5

$1200 Initial Investment (e.g. R&D, Tests)

PV₅ = $1667.67

$500 $500 $500 $500 $500 $500 $2173

$100

Initial Investment

$1200

risk free rate = 6.5%
discount rate = 30% - reflects risks correlated with overall economy
10% volatility around the growth of cash flows

What is the option to invest worth?

\[ E[\text{MAX}(PV_5 - I_5, 0)] \left( \frac{1}{1 + r_{\text{adj}}} \right)^5 \]

How do you calculate \( r_{\text{adj}} \)? Is it greater or less than 30%?
Simulate future cash flows

With a commitment to invest, the expected value of the investment in year 5 has a mean of $468.34 and a 14.50% probability NPV < 0.

However, Latest Tech Company has the option not to exercise the investment if the NPV at year 5 is less than zero. Therefore, the distribution of NPV outcomes is the same as the commitment to invest with no downside. The mean is now $491.27 with 0% prob <0.

\[
PV = EV (PV_5-I)
\]

\[
PV = S\text{Max}(PV_5-I,0)*\text{prob}(PV_5)
\]

Mean = 468.34
St. Dev = 466.93

Mean = 491.27
St. Dev = 436.36
Alternative valuation approaches

- What is the NPV today if the future investment of $1200 must be made?
  - Assuming certain cost of investment: PV = -$448.39, NPV = -$548.39
    (using the risk-free rate for the fixed investment, and the 30% rate for earnings)
  - Clearly investing $100 today looks like a terrible investment if the future option is ignored.

- What values are obtained by discounting the expected value of the investment option (491.27) by the following discount rates?
  - 20% -> PV = $198.15, NPV = $98.15
  - 30% -> PV = $132.80, NPV = $32.80
  - 40% -> PV = $91.68, NPV = -$8.32

- What value of the investment is obtained using the Black-Scholes formula?
  - PV = $99.47, therefore NPV = -$0.53

- The implied discount rate to arrive at a present value equal to the Black-Scholes value is $r_{adj} = 37.7\%$! (How could we have known that?!)
Why is the discount rate higher than 30%?

• The initial investment of $100 is similar to purchasing a call option. A call can be decomposed into two parts (from put-call parity):
  – A commitment to make a fixed investment in the future in return for a risky cash flow (or PV of cash flows)
  – An option to not invest (or insurance to compensate from making a bad investment)
Options are always riskier than the PV (stock)

\[ \frac{\sigma_{\text{option}}}{\sigma_{\text{PV}}} \]

\( \sigma_{\text{option}} \), \( \beta_{\text{option}} \) and \( r_{\text{option}} \) all depend on the degree of leverage (i.e., present value vs. investment) as well as the volatility and time to maturity.

As the present value gets larger, the difference between the risk of the option and the risk of the underlying cash flows becomes smaller. The option becomes less risky because the leverage is significantly reduced (the probability of exercise is also much higher for these “in-the-money” options).
Are discount rates always higher?

• Unfortunately, we have to be quite careful here. Call options always have higher discount rates than the underlying asset. For put options, the opposite is true. Though riskier than the underlying, the risk is in the “opposite direction” - they act as hedges to the underlying asset (e.g. flexibility options).

• The point is not that discount rates in our real options analyses should always be higher than for the underlying investment opportunities, but rather that it is very difficult to divine what the discount rate (or rates) should be.
So, how do we value options?!

- There are a few different approaches to value options, including:
  - Black-Scholes formula (or variations thereof)
  - Binomial Option Pricing Model
  - Monte-Carlo Simulation

- However, all of these are based on the same underlying idea - rather than try to risk-adjust discount rates (the denominator in the valuation equation), they risk-adjust the probabilities of obtaining different cash flows (or, equivalently the expected future cash flows in the numerator).
Consider a one-period “binomial tree”

PV (Stock price)

<table>
<thead>
<tr>
<th>t=0</th>
<th>t=1</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>q (or p)</td>
<td>1-q (or 1-p)</td>
</tr>
</tbody>
</table>

Option tree

<table>
<thead>
<tr>
<th>t=0</th>
<th>t=1</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>MAX(150-100,0)</td>
</tr>
<tr>
<td>1-q (or 1-p)</td>
<td>MAX(70-100,0)</td>
</tr>
</tbody>
</table>

(Volatility =40%)

Method 1 - Replicate option

Buy .625 shares of stock
Borrow $41.67

Cost Today Payoff at t=1

=$20.83
if S=150; 50
if S=70; 0

Method 2 - Use risk-adjusted probabilities (p = .437)

\[ C = p(50) + (1-p)(0) = 20.83 \]

1) risk adjust cash flows downward
2) use a risk free rate

But, how do we get p?
Risk-adjusting probabilities

- We can back out the risk-adjusted probabilities by looking at the underlying PV (PV of the stock price).

\[
PV = \frac{110}{1+.10} = 100
\]

Risk adj rate for the stock \( r_v = 10\% \)

\[
PV = \frac{105}{1+.05} = p(150) + (1-p)70 = 100
\]

Risk adj rate \( r_f = 5\% \)

Note: 105 is the Certainty Equivalent Value (CEV)
What information is needed?

In addition to the volatility, the interest rate, the exercise price and the time-to-maturity, we need the underlying present value (PV) of the project. The PV is analogous to a stock price, but is not readily observed. Thus we need the underlying discount rate (10%), which then allows us to back out the CEV and thus the risk-adjusted probabilities.

OR

If forward prices for an underlying commodity are available, no discount rates need to be estimated. The CEV is in fact based directly on the forward prices, since these are certain values for future prices that can be locked in today!
Complex decision problems

Complexities

Several decisions / stages (one uncertainty)
Several uncertainties (possibly correlated)
Complex price processes for uncertainties
Competition is key uncertainty

Approaches

Decision tree helps to map out problem
Spreadsheet binomial model (Excel)
Programming language (Matlab)
Use Monte-Carlo Simulation
Game theory (extended form trees)
Monte-carlo simulation

WHY?
- Multiple uncertainties
- Complex pattern of uncertainty resolution
- Special distribution for underlying value
- “Path-dependent” cash flows for project

HOW?
- Estimate distribution (type of distribution, and volatilities, correlations, etc.)
- Risk-adjust the distribution
- Generate samples from this distribution (runs)
- Calculate project/option payoff based on samples
- Average payoffs and discount at risk-free rate
Is option pricing magical?

- The idea behind valuation (capital budgeting) is that we compare an investment opportunity to others in the market that have the same risk profile. We try to find a “twin security” from which to get a discount rate to apply to our project’s cash flows.

- The point of real options analysis is that it is *usually* easier to find a twin security for the underlying opportunity than for the option itself, since the risk of options varies greatly depending on time-to-maturity, the relative value of the PV (stock price) to the exercise price, etc.
Review of parameters that must be estimated

- Start with the easy ones:
  - T (time to maturity)
  - r (risk-free interest rate)
  - X (investment required if exercise option)

- Next, value the underlying opportunity (PV):
  - forecast expected cash flows, taking into account technical, economic, and other risks when estimating a distribution
  - estimate appropriate discount rate from comparables
  - or, use forward prices to directly calculate risk-adjusted expected cash flows, and then discount at risk-free rate
Estimating Volatility

- If the problem has been set up where the underlying “asset” is the PV of an investment, then we must estimate the volatility of this PV, much like we estimate the volatility of a stock price.

- The DCF model that calculates the PV can also be used to estimate the volatility of the PV. Consider the possible PVs that may result in year one depending on the outcome of the underlying uncertain variables. This distribution of PVs (divided by the time zero PV) can be used to calculate the PV volatility (at least for the first year).
Estimating the “dividend yield”

There are three possible reasons for including a dividend yield in the option valuation analysis:

- There are cash flows that could be obtained if the investment opportunity were taken today, and thus are foregone if the option is not exercised.
- Competition erodes the present value of the underlying opportunity (assume a continuous drain on project value).
- If a commodity price is used as the underlying variable in the analysis (instead of the PV of the underlying project), then there is a “convenience yield” (that the dividend yield represents) which equals the (yearly) benefit of holding the underlying commodity (apart from the price appreciation of that commodity).
Other considerations

- While the distribution of stock prices is reasonably well approximated by a lognormal distribution, this may not be true for the PV of an investment project.

- There may be mean reversion in the underlying variables (due to business cycles, the gradual elimination of supply-demand imbalances, etc.). There may also be jumps in asset values.

- The volatility of the PV may also change over time (e.g. significant uncertainty is resolved in the early periods).
Real Options and Corporate Finance

Communicating to Executives and Shareholders

Strategic Investment
Recognizing Options
Creating Options
Enhancing Option Value
Information Acquisition

Other Corporate Decisions
Project Portfolio Analysis
Financing Policy
Enterprise Risk Management
Compensation Structure

Valuing Real Options