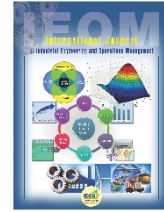




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Real Options Framework for Dealing with Uncertainty in Project Management: A Moroccan Infrastructure Project

Jihane Gharib and Abdelaziz Berrado

Team AMIPS, Department of Industrial Engineering
Ecole Mohammadia d'Ingénieurs
Mohammed V University
Rabat, Morocco
Jihane.gharib@gmail.com, berrado@emi.ac.ma

Loubna Benabbou

Département des sciences de gestion, Campus Lévis-UQAR
Québec, Canada
Loubna_benabbou@uqar.ca

ABSTRACT

The Real Options Valuation allows for the consideration of possible options that are instinctively embedded in investment projects, in which the decision-makers have the flexibility to respond to the outcome of uncertainty. The business managers' abilities to react to future market conditions tend to impact the value of the investment project by maintaining or improving the upside potential and limiting the downside loss. This process must be regulated by a decision analysis model, capable of capturing the particularities of each project. This paper presents detailed literature review of the real options, includes their area of applications in the literature, then proposes a framework to ease the understanding and the use of this method. Later, a case study of a Moroccan infrastructure project, that had already undergone an evaluation, is outlaid. The paper fully addresses the gaps of the previous study, provides a corrected model for an improved valuation of this project and a suitable use of real options. It also illustrates its application and analyzes the obtained results.

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1. Introduction

Since 1977, Real Options has gained acceptance and has proven to be a strategic complementary tool to the Discounted Cash Flows (DCF) and to the Net Present Value (NPV) classic methods of the project's profitability. Real Options has been applied to several types of projects and has motivated numerous scientific articles published in prestigious journals and conferences. Nevertheless, the ambiguity around it is yet still bothering managers in the real world. The necessity of understanding the valuation methods of real options by all managers is quite difficult to overcome, it even discourages the application of real options in Moroccan companies.

This paper aims to demystify Real Options (RO), to provide a simplified framework of its application, and to address existing models of investment project analysis using this approach in Morocco. The framework developed herein helps investors in their strategic decision process in all projects in general and in infrastructure projects like the water desalination in particular.

To achieve this, this paper focuses on the problematic of managing the uncertainty sources of an investment projects by formulating the lack of consideration that traditional methods such as the NPV of the Decision Trees (DT) provide to this problematic. Moreover, this paper presents a literature review of the real options approach, introduced as the proactive alternative to NPV. To ease the understanding of the valuation tools of the real options, this paper provides a framework for the decision analysis of investment projects. Afterword's, it reviews and analyses a case-study conducted for the evaluation of the feasibility and the profitability of a major infrastructure project in Morocco. This project consists on building a seawater desalination plant and providing for the needs of the population that will increase in the years to come. For this project, the study conducted by Kmad et al.(2011) showed a positive NPV, however it did not appear to be the appropriate technique to capture the flexibilities available in decision-making, and thus underestimated the value of the project by neglecting to examine the positive influence of future management actions during this value. In order to improve this evaluation, Kmad et al. (2011) urged the use of appropriate techniques for their planning and evaluation, essentially, Decision trees and Real Options.

Therefore, this paper deals with their choice of the real options valuation model and its outcomes. Section 2 outlays the problematic of managing uncertainties of investment projects using different evaluation techniques. Section 3 is a detailed literature review of the real options, their application fields and their valuation methods. Section 5 outlays their results and their calculation method with a description of their chosen option for calculation. Section 6 establishes a profound analysis of their reasoning and identifies its major gaps. Finally, Section 7 proposes a corrected decision analysis model that will improve the use of real options by providing a more suitable types of options in adequacy with this project, capable of solving the issues of faced before and of correctly quantifying the value of this infrastructure project, in addition of running the calculations, examining and comparing the obtained results.

2. Problematic of Managing Investment Projects' Uncertainties

Investment decisions today help shape the future of every country and are crucial to its raising its development rate. The project's profitability evaluation techniques used by academic researchers and by managers in all kind of businesses are:

- Payback Period (PP)
- Profitability Index (PI)
- Discounted Cash Flows & Net Present Value (DCF & NPV)
- Internal Rate of Return (IRR)
- Decision Trees (DT)
- Monte Carlo Simulations (MCS)
- Sensitivity & Scenario Analysis (SA)

However, Ann Wang (2010) suggests that the most commonly recognized method by practitioners is the DCF (the NPV & the IRR). The DCF approach is an important tool in the analysis of a capital investment. This method typically focuses on a series of fixed future cash flows that are expected to be generated from a given investment by estimating the future cash flows, discounting these flows to the present using the appropriate project cost of capital, and comparing the present value of these cash flows with the present value of the investment outlays.

Traditionally, the net present value and the discounted cash flow methods are worldwide used to evaluate project investments. However, given that, today investments are characterized by high risks and uncertainty, DCF methodologies are inadequate to deal with these issues. These techniques implicitly assume the reversibility of investments; as if an investment can be undone and the expenditures recovered, which is obviously wrong.

Although, there are some investment projects that have these features, most of them do not have it. In fact, the ability to delay an investment, in order to obtain more information and thus reducing uncertainty, provides management with a valuable opportunity to modify both investment and the strategy to follow, in order to get better future opportunities or to reduce future losses. Many investments in real assets have opportunities, such as abandonment, expansion, and deferment, that may alter the investment's future cash flows and thus its value. These options generally involve the flexibility to revise decisions in the future; hence, they are often referred to as flexibility options.

Ann Wang (2010) insisted that the Net present value (NPV) is a methodology that firms have used for a long time to evaluate a project investment. However, Myers (1984), Brennan and Schwartz (1985), Kester (1984, 1993), McDonald and Siegel (1986), Pindyck (1991), and Trigeorgis (1993) all pointed out that NPV modeling ignores the value of

flexibility of real asset investment. Hence, the real asset investment is undervalued. More particularly, strategic value of a project is missing in NPV, as pointed by Myers, Pinches and Lander (1997). Consequently, NPV kills many projects with strategic value with an expected NPV benchmark. They proposed that the true value of real asset investment should be adjusted by adding the values of all embedded options to the net present value of the underlying asset.

Investment projects have often opportunities making it possible to expand their profitability. These opportunities are available options for a more proactive management of the projects. Therefore, the rise of the uncertainties presents a valid opportunity for managers to explore these options and reinforce the project's analysis. The idea is that as the uncertainty clears in the future, management can make appropriate decisions at that time by comparing the expected payoff with the investment cost. This calls for the introduction and the explication of the theory of real options in the next section.

3. Literature Review of the Real Options Approach

3.1 Definitions and historical literature review of the real options

3.1.1 Definition and conditions of use of the ROA

Yezhi He (2007) defined real option in his thesis as the right to make favorable future choices regarding real asset investments. Real options are opportunities that are associated with investment projects characterized by a degree of flexibility. Real options involve choices: to invest or not, to terminate or continue an investment, or to defer or carry on with an investment, to name a few. The methodology of real options is still unknown by many project managers. Yet this approach is derived from financial options. With the Real Options Valuation (ROV) method, a project is considered an option on the underlying cash flows and the optimal investment strategies are just the optimal exercise rules of the option. To use the value of real options as a selection criterion, a project must include a least one source of uncertainty large enough that it is sensible to wait for more future information. The investment must be fully or partially reversed and the project allows for the flexibility in decision taking in order to apply active management.

3.1.2 Historical Review of the literature on RO

Myers (1977) was the first one to propose the "real options" term, and pointed out the similarities between the financial options and real options. Ross (1978) made an analysis of risky projects. He found the inherent potential investment opportunities, he considered such an investment opportunity as real options, and then discussed the theory of real option valuation. The first person to have explicitly recognized the value of this flexibility was Kester (1984). Myers (1984) laid out the limitations of Discounted Cash Flow (DCF), and analyzed the importance of a company's strategy in the capital budget process. In 1985, Brennan and Schwartz (1985) applied option pricing techniques to the evaluation of irreversible natural resource investments. They studied the problem of how to estimate the value of a copper mining project with a high-risk cash-flow. Applications of real options to the oil industry followed quickly. Paddock et al. (1988) evaluated offshore petroleum leases; Ekern (1988) worked on evaluating oil projects and Copeland et al. (1990) presented a case study involving an option to expand oil production.

Brealey and Myers (1992) found that R&D investment will bring an option for the company within a specified time period. Trigeorgis (1993) divided the real options into seven categories according to the differences in flexibility: Option to Defer, Staged Investment option, Option to Alter Operating Scale, Option to Abandon, Option to Switch, Growth Option, and Interacting Option. Dixit and Pindyck (1995) maintained that traditional investment decision-making assumes that the strategic decision-making of corporate planners cannot be deferred. Trigeorgis (1996) stated that the managers' abilities to react to market conditions tend to expand the value of the investment project by maintaining or improving the upside potential and limiting the downside loss. As a result, the real options method may accept a project with a negative NPV. With an option to wait, the real options method may delay the execution of the investment activity.

3.2 Origins & Analogy with Financial Options

Real options evolve from the financial option. Its original intention was to deal with future uncertainties of a project's implementation. Real options are features that make a project flexible. The word real signifies that the options concern real assets rather than financial ones. The value of a real option derives from the fact that managers have the right to make ongoing favorable decisions concerning a project's investment and about its subsequent operation. RO use the same pricing model that is used to value financial assets; this pricing mechanism was developed by economists Robert Merton, Fischer Black and Myron Scholes in the early 1970s, and recorded in two papers: "The Pricing of Options and Corporate Liabilities" (Black and Scholes, 1973), and "The theory of Rational Option Pricing", (Merton, 1973). This theory won both Myron Scholes and Robert Merton the Nobel Prize in Economics in 1997. For this to work, there needs to be a correspondence between the investment's characteristics and the variables that determine the price of a financial option. The Black-Scholes' option pricing models are based on some assumptions, the most important one is that the

underlying price follows a Geometric Brownian motion, which implies that the stock price follows a lognormal distribution. Denote S as the underlying stock price, T as the time to maturity, σ as the volatility of the stock price, and r as the risk-free interest rate. The Geometric Brownian motion assumption implies

$$dS = \mu Sdt + \sigma Sdz \quad (1)$$

where μ is the growth rate of the price, and $\{z_t, t > 0\}$ is a Brownian motion process.

Then the value of a European stock call option at time t is given by the Black-Scholes formula:

$$C = N(d_1)S_0 - N(d_2)Xe^{-rT} \quad (2)$$

Where:

C = value of the call option

S_0 = current value of the underlying asset

X = cost of investment or strike price

r = risk-free rate of return

T = time to expiration

σ = annual volatility of future cash flows of the underlying asset

$$d_1 = \frac{[\log \frac{S_0}{X} + (r + \frac{\sigma^2}{2})T]}{\sigma\sqrt{T}} \quad (3)$$

$$d_2 = d_1 - \sigma\sqrt{T} \quad (4)$$

$N(d_1)$ and $N(d_2)$ are the values of the standard normal distribution at d_1 and d_2 .

The definition of these parameters can be presented as follows:

- Value of the Underlying Risky Asset (S) is the value of the underlying stock on which an option is purchased. As such, it is simply the market's estimate of the present value of all future cash flows dividends, capital gains, and so on, associated with that stock. Its equivalent in a real option is, therefore, the present value of cash flows expected from the investment opportunity on which the option is purchased.
- Exercise Price (X) is the predetermined price at which the option can be exercised. Its real-market equivalent is the present value of all the fixed costs expected over the lifetime of the investment opportunity.
- Volatility (σ): Standard Deviation of the value of the underlying asset is a measure of the unpredictability of future stock price movements: more precisely, the standard deviation of the growth rate of the value of future cash inflows associated with the stock. The real-market equivalent is the same, but in relation to the cash flows associated with the asset.
- Time to expiration of the option (t) is the predetermined price at which the option can be exercised. Its real-market equivalent is the present value of all the fixed costs expected over the lifetime of the investment opportunity.
- Risk-free rate (r) is the yield of a riskless security with the same maturity as the duration of the option, whether with regard to financial options or real options.

Table 1. Equivalence between Real Options and Financial Options.

Financial Option	Variable	Real Option
Stock or Commodity Price	S	Present Value of Asset to be Acquired
Exercise Price	X	Required Investment to acquire option over asset
Time to Expiration	T	Time over which decision can be deferred
Risk-Free Rate	r	Value of money over time
Volatility of Stock Price	σ	Project risk (volatility of expected cash flows)

Table 2. Differences between Financial and Real Options.

Financial options	Characteristics	Real Options
Short, months	Maturity	Long, years
Tradable	Underlying asset	Non-tradable
Do not affect pricing	Competition and markets effect	Affect value
Does not affect pricing	Managerial effect	Affect value

3.3 Real Options Valuation: Types of Valuation Methods and Options Pricing

These methods for real options valuation can be divided in two major categories: Analytical and numerical methods.

In the diagram below a further taxonomy is presented in Figure 1. This taxonomy is presented in more or less the same way by Schulmerich et al. (2010) who presented the most thorough analysis of the approaches aggregating the relevant literature.

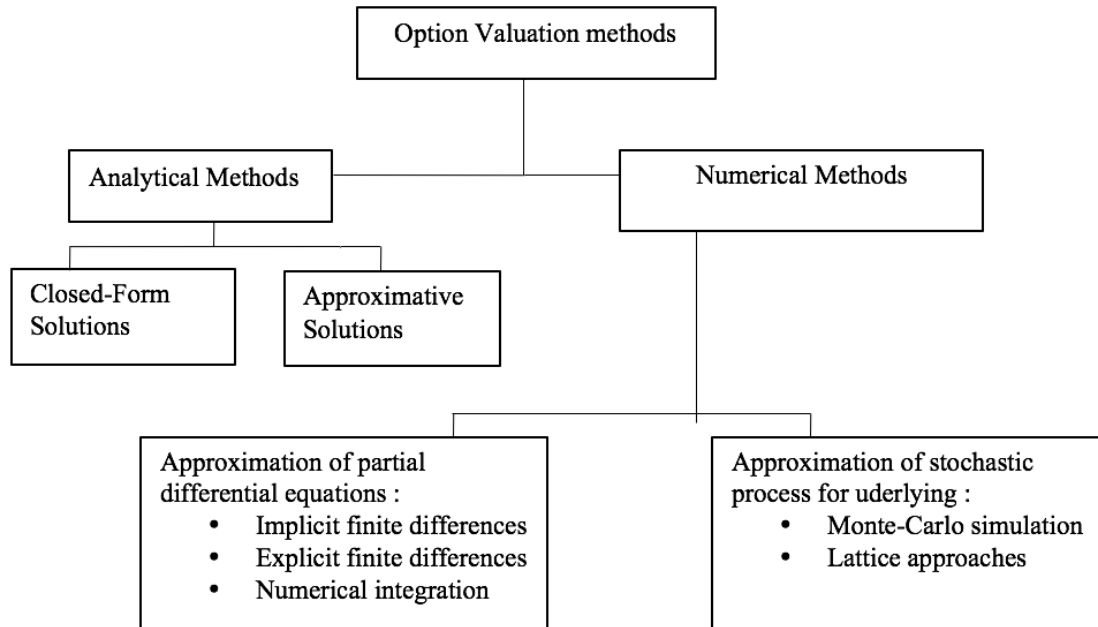


Figure 1. Classification of Valuation Methods of Real Options

The most commonly used ones are the Black & Scholes equation, the Monte-Carlo simulations and the lattice approaches. For this paper, the selected valuation tool for the real options valuation is the binomial trees, a variety of the lattice approach. The binomial method offers the most flexibility compared to Black-Scholes and the Monte-Carlo simulation approach. Input parameters such as the strike price and volatility can be changed easily over the option life. The key advantage the binomial method offers to a practitioner is that it is transparent in its underlying framework, making the results easy to explain to upper management for buy-in and approval.

While Black-Scholes gives the most accurate option value, the binomial method is a close approximation to it. Because of the underlying mathematical framework of the binomial method, it will always be an approximation of the Black-Scholes equation. The higher the time increments used in the binomial method, the closer you will get to this value. However, with only four to six time steps, a relatively good approximation can be obtained. This is adequate for practical purposes, especially considering the errors involved in the input parameter estimates. Binomial is the preferred method for most practitioners because its advantages far outweigh the drawbacks.

3.4 Review of the applications in the Literature of the real options

Since 1977, a range of applications had widened to include high-risk, high-tech industries such as research and development, information technology infrastructure, energies, gas & oil, industrial engineering and other types of services. Table 3 represents the most accurate papers up-to-date that have been a reference and a motivation of the work on this paper.

As stated by Rigopoulos (2015), real option theory can be applied to a broad range of business conditions and problems and there has been proposed numerous types of real options and variations of them. In this context of uncertain future cash flows, real option comes to provide managerial flexibility as every time new information arrives uncertainty is being reduced and management may alter its strategy and decision to operate in a way either to reduce losses or to capture future opportunities until the next milestone of novel information arrival.

This paper has selected the more prominent areas of research literature to be reviewed. The main areas of the application of real options available in the literature that are assembled in Table 3 and are presented in Figure 2.

Table 3. Application of RO in the literature.

AUTHORS	YEAR	APPLICATION
Myers	1977	Theory and similarities to FO
Ross	1978	Theory of Risk Investment
Kester	1984	Theory & Strategy
Myers	1984	Company's capital budget
Hodder and Riggs	1985	Theory & risks
Brennan and Schwartz	1985	Natural Resources
Trigeorgis and Manson	1987	Theory and DCF downfalls
Siegel et al.	1987	Oil industry
Paddock et al.	1988	Oil industry
Ekerm	1988	Oil industry
Copeland et al.	1990	Oil industry
Brealey and Myers	1992	R&D
Kemma	1993	Strategy
Dixit and Pindyck	1994	Natural Resources
Ross	1995	Theory and Strategy
Trigeorgis	1996	Natural Resources
Laine	1997	Theory & Strategy
Amram and Kulatilaka	1999	Natural Resources Energy
Gallant et al.	1999	Oil industry
Kellogg and Charles	2000	High-tech biotechnology
Galli et al.	2001	Natural resources Energy
MacMillan and McGrath	2002	R&D
Colwell et al.	2002	Natural Resources Mining
Amstrong et al.	2004	Oil industry
Botterud and Korpas	2007	energy market
Bonis et al.	2009	energy market
Fleten and Näsäkkälä	2010	Natural Resources & Energy
Zeng & Zhang	2011	Theory Studies
Haque et al.	2014	Natural Resources Mining
Chen et al.	2015	Natural Resources Mining
Amini et al.	2015	Natural Resources Mining
Chen et al.	2016	Natural Resources Mining
Haque et al.	2016	Natural Resources Mining
Trigeorgis et al.	2017	Operations Research
Dockner et al.	2018	Investment Choices

APPLICATIONS OF REAL OPTIONS IN THE LITERATURE

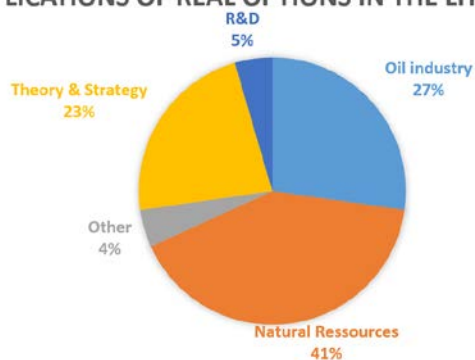


Figure 2. Application of the Real Options in the Literature

The richest area of the application of real options is the natural resources investment. The product price in the area of natural resources investment has the characteristic of a high degree of random fluctuation, which also requires enterprise management capabilities to use arbitrage opportunities.

4. Real Options Framework for The Profitability Analysis of an Investment Project

The following step-to-step decision analysis model presented in Figure 3 will help judge the validity of the option results and give a better insight into the option characteristics of the project, so that managers can ultimately make better investment decisions. It's basically done using the binomial method in order to map out the structure and sequence of options for easier understanding and valuation.

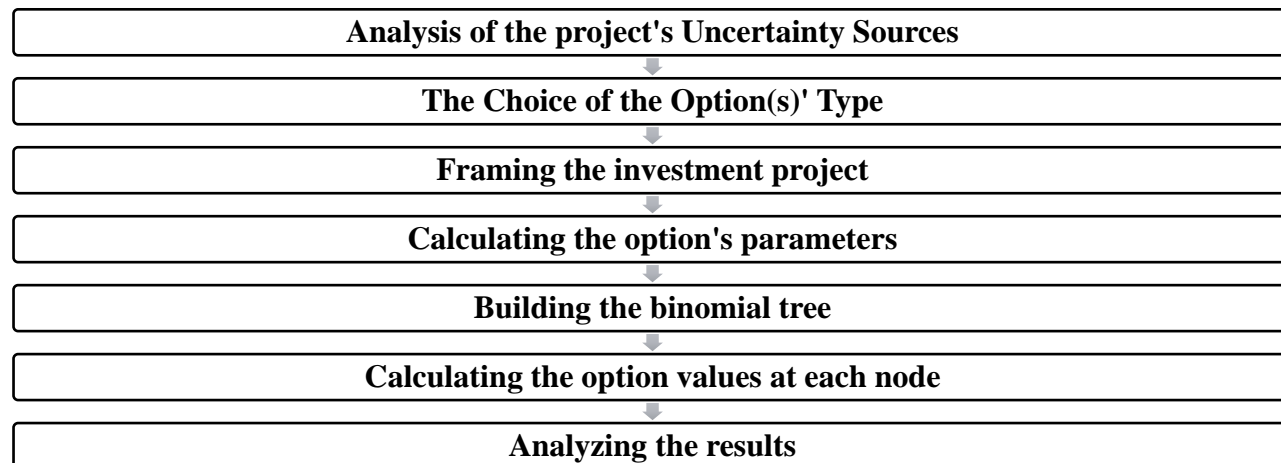


Figure 3. Proposed Step-to-Step Real Options Valuation Model

i. Analysis of the project's uncertainty sources

When managers estimate what it costs to invest in a given project and what its benefits will be in the future, they are coping with uncertainty. The uncertainty arises from different sources, depending on the type of investment being considered, as well as the circumstances and the industry in which it is operating. Uncertainty can result from economic factors, market conditions, taxes, and interest rates, among many other sources. In addition of the primary classic calculations of the project's NPV, the determination of the sources of uncertainty is fundamental for the profitability analysis of an investment project. It can be done by assembling all the criteria capable of influencing the project's durability. An investment project has definitely uncertainties virtually embedded in it. Their identification and the assessment of their impact is crucial for the profitability analysis of the project.

This is typically done following a general analysis of the project's environment and the multiple factors that have an effect on its life. They can be directly related to its economic valuation. However they also can be political, social, etc. The analysis of the uncertainties sources might be done with sensitivity simulations software such @Risk, StatTools & Monte Carlo. Running a sensitivity analysis helps clarifying the uncertainty, and enhances the understanding of the project's particularities. It also shows how each parameter influences the project's profitability, by simulations while varying parameters and seeing their effect on the NPV. Although the sensitivity analysis might give a sense of active management of the uncertainties, it's still not able to fully capture the proper value that the flexibility to respond properly to the future market changes. Thus this step is followed by the selection and the valuation of the real options approach. Therefore, selecting the source(s) of the uncertainty that effects more the profitability of the project is essential to be able to evaluate the chosen real option(s) suitable and available to it.

ii. Choice of The Option(s)' Type

By the type of flexibility that the operators may have in the operation of an asset or a project, real options are classified into several categories. Following the rich literature, we briefly introduce Simple & Advanced options. Simple options have only one source of uncertainty, namely, the price of the underlying asset. However, most real options' value is driven by multiple sources of uncertainty. These options are called rainbow options.

Simple Options:

- The option to abandon
- The option to expand
- The option to contract
- The option to wait
- The option to choose

Advanced Options:

- Rainbow Options
- Options with changing volatility
- Compound options
- Switching options
- Exit options

The classification of real options provides an easy intuition for understanding the flexibility features in an asset. However, this taxonomy is not rigid. A real-life real option does not necessarily fall into only one of the listed categories. Fortunately, this ambiguity in real options taxonomy does not affect our quantitative analysis of the option value, since when we price these options, it is the generated cash flows in different scenarios that matters, not the name they're called.

iii. Framing the investment project

Framing it involves describing it simply, identifying the type of investment and the project's particularities. It is an intuitive step but an important one; it helps lay down the project's data and know its context. Calculations of the NPV is crucial to have an insight of the project's profitability.

The first question to ask is whether there is even a need for real options valuation in the first place. If the Net Present Value is positive and there aren't much uncertainties, RO may not provide much results. Nevertheless, if sources of high uncertainty exist and if the project's execution may benefit from the flexibility to react to future learning, then the application of real options is mandatory.

Once the decision of using RO is made, the framing of a real option application is necessary. It means identifying the appropriate type of option or options (depending on the context of the project), for example, options may include abandon, defer, expand, contract, and other types. Moreover, the identification of the option is done regarding the uncertainties that the investment faces. The type of uncertainty makes the choice of the option easy.

iv. Calculating the Option's parameters

If RO is indeed the right tool, the next question is what options solution method would be appropriate to capture the value of the flexibility available. This framework's suggestion is to use the binomial tree method for its flexibility, transparency, and easy communication.

The basic input for the binomial lattice method to value any type of option include:

- the underlying asset value S_0 ,
- the strike price X ,
- the option's life T ,
- the volatility factor σ ,
- the risk-free interest rate r ,
- the time increments δt ,
- The option payoff F_t at the time t .

Thus the option's parameters are equal to :

$$u = e^{\sigma\sqrt{\delta t}} \quad (5)$$

$$d = \frac{1}{u} = e^{-\sigma\sqrt{\delta t}} \quad (6)$$

$$p = \frac{(e^{r\delta t} - d)}{u - d} \quad (7)$$

v. Building the Binomial Tree and Calculating the option's value at the last nodes

Once the values of the parameters are calculated, the binomial tree is built easily based on the number of time increments selected. The underlying asset value at each node of the tree is calculated starting with S_0 at time zero and moving toward the right by using the u & d until the option expires. We can lay out evolving asset prices from the starting node to the terminal nodes: $S_u = u \cdot S_0$, $S_d = d \cdot S_0$, $S_{ud} = u \cdot d \cdot S_0$, and so on.

Calculating the option values at each node: Starting at the far right side of the binomial tree, the option value is identified as the asset value that reflects the optimal decision. The options payoffs at the far right of the tree are:

$CT = \text{Max}\{S_u^T - X, 0\}$ if the option is a buy one (call), or $PT = \text{Max}\{X - S_u^T, 0\}$ if the chosen option is a sell one (put).

Moving toward the left of the tree, the option value at earlier nodes is calculated using the option values from the latter two nodes (either up or down) weighted by their respective probabilities, p for up, and $(1 - p)$ for down.

vi. Calculating the option's values of the rest of the tree nodes

A recursive induction process with the following algorithm will work out the option value at the starting time point:

$$F^t = e^{-r\delta t} [p \times F_{t+\delta t}^u + (1 - p) \times F_{t+\delta t}^d] \quad (8)$$

as F^t represents an option payoff (call or put) at the time t , $F_{t+\delta t}^u$ is the option value at time $t + \delta t$ given the underlying price at time $t + \delta t$ goes up by a rate of u from time t , and $F_{t+\delta t}^d$ is the option value at time $t + \delta t$ given the underlying price at time $t + \delta t$ goes down by a rate of d from time t .

This process is continued until you reach the far left end of the tree, which reflects the option value of the project for European options; as $\delta t \rightarrow 0$ the binomial method result converges to the Black-Scholes value. Nevertheless, for American options, the decision needs to be made at each node choosing the immediate exercise or continuing to wait. Mathematically, the choice is determined by:

$$\text{Max} \{ (S_t - X), e^{-r\delta t} [p \times F_{t+\delta t}^u + (1 - p) \times F_{t+\delta t}^d], 0 \} \quad (9)$$

vii. Analyzing the results

After the option value has been calculated, compare the NPV versus RO valuation and evaluate the value added as a result of the flexibility created by the option(s). Basically, the valuation of a real options of a project incorporates the value created by the uncertainty of the asset value and flexibility due to the contingent decision. The option valuation step identifies the asset value that reflects management's optimal decision at that node.

In order to get a better perspective on the option solution, several analyses can be performed by asking the following questions, among many others:

- What is the sensitivity of the option value to the uncertainty represented by the volatility factor, investment cost, discount rate, time to expiration, etc.?
- What is the probability that an option may have to be abandoned versus continued, expanded, or contracted?
- How do the option values based on the binomial method versus Black-Scholes compare?
- Is the asset value influenced by market uncertainty only? If private uncertainty also exists, does it precede or co-exist with market uncertainty?
- Are there multiple sources of uncertainty, and if so, what is their individual impact on the real options value?
- Does the exercise of the current option create one or more additional options?
- What if the framing of the option is changed?

These and other similar questions help in gauging the validity and reliability of the option results and give better insight into the option characteristics of the project, so that you can ultimately make better investment decisions.

5. Existing Model of the Infrastructure Project

5.1 Context and data of the project

According to Kmad et al. (2011), the demand for drinking water in Morocco is increasing, in a context of deteriorated natural resources. The expected increase in water demand makes the realization of a seawater desalination infrastructure necessary to ensure the supply of drinking water, and substitute conventional water resources.

A business analysis of this project has been conducted. Results using the NPV of the project showed a value of more than 2 Million MAD. The NPV of the project being positive, the project is therefore profitable and will pay back the funds invested. This estimation does not take into account flexibility, and possible uncertainties about key variables. A first step is to recognize these uncertainties by performing a sensitivity analysis. Involving the software @Risk, they were able to determine the influence of a variation of the parameters on the value of the investment project. The Project Sensitivity Analysis revealed that cash flows are very sensitive to future changes and allowed us to identify several factors that had an impact on the project's profitability. To simplify the analysis and make the process and results of the application of the real options approach more understandable, this study took into account a single source of uncertainty: the demand of drinking water for the desalination plant.

5.2 Real Options Valuation of the Project

The decision was to use the real options approach to evaluate the profitability of the desalination plant, by using the option to abandon which is the equivalent of an American put (sell) option for the financial market. The calculations of

the option's value have been made using the binomial tree method as a valuation tool given its transparency and its flexibility to respond to future changes. The Table 4 gathers the input parameters of this application.

Table 4. Input parameters (Kmad et al. 2011).

The discounted present value of the payoff	2 183 864
The Time to expiration	9 Years
The continuous annual risk free interest rate	4.17%

After computing the volatility of the cash flows of the project (σ) estimated at: $\sigma = 12.58\%$, the study launched the calculations of the option parameters as presented in Table 5, which are the up (u) and down (d) factors and the risk-neutral probability (p), with the consideration of a one year time step ($\delta t = 1$).

Table 5. Option's parameters (Kmad et al. 2011).

The up factor	$u = e^{\sigma\sqrt{\delta t}}$	1.134055
The down factor	$d = \frac{1}{u} = e^{-\sigma\sqrt{\delta t}}$	0.881791
The risk neutral probability	$p = \frac{(e^{r\delta t} - d)}{u - d}$	0.637389

Afterword's, they build the binomial tree of the abandonment option, and recovered the value of the option to finally deduct the best strategy for the construction of the seawater desalination plant. Thus, the results obtained using their valuation of the real option approach stated that, the underlying asset is worth 2183864 MAD while the value of the calculated abandonment option is worth 1909151MAD. Therefore, the option to abandon the project was judged by Kmad et al. (2011) not to be exercised and the project profitable.

5.3 Results and Gaps Analysis

In order to quantify the uncertainties and the flexibilities embedded in this project, the choice of Kmad et al, (2011) was to use the option to abandon if the project turns out to be unprofitable in the future. The definition of this option is the right to sell off all the assets and totally terminate the project at any time during its life. As stated by Kodukala, P. et al (2006) the abandon option is an American put option, where you can exercise the option on or before its expiration date by selling your project's assets. This type of options does exist in the literature but is not very commonly used or recommended. Indeed, the most famous paper that has been read and studied by all the scientific researchers and risk management practitioners in all over the world is the Brennan and Schwartz (1985); one of the most often cited papers in the area of real options. It has been credited as the first theoretical paper to pioneer the use of options methodology in valuing physical assets. They proposed in this paper, a simple and stylized model to quantify the value of temporarily closing, or even abandoning, mines as a response to a drop in metal price. Though mathematically elegant, this kind of approach was never embraced by many managers. On the contrary, it has been so rejected that "real option" now has a very bad name in the mining industry for example, on the erroneous belief that real options were limited to the simplistic abrupt shut-down option studied in Brennan and Schwartz (1985). One major complaint from infrastructure companies against this type of strategy is that social costs make the option of closing a mine very unappealing. Building a mine, hiring and training local workers, bringing skilled workers to remote mining areas, are all huge efforts that make a closure hard to revert.

Therefore, in this case-study several steps of the conduction of this project must have been taken into consideration as the implied costs, that cannot be ignored by project managers: the construction of the desalination plant, the hiring of engineers and workers, the down payment for land appropriation and the building permissions, the consultations of experts, etc. As any project with heavy investments, a large part of the outlays is done at the very beginning of the project. Thus, these spending must have been quantified properly and taken into consideration while proposing the model of an abandon option to value this investment. To abandon a project completely without any eventual losses and damages is simply an unrealistic scenario. This type of decision needs to take into account the fixed costs mentioned before, in order to be practical and manage to include the uncertainties of the project.

Thus, the model of the abandon option must be improved by admitting that this type of option is embedded in virtually every project. This option is especially valuable where the net present value is marginal but there is a great potential for losses. As the uncertainty surrounding the payoff clears and if the payoff is not attractive, managers can abandon the project early on, without incurring significant losses. The losses can be minimized by selling off the project assets either on the spot or preferably by prearranged contracts. The contingent decision in this option is to abandon the project if the

expected payoff (the underlying asset value) falls below the project salvage value, the strike price. Moreover, this salvage value represents the value of selling and closing the project, and is equal to the abandonment costs of the project. Thus, the value of the put option in the respective node is equal to the salvage costs when the value to keep the option open is below the strike price.

Since the abandon option is an American sell option, it only makes sense to consider the maximization of the value of the option at each node of the binomial tree. This must be done by comparing at each node the salvage value (abandon value) and the expected asset value. Thus, the value of the project using the real options approach is equal to the expected asset value in the node $t=0$. Moreover, this value should exceed the value of the expected payoffs of the project to be able to consider the project profitable and to recognize the added-value of the option to abandon.

In the previous example, the decision-makers didn't express the actual salvage value of the project, therefore they didn't take it into consideration while maximizing the values of the nodes of the binomial tree. In addition, they didn't address the difference between the value of the abandon option for each node of the tree and the expected asset value at $t=0$. They didn't quantify the real salvage value of abandoning the desalination plant in Agadir, and they estimated that the value at node $t=0$ of 1909151 MAD as the actual value of abandoning the project. This is a mix up due to the fact that they considered it to be the value of the option to abandon the project, while it's actually the value of the project using the real options approach, thus the option to abandon.

This confusion pushed to undervalue this option and made them forget to recognize the loss inherent with the abandon option. Given their results, the judgement is that the project is not profitable and the abandon option is not adapted to this type of investment.

6. Proposed Corrected Model of the Real Options Valuation of the Project

We aim to address these gaps in this section by quantifying the salvage value of the abandon option, and by submitting a corrected model using the option to choose from a combination of options rather than settling for just one type of option. We will introduce new options and explain them briefly, and in addition, we will conduct the same application as the case-study of the desalination plant in Agadir, and express the improved variances of our model.

6.1 Adjustments to the previous model

To properly use the abandon option, several modifications should be applied to the latter application. When the source of uncertainty considered in a real options approach decreases over a protracted period, the management should take the abandon option and minimizes the losses by selling off the capital equipment or the whole project. Therefore, the value of the option to abandon is directly calculated by estimating the value of this sell, which is normally indicated in prearranged contracts. Thus, the abandon option value equals the salvage assets value for the entire life of the project. In addition, in each node of the binomial tree, managers must compare for a maximization between the estimated value of the abandon option and the expect asset value at the respective node. If the latter is higher, it indicates that it's preferable to leave the option open for another year and learn from future changes. In this case-study, they should have properly calculated the salvage value of selling off this desalination plant, taking into consideration all the implied costs of conducting this project.

For example, an estimation of the implied costs of the desalination plant can be equal to 1000000 MAD. Thus, the option to abandon the project is respectively equal to the difference between the the discounted present value of the payoff and the implied cost: 1183864 MAD. The binomial tree analysis should have been conducted by comparing at each node, starting year 9, this value of the abandon option with the expected values of keeping the option open and not exercising it. The results of this correction showed a slight improvement of the new project's value using the option to abandon compared to the previous study, of 2075497 MAD, though the real options valuation of the project is still below the present value calculations. Clearly, the use of this option is not suitable for this type of investment. Therefore, an adjusted new model of options is mandatory for a defined valuation using real options theory.

6.2 Proposed corrected model using new options

To avoid the confusion of using an option that has a "bad reputation" in the literature and among practitioners in large sites construction's projects, we will not use the abandon option. Instead, this paper will introduce the option to choose between a combination of two innovative options at any time of the life of the project:

- The option to choose

As stated by Kodukala et al. (2006), the option to choose consists of multiple options combined as a single option. The multiple options can be abandonment, expansion, and contraction. The reason it is called a chooser option is that you can choose to keep the option open and continue with the project or choose to exercise any one of the options to expand,

contract, or abandon. The main advantage with this option is the choice. This is a unique option in the sense that, depending upon the choice to be made, it can be considered a put (abandonment or contraction) or a call (expansion) option.

- The option to contract

The first one is the option to contract. involves the right to scale back on a project by selling some of the assets when market conditions are not favorable to the investors. It's a corrected version of the abandon option, significant in today's competitive marketplace, where companies need to downsize or outsource swiftly as external conditions change. Organizations can hedge themselves through strategically created options to contract. The option to contract has the same characteristics as an American put option, because the option value increases as the value of the underlying asset decreases. Managers can exercise the option on or before its expiration date by selling parts of your project assets and restoring some benefits from it. Basically, by contemplating scaling down its operations by either selling or outsourcing one of its assets to gain efficiencies through consolidation within the next years, the company frames an option to contract the size of its current operation by an estimated factor and gains a relative amount in savings because of lower general overhead expenses.

- The option to expand

The second option that we will be introducing is the option to expand an investment. This is another common example, where managers have the right to expand a project through additional future investments by investing more to expand the production of the project. The option to expand is common in high-growth companies, especially during economic booms. For some projects, the initial NPV can be marginal or even negative, but when growth opportunities with high uncertainty exist, the option to expand can provide significant value. You may accept a negative or low NPV in the short term because of the high potential for growth in the future. Without considering an expansion option, great opportunities may be ignored due to a short-term outlook. Investment for expansion is the strike price that will be incurred as a result of exercising the option. The option would be exercised if the expected payoff is greater than the strike price, thereby making it a call option. The expand option is an American option, where the option can be exercised on or at any time before the expiration date and you acquire the right to invest in the project.

7. Application, Results and Analysis

The managers decided to apply the choosing option and are facing the dilemma of choosing among three strategies (continuation, expansion, or contraction) for the sea water desalination plant in Agadir. At any time during this time period of the project (9 years), the company can either:

- Expand the project by 30% by investing 600000 MAD,
- Contract one-quarter of its current operations to save 500000 MAD,
- Continue with the project by keeping the options opened.

7.1 Building the binomial tree and calculating latter nodes

The projects inputs are still the same as the ones available in section 5, and the up and down factors as well as the risk-neutral probability are unchangeable. Therefore, we build a binomial tree following the framework of the decision model established in section 4, as shown in Figure 4, using one-year time intervals for nine years and calculate the asset values over the life of the options. Starting with S_0 at the very first node on the left and multiply it by the up factor and down factor to obtain S_{0u} (2183864 MAD * 1.134055 = 2476562 MAD) and S_{0d} (2183864 MAD * 0.881791 = 1925760), respectively, for the first time step. Moving to the right, continue in a similar fashion for every node of the binomial tree until the last time step.

Figure 4 shows the option values at all times in the binomial tree calculated by backward induction. Each node represents the value maximization of different mutually exclusive options available. At every node, we have the option to either continue the operation and keep the option open for the future or:

- Expand 30% with an investment cost of 600000 MAD,
- Contract 25% to save 500000 MAD.

This means we need to calculate the asset values for each of the above options at each node and compare them against the continuation alternative. If continuation turns out to provide the maximum return, we would keep the option open for the future. Otherwise, we would exercise the option that provides us the maximum return.

Thus, starting with the terminal nodes that represent the last time step, at node S_{0u}^9 , the expected asset value is equal to 6 774 050 MAD. Now calculate the asset values for exercising each of the available options:

- Keep the option: 6774050 MAD
- Expand: $(1.3 * 6774050 \text{ MAD}) - 600000 \text{ MAD} = 8206266 \text{ MAD}$

- Contract: $(0.75 * 6774050 \text{ MAD}) + 500000 \text{ MAD} = 5580538 \text{ MAD}$

Maximization shows that the option to expand would be exercised at this node, so the option value here becomes 8206266 MAD. It turns out that you also would exercise the option to expand at nodes S_{0u^8d} , $S_{0u^7d^2}$, $S_{0u^6d^3}$ and $S_{0u^5d^4}$. Meanwhile, in nodes $S_{0u^4d^5}$, $S_{0u^3d^6}$, $S_{0u^2d^7}$, S_{0ud^8} and S_{0d^9} , we would exercise the option to contract the project because the maximization in those nodes turned out to be in its favor.

7.2 Intermediates nodes calculations

Next, moving on to the intermediate nodes, one step away from the last time step. Starting at the top, at node S_{0u^8} , we calculate the expected asset value for keeping the option open and accounting for the downstream optimal decisions. This is simply the discounted (at the risk-free rate) weighted average of potential future option values using the risk-neutral probability. That value, for example, at node S_{0u^8} , is:

$$[p * (S_{0u^9}) + (1 - p) * (S_{0u^8d}) * e^{-r\delta t}] = [0.637398 * (8206266) + (1 - 0.637398) * (6248708)] = 7190261 \text{ MAD} \quad (10)$$

Now calculate the asset value for exercising each of the available options:

- Keep the option open: 7190261MAD
- Expand: $(1.3 * 5973298 \text{ MAD}) - 600000 \text{ MAD} = 7165287 \text{ MAD}$
- Contract: $(0.75 * 5973298 \text{ MAD}) + 500000 \text{ MAD} = 4979974 \text{ MAD}$

Maximization shows that we would keep the option open at this node. Therefore, the option value at this point becomes 7190261 MAD.

Similarly, at nodes S_{0u^7d} , $S_{0u^6d^2}$, $S_{0u^5d^3}$ and $S_{0u^4d^4}$, we calculated the expected asset value for keeping the option open and accounting for the downstream optimal decisions, that turned out greater than the expand and the contract options. Moving to $S_{0u^3d^5}$, calculations of the asset value for exercising each of the available options gave these results:

- Keep the option open: 1753134MAD
- Expand: $(1.3 * 1698160 \text{ MAD}) - 600000 \text{ MAD} = 1607608 \text{ MAD}$
- Contract: $(0.75 * 1698160 \text{ MAD}) + 500000 \text{ MAD} = 1773620 \text{ MAD}$

Thus, as in Figure 4, there is a slight difference between the values of keeping the option open to learn from future changes and exercising the option to contract. We chose to apply the contraction option for further safeness. Therefore, the option value at this node becomes 1773620 MAD.

Likewise, we continued calculations in the nodes $S_{0u^2d^6}$, S_{0ud^7} and S_{0d^8} , results showed that we will be applying the option to contract as well. Proceeding in parallel, we established that in nodes S_{0u^7} , S_{0u^6d} , $S_{0u^5d^2}$, $S_{0u^4d^3}$ and $S_{0u^3d^4}$, we're keeping the option opened. However, in node $S_{0u^2d^5}$, it turns out to be a quit similar situation as in the previous analysis of node $S_{0u^3d^5}$; that is why we chose the option to contract at that node to maintain the same insight. Therefore, the value at node is 1623094 MAD.

7.3 Analysis & Recommendations

Alike, we completed the calculations until time $t=0$ and we carried on with the same logic until we reached node S_0 . Node S_{0d^4} was the last node where the option to contract was chosen. All the other previous nodes provided an option open to continuity as represented in the final version of the binomial tree of this case-study in Figure 4. Numerical results of the real options valuation of the sea water desalination plant in Agadir, using the option to choose, provided a value of 2448344 MAD. The NPV of the project was 2183864 MAD and our real options valuation turned out greater than the NPV valuation. The difference of 264480 MAD is the substantial added-value to the project by real options which management can take into consideration in making the project decisions. Figure 3 shows the strategic choices this project's managers would make at different points during the option life. It appears that they would either continue the project keeping the options open, contract, or expand depending on the expected asset values.

As we might expect, the combined option has more value than any one of the individual options. Summation of the individual options may not necessarily be the same as the combined chooser option. This is because the individual options are mutually exclusive and independent of each other. For example, we cannot contract and expand the project at the same time. The value of a chooser option will always be less than or equal to the summation of the individual options that make up the chooser option. At each node of the binomial lattice, among the choices available, we choose whichever provides the maximum value; we do not add up the individual option values. With the chooser option, we can change the salvage value, analyze the impact of volatility, calculate the probability of exercising a given option at a given time. The binomial method gives us the flexibility and makes the calculations visible, so the results can be easily understood and communicated to management.

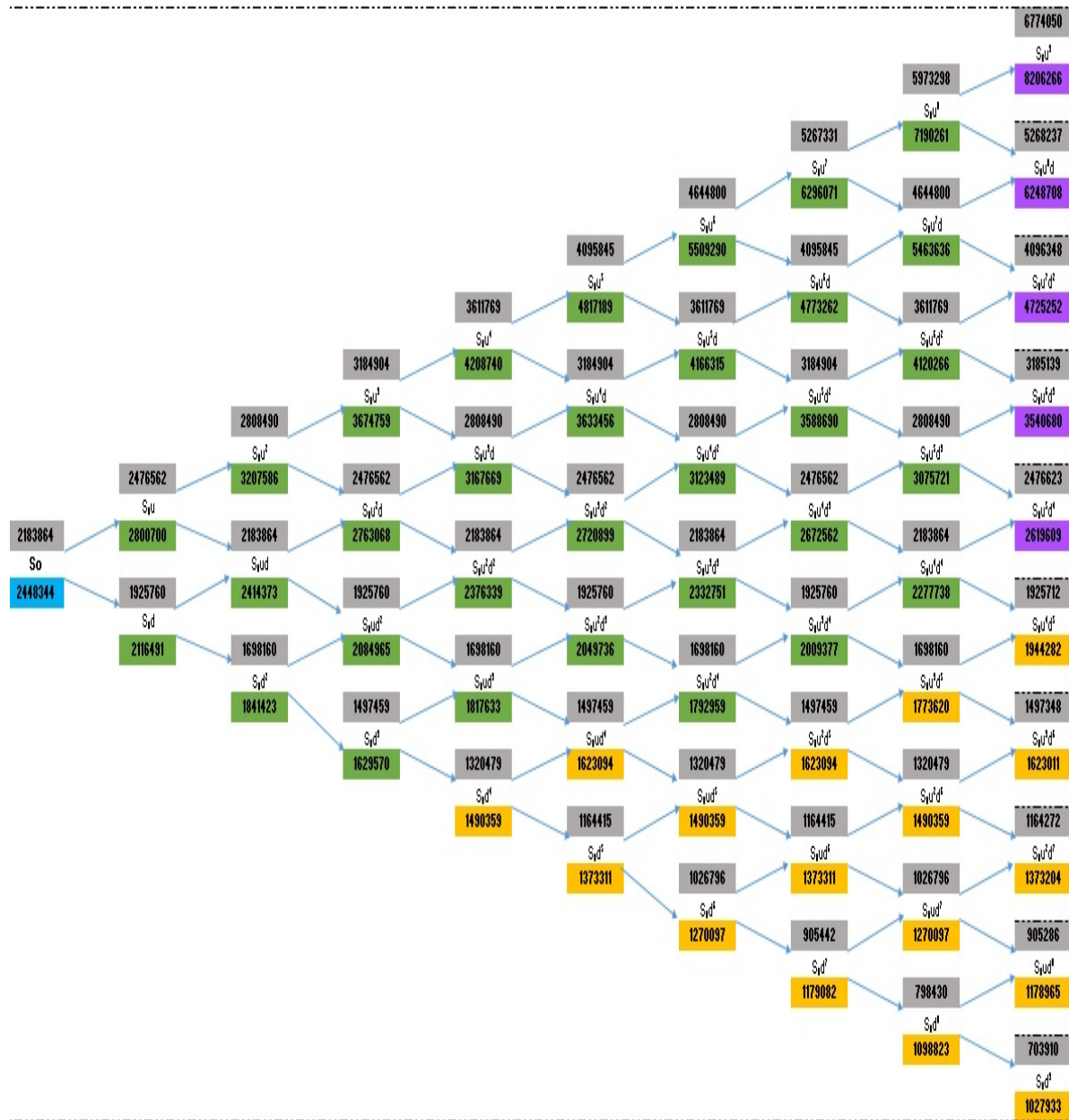


Figure 4. The binomial tree of the proposed corrected model

8. Conclusion

“To invest or not to invest?” is a question pondered over every day by business executives across the globe. They are frequently faced with the dilemma of deciding whether or not to invest in developing a new product, introducing a new technology, testing a new drug, or launching a new service, to name just a few examples. Although the decision to invest in a project depends on several factors, it is primarily dictated by the expected financial return and risk associated with that project. Discounted cash flow analysis is a commonly used method which accounts for the market uncertainty with a risk-adjusted discount rate (the higher the uncertainty, the higher the discount rate) to calculate the present value of the payoff. While this approach focuses on the downside, the reward side is ignored. However, in today’s constantly changing environment, managers have the flexibility to alter the project outcome (for example, expand, contract, postpone, or abandon a project) in order to maximize the payoff or minimize the loss. This flexibility is not accounted for in the DCF approach.

The evaluation of the desalination plant of the sea water in Agadir using the chooser option and the real options methodology provided a much sophisticated and elaborated analysis for taking investment decisions than the early study using the abandon option, that drags along a bad reputation and an unrealistic application. This framework covered not

only the valuation of real options but also the organizational, strategic, and controlling aspects necessary to apply real option valuation accurately. In particular, this paper focused on uncertainties underlying any real option and their added-value to the project's valuation. Uncertainties are being used not only to identify options but also to link the interaction of uncertainties with the interaction of options.

More importantly, the real options approach is a state of mind, an ability and a desire to detect decisions that create opportunities and protect against setbacks, by acting on them to create value in the future and profit of the company. For a full review of the project we would have to consider other uncertain factors, for example, the project's estimation of the volatility factor, that might trigger a substantial alteration of the valuation's results.

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Biographies

Jihane Gharib is a Moroccan PhD holder from the Industrial Engineering department of Mohamadia School of Engineers (EMI) in 2018, also an engineer who graduated from the same school in 2013. She teaches several courses in Engineering and Management Schools in Rabat and Casablanca, and is very passionate about Financial Analysis and

Risk Management; currently working on the Analysis and the Quantification of Financial Risks in the Investment Project field. She has been a project manager and a financial analyst in a construction company before deciding to fully concentrate on her thesis and researches. She had previous experience with the IEOM community as she had published several articles and had won the “best track paper” award in the 2nd European IEOM conference in Paris.

Dr. Abdelaziz BERRADO is an Associate Professor of Industrial Engineering at EMI School of Engineering at Mohamed V University. He earned MS/BS in Industrial Engineering from same institution, an MS in Industrial and Systems Engineering from San Jose State University, and a PhD in Decision Systems and Industrial Engineering from Arizona State University. His research interests are in the areas of Data Science, Industrial Statistics, Operations and Supply Chain Modelling, Planning and Control with application in different industries. His research work is about developing frameworks, methods and tools for systems’ diagnostics, optimization and control with the aim of operational excellence. He published several papers in international scientific journals and conferences’ proceedings. In addition to academic work, he is a consultant in the areas of Supply Chain Management, Data Mining and Quality Engineering for different Industries. He was also a senior engineer at Intel. He is member of INFORMS and IEEE.

Dr. Loubna BENABBOU is an Associate Professor of Industrial Engineering at Ecole Mohammadia d’Ingénieurs (EMI) at Mohamed V University. Her research work lies in the application of decision/ management sciences and machine learning techniques to transform data for making better decisions and improving operational processes. Dr Benabbou has been supervising several undergraduate and graduate students in projects for different Industries related to the areas of Decision sciences, Data valorization and Operations Management. Several of her research paper related to these fields has been published in international scientific journals and conferences’ proceedings. She was also a trader at Casablanca stock-exchange and financial analyst and risk manager at the Caisse Marocaine des retraites the Moroccan largest intuitional fund manager. She is member of INFORMS, IEEE and International society of MCDM. Dr Benabbou is an industrial engineer from EMI, she earned MBA and PhD in Management and Decision sciences from Laval University.