

Real Options: A New Approach for Economic Evaluation of Mining Projects

Sabry Sabour, Ph.D., P.Eng.
Assistant Professor
UAF Mining & Geological Engineering
ssabour@alaska.edu

Contents

- Conventional cash flow model: Where are the flaws?
- What is the real options valuation?
- How can the real options help? Some applications
- Conclusions

Conventional cash flow model: Where are the flaws?

Calendar year			2009	2010	2011	2012	2029	2030
Project year			1	2	3	4	21	22
Production year			-2	-1	1	2	19	20
Mine Production		Life of Mine						
Waste	kt	99,322			3,415	1,550	6,810	6,501
ore	kt	18,640			539	697	781	834
Grade	g/t	2.90			3.93	3.48	2.38	2.41
Gold Price	\$/oz		650	650	650	650	650	650
Revenue	\$ million	911.60			34.57	41.88	30.72	34.60
Production costs	\$ million	(403)			(18.12)	(16.56)	(20.33)	(20.19)
Smelter deductions	\$ million	(18)			(0.69)	(0.84)	(0.61)	(0.69)
Refining charges	\$ million	(7)			(0.26)	(0.32)	(0.23)	(0.26)
Freight & Insurance	\$ million	(6)			(0.23)	(0.28)	(0.21)	(0.23)
Operating cash flow		477			15.26	23.88	9.34	13.23
Total Capital Expenditure	\$ million	(320)	(40.00)	(35.00)	(44.59)	(16.62)	(8.27)	(12.66)
Net project cash flow	\$ million	157	(40.00)	(35.00)	(29.33)	7.26	1.07	0.57

- **Grade** up to year 2030 are known with certainty
- Standing in Year 2009, gold **prices** up to Year 2030 are known with certainty
- Once the project starts, it will run to completion under current **capacity**

Conventional cash flow model: Where are the flaws?

Calendar year			2009	2010	2011	2012	2029	2030
Net project cash flow	\$ million	157	(40.00)	(35.00)	(29.33)	7.26	1.07	0.57

Summary		
Cumulative undiscounted net cash flow	\$ million	157.00
Net present value (NPV)		
Discounted at 5%	\$ million	64.56
Discounted at 8%	\$ million	31.68
Discounted at 10%	\$ million	15.61
Discounted at 12%	\$ million	2.99
Discounted at 15%	\$ million	-11.14
Internal rate of return (IRR)	%	12.6%
Payback period	Years	6.7

- What is the “appropriate” **discount rate**?
- Future revenues and costs are discounted at the **same rate**

Conventional cash flow model: Where are the flaws?

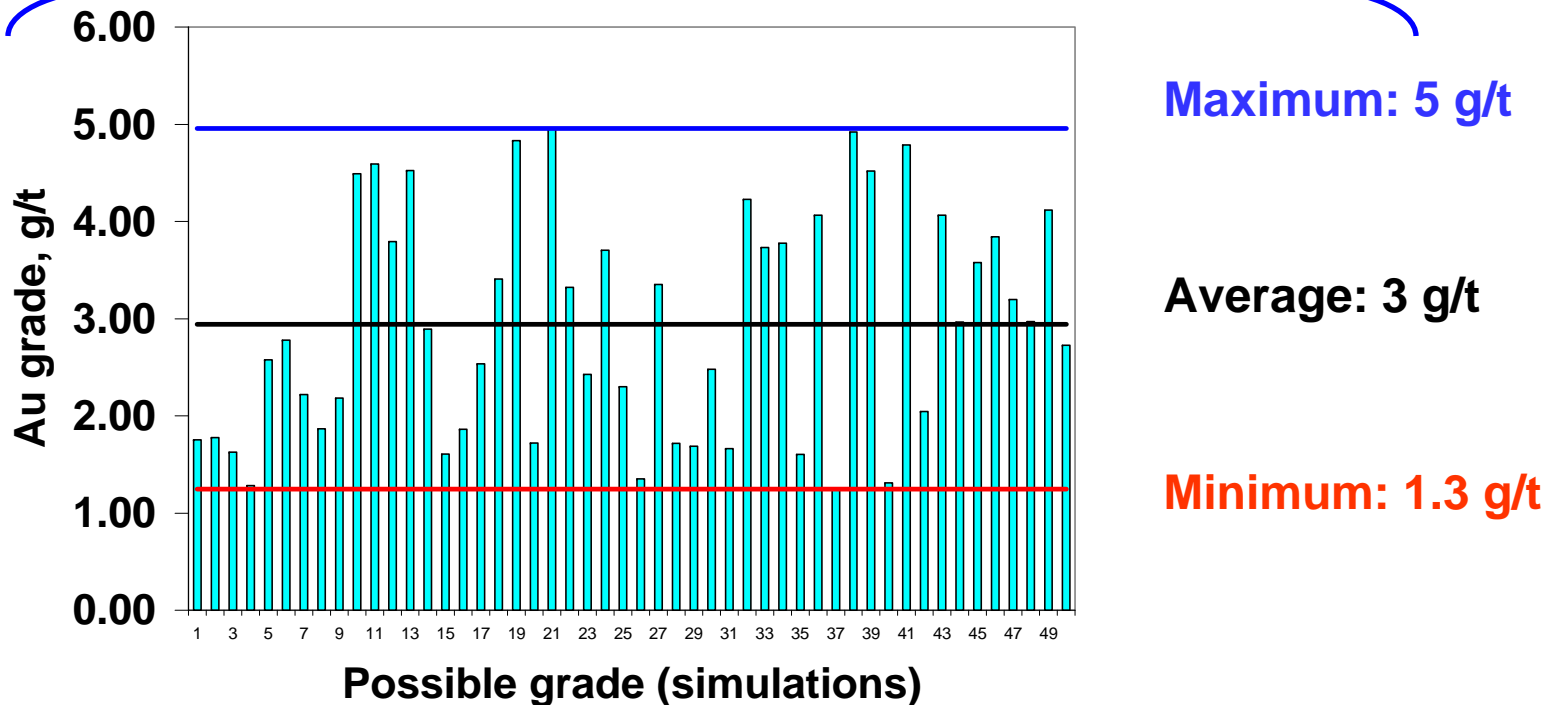
Assumptions:

- Ore grade is known
- Metal prices are known and fixed
- Mine will run under the initial capacity through the end
- Costs (capex & opex) are as risky as metal prices

Conventional cash flow model: Where are the flaws?

Assumption 1: **Ore grade is known**

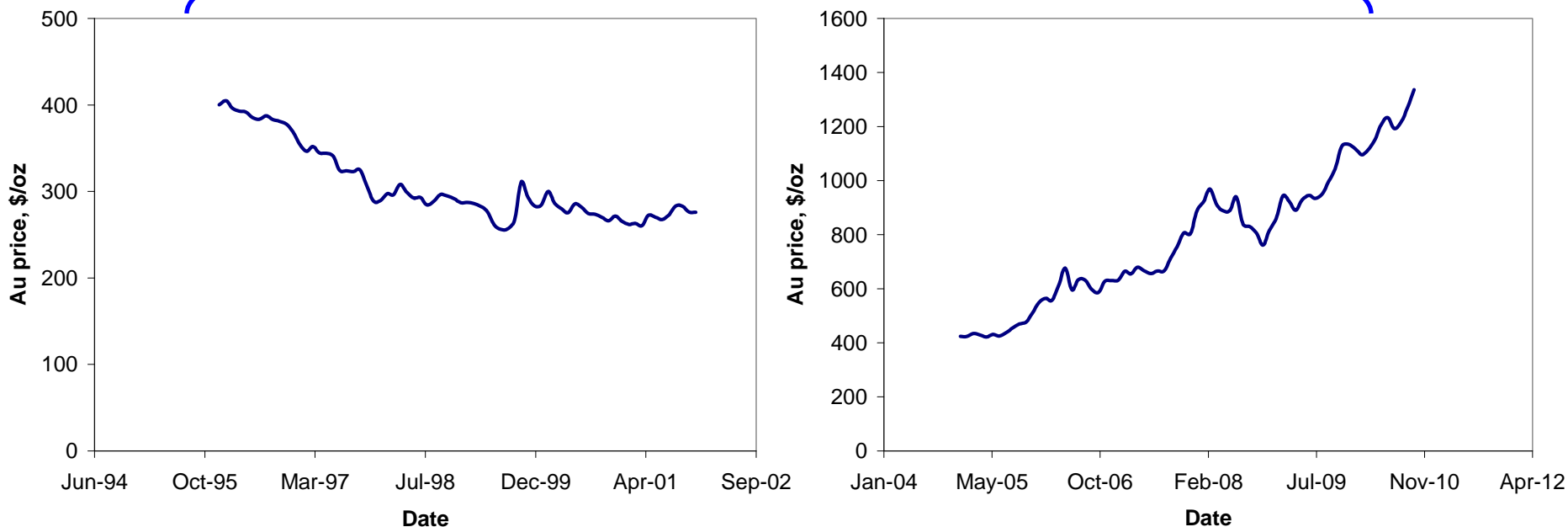
Reality:



Conventional cash flow model: Where are the flaws?

Assumption 2: **Metal prices are known and fixed**

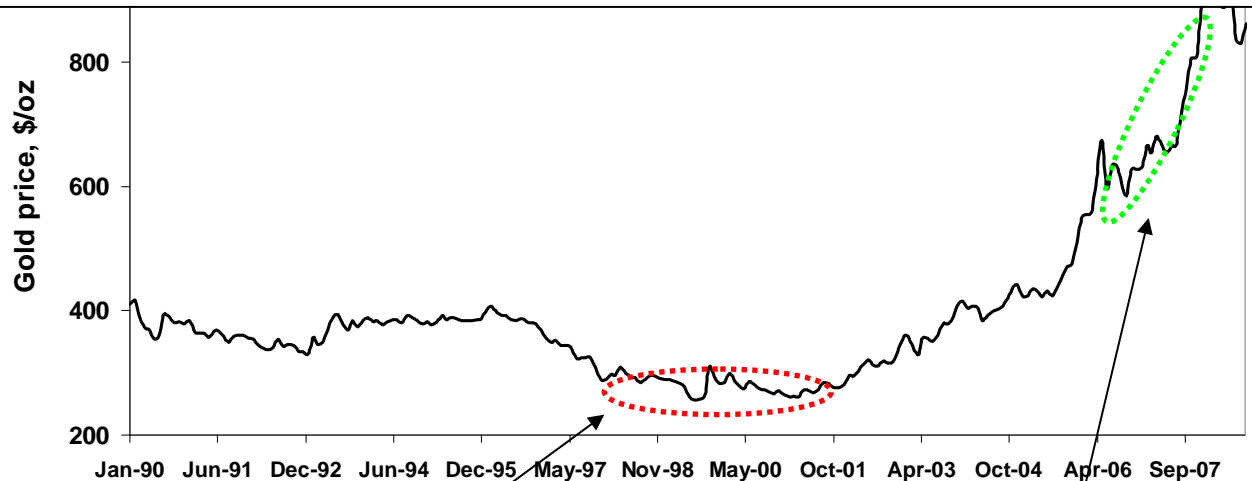
Reality:



Conventional cash flow model: Where are the flaws?

Assumption 3: **Mine will run under the initial conditions through the end**

Reality:



Declining market

- Increase the cut-off grade
- Postpone the whole project
- Postpone further developments
- Stop temporarily/ Abandon

Soaring market

- Reduce the cut-off grade
- Expand mine capacity
- Go deeper, higher cost
- Reopen closed mines

Conventional cash flow model: Where are the flaws?

Assumption 3: **Mine will run under the initial conditions through the end**

Reality:



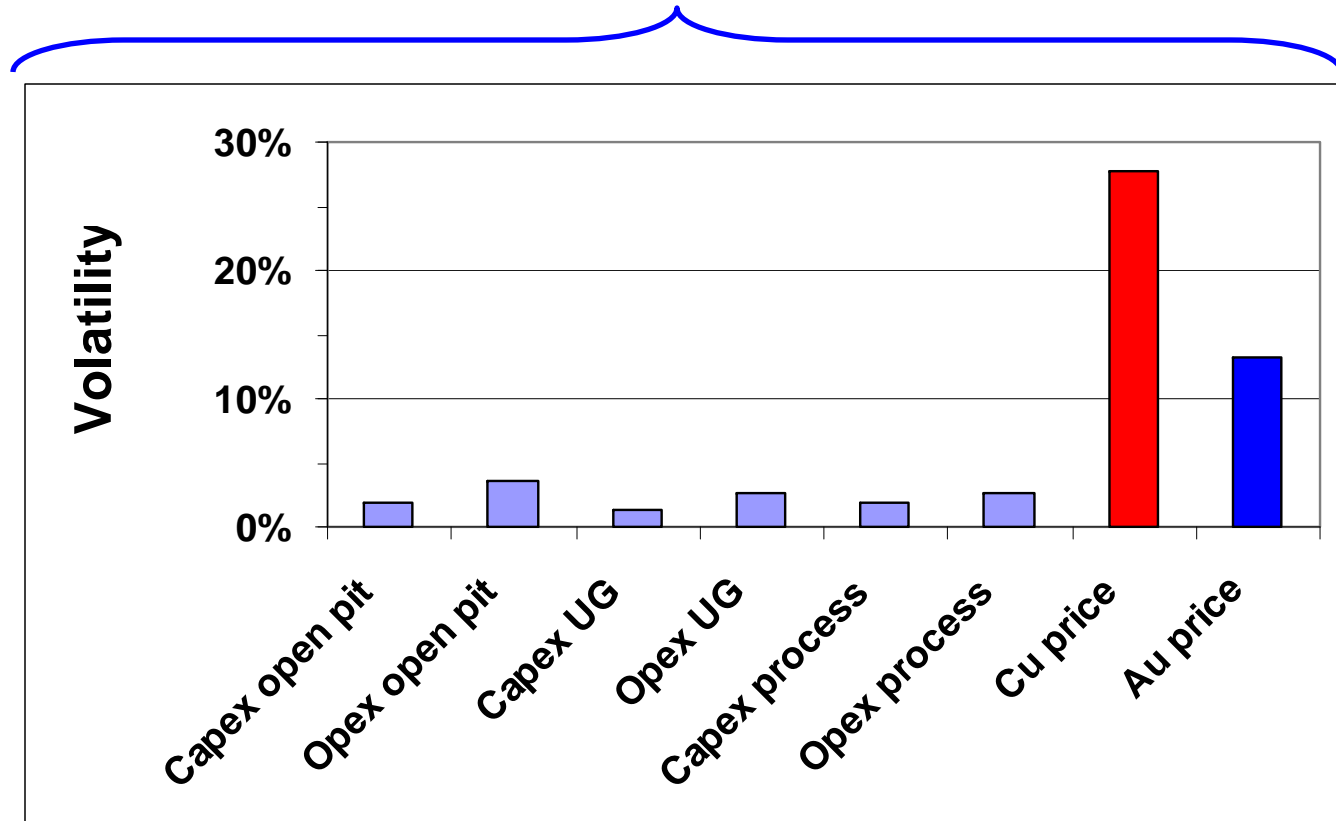
existing mill. The heap leach facility will allow the mine to process some of these low-grade materials, as well as zones of lower-grade ore that have not yet been mined.

The Fort Knox Project is expected to extend the mine life of the mine from 2012 until 2018. The project will

Conventional cash flow model: Where are the flaws?

Assumption 4: **Costs (capex & opex) are as risky as metal prices**

Reality:



What is the real options valuation?

Real options valuations: ROV, technique is a “**dynamic**” DCF technique

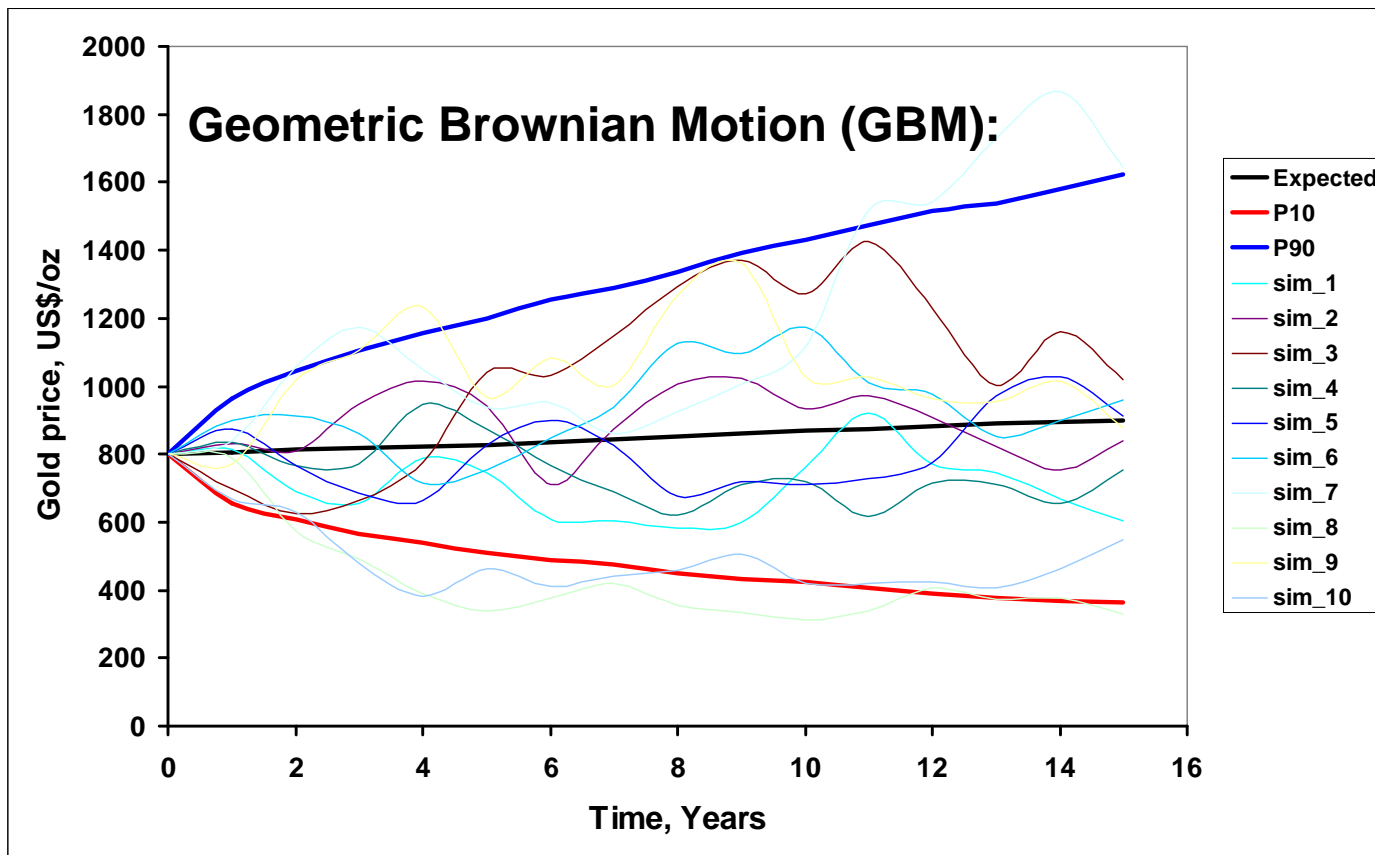
Assumption	Conventional DCF	Real Options
Grade & price	Known	Uncertain
Mine operations	Mine will run under the initial conditions through the end	It is possible in the future to expand, contract, shutdown, reopen
Costs and price risk	Costs are as risky as metal prices, single risk-adjusted rate applied to the net future cash flows	Prices riskier than costs, differential discounting is applied

What is the real options valuation?

- An option is the right but not the obligation to make an operating decision
- Similar to call/put options in the stock market
- Having an option does not mean you have to exercise it
- But it means you are better off as you have choices
- Examples of real options:
 - Timing option
 - Option to do exploration work
 - Option to develop/expand the mine
 - Continue/hold/resume production
 - Abandon the mine/lease

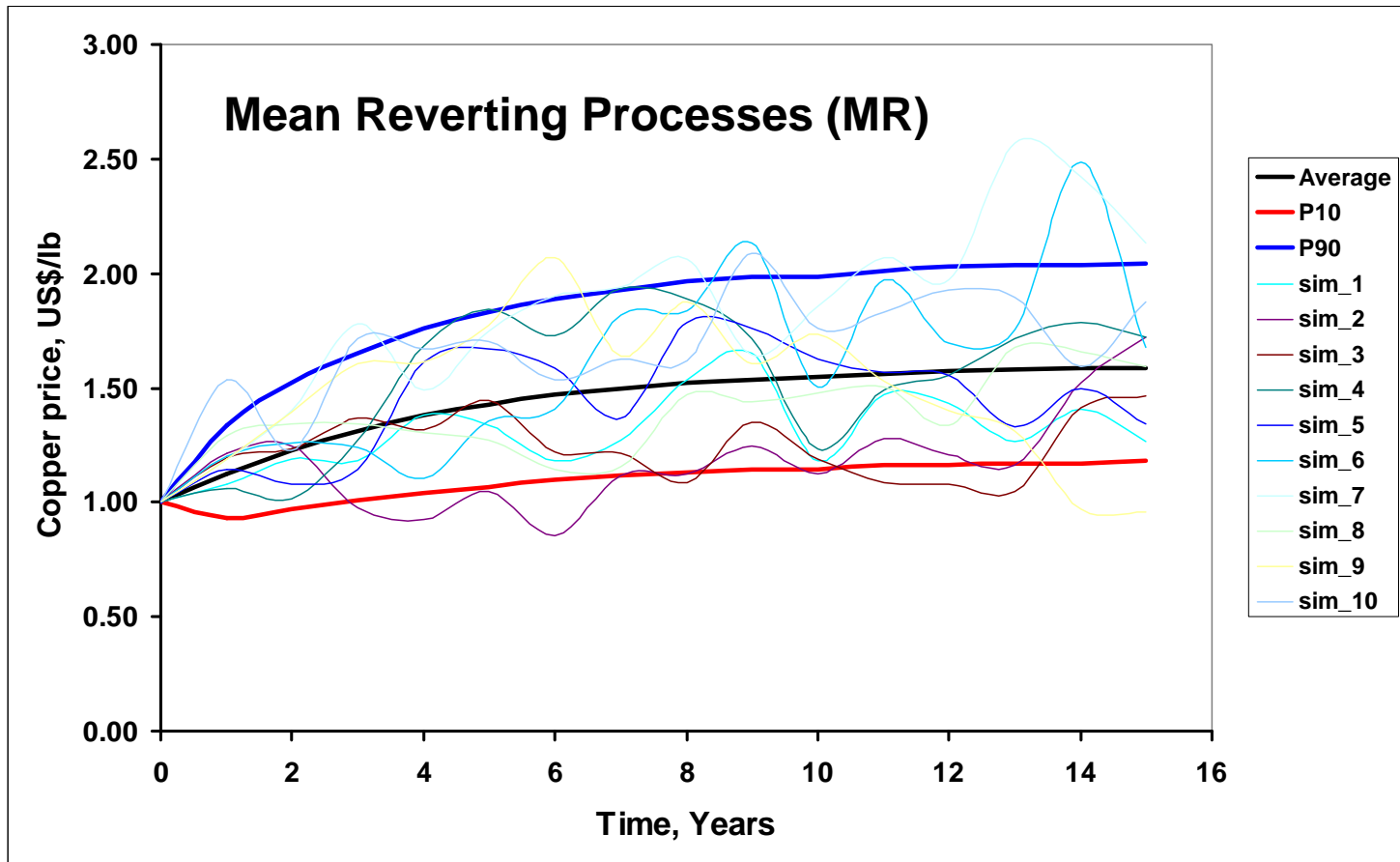
What is the real options valuation?

Considers multiple price scenarios rather than a fixed price



What is the real options valuation?

Considers multiple price scenarios rather than a fixed price



What is the real options valuation?

Computing techniques:

- Finite difference
- Binomial Lattice
- Monte Carlo Simulation

How can the real options help?

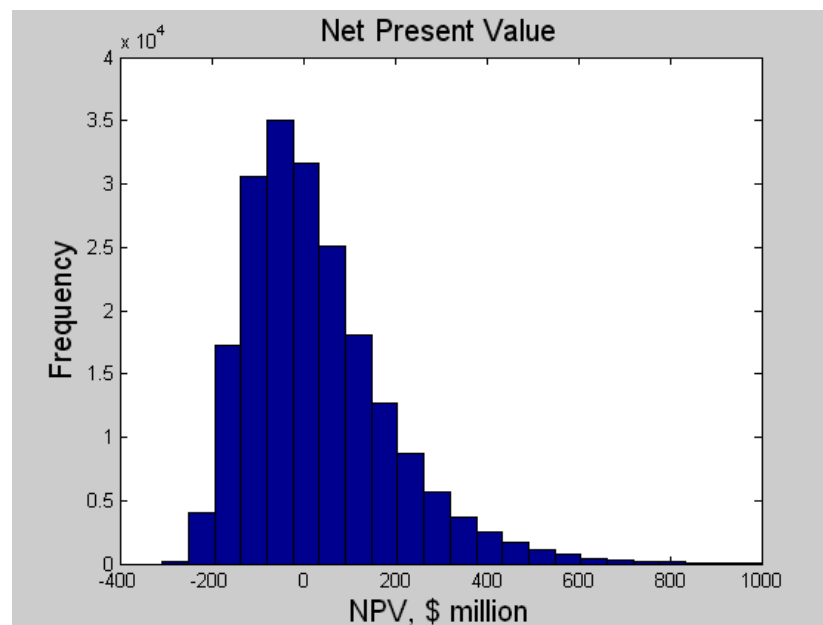
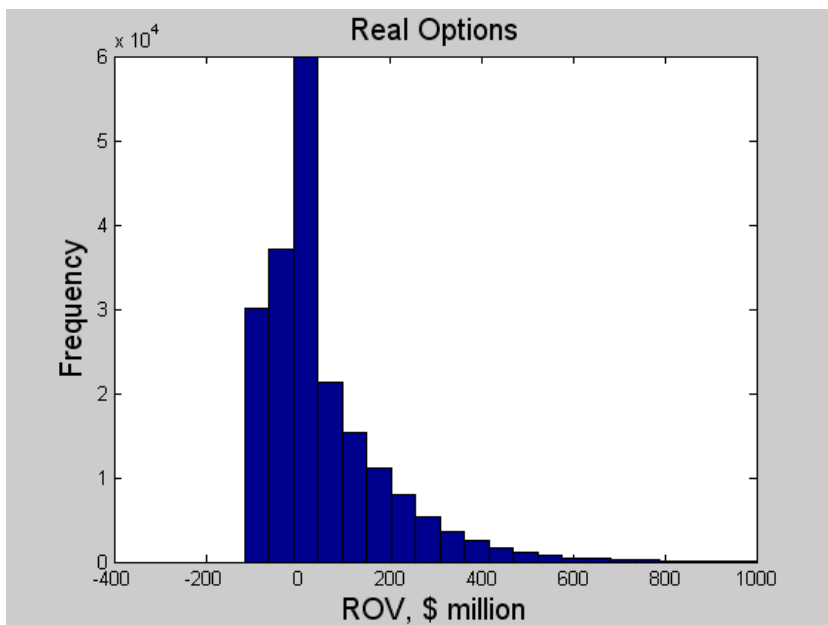
Applications:

- Valuing a simple gold mine
- Long-term mine planning: What is the optimum mine life?
- Owner versus contract mining
- Mine expansion

Valuing a simple gold mine

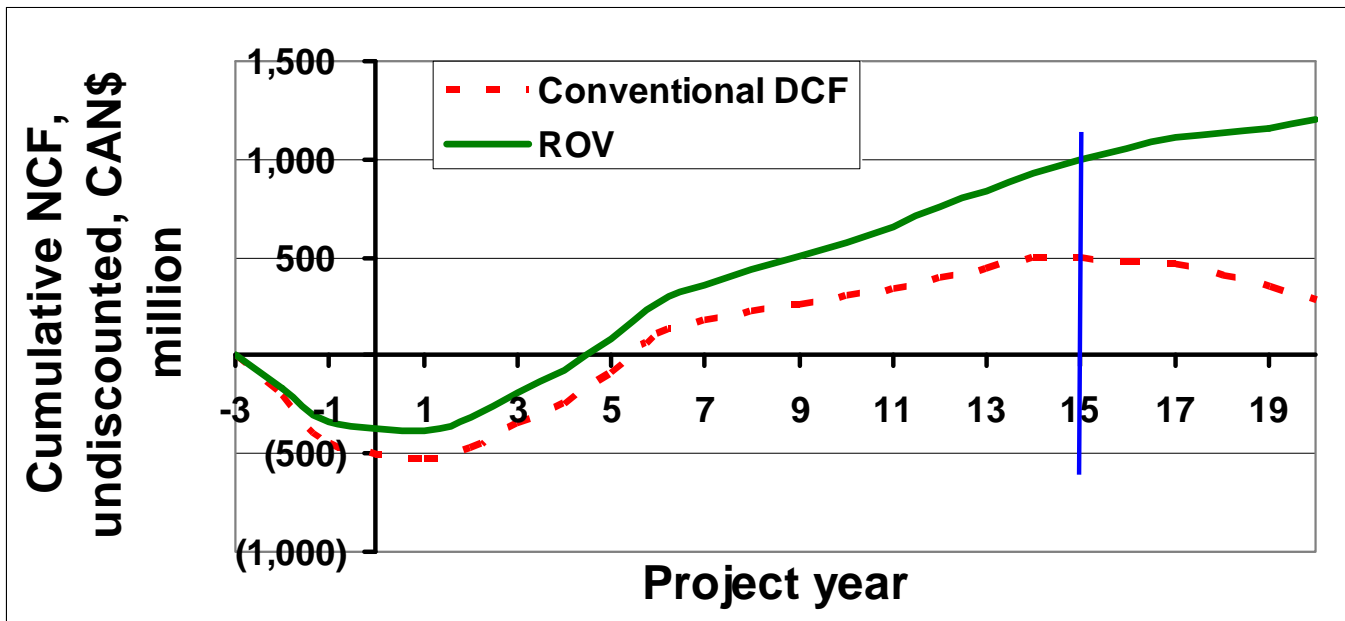
Cash Flow (\$ million)	ROV	NPV
Revenue	691.4	911.5
Operating costs	247.1	403.2
Smelter deductions	13.8	18.2
Refining charge, transportation, marketing	7.1	11.2
Insurance charge	1.3	1.8
Capital expenditure	210.5	308.4
Abandonment costs	6.9	11.8
Net cash flow	204.6	157.0
Discounted net cash flow (NPV @ 8% discount rate)	52.8	31.7

Valuing a simple gold mine



Where does the difference come from?

Long-term mine planning: the optimum life mine for a Cu-Au open pit



NPV Curve reaches the peak in Y 15

ROV curve keeps increasing

Design a 15-Y pit

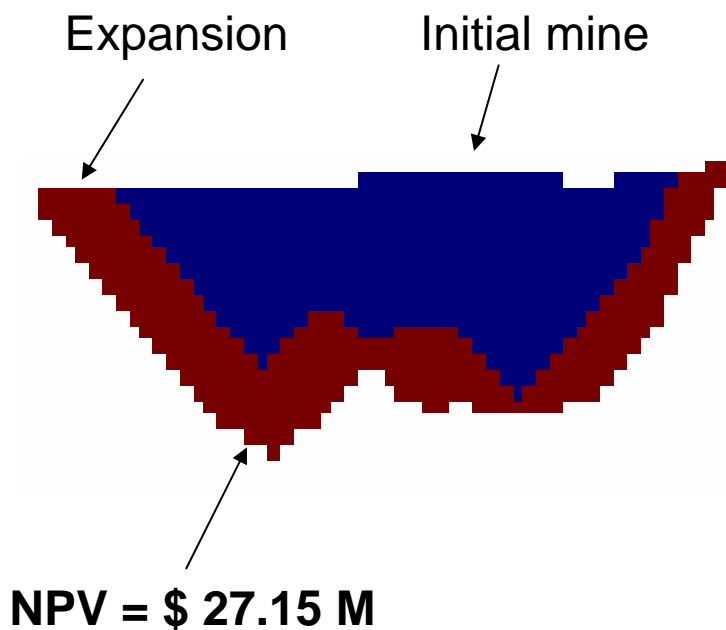
Design a 20-Y pit

Owner versus contract mining

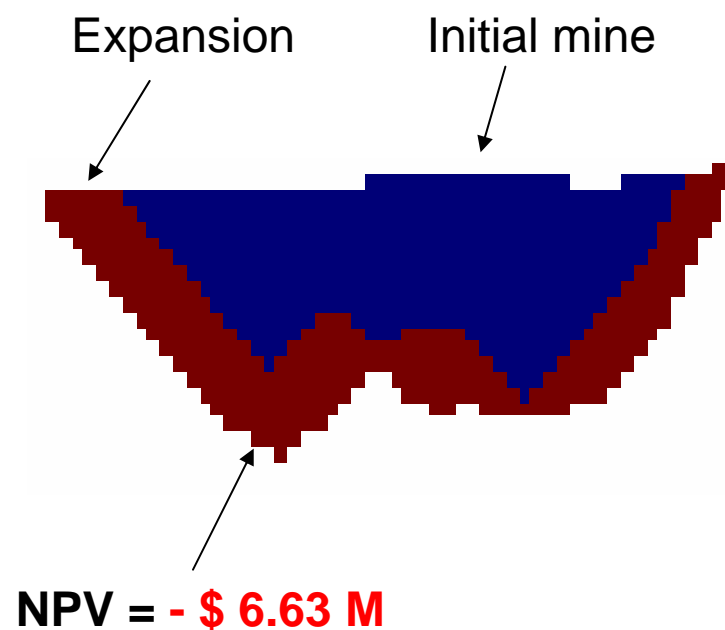
Cash Flow (\$ million)	Conventional NPV		ROV	
	Owner	Contract	Owner	Contract
Revenue	2041.34	2041.34	1815.10	1650.65
Operating Costs	661.03	1065.93	494.79	698.81
Smelter Deductions	68.04	68.04	60.50	55.02
Refining Charge, Transportation, Marketing	131.57	131.57	98.72	83.86
Capital Expenditure	396.44	149.17	376.57	136.36
Net Cash Flow	464.16	306.54	544.34	472.57
Discounted Net Cash Flow (NPV @ 8%)	62.28	62.28	93.04	130.26

- Conventional NPV cannot help in such a situation
- RO can capture the difference between owner and contract mining

Mine expansion



Uncertainty-based
evaluation



Conventional
evaluation

Conclusions:

- Decision-making in mining is carried out under multiple market and geologic uncertainties
- Conventional DCF analysis cannot handle uncertainty and assess opportunities
- RO provides informative information
- In reality, management and decision-makers act similar to RO, qualitatively
- This can be done quantitatively with the RO

Mine Evaluation Laboratory

Advanced economic analysis: From exploration to mine optimization

Goals:

- Improve mine evaluation and decision making techniques
- Undertake techno-economic applied research tailored to the needs of the mining industry
- Integrate sustainable mining development into mine evaluations as a means of maximizing value to both the society and the industry
- Provide training & short courses on mine evaluation