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A Framework for Valuing, Optimizing and Understanding Managerial Flexibility

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Abstract

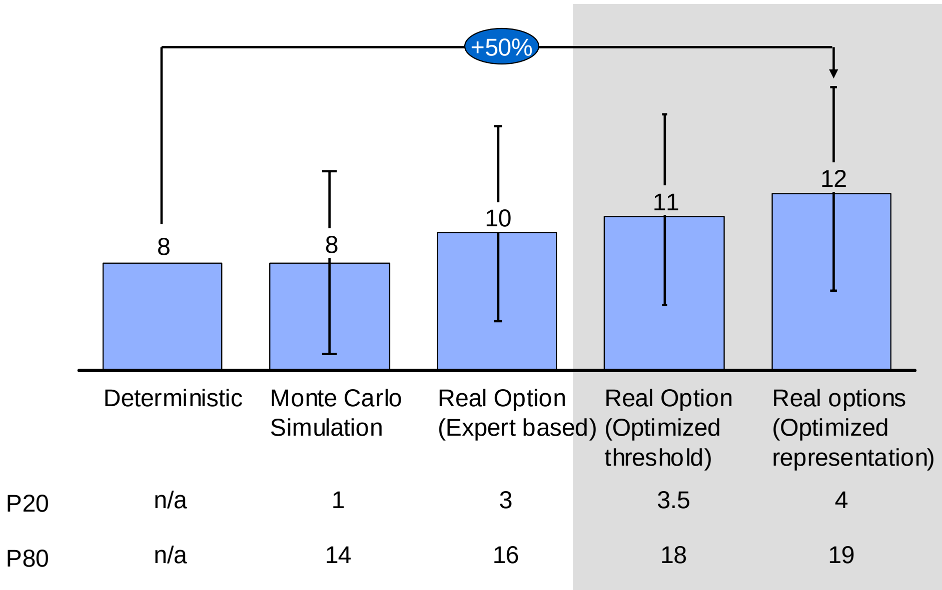
As NPV and Stochastic type analysis become more commoditized in the industry, many stakeholders are becoming increasingly aware and interested in the added value of managerial flexibility and options contained in projects. Based on a real project example this paper attempts to bring real options into the mainstream by providing a 3-step framework to be used by management and valuation teams to i) determine the risk factors and possible operational states of the project, ii) identify the real-options contained in each state of the project life cycle and iii) use genetic programming to optimize the valuation and understand the underlying value of each option. To illustrate the framework, the case of a company investigating the development of an oil sands project is used. A graphical state space map (influence diagram) is created along with defined business constraints and genetic programming is used to optimize the representation with the objective of maximizing the value of the project under stochastically generated scenarios. Moreover the genetic programming approach allows for a thorough exploration of the embedded options by computing the value of each option, the optimal decision thresholds and highlighting overlooked value creating optionality. In our case example applying this real option framework increased the expected value of the project by 50%, more than doubling the increased value of previously used ad hoc real option approaches.

Introduction

In attempt to maximize stakeholder value, decision makers have to consider not only if potential projects are value adding, but what impact investment decisions have on risk. Net present value (NPV) calculation is the standard tool used for assessing an investment decision's expected value, the point-estimate of the NPV calculation can be extended to incorporate risk. The use of Monte-Carlo analysis has become commonplace in helping managers frame risk-return tradeoffs of their investment decisions especially with the increased use of software like *@RISK*^{tm} or *Crystal Ball*^{tm}. Although NPV and Monte-Carlo analysis yield the same return [Exhibit 1], Monte-Carlo analysis has the advantage of providing management with other descriptive metrics such as Potential Upside, Potential Downside and Risk-Return ratios allowing managers to make more risk informed decisions.

EXHIBIT 1 – THE IMPACT OF REAL OPTIONS ON PROJECT IS SIGNIFICANT, ESPECIALLY FOR OPTIMIZED RESULTS PRELIMINARY

USD/bbl



As NPV and Monte-Carlo analysis become more commoditized, real option techniques have emerged as the next step forward in the project analysis toolbox of savvy managers. However, in main stream corporate environments, incorporating managerial flexibility into the valuation model has always been a difficulty, with ad hoc rules often being applied in valuation models. On the one hand, real option models based on expert inputs work well adding in the range of 25% to a projects expected value [Exhibit 1]. On the other hand, they do not capture the full value of the embedded managerial flexibility. There are two critical reasons that explain this: 1) the thresholds at which each option should be triggered are not optimally set and 2) the dynamics and interaction between the various sources of flexibility are very complex, making it difficult to model accurately. Using the example of an oil sands project, we illustrate how to extend the traditional expert based approach and to optimally value the embedded real options using an end-to-end framework.

Description of the business situation

A large integrated oil company has the ambitious plan to increase their oil production by 200 kbd over the next 3 years, in attempt to increase its North American market share by 5%. With this goal in mind senior management is exploring different expansion opportunities and the future investment options and flexibility that each potential opportunity creates. One example of a project they are investigating is the valuation of an oil sands mine expansion project on one of their current sites. This project has a number of embedded real options that could add substantial value, that would not be captured through simple NPV calculation. An example of managerial flexibility would be if oil prices in the future should fall below production cash cost, which would produce a negative NPV in a simple model, management would have the option to decrease or cease production under certain constraint. The question, then, is at which oil price should this decision then be made? There are numerous embedded options in large capital investment such as this one, the delay of construction in the event of dropping prices, ramping up production in the event of high future prices or the choice to idle or decommission the mine in the future if prices fall drastically. To correctly assess the value of a proposed investment decision it is clear that managerial flexibility must be incorporated to capture all of the project's value. Previously option threshold prices have been set through expert opinion, now it can be shown that an optimized real option model can outperform a model generated by an expert by an average of 25%.

Approach and proposed framework

A three step framework [Exhibit 2] is developed that brings together the management and evaluation team. The first 2 steps in the framework are workshops aimed at developing the state space diagram that define the managerial flexibility available in the project, providing a clear graphical depiction of the options, their interdependencies and effect on the project at hand. The third step in the framework uses genetic programming to optimize the real option representation by maximizing value to the stakeholders under the defined business constraints. In preparation, the team will have prepared a standard NPV model of the project with a standard Monte-Carlo risk analysis, with each of the key risk factors modeled in to provide insight into the key drivers of risk and their impact on the value of the project [Exhibit 3].

EXHIBIT 2 – A THREE STEP FRAMEWORK TO LEVERAGING MANAGERIAL FLEXIBILITY

States
Options

	Identify risk drivers and options	Identify options available at each state	Optimize
Description	• Indentify and understand the impact of all of the key risk drivers needed to evaluate options • Define possible project states	• Identify possible transition options in each state • Define business constraints that don't allow certain options • Estimate a threshold estimate	• Defined thresholds for option exercising • Optimized real-option representation

Illustration

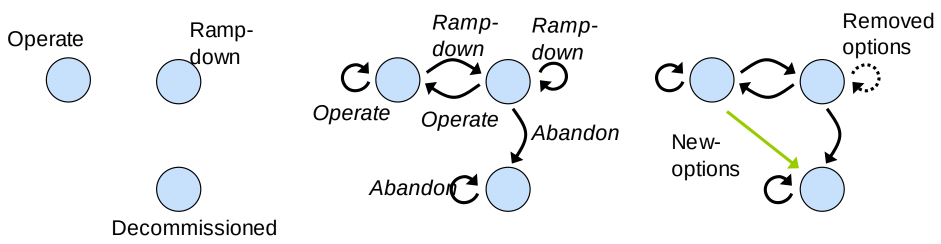
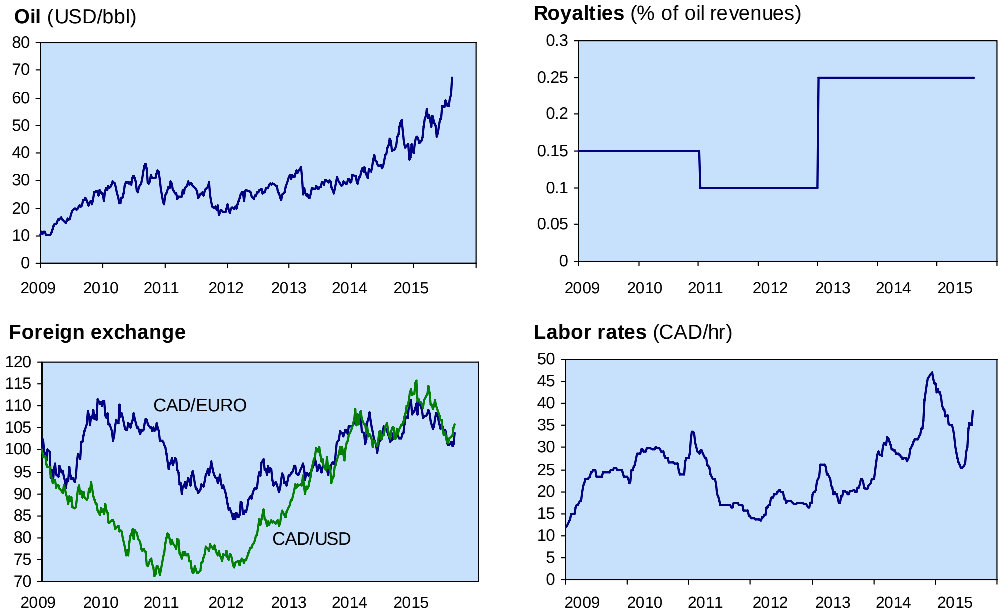


EXHIBIT 3 - MONTE-CARLO SIMULATION OF KEY RISK DRIVERS



1. Workshop 1: Determine what are the different operational states of the business and the risk factors affecting them

During this first workshop managers, operators and a facilitator get together and brainstorm the different actions that they could take when faced with changing input costs and output prices. The discussion is supported with a set of risk analysis illustrating the impact of the key risk factors on the project performance. For instance, continuing with the oil sands example, potential states could be *decrease production* – where output is decreased in times of lower margin or *expand production* – in times of high oil prices. At the end of this first workshop the team has built a common opinion of the key sources of flexibility and the identified risk factors that prompt the execution of the option [Exhibit 4].

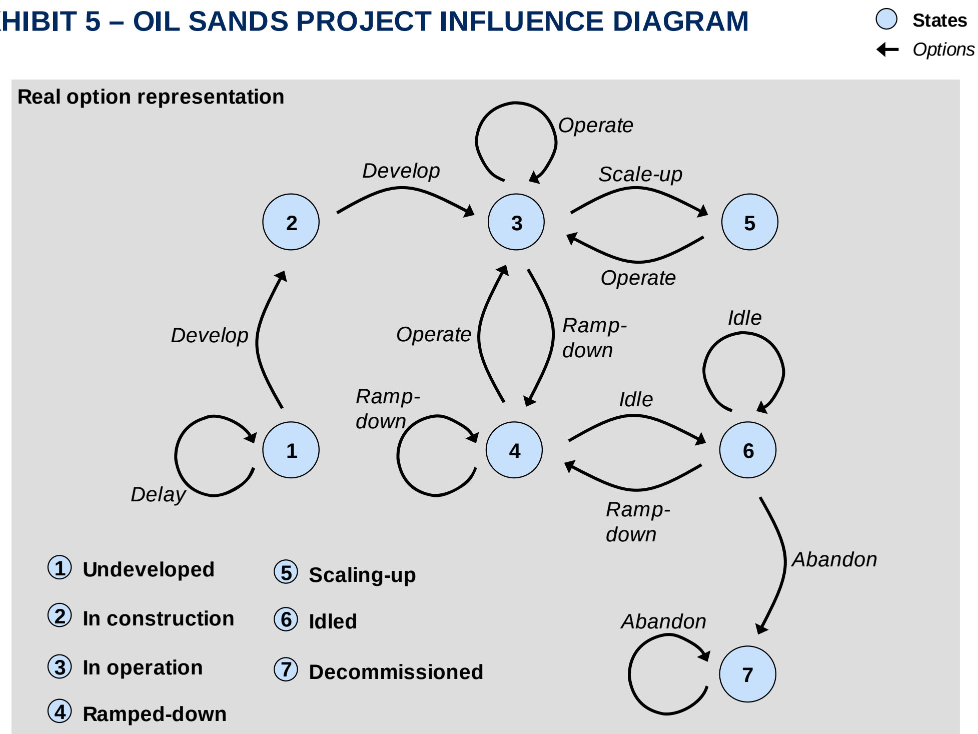
EXHIBIT 4 – SUMMARY OF REAL OPTIONS AVAILABLE

Option definitions

Delay	• Postpone construction of the plan by 1 year with a one time cost
Develop	• Start the construction period and lock in the required capital
Operate	• Run asset at full available capacity
Scale-up	• Increase production capacity by 50% with half the capital cost per barrel scaling fixed and semi-fixed cost with production level
Ramp-down	• Reduce production to 60% of available capacity – minimum output rate of the processing plant
Idle	• Temporarily stop production of the mine saving on variable and semi-variable costs
Abandon	• Terminate production of the site and pay for decontamination

2. Workshop 2: Determine what are the managerial options within each state
The aim of the second workshop is to address the various interdependencies between the options. This is required because of the high degree of path dependency that often impacts the possibility of exercising certain option. For instance, ,if the mine is working in a *decreased production* state it is not possible to move directly into a *scaled-up production* state but the option to move back into *normal operation* exists. Questions such as “If we are in the process of construction, are we are we able to idle production if prices turn?” should be asked to determine the available managerial flexibility in each state. The product of this second step is a state-space representation of the options, their relation to each other and estimated thresholds at which they are triggered [Exhibit 5].

EXHIBIT 5 – OIL SANDS PROJECT INFLUENCE DIAGRAM



3. Optimize using genetic programming

Use genetic programming [Exhibit 6] to optimize the constrained graphical representation to maximize the project's value of managerial flexibility and to identify the key input factors to decision making (e.g., oil prices, energy costs, labor rates). The topology of the graph, the actions and the threshold can be optimized all together or separately [Exhibit 6 and 7]. This optimization process allows the team to a) understand the relation between option triggers and the value created through optimization, b) compare the relative importance of each of the risk factors in the real options representation and c) identify the most effective way to employ the project's optionality. We show that very often a simpler and more successful representation can be found compared to the expert based model, especially when highly volatile risk parameters are involved.

EXHIBIT 6 – DESCRIPTION OF THE GENETIC OPTIMIZATION PROCESS

	Description
Step 1 – Encode and Initialize	• Encode the model logic into a genome: a binary "DNA like" representation • Randomly generate a population of genomes
Step 2 - Evaluate	• Test each genome of the population against the objective function (e.g. Maximize average NPV over 1000 stochastic paths) and tag the fitness score to each individual • Identify the top performing individual out of the population
Step 3 - Reproduce	• Out of the top performing trench of the population, randomly select 2 genomes (the parents) and a crossover point • Create a new individual from the genetic material of the parents • Include mutations by randomly changing the DNA sequence
Step 4 - Repeat	• Repeat for a selected number of generation step 2 and 3 with a new population • The population will converge towards individual which perform best against the selected objective function

The goal of this paper is to highlight the use of genetic programming and the state space graphical representation in the valuation of real options in the context of evaluating strategic business decisions. Managerial flexibility adds a tremendous amount of value to business operations, by not fully incorporating the value of this flexibility managers could be leaving value on the table when making strategic decisions. The remainder of this paper will focus on the oil sands expansion case example mentioned above implemented in Excel-VBA [Exhibit 7 and 8]. We show that this innovative 3 step framework increases the expected value of the project by a factor of 50%, unlocking more than double the value of ad hoc expert opinion created models [Exhibit 9]. In addition to this incremental value, the framework identifies the key inputs to be monitoring, the thresholds that should be used in decision making and the value of each of the embedded options which allows the manager to focus on the most important elements of the investment decision. This analysis is complemented by a discussion of the business implications of using this real options framework in a business context.

EXHIBIT 7 – TABLE DESCRIPTION OF THE INFLUENCE DIAGRAM

A table representation of the influence diagram is built…

State	Input #	Condi-tion	Thres-hold	Input #	Condi-tion	Thres-hold	Action 1	Next state	Action 2	Next state	Action 3	Next state	Action 4	Next state
1	1	>	60	3	<	0.25	Delay	1	Delay	1	Delay	1	Develop	2
2	5	>	0	5	>	0	Develop	3	Develop	3	Develop	3	Develop	3
3	2	>	0	2	>	40	Ramp-down	5	Operate	3	Nil	1	Scale-up	4
4	2	>	0	5	>	0	Ramp-down	5	Operate	4	Nil	1	Nil	1
5	2	>	-5	2	>	0	Idle	6	Ramp-down	5	Nil	1	Operate	8
6	1	>	-10	4	>	500	Abandon	7	Idle	5	Idle	6	Idle	5
7	5	<	0	5	<	0	Abandon	7	Abandon	7	Abandon	7	Abandon	7
8	2	>	5	5	>	0	Ramp-down	5	Operate	8	Nil	1	Nil	1

… and used to drive the model

Inputs			1	2	3	4	5
1	**Oil price**	**$/bbl**	50	80	75	60	60
2	**Spread**	**$/bbl**	na	na	na	15	-5
3	**Royalties**	**%**	0.15	0.15	0.2	0.2	0.2
4	**Reserve**	**Mbbl**	1000	1000	1000	1000	1000
5	**-**		-1	-1	-1	-1	-1
Action			**Delay**	**Construct**	**Construct**	**Operate**	**Ramp-down**
Next state			**1**	**2**	**3**	**3**	**5**

EXHIBIT 8 – EACH STATE OF THE STATE SPACE MODEL IS ENCODED USING A GENETIC REPRESENTATION

State 1

Element	Nb bits	Genome compenets						Limits		Results
Input 1	3	**0**	**0**	**0**						**1**
Condition 1	1	**1**								**>**
Treshold 1	6	**1**	**1**	**0**	**0**	**1**	**0**	0	200	**60.0**
Input 2	3	**0**	**1**	**0**						**3**
Condition 2	1	**0**								**<**
Treshold 2	6	**1**	**1**	**1**	**1**	**0**	**0**	0	1	**0.3**
Action 1	3	**1**	**0**	**1**						**Delay**
Next state 1	3	**0**	**0**	**0**						**1**
Action 2	3	**1**	**0**	**1**						**Delay**
Next state 2	3	**0**	**0**	**0**						**1**
Action 3	3	**1**	**0**	**1**						**Delay**
Next state 3	3	**0**	**0**	**0**						**1**
Action 4	3	**1**	**0**	**0**						**Develop**
Next state 4	3	**1**	**0**	**0**						**2**

Elements of the state and the number of bits used to encode it

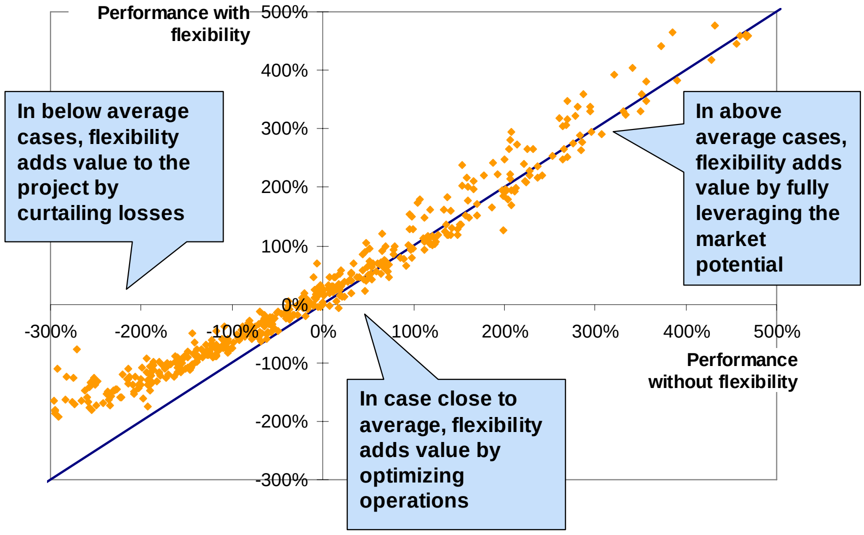
Each element is encoded using a binary “DNA like” representation

Each threshold is bounded by user defined limits

The genome is decoded using set rules

EXHIBIT 9 – IMPACT OF THE REAL OPTIONS MODEL ON THE RESULTS OF THE MONTE-CARLO SIMULATION

Performance relative to the average



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