Real Options

Major project development assessment and approvals: use of a real options approach

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ACIL Tasman

Economics Policy Strategy

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1 Introduction

This submission is an input into the Productivity Commission's enquiry on Australia's major project development assessment and approvals process.

Major projects are often subject to considerable uncertainty, either on the supply side (e.g. uncertainties about whether there will be unexpected hydrological problems) or the demand side (e.g. long-term Chinese demand for iron ore). The technique to manage uncertainty that is commonly used by developers of major projects is real options, the subject of this paper.

For example, option theory has been used extensively in the analysis of oil and gas exploration, where there is uncertainty as to the quantity of oil in the field in addition to the future price. Additional information can be obtained by delaying full development of the field and undertaking exploratory drilling to discover its likely size. The cost of exploratory drilling can be compared to the option value of the additional information in deciding whether to undertake the full investment.

The paper draws on ACIL Tasman's work for project developers and for public and private sector entities involved on the economic side of project approval. Although it is oriented towards an investor's decision about whether to proceed with the project, or delay, modify or cancel it, we consider that the real options approach is also relevant to assessment and approvals related to environmental, social, heritage and other federations.

At present a project developer has to anticipate the environmental and other impacts of a potential project, prepare a large environmental impact statement, and go through an extensive scrutiny and appeals process. The regulator has to commit substantial resources to analysing the environmental statement and defending appeals. The emphasis of the approach is on gathering information at the outset, scrutiny of it, and on legal process.

Where projects are subject to uncertainty about timing and/or scope, a preferable approach would have more interaction between the developer and the regulator at different stages, with fewer resources committed upfront to something that may change. The process would involve a preliminary and simplified environmental assessment that would identify the main issues and the regulator's response to them; this provides the basis for a detailed assessment that would be delayed until shortly prior to commissioning the project (the project meanwhile possibly having been modified as new information is obtained on supply or demand aspects). We note a similarity with the staged approach proposed in submission 002 to the inquiry from Dr Ian Woodward of pitt&sherry.

ACIL Tasman hopes that this paper on the application of real options to project evaluation will help the Commission determine whether such an approach should be a component of more efficient regulatory arrangements on which it has been asked to make recommendations.

2 What are real options?

2.1 Introduction

"Real options" is the application of option theory (initially developed for financial markets) to "real investments" which involve uncertainty and flexibility.

Options analysis (for both financial and real options) emerged out of the desire for ways of better managing downside risk, while retaining access to upside opportunities, and of providing a sound basis for the valuation of opportunities. Real options analysis recognises the reality that managers can, and do, adapt to technological or market changes and that the scope for doing this is important to the value of a project.

This differs from the traditional view of a project, as used in NPV valuations, whereby the prospective project is too often evaluated under the artificial assumption that all the decisions – regarding nature and scale of project, economic life etc, are made up front and then implemented over time, without any flexibility to change. Risk and uncertainty are often introduced late in the assessment in the form of sensitivity analyses – and typically consider only external uncertainties rather than the form of the project or investment over time.

Real options methods will often lead to higher project valuations than traditional deterministic approaches, because they recognise that risks can be managed to avoid bad outcomes or to take advantage of good outcomes. Examples include expanding, abandoning or delaying a project. In other words, the option analysis values the strategic options – the flexibility – available to a firm or a project, which will influence its value.

Also important is the ability of real options analysis to enable the overall value of the project to be increased. Identifying irreversible costs can enable management to design the project in ways that maximise the benefits of flexibility and that improve the information available before needing to decide on a commitment to large irreversible costs. The example of water supply augmentation decisions during the recent drought are discussed as one of the examples below.

The distortions that result from traditional deterministic NPV valuation methods tend to be most acute when uncertainties are greatest (for example during the height of a drought) and when there is greatest scope for adaptive decision-making – and these are common characteristics of major projects.

Many of the benefits of real options analysis can often be derived, relatively simply, through the intelligent application of decision tree tools. In other cases, especially where key contributors to risks involve almost continuous change in key variables – such as market values of a resource product, real options offers an expanded set of tools well suited to the planning and valuation task.

Modern real options theory, as applied to major projects, should be viewed as a powerful combination of both a set of valuation tools and a way of looking at investment, and investment management, opportunities – to maximise value derived over time, and to manage risk sensibly and in a way that builds value, despite high levels of uncertainty.

2.2 Simple example

Table 1 provides a simple numerical example that illustrates some key aspects of real options analysis. It considers a simple investment, which costs $3m to undertake. The product produced by the investment is worth $2.5m pa at current prices, and involves variable operating costs of $2m pa. For simplicity assume that production ceases at the end of period three, and that the plant closes costlessly.

Uncertainty is introduced into this example by assuming that in period 1 the price of the product might rise to provide revenues of $4m pa, or equally it might fall to $1m pa. Thereafter the price remains constant at the new level.

Under a traditional NPV calculation, the expected value of revenue would be calculated, and discounted along with the costs to determine the expected NPV. At a discount rate of 10%, the NPV is -$1.257m and the project would be discarded. This is shown in Part B of the table.

Part C shows the value attaching to the option of waiting for one period before investing in the project, to determine whether prices rise or fall. If price rises, the investment will be undertaken in period 1 in which case revenues will be $4m pa and the costs are as before. If prices fall then the investment will not be undertaken, so that revenues and costs are zero. This gives an expected

NPV of $1.1m, so that the option of waiting one period and then undertaking the investment is valuable.

Indeed, if these were the only uncertainties, then the analysis suggests a value for this option – the maximum 'option fee' that it would be worth paying to secure the rights – of $1.1m. The simple calculation provides a basis for valuing this option.

Table 1 **Investment project with uncertain revenue**

Period	0	1	2	3	Prob
A. Assumptions					
Revenue period 0	2.5				
Possible Revenue periods 1 to 3		4	4	4	0.5
Possible Revenue periods 1 to 3		1	1	1	0.5
Investment cost	3				
Variable cost	2	2	2	2	
B Cashflow: undertake in period 0					
Expected Revenue	2.5	2.5	2.5	2.5	
Cost	5	2	2	2	
Discount rate	0.1				
NPV	-2.5	0.455	0.413	0.376	
Total NPV				-1.257	
C Cashflow: wait and invest if price goes up					
Revenue if price goes up		4	4	4	0.5
Cost if price goes up		5	2	2	0.5
Discount rate	0.1				
NPV of expected revenues		-0.455	0.826	0.751	
Total NPV of cashflows				1.123	

In this simple example the value of waiting one period relative to committing immediately is $1.123m less -$1.257m = $2.380m.

Often the option of discovering additional information is not costless. In the above example, the cost of learning the Year 1 price before committing to the project was a loss of net production revenues of 0.5m.

This highlights an important aspect of real options analysis, namely the ability of management to use the insights gained to improve the value of the project. In this very simple example, the source of uncertainty was clear, and the action needed to gain additional information (ie wait one period) was also very clear. However in real-world examples, the source of inflexibility and the means of reducing the impact of irreversible costs are often far from obvious. Therefore options analysis can be used to add value to a project through a clear understanding of the uncertainties involved and the strategic options open to management. It can offer a powerful tool for assessing whether the incremental costs of deeper probing are likely to be cost-justifiable.

2.3 Types of options

A financial option provides the holder with the right to buy or sell a specified quantity of an underlying asset at a fixed price (called the exercise price) at or before the expiration of the contract. The right to buy the asset is termed a call option, and the right to sell is a put option[1].

Under a call option, if the value of the share is less than the exercise price at the expiration date of the option, the option will not be exercised and it expires worthless. On the other hand, if the share value is greater, the option holder will buy the shares at the exercise price and achieve a payoff equal to the difference between the asset value and the exercise price.

Conversely, a put option gives the buyer of the option the right to sell the underlying asset at a fixed price, the exercise price, at a given date in the future. If the price of the underlying asset is less than the exercise price, the holder of the put option will exercise it. If not, the option will expire worthless. Thus the payoff function is the mirror-image of the payout for a call option, with the payoff increasing as the value of the underlying asset falls.

In the real world, real options often take more complicated forms. In particular, most projects can be regarded as a portfolio of options. Some investments may be a necessary pre-requisite for others and/or some investments may effectively extinguish other options. Thus the interaction between options is important, and the challenge is to design an "optimal portfolio" of investment projects and options within technical and market constraints.

Options that derive their value from other options, instead of an underlying asset, are called compound options. Options that derive their value from two or more sources of uncertainty are called rainbow options. Rainbow options commonly arise in investment projects, which typically have to deal with several sources of uncertainty. In many electricity markets, investment in peak electricity generation capacity can provide the investors with real put options in respect of sale of power at abnormally high prices, whether due to exceptionally high demand levels, or because of constraints on supply because of a generator or distribution failure – or a combination.

Decision trees are often well-suited to dealing with rainbow options. Under the partial differential equation approach, by contrast, introducing several sources of uncertainty typically involves complex mathematics.

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1 Under European options there is no ability to exercise the option early: The option can only be exercised at the end of the contract period. American options can be exercised at any point within the term of the contract. Hybrids are also possible.

3 Approaches to option analysis

3.1 Decision analysis

A decision tree maps the sequence of decision and chance nodes which define the project under consideration. The decisions emanating from a decision node represent the options available to the decision maker. The chance nodes identify where an external event will influence the project, and assign probabilities to each outcome. These outcomes need to be specified as discrete possibilities – unlike other real options tools – even if this means approximating a continuous outcome. For example, a price outcome might be approximated by two or more 'representative' prices, each with a specified probability.

Decision analysis corrects some of the inadequacies of NPV calculations because it recognises that only with the resolution of uncertainty will the most appropriate decision be revealed. It does not pre-commit to a decision in the first time period, and instead identifies an array of options.

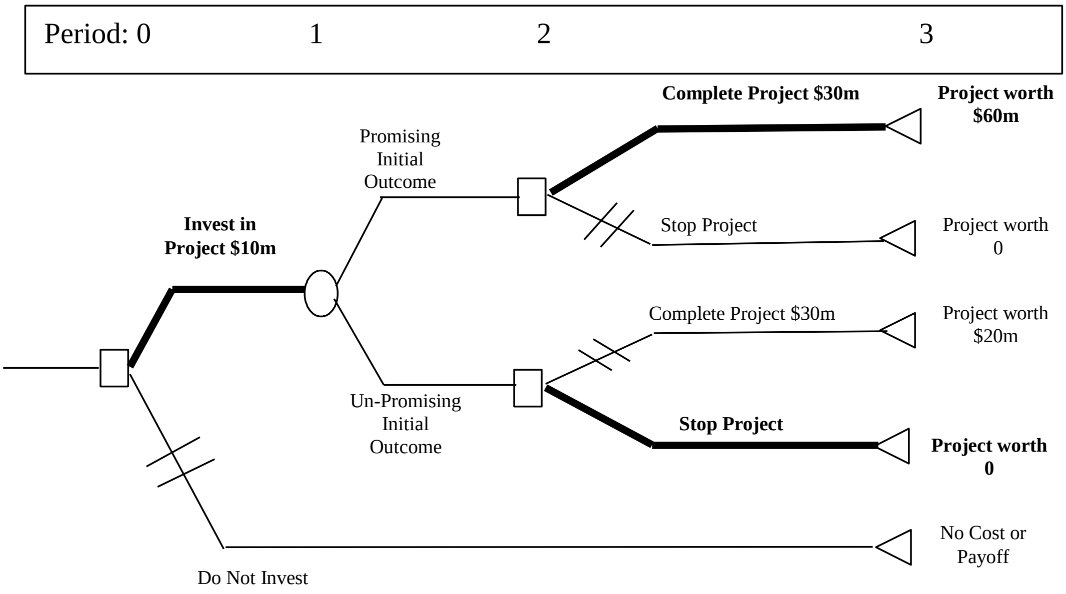
Decision analysis:

- Structures the problem in a way that is intuitively understandable;
- Is able to deal with multiple sources of uncertainty;
- Defines optimal choices based on the consideration of the probabilities and outcomes of each choice; and
- Identifies an 'optimal' strategy over many periods of time.

The discipline of identifying the different states of the world and the decision points is itself valuable in developing management's understanding of the project. By contrast, under a classic 'Black-Scholes' type of approach to real options it can be hard to identify the states of the uncertain variable that leads to a given asset value (especially when there is more than one source of uncertainty). This can be a strength in dealing with volatility where causes are not well understood, and a weaknesses in slurring over sources of uncertainty that might prompt better design of options and other risk management strategies.

Figure 1 shows the structure of a decision tree for a simple project. In the diagram, squares denote decision points, and the circle denotes a chance point. The project involves an initial decision about whether to start the project, which costs $10m, and a later decision whether to complete the project or abandon it. Completing the project costs a further $30m. Before making the second decision, managers are able to observe the initial outcomes, and determine whether these are favourable.

Figure 1 **Decision tree structure**



Once the tree has been laid out, decision analysis solves the tree from right to left, in principle working down each branch, to find the best possible decision at each point. One decision rule commonly used is to select the decision which offers the best average value, where average is a weighted average of the present values by their probabilities[2].

At the decision point in period 2, the value of completing the project is 60/1.1 less 30 = $24.54m, ie the discounted worth of the project less the cost of completing the project. If the project is stopped at this point, its value is 0. Weighting each of these outcomes by their respective probabilities and discounting by one period gives the expected value in period 1 of investing in the initial project, [0.5 (24.54) +0.5 (0)]/1.1 = $11.16m. Discounting this value back a further period and comparing with the initial cost of the project suggests that it would be worthwhile undertaking, but only just. Figure 2 shows this process of rolling back the decision tree to determine the optimal initial decision.

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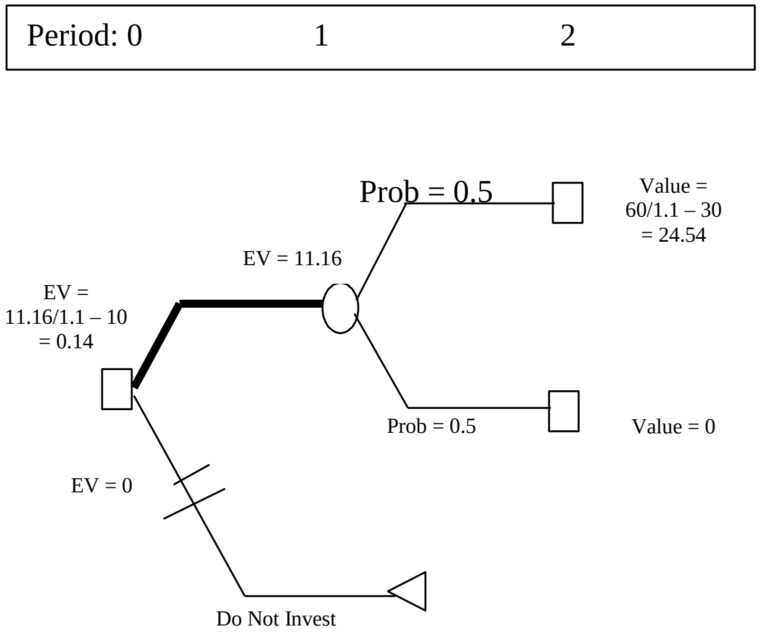
2 Another rule used is to take account of the risk attitudes of the user/firm, and build a risk-adjusted objective function.

Figure 2 **Rolled back decision tree**



3.2 Other techniques

Other techniques developed from financial markets – the Black-Scholes model and numerical techniques – have been applied to real investments, but suffer from unrealistic assumptions or from insufficient data.

It is our experience that, in many cases, the construction of a standard decision tree, combined with appropriate sensitivity testing, will yield the key insights required for informed decision-making. Usually the additional complexity involved in calculating risk-adjusted probabilities is not justified.

4 Insights from real options

4.1 When option analysis is useful

Real options analysis is valuable when:

- There is a contingent valuation decision
- There is sufficient uncertainty that it may sensible to wait for more information – or to invest, before commitment, in gathering information
- Value flows from the possibility of future growth options rather than just current cash flow
- Uncertainty is great enough to make flexibility worthwhile
- There will be project updates and mid-course corrections.

Many different types of issues have been examined by option theory:

4.1.1 The option to delay

The option to delay a project may confer a positive value on a project with a negative NPV based on current expected cashflows – as was illustrated earlier. Similarly, a project with a positive NPV may not be undertaken immediately, because the option of delaying the project may increase its value further. In particular, the possibility of a downturn, and the ability to avoid an action that could prove to be a mistake, is what makes waiting valuable. The option to delay is most likely to be valuable when the firm has the rights to a project for a long time (for example, control over the natural resource), and the variance of project cashflows is high.

It may also be appropriate to temporarily shut-down – to delay the project even after it has entered production – if revenues fail to cover variable cost. If there is a fixed cost associated with shutting down and/or re-starting (as is the case in many production lines), the firm will consider the value of temporarily stoping given the option of subsequently re-starting, as against the option of continuing to operate at a loss given the possibility of revenue subsequently improving.

4.1.2 Growth options

Traditional valuation tools undervalue investments that contain options to expand into new markets or products at later stages, based upon favourable outcomes in the initial stages. If the initial project is a pre-requisite for subsequent expansion, its valuation should take account of the option to expand. Where future projects have the possibility of high NPVs, a firm may accept a negative NPV for the initial investment because of its option value. An extreme, but common, example of this is a feasibility study – which almost always has a negative NPV if assessed out of context.

Similarly a firm may build initial production capacity in excess of the currently expected level of output, in order to provide the option of increasing production later if conditions are favourable.

4.1.3 Investment platforms

Platform investments create valuable follow-on contingent investment opportunities. For example, an R&D project may lead to further marketable products. Similarly a product patent provides a firm with the right to develop a product and market it – while investment in a marketing chain for the product may have option value as a platform for marketing a wider product range in the future. Traditional tools can greatly under-value these options.

4.1.4 Flexibility investments or switching options

Flexibility investments build options into the design of the project. For example, manufacturing equipment could be switched across products, or plant switched between input fuels. The value of the additional flexibility is traded off against the higher initial cost of the project, and sometimes higher operating costs.

4.1.5 Modular investments

Modular investments create value through product design. A modular design allows modules to be changed and up-graded independently. Thus they preserve flexibility, by allowing the design of a component to be changed later, or by lowering the costs of exercising flexibility. The value of this flexibility is traded-off against the up-front cost of developing and delivering a modular design.

4.1.6 Learning investments

Learning investments are made to obtain information that is otherwise unavailable. The learning effort is designed to create the highest-valued information in the shortest amount of time (or to maximise the net value of the investment, taking into account the opportunity cost of time). As indicated above, oil exploration is an example of a learning investment as it provides geological information on the likely size of the reserves. The value of this information is then determined by the outcome on all sources of uncertainty –

thus the option value of the reserves will depend on the expected oil price and their volatility[3].

4.1.7 The option to abandon

As the simple example above showed, the option to abandon enables a firm to contain its downside risk. Thus the option to abandon has value because firms can scale back or terminate projects if they do not measure up to expectations.

4.1.8 Shadow costs

Standard valuation techniques may overvalue some projects because they fail to recognise the loss in flexibility that results in implementation if acceptance of one project eliminates options attaching to other projects. For example, building a plant in one city may eliminate the option to expand the capacity of plants in nearby cities.

4.2 Real-life examples of option analysis

Many academic studies have applied real options, across industries as diverse as R&D, real estate development, forestry and high tech companies. Industries where options analysis has been applied are oil and gas exploration and power generation, and more recently the Australian water industry.

4.2.1 Oil field development

Much of the development of option theory has been undertaken in the context of oil exploration. The licensing, exploration, appraisal and development process falls into stages, each of which can be pursued or abandoned according to the results of the previous stage. Hence the licensing delivers an option over the subsequent stages. Further, the initial exploration can be regarded as a learning option, whereby the decision to proceed with full development of the field, on what scale and in what form, is made after the additional information gained from initial exploration and based on monitoring of market conditions. The option value of the additional information is compared to the cost of obtaining the information in deciding whether to exercise the learning option – in this case undertake the exploration, during which time additional market information may become available.

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3 To the extent that rates of oil production can be modified, in-ground storage offers value in the scope it affords for adapting production to price. Effectively, the producer has access to as sequence of American call options, all real options, that will be exercised on the basis of market price.

Market-based risk has a significant influence on exploration decisions, in a form that makes it particularly well suited to options analysis. Instead of valuing the field on the basis of what it would be worth if development started immediately, the oil field is valued on the basis of its value as an opportunity to develop in the future, given variability in the estimated price of oil and the potential for new technologies to increase the size of the recoverable reserves. The several stages in oil exploration, each of which "purchases" an option to continue with the following stage, make it a good example of a compound option.

Similarly the decision to abandon a field can be examined in terms of the option value of keeping the field open and possibly benefiting from the development of new technologies. For example, the satellite unmanned gas platforms in the southern North Sea now make it possible to use processing capacity that would otherwise have become surplus as soon as the original reservoirs were exhausted. (See Leslie and Michaels (1997)).

4.2.2 The Australian water industry

The recently ended extreme drought across much of Australia has left a legacy of commitments to large and expensive projects, such as desalination plants and major pipelines. Many commentators, including the Productivity Commission, have pointed to a range of planning failures which have contributed to what now amounts to regret of expensive sunk infrastructure.

These criticisms included:

- the failure to consider the full portfolio of available supply augmentation and demand management options, which policy bans serving to increase the cost of achieving supply security
- the provision of subsidies for certain supply options served to distort investment choices
- unwarranted preference was given to certain re-use and conservation programs, and excessive reliance placed on restrictions, and
- a failure to use real options approaches to planning.

In Melbourne, commitment was made to a massive augmentation of supply capacity, through the Wonthaggi desalination plant and the North-South pipeline. While desalination did offer viable insurance against the threat of continued drought, the issue is whether Melbourne needed to trigger the insurance at that point, and if so whether the right investment in insurance was made.

A robust investment planning process would have investigated whether there were smaller (and high unit cost) supply options that could have been implemented to buy additional time and information as to whether the drought would break and avoid an irreversible commitment to the large projects. Such time could have been lengthened with commitment to a "virtual desalination plant", whereby preparatory work in terms of land acquisition, environmental studies and planning permissions are gained and an appropriate trigger (in terms of dam levels) for commencing construction of the plant identified.

Melbourne committed to a desalination plant that is acknowledged to be excessively large, and probably insufficiently scalable, relative to needs. The plant was built with the capacity to supply over 40 per cent of Melbourne's 2010 potable water usage, and has been designed to be scalable up to 56 per cent of that consumption. By contrast, the Sydney desalination plant was designed to be substantially smaller initially, but scalable in modules to more than double initial capacity. The Sydney plant was built for intermittent operation, and used a design which allowed delaying the commitment to build as late as possible.

Bibliography

Amram and Kulatilaka (1999), *Real options: Managing strategic uncertainty in an uncertain world*, Harvard Business School Press, Boston Massachusetts.

Amram and Kulatilaka (2000), "Strategy and shareholder value creation: the real options frontier", *Journal of applied corporate finance,* Vol 13, number 2.

Borison (2003), *Real options analysis: where are the emperor's clothes?*, at http://www.realoptions.org/abstracts/abstracts03.html

Brealey and Meyers (2000), *Principles of corporate finance: 6th Edition,* Irwin McGraw-Hill, Boston.

Damodaran (2000) *The promise and peril of real options,* Stern Business School, New York, NY

De Neufville (2001), *Real options: dealing with uncertainty in systems planning and design",* Paper prepared for the 5th Internatonal Conference on Technology Policy and Innovation, Technical University of Delft, Netherlands

Dixit and Pindyck (1994) *Investment under uncertainty*, Princeton University Press, Princeton, NJ.

Harbord and Yarrow (1995), *"State Aids, Restructuring and privatisation: A study for Directorate-General II of the European Commission".*

Juan, Olmos, Perez and Casasus (2002), "Optimal investment management of harbour infrastructure – An options viewpoint", *6th Annual Conference on Real Options,* Paphos, Cyprus.

Kulatilaka (1993), "The value of flexibility: the case of dual-fuel industrial steam boiler", *Financial Management,* Vol22, no 3, 271-280.

Leslie and Michaels (1997), "The real power of options" *The McKinsey Quarterly*, 1997 Number 3, pp5-22

Merton (1973) "Theory of rational option pricing", *Bell journal of Economic and Management Science,* Vol 4, Spring 141-183.

Myers (1987) "Financial theory and financial strategy", *Interfaces*, 14, Jan-Feb, 126-137.

Ramirez (2002), *Valuing flexibility in infrastructure developments: the Bogota water supply expansion plan,* Masters Thesis, MIT

Smith and McCardle (1999), “Options in the real world: Lessons learned in evaluating oil and gas reserves”, *Operations research,* Vol 47, No 1, p1-15

Trigeorgis (1996): *Real options: Managerial flexibility in resource allocation”,* MIT Press, Cambridge, MA