

# Valuation with Simulation of Flexibility “on” and “in” a System

Capital Investment and  
Engineering Flexibility  
in the development of  
the Antamina mine (Peru)

## Definition; “on” and “in” flexibility

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Class focuses on design features that enable systems to evolve easily (e.g., more floors to garage). This is flexibility “**in**” system.

We can also discuss flexibility to abandon a project, to delay its opening. Such flexibilities have nothing to do with design. This kind of flexibility is known in finance as a “real option”. More about those important flexibilities later in course. This is flexibility “**on**” a system.

# Note

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This presentation is based on the case developed by Peter Tufano and Alberto Moel from the Harvard Business School.

It contains simplifications. The figures appearing here differ from those presented by Tufano and Moel. They reflect the assumptions of the authors of this presentation about the treatment of uncertainty and the cash flows projection.

## Antamina Project Description

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- State-owned copper and zinc mine in Peru, ~480km (300miles) north of Lima
- Privatization in 1996: call for bids. Small upfront payment + promise to develop
- Little reliable geological information
- Geological study to take two years, start after the bidding, be available before construction
- Proceed with development if survey suggested the mine could be developed economically

# Antamina Auction Process

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- Government Required:
  - Bidding on 2-stage process
  - Companies must bid for right to explore and must decide on development in 2 years
  - Big penalty for not developing (why?)

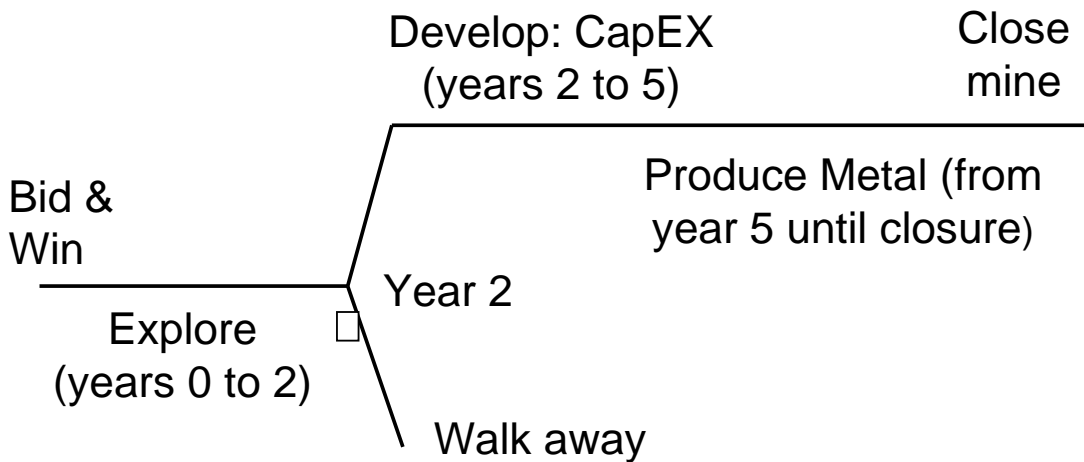
# Antamina Mine Time Line

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- Step 1: explore geology, topography for access
- Step 2: decide to develop and spend 3 years on building facilities before getting profits in Year 6

# Project Time Line

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**This is Flexibility “on” System. Why?**

# Antamina Mine Flexibilities

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- “on” Flexibility
  - Winning Company has flexibility to **abandon** mine in 2 years
- “in” Flexibility
  - Designers can create flexibility “in” system
  - Ex: create port during exploration period, to provide flexibility to expedite development to 2 years (from 3) – and thus advance revenue stream by 1 year and increase NPV



# Antamina Mine Simulation

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- System Model: NPV depends on:
  - ore quality, quantity
  - cost of mining
  - value of metals (mostly copper, zinc and “moly”)
  
- Distributions for Key parameters
  - Estimated: Technical Cost Models (of mine ops)
  - Assumed: Market data (historical data)
  - Guessed: Expert Judgment on ore quality

## Sources of Uncertainty

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<b>Revenues</b>		<b>Uncertainty treatment</b>	
▪ Mine's life	→	▪ Deterministic	
▪ Future prices of zinc and copper	→	▪ Stochastic process (Lattice, Years 0 to 2)	
▪ Quantity of ore	}	▪ Probability distributions Monte Carlo simulation	
<b>Costs</b>			
▪ Operation expenses			
▪ Capital Expenditures			

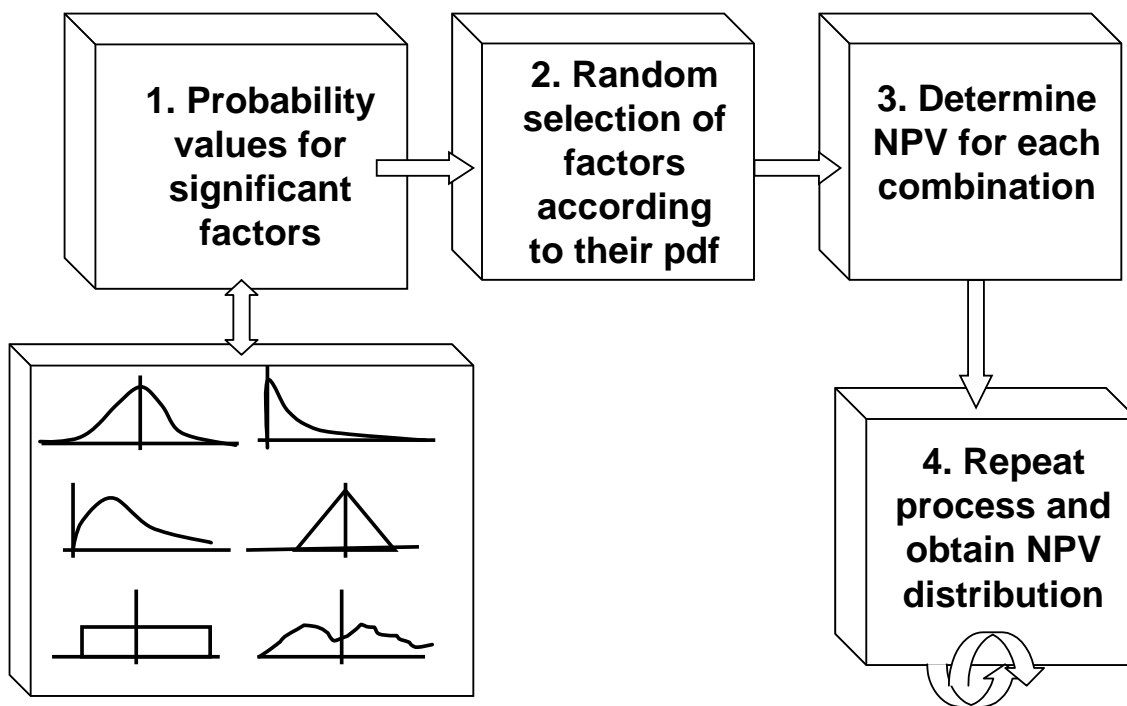
## Sources of Uncertainty

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- Price and quantity uncertainty prevails only during the first two years
- Price risk is assumed to be eliminated in year 2 by entering forward contracts to sell the output of the mine (this is assumption M&T made – a bit of a stretch...)
- All other sources of uncertainty are modeled in the Monte Carlo simulation after year 2

⇒ Simulation result: Realization of expected NPV

# Monte Carlo Simulation



# Antamina Mine Valuation

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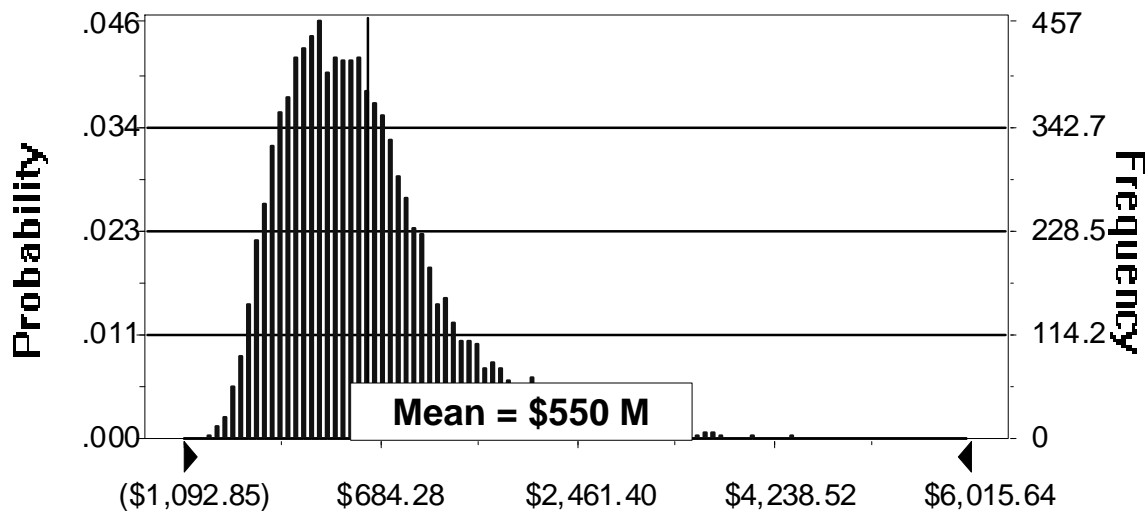
- Assumed operators could “lock in” price for metal by long-term contracts over life of mine
  - Probably not possible. Necessary assumption to for financial analysis to get life-time NPV of mine
- Value of “on” Option =  $EV(\text{all positive NPV}) - EV(\text{project without option to abandon})$
- Value of “in” Option = further improvements in NPV due to flexibility provided

# Results: Base Case – No Flexibility

Crystal Ball Student Edition **Forecast: NPV (base case)**  
Not for Commercial Use

**10,000 Trials**

**Frequency Chart**



Massachusetts Institute of Technology  
Engineering System Analysis for Design

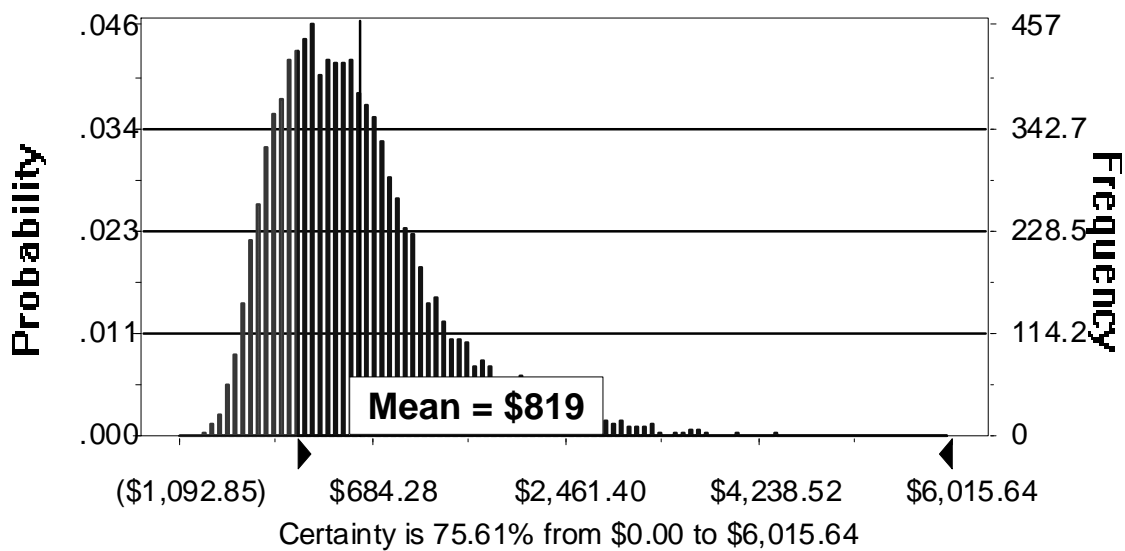
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Michael Benouaich Slide 14 of 23

# Simulation Results: Flexibility to Abandon

Crystal Ball Student Edition Forecast: NPV (base case)  
Not for Commercial Use

10,000 Trials

Frequency Chart



Massachusetts Institute of Technology  
Engineering System Analysis for Design

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# What “rule for exercising flexibility”?

What Rule Useful for Antamina?

Rule for exercising flexibility defines time, conditions for choosing to exercise flexibility

In this case:

- Only 1 time available;
- Condition obvious: get out if expect losses



# Valuation: Flexibility to Abandon

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Value of flexibility to abandon:  
 $\$819 - \$550 = \$269$  million

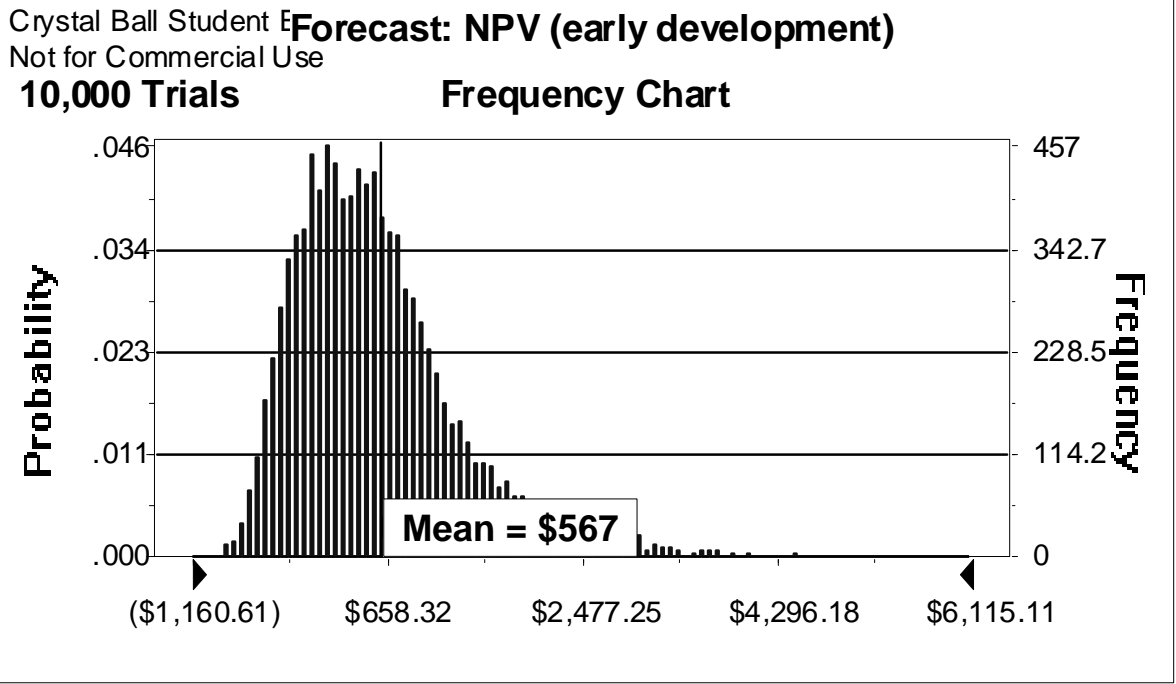
# Engineering Flexibility

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- Add flexibility, add value?
- Starting engineering study earlier and faster would allow you to shorten construction to two years and ramp up production faster

⇒ What would you pay for this flexibility?

# Simulation Results: Early Development



## Valuation: Flexibility of Early Development

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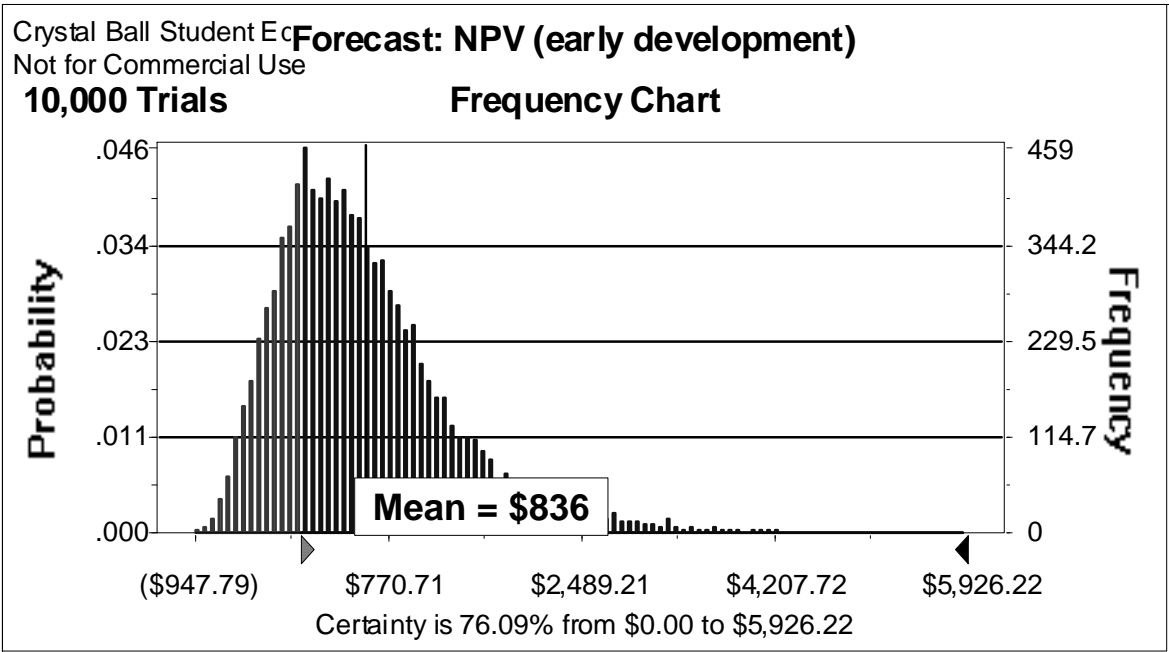
Early Development Flexibility (alone):

$\$567 - \$550 = \$17$  million

Would easily justify several million \$  
spent early on design work

This flexibility would in fact be compounded  
with the flexibility to abandon  
Generally not additive!

# Simulation Results: Both Flexibilities



## Valuation: Both Flexibilities Together

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Value of both Flexibilities together:  
 $\$ 836 - \$550 = \$286$  million

Incremental Value of Early  
Development Flexibility:  
 $\$ 836 - \$819 = \$17$  million

Appears additive, but actually a difference.  
In this case rounded out and insignificant

## References

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- Tufano, P., Moel, A., (1997) “Bidding for Antamina”, Harvard Business School Case number 9-297-054, Rev. Sept. 15.
- Tufano, P., Moel, A., (2000) “Bidding for the Antamina Mine – Valuation and Incentives in a Real Option Context”, in “Project Flexibility, Agency, and Competition,” edited by Brennan, M. and Trigeorgis, L., Oxford University Press
- Hertz, D. (1979) “Risk Analysis in Capital Investment”, Harvard Business Review September-October, pp. 169-180