Making Decisions under Uncertainty Using Real Options Analysis

Sæmundur Ingi Johnsen

Thesis of 12 ECTS credits

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at Reykjavík University in partial fulfillment
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Master of Project Management

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Supervisor:

Dr. Sverrir Ólafsson
Professor, Reykjavík University, Iceland.

Examiner:

Dr. Helgi Þór Ingason
Dosent, Reykjavík University, Iceland.

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Abstract

Valuing a project based on net present value does not easily capture the flexibility that the project offers and therefore undervalues and restrains that project. Real Options, based on financial option valuation, can capture this flexibility more efficiently and give the project manager the opportunity to alter the project when new information comes to life. The flexibility comes in the form of options, such as the option to defer, abandon, expand or default on a project.

The purpose of this thesis is to find the required knowledge needed, to use Real Options and to show the importance of valuing flexibility in projects, by using a case study and going through the process of solving it using Real Option Analysis (ROA). As a result, the advantages of using this method becomes clear.

The potential of Real Options arises with increased uncertainty and risks of a project. When a project has a negative net present value, or is not considered profitable, the usage of Real Options reaches its maximum capacity. Using the Real Options Analysis could alter the estimations on profitability and therefore the analysis should be done prior to execution of a project or in the planning phase. The knowledge needed to use for this methodology is summed up in three categories: Mathematical-, analytical- and ROA knowledge.

Project managers who want to be able to value a project should examine the methodology of Real Options, either for the calculations or for the mindset, since flexibility of a project is a valuable asset which could alter the decision making in a situation of high uncertainty and risk.

Keywords and phrases: Project management, risk management, uncertainty, Real Options, binomial option pricing.

Contents

1. Introduction

The studies of project management have been around for many decades, even if they did not bear a formal name. The roles of these studies have developed over the years and have become more defined and structured. Project managers are under constant pressure to meet short deadlines, to be within budget, to work with low manpower or even overflowed manpower, and make hard decisions. Examples of the skills that a modern project manager needs to acquire to manage projects comprise both of the human factor and the hard skills (planning, budgeting, risk management, among other calculations).

All projects have one thing in common, they have a starting point and an endpoint. In order to go from a starting point to the endpoint, normally the project manager needs to put time, effort and money into the project. Therefore, we can look at a project as an investment, and when it comes to an investment decision, normally the cost is irreversible and there is risk involved.

This thesis is about decision making and active risk management. In order to explain any further we need to understand what the term risk is and how it can impact projects. According to the Oxford Dictionary, the singular word of risk is defined as "The possibility that something unpleasant or unwelcome will happen". (Oxford Dictionaries, 2014) Uncertainty on the other hand can be either positive or negative, but it always implies risk. Uncertainty in projects could turn out to be a limiting barrier or an opportunity. Therefore it is important to identify the flexibility that projects need to have in order to manage the risk that follows from the uncertainty.

When investing, often managers make an investment decision based on net present value (NPV) and the estimated future cash flow. By using this method the investment is considered to be profitable if the NPV is positive or if the NPV is negative then the investment is not expected to be a good investment choice as it is not considered to be profitable. The problem that follows this method is that it is hard to put monetary value on the flexibility of a project based on its NPV, and therefore the value of the investment might not be properly captured as it would possibly be undervalued.

Treating project risks can be done in various ways, one of them being through Real Options analysis (ROA). At first it looks simply impossible as this can be a tricky process. This thesis will explain the requirements needed to use ROA in order to capture flexibility in projects and the importance of this flexibility.

2. Literature review

Various articles have been written about valuing options and the methods behind it. The following section reveals the connection between decision making in projects and the usage of Real Options.

The act that results in an immediate cost for the expectation of future rewards, is considered as an investment in economics. Most investment decisions share the common fact that they are characterized by irreversibility, partially or completely, and that the future rewards are uncertain. What compensates this is that investments have some leeway in the timing of the investment. The investor has an option whether he invests and/or postpones it. Therefore investment opportunities are analogous to financial options. (Dixit & Pindyck, 1994).

“An option is a security giving the right to buy or sell an asset, subject to certain conditions, with a specific period of time” (Black & Scholes, 1973, p. 637). Options are of two kinds, American and European option. The American option can be exercised at any given time, up to the expiry date of the option. The European option can only be exercised at a specified future date.

Options have a predefined cost and time. The predefined cost is called an exercise price and the predefined time is the lifetime of the option. One of the ways to evaluate the price of options is with a mathematical formula, called Black-Scholes model. (Black & Scholes, The Pricing of Options and Corpurate Liabilities, 1973).
Options that are used to modify a project and manage flexibility are called Real Options. The value of these options increases with the uncertainty and the risks of the project. When a

project is under a great uncertainty or high in risk, so are the potential future rewards. Therefore the flexibility of the project becomes more valuable. (Brealey, Myers, & Allen, 2011).

Reducing possible financial risk in operations or investments is called hedging. Buying an insurance at a fixed price (premium) for protection against specified possible risk and the losses associated with it, is one way of hedging. The act of hedging against losses is important in financial markets and industrial activity. (Luenberger, 2006)

One of the most basic principles of finance: “a dollar today is worth more than a dollar tomorrow,” (Brealey, Myers, & Allen, 2011, p. 49) states that money has a time value. Present value (PV) is calculated to see what future amount of money is worth today and where discount rate is used to discount the cash flow at each time. NPV is a series of cash flows over time, or the sum of all PV of individual cash flows. It calculates the stream of both negative and positive cash flows. (Brealey, Myers, & Allen, 2011)

NPV is explained as the difference between the value and cost of an operation. When NPV is positive the operation or project is considered profitable. The problem is that when a project is valuated, based on NPV, assumptions are made that the project will go on passively and the Real Options attached to the project are ignored. This approach does not properly capture the flexibility to adapt to unexpected changes during the project lifetime, even if they exist. As new information arrives over the lifetime, the uncertainty and risks gradually resolve, whether it is from market conditions or the future cash flow. Throughout this period projects may have valuable flexibility to alter the initial strategic plan. Just like financial options, the flexibility to adapt can significantly improve the value of the project. Managers that use Real Options may be able to abandon, expand, contract, defer or switch a project among many other options to alter a project during its lifetime. (Trigeorgis, 2000; Parrino & Kidwell David, 2009)

Valuing Real Options depends on five main variables:

1- The value of the underlying risk in the project or the investment. The value of the option follows the underlying asset: When the value of the asset goes down, the value of call option (right to buy) goes down and put option (right to sell) goes up.

2- The exercise price is the amount of money required to invest in order to exercise the option or the amount of money received if selling the option.
3- The time to the expiration of the option influences the value of the option: The value of the option rises with increasing time to expiry.
4- The standard deviation of the value of the underlying risky asset influences the value of the option: The value of the option increases with higher risks.
5- The risk-free rate of interest over the lifetime of the option influences the value of the option: The value of the option increases when the risk free rate increases. (Copeland & Antikarov, 2003; Parrino & Kidwell David, 2009)

According to the book "A Guide to the Project Management Body of Knowledge", projects involve five process groups; Project- initiation, planning, execution, monitoring and control, and project closure.

- Project initiation is where selection of the best project is given its resource limits, the benefits of the project are recognized and the project is assigned to a project manager.
- Project planning is where work requirements, quality and quantity, as well as necessary resources are defined, along with scheduling of activities and evaluations of risks. In order to call a project successful, it should be defined as having achieved the project objectives; within time, within budget, at the desired performance, with resources assigned effectively and efficiently as well as the project to be accepted by the customer. (Kerzner, 2009)

British Standard Institution (British Standard, 2000) has listed the most common risks that can occur in business and its projects. The following points are examples:

- Unexpected regulatory controls or licensing requirements
- Failure to obtain appropriate approval
- Natural disasters
- Exchange rate fluctuation
- Failure to meet revenue targets
- Market fluctuations
- Operation lifetime lower than expected

Decision trees are widely used as a graphical representation of events that could occur and assist in decision making. They are strategic and illustrate all possible paths a project can take. This method should not be used alone to value Real Options as it is better to combine it with Real Options Analytics (ROA). The reason is that it requires subjective probabilities [Hull, 2009] and different discount rates at each node.

The option pricing theory is great to simplify complex decision trees. Binomial trees are calculated backwards, from the future payoffs to the present value. There are many circumstances where the Black-Scholes model cannot be used to value an option but binomial lattice can give a good measurement of the value. (Brealey, Myers, & Allen, 2011). Binomial lattice can be changed later on to a decision tree. (Mun, 2006).

Black-Scholes formula is used to calculate a value of an option when the stock price is constantly changing with continuum possible future values. The formula depends on the price of underlying stock, its volatility, the exercise price, maturity of the option and interest rate. (Black, How we came up with the option formula, 1989).

The following table demonstrates the connection between financial call option on a stock and Real Options on a project:

Financial call option of a stock	Real option on a project
Current value of the stock	Present value of expected cash flow
Exercise price	Investment cost
Time to expiry	Life of project opportunity
Stock price volatility	Uncertainty of the project
Risk free interest rate	Risk free interest rate

(Bjarnadóttir, 2003, p. 21)

The following table demonstrates the connection between changes in option price where underlying parameters are changed.

	European call	European put	American call	American put
Current stock price	+	-	+	-
Strike price	-	+	-	+
Time to expiry	Uncertain	Uncertain	+	+
Volatility	+	+	+	+
Risk-free rate	+	-	+	-

+ indicates an increase in parameter causes higher option price

- indicates an increase in parameter causes a lower option price

(Bjarnadóttir, 2003, p. 14)

3. Method

3.1 Project description and objectives

This research will examine what knowledge a project manager needs to acquire in order to make strategic decisions based on ROA. Furthermore, it will demonstrate the importance of flexibility for the value of projects.

3.2 Research methodology

Although ROA is a well-known method, it can be complicated to put into usage. In order to see the complications and knowledge required to use ROA we will work through a case study where we apply this methodology and analyze the required knowledge the project manager needs. The reason why a case study has been chosen, is to find the connection between decision making and Real Options, what tools and techniques the project manager needs to use, and the mindset he needs to put himself into. In order to do so calculations with ROA are required. Questionnaire survey could perhaps capture how project managers estimate some of the variables needed for the calculations, but not how they actually calculate them.

The following case study is based on information, provided by Landsnet. Landsnet is an Icelandic utility company and its role is to operate and administer Iceland´s electricity and transmission systems. (Landsnet, 2014)

For the sake of Landsnet, part of the information was slightly modified in order to keep confidentiality and get acceptance for usage.

3.3 Case study: New submarine cable

Vestmannaeyjar is an island located 13 km offshore Iceland with the population of 4.270 people. (Hagstofa Íslands, 2014). All of the electricity that the island uses comes from the mainland through two submarine cables, VM1 and VM2. Each submarine cable has 33kV capacity. The expected operational lifetime of these submarine cables is about 40 years. VM1 which was installed in 1962 has therefore passed its operational life time but is still operating whereas VM2 which was installed in 1979 has failed three times over its lifetime and is currently broken.

With only one working submarine cable, the island faces the uncertainty of having no electricity if VM1 would fail. Additionally, Vestmannaeyjar's major fish industry companies have announced the need of receiving more electricity in order to expand their operations. Landsnet have decided to take on the project and insert a new submarine cable (VM3) which will replace VM2. The project needs to be finished as quickly as possible in order to prevent Vestmannaeyjar from the risk of ending up without electricity. With this project Landsnet is facing the following underlying uncertainties and risks:

- Failure to obtain appropriate approvals
- Lack of time to finish the design
- Failure to meet revenue targets

Landsnet has estimated that they could finish the project in one year and the lifetime of cash flow is calculated for 25 years. The cost of the project is estimated to be 1750 million ISK and all of the investment is to be made within the first year. The annual free cash flow is estimated to be constant 114 million ISK per year and the PV of the cash flow over these 25 years is 1120 million ISK. The volatility of the annual free cash flow is assumed to be 20%. Risk-free interest rate is assumed to follow the current account interest rates of 5%. The WACC of the project is assumed to be 9%.

Instead of valuing the project based on NPV where flexibility cannot be easily captured, Landsnet would like to value the project with ROA and take the following flexibility into account to hedge against the underlying risks:

- Being able to defer the investment decision for 1 year until more information about the project is available
- Being able to abandon the project if it turns out to be unsuccessful and sell it for its salvage value

4. Results

In this section the research results from calculations will be examined.
Three different types of Real Options are introduced and used to alter the NPV of the project. Each of the option has a different logic behind it that is used to hedge against different type of risk. By solving the case study, the results will help answering the main research question: What knowledge a project manager needs to acquire in order to make strategic decision based on ROA.

4.1 NPV without flexibility

With normal NPV calculations the project would be rejected because NPV is negative (Trigeorgis, 2000):

$$NPV_0 = \sum_{t}^{T} \frac{C_t}{(1+r)^t} - I_0 \tag{4.1}$$

$$NPV_0 = \sum_{t=1}^{25} \frac{114}{(1+0{,}09)^t} - 1750$$

$$NPV_0 = -630$$

Where,

$I_0 = Initial\ investment$

$C_t = Annual\ free\ cash\ flow\ at\ time\ t$

$r = WACC$

$T = Number\ of\ time\ periods$

4.2 Option to defer

The project is associated with uncertainties due to new regulations on the market and because Landsnet is not certain whether they will get appropriate license to operate. They would like to examine the option of deferring the project for one year and the value of being able to do so. This option can be looked at as a call option.

WACC	R	9%
Initial investment	K	1.750
PV of cash flow	P	1.120
Volatility	σ	20%
Risk-free rate	r	5%
Time to maturity	T	1
Time between nodes	Δt	0,5

Table 4.1 *Presumptions for the option to defer*

In order to calculate the NPV and illustrate it in a tree, the multiple factor for the cash flow of the project, the up- and down movement, is found (Hull, 2009):

$$u = e^{\sigma\sqrt{\Delta t}} \tag{4.2}$$
$$= e^{0,2\sqrt{0,5}} = 1,152$$
$$d = e^{-\sigma\sqrt{\Delta t}} = \frac{1}{u} \tag{4.3}$$
$$= \frac{1}{1,152} = 0,868$$

Where,

$u = up\ movement\ of\ the\ project$

$d = down\ movement\ of\ the\ project$

The objective probabilities for up- or down movement for each node of the tree can be calculated as follows (Hull, 2009):

$$
\begin{aligned}
q_u &= \frac{e^{R\Delta t} - d}{u - d} \qquad (4.4) \\
&= \frac{e^{0,09 \cdot 0,5} - 0,868}{1,152 - 0,868} \\
&= 0,63 \\
q_d &= 1 - q_u \qquad (4.5) \\
&= 1 - 0,63 \\
&= 0,37
\end{aligned}
$$

Where,

$q_u = probability\ of\ project\ going\ up$

$q_d = probability\ of\ project\ going\ down$

With the information from above, the PV of the cash flow for each node can be calculated (Hull, 2009):

$$PV_u = PV_0 \cdot u \qquad (4.6)$$

$$PV_d = PV_0 \cdot d \qquad (4.7)$$

$$
\begin{aligned}
PV_u &= 1.120 \cdot 1,152 = 1.290 \\
PV_{uu} &= 1.290 \cdot 1,152 = 1.486 \\
PV_{ud} &= 1.290 \cdot 0,868 = 1.120 \\
PV_d &= 1.120 \cdot 0,868 = 972 \\
PV_{dd} &= 972 \cdot 0,868 = 844
\end{aligned}
$$

With this calculated information, the expected cash flow can be put into a tree. Working from left to the right:

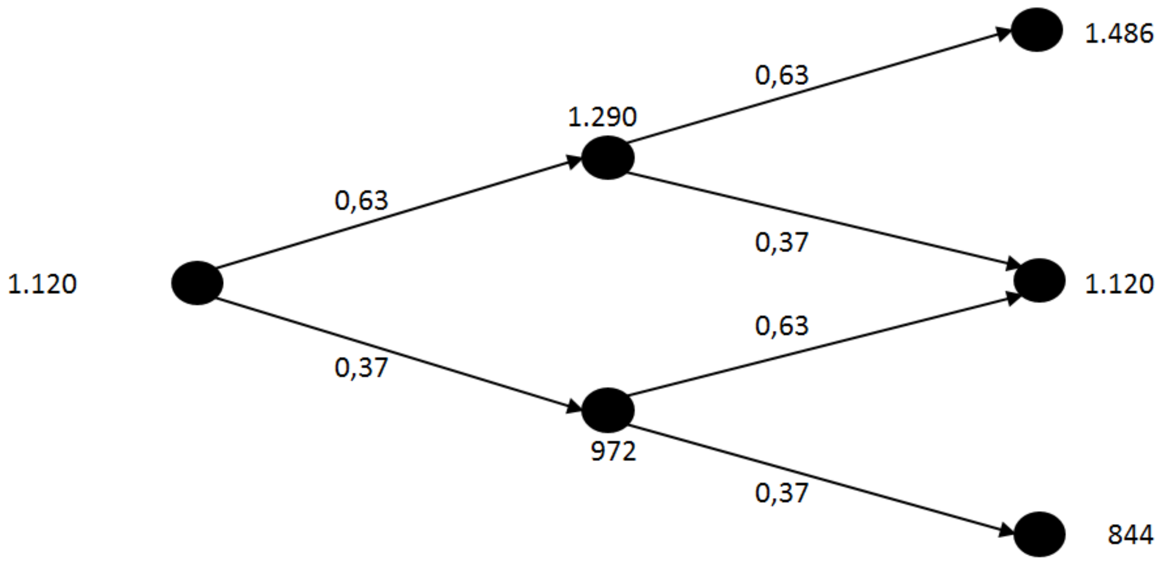


Figure 4.1 *Option to defer; expected cash flow*

Therefore, NPV calculations for the project based on Decision Tree Analysis (DTA), where the cash flow is represented in a tree, and no flexibility in a form of real options.

$$
\begin{aligned}
NPV &= PV\ cash\ flow - Initial\ investment \\
&= 1.120 - 1.750 \\
&= -630
\end{aligned}
$$

Risk neutral probabilities are calculated for the up- or down movement on the binomial tree [Hull, 2009]:

$$
\begin{aligned}
p_u = p &= \frac{e^{r\Delta t} - d}{u - d} \\
&= \frac{e^{0,05 \cdot 0,5} - 0,809}{1,236 - 0,809} \\
&= 0,55
\end{aligned}
\tag{4.8}
$$

$$
\begin{aligned}
p_d &= 1 - p \\
&= 0,45
\end{aligned}
\tag{4.9}
$$

Where,

$p_u = probability\ of\ an\ up\ movement$

$p_d = probability\ of\ option\ a\ down\ movement$

In order to find the end nodes of the tree, the intrinsic value of the options is calculated with formula 4.10. As the option to defer is a call options:

$$f \quad = \max[S - K, 0] \tag{4.10}$$

$$\begin{aligned} f_{uu} &= \max[1.486 - 1.750, 0] = 0 \\ f_{ud} &= \max[1.120 - 1.750, 0] = 0 \\ f_{dd} &= \max[844 \quad - 1.750, 0] = 0 \end{aligned}$$

Value of option can be calculated, working backwards from the tree [Hull, 2009]:

$$f = e^{-r\Delta t}(pf_u + (1-p)f_d) \tag{4.11}$$

$$f_u = e^{-0,05 \cdot 0,5}(0,55 \cdot 0 + (1 - 0,55) \cdot 0) = 0$$

$$f_d = e^{-0,05 \cdot 0,5}(0,55 \cdot 0 + (1 - 0,55) \cdot 0) = 0$$

$$f_0 = e^{-0,05 \cdot 0,5}(0,55 \cdot 0 + (1 - 0,55) \cdot 0) = 0$$

According to the calculations the value of the option to defer is worthless and with given information the binomial tree can be illustrated:

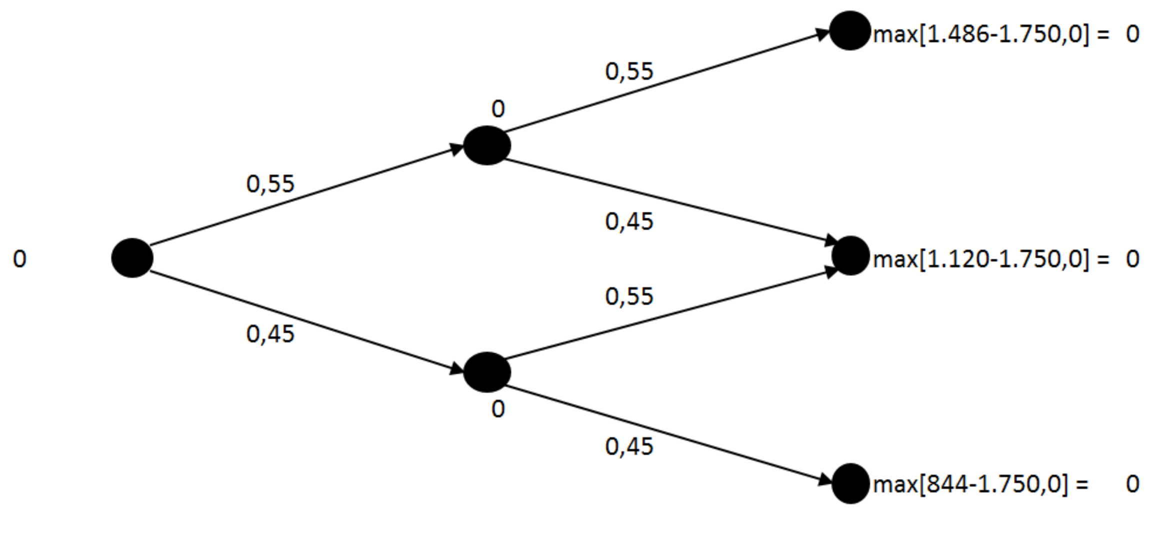


Figure 4.2 *Option to defer; price of option*

The option does not change the NPV of the project because the value of it is zero:

$$NPV = -630 + 0$$
$$= -630$$

4.3 Option to abandon (I)

The project is highly political and the Icelandic Government sees that the project is important for the offshore residents in Vestmannaeyjar. Landsnet is willing to take on this risky project if the Government is willing to buy it for its salvage value of 1.100M should the project become unsuccessful in the second year.

WACC	R	9%
Initial investment	S	1.750 M
PV of cash flow	PV	1.120 M
Salvage value	K	1.100 M
Volatility	σ	20%
Risk-free rate	r	5%
Time to maturity	T	2
Time between nodes	Δt	0,5

Table 4.2 *Presumptions for the option to abandon (I)*

With formulas (4.2) and (4.3) the up- and down movement of the project cash flow is calculated:

$$u = e^{\sigma\sqrt{\Delta t}} = e^{0{,}2\sqrt{0{,}5}} = 1{,}152$$
$$d = \frac{1}{u} = \frac{1}{1{,}152} = 0{,}868$$

With new time to maturity of the option, we calculate the objective probabilities for up- or down movement for each node of the tree based on formulas (4.4) and (4.5):

$$q_u = \frac{e^{R\Delta t} - d}{u - d} = \frac{e^{0{,}09 \cdot 0{,}5} - 0{,}868}{1{,}152 - 0{,}868} = 0{,}63$$
$$q_d = 1 - q_u = 1 - 0{,}71 = 0{,}37$$

Then the expected cash flow can be illustrated in a tree:

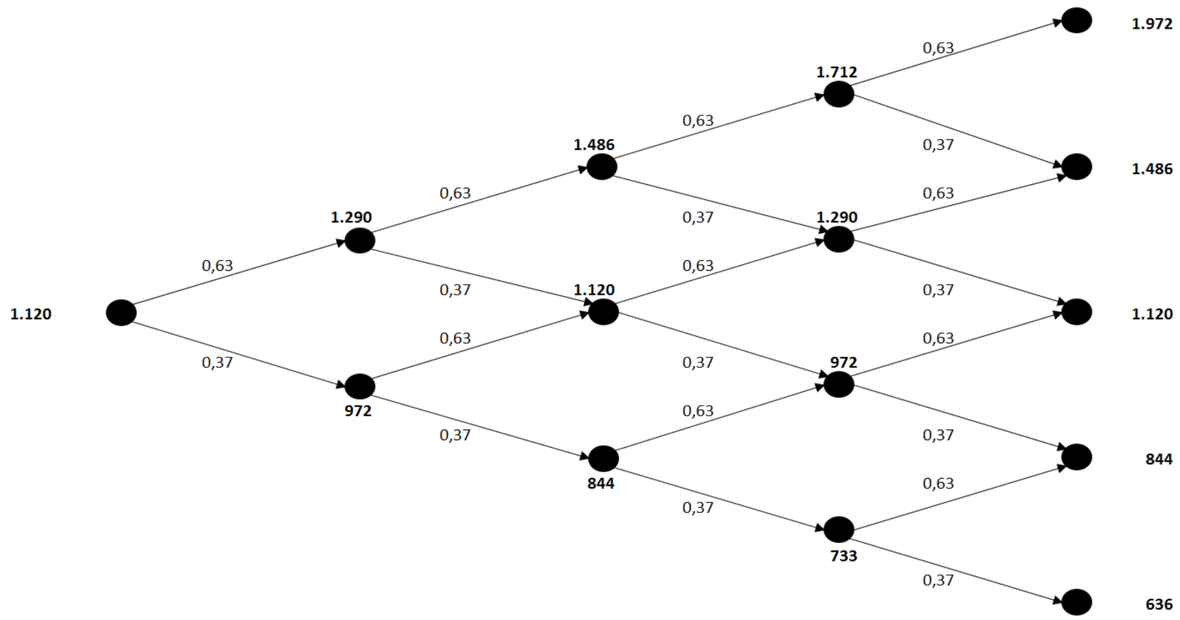


Figure 4.3 *Option to abandon (I); expected cash flow*

Here we assume that the option to abandon can be valued as a financial put option, where the owner of the option has the right but not the obligation to sell. In this case the owner of the option could sell the project based on its salvage value of 1.100. Therefore the strike price is the salvage value. We use formula (4.12) to find the end values of the binomial tree:

$$f = \max[K - S, 0] \tag{4.12}$$

$$f_{uuuu} = \max[1.100 - 1.972, 0] = 0$$
$$f_{uuud} = \max[1.100 - 1.486, 0] = 0$$
$$f_{uudd} = \max[1.100 - 1.120, 0] = 0$$
$$f_{uddd} = \max[1.100 - 844, 0] = 256$$
$$f_{dddd} = \max[1.100 - 636, 0] = 464$$

Risk neutral probabilities from formulas (4.8) and (4.9):

$$p = \frac{e^{r\Delta t} - d}{u - d}$$
$$= \frac{e^{0,05 \cdot 0,5} - 0,868}{1,152 - 0,868} = 0,55$$
$$p_d = 1 - p$$
$$= 1 - 0,55 = 0,45$$

We can now calculate the value of the option, backwards from the binomial tree with repeated use of formula (4.11):

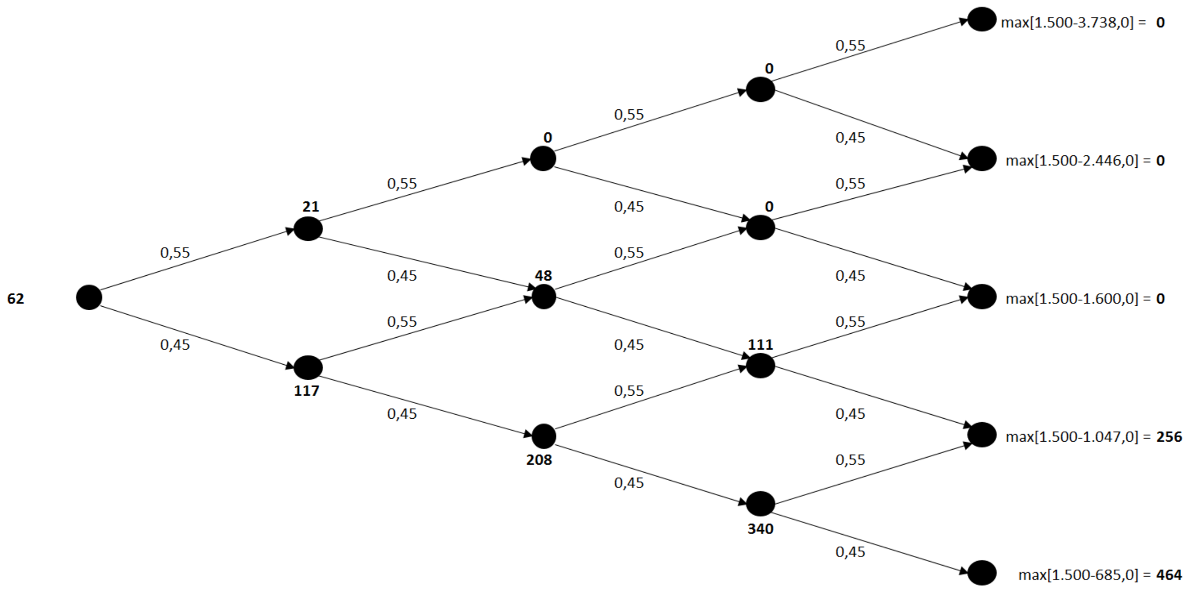


Figure 4.4 *Option to abandon (I); price of option*

The calculations give us the value of the option, 62. If only looked at the option to abandon with the initial NPV of the project, the NPV changes to:

$$-630 + 62 = -568$$

4.4 Option to abandon (II)

Landsnet would like to see the value of the option to abandon if the volatility of the annual free cash flow would be 30%.

WACC	R	9%
Initial investment	S	1.750 M
PV of cash flow	PV	1.120 M
Salvage value	K	1.100 M
Volatility	Σ	30%
Risk-free rate	R	5%
Time to maturity	T	2
Time between nodes	Δt	0,5

Table 4.3 *Presumptions for the option to abandon (II)*

The presumptions to calculate up and down movement of the project have changed from previous calculations because the volatility has changed, u and d are now as follows:

$$u = e^{\sigma\sqrt{\Delta t}} = e^{0,3\sqrt{0,5}} = 1,236$$

$$d = \frac{1}{u} = \frac{1}{1,236} = 0,809$$

Objective probabilities can now be calculated:

$$q_u = \frac{e^{0,09 \cdot 0,5} - 0,809}{1,236 - 0,809}$$

$$= 0,55$$

$$q_d = 1 - 0,64$$

$$= 0,45$$

From formula (4.5) we can calculate the expected cash flow and illustrate it in a tree:

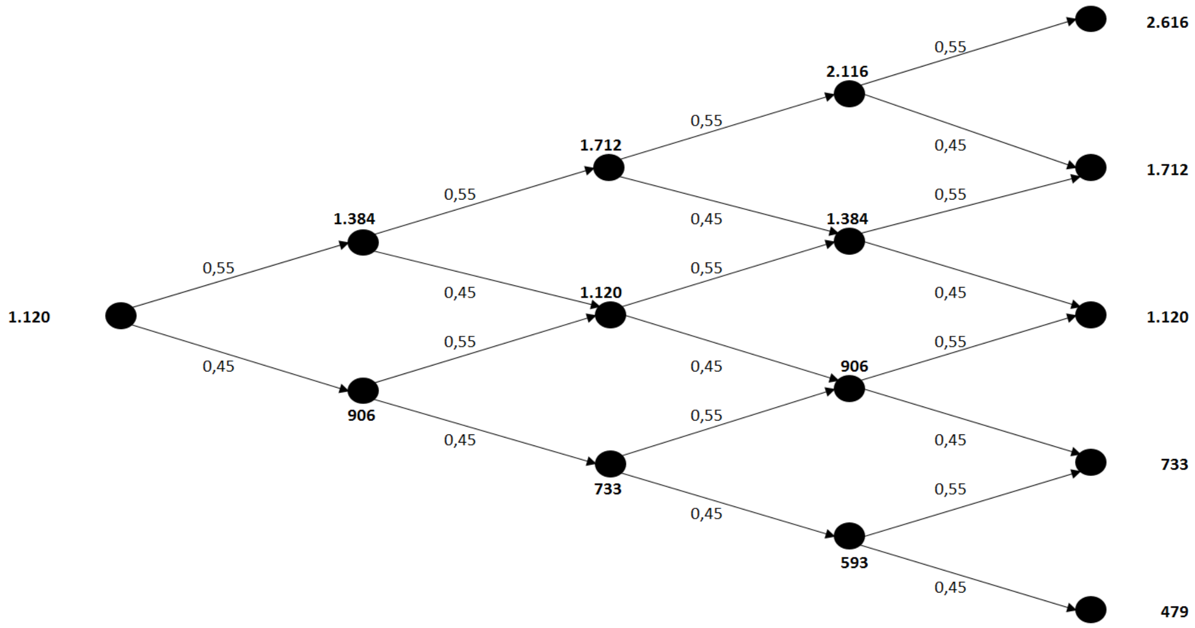


Figure 4.5 *Option to abandon (II); expected cash flow.*

This shows us that the NPV for the project without flexibility is 1.120

By looking at the option to default as a European put option, we can calculate the value of the end nodes based on previous calculations:

$$f_{uuuu} = \max[1.100 - 2.616, 0] = 0$$
$$f_{uuud} = \max[1.100 - 1.712, 0] = 0$$
$$f_{uudd} = \max[1.100 - 1.120, 0] = 0$$
$$f_{uddd} = \max[1.100 - 733, 0] = 367$$
$$f_{dddd} = \max[1.100 - 479, 0] = 621$$

With this information we can calculate the value of the option with formula (4.9) and illustrate the binomial tree.

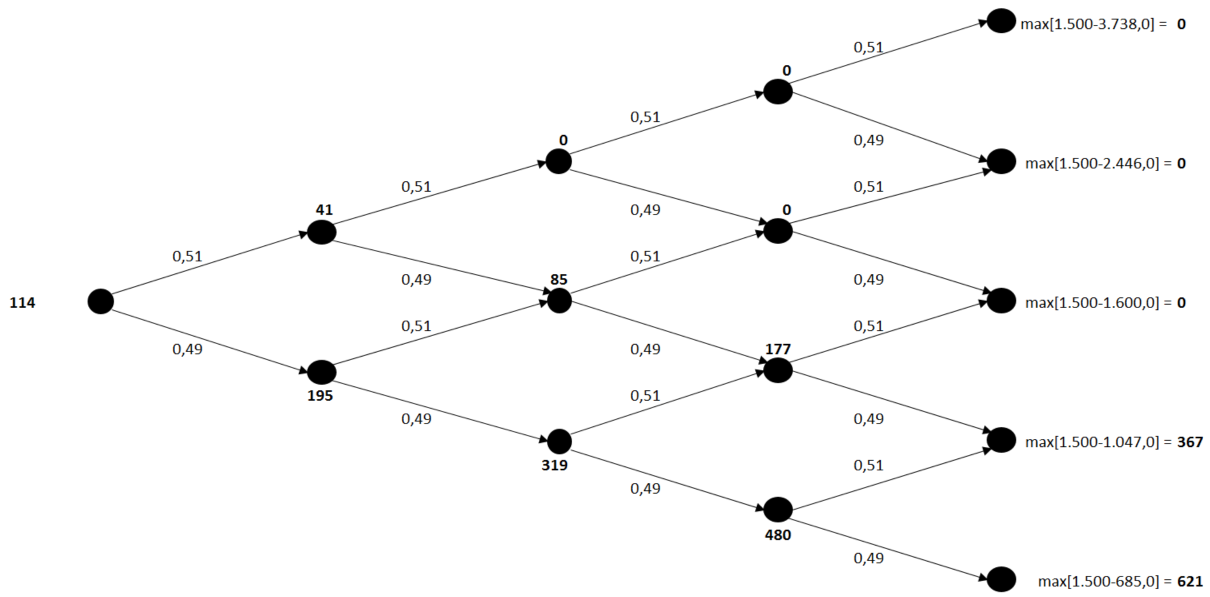


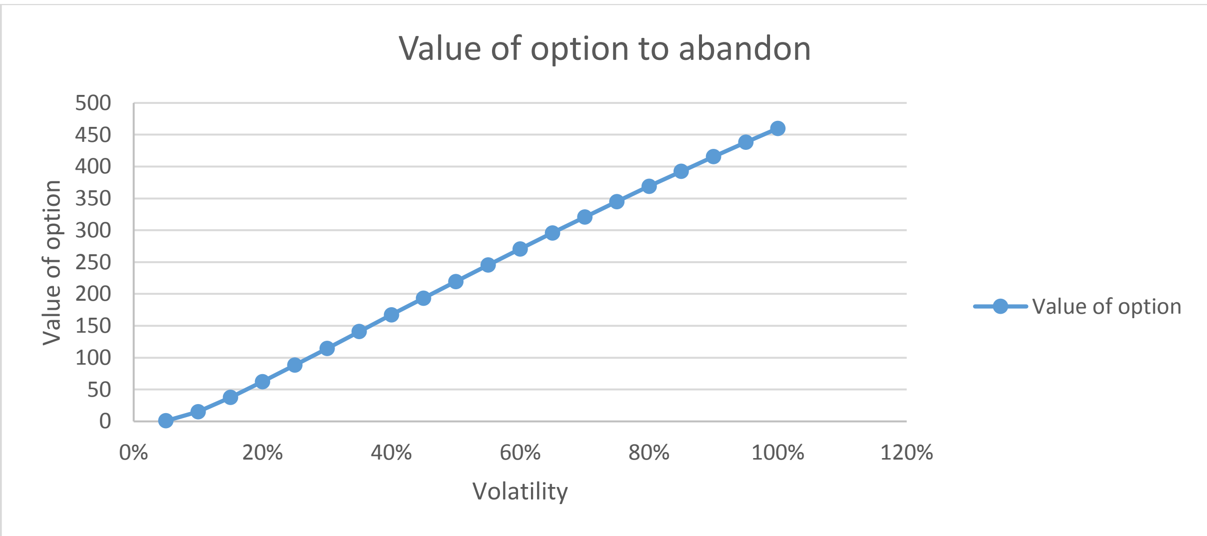
Figure 4.6 *Option to abandon (II); price of option*

The binomial option pricing model gives us the value of the option, 114. With the flexibility of abandoning the project at the strike price of 1.100 the NPV of the project becomes:

$$-630 + 144 = -516$$

The flexibility has therefore increased the value of the project.

On graph 4.7 we can see the connection between volatility and the value of option to abandon:



Graph 4.7 Connection between volatility and the value of option to abandon

4.5 Real value of the project

The calculations above give us the necessary information to be able to look at the project in terms of well-defined flexibilities and their impact on the projects real NPV. The outcome could be in two ways, depending on what option to abandon would be taken into the calculations.

$$NPV\ (I) = -630 + 0 + 62 = -568$$

$$NPV\ (II) = -630 + 0 + 114 = -516$$

4.6 Required knowledge

The purpose of this paper has been to examine the obstacles that a project manager needs to overcome in order to use ROA in projects and the importance of flexibility within the projects. The required knowledge was examined and evaluated by using ROA in a case study. We sum this up in three categories:

- Mathematical knowledge
    - Basic algebra
    - Being able to calculate NPV
    - Understanding basic probabilities
    - Understanding how binomial trees work
- Analytical knowledge
    - Estimating cost
    - Estimating risks
    - Estimating probabilities
- ROA knowledge
    - Understanding what an option is
    - Ability to think in terms of options; Projects usually have some flexibility that could alter the NPV.

5. Discussions

In this thesis, methods of Real Options analysis were examined and compared to method of net present value. In particular the contribution of ROA in decision making was investigated. When projects are risky and the underlying uncertainty is great, the value of flexibility becomes more valuable.

Valuing a project based on its NPV does not capture the flexibility of the project and tends to undervalue it. When decisions are made by using the NPV method there are high risks of losing the opportunity to improve the project.

Real Options analysis is able to capture the flexibility of projects and reducing the risk factor by hedging it. It is possible to use both Binomial trees and Black-Scholes formula to value options. If a project is considered low in risks, then the option is less likely to be exercised.

This methodology could be used in projects that are high in risk and depending on political views. Projects like the construction of a train from Keflavík to Reykjavík or a new submarine cable from Iceland to Europe. If we think of the second example there is an interesting option that could be valued, the switching option; where the price of electricity is uncertain and different in each country and we could switch between selling and buying electricity from each location. It would be interesting to calculate the value of such an option.

This methodology is not flawless and there are factors that could alter the whole analysis if they are done wrong. Here are examples of challenges when using ROA.

- Estimation of expected profit for a project
    - If there are no direct revenues of a project, like in improvement projects, it is difficult to record its benefit.
- What discount rate(s) should be used
    - Could be different discount rates over the project life
    - It is possible to look at the case where uncertainty in projects becomes less with time, and therefore in practice the WACC of a project should change as the project moves forward.

- Estimation of volatility
    - High risk = high volatility
        - It could be difficult to determine what is considered to be high risk.

Instead of rejecting a project that has a negative NPV, project managers or other stakeholders that contribute to the planning of the project can use ROA to identify and value flexibilities associated with a project. This methodology gives them the opportunity to take on a project that otherwise would be rejected based on NPV calculations.

ROA is not only based on calculations and estimating the value of a project. It is a new way of discerning how projects could be taken on, where only by thinking in “options” the possibly hidden flexibility of the project can become clearer and recognized, not ignored.

How much is flexibility worth for your project?

6. Conclusion

When a company or an individual decides to initiate a new project, it should be considered as an investment decision. In most investments there are underlying risks and uncertainties. In order to overcome or avoid these risks, ROA is a helpful tool to acknowledge the flexibility of the project and see the flexibility as an asset.

The optimal use of ROA analysis is in the planning phase of a project, when estimations of the cost and the future benefits are taking into consideration.
It is important that decision making with ROA in projects is done prior to the project initiation. Real options reach their maximum value when a project has high risks and uncertainties and where the NPV is close to zero. The reason for this is because when a project has a high NPV or low risks, the project is in less need of flexibility and therefore less likely to exercise the option.

Project managers who want to use the methodology of ROA should be able to do so by:

- Having simple math background to understand the calculations behind the method, NPV and probabilities.
- Being able to analyze and estimate cost, risks and revenues of the project.
- Understanding the basic concept of ROA and the mindset of options.

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9. Appendix A – Equations and Formulas

NPV

$$NPV = -I_0 + \sum_{t=1}^{N} \frac{C_t}{(1+r)^t}$$

Where,

I_0 = Initial investment

C_t = Annual free cash flow at time t

r = WACC

Up and down movement of underlying asset

$$u = e^{\sigma\sqrt{\Delta t}}$$

$$d = e^{-\sigma\sqrt{\Delta t}} = \frac{1}{u}$$

Where,

$u = up\ movement\ on\ binomial\ tree$

$d = down\ movement\ on\ binomial\ tree$

Present value of underlying asset (project cash flow)

$$PV_u = PV_0 \cdot u$$

$$PV_d = PV_0 \cdot d$$

Where,

$PV_0 = Present\ value\ of\ project\ at\ time\ 0$

$u = up\ movment\ on\ binomial\ tree$

$d = down\ movment\ on\ binomial\ tree$

Risk neutral probabilities

$$p_u = \frac{e^{r\Delta t} - d}{u - d}$$

$$p_d = 1 - p_u$$

Where,

$r = risk\ free\ rate$

$\Delta t = time\ between\ nodes$

$u = up\ movement\ of\ project\ value$

$d = down\ movment\ of\ project\ value$

Value of option at end nodes

$$f_{call\ option} = \max[S - K, 0]$$
$$f_{put\ option} = \max[K - S, 0]$$

Where,

$S = Current\ value\ of\ project$

$K = Exercise\ price$

Value of option

$$f = e^{-r\Delta t}(pf_u + (1 - p)f_d)$$

Where,

$r = risk\ free\ rate$

$\Delta t = time\ between\ nodes$

$p_u = risk\ neutral\ probabilities\ for\ up\ movements$

$f_u = value\ of\ option\ going\ up$

$f_d = value\ of\ option\ going\ down$

Objective probabilities

$$q_u = \frac{e^{R\Delta t} - d}{u - d}$$

$$q_d = 1 - q_u$$

Where,

$R = WACC$

$\Delta t = time\ between\ nodes$

$d = down\ movement\ of\ project$

$u = up\ movement\ of\ project$