

Real Options for Dealing with Uncertainty in Project Management: A Case Study of Moroccan Infrastructure Project

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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 uncertainties. 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 a case study of a Moroccan infrastructure project, that had already undergone an evaluation, and its purpose is to review this project's application and valuation of Real Options. 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.

Keywords

Project Management, Investment Project, Decision Analysis, Real Options Valuation, Uncertainty.

1. Introduction

The Real Options methodology was developed, at least partly, as a response to the inadequacy of traditional methods for the evaluation of capital budgeting decisions under uncertainty, namely Net Present Value (NPV). Since its inception in 1977, the Real Options methodology has gained acceptance among the finance community, and has been applied to a variety of capital investment decisions, and recently to the evaluation of infrastructure projects.

The approach, derived from the financial option pricing theory, overcomes NPV disadvantages by allowing analysts to account for non-easily quantifiable elements such as managerial flexibility and strategic interventions during the development of a project. Accounting for these elements radically changes the nature of any investment or project, by incorporating flexibility into the structure of the project itself. In addition, it also corrects the expected pricing inaccuracies, by determining a fairer value of flexibility through the use of arbitrage pricing techniques [1].

Nevertheless, introducing real options valuation lays down the additional difficulty of being almost completely unknown to the engineers in charge of evaluating infrastructure investments, plus implementing and choosing options can't be arbitrary. The mathematical complexity included in project uncertainties, as well as the difficulty of solving the complex mathematical models, do not make the real options valuation methods more useful to practitioners [2].

This paper aims to clarify the scientific ambiguity around Real Options (RO), and to address existing models of investment project analysis using this approach. It's a review and an analysis of 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 & al. [3] 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 & al. [3] 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 in [3] and its outcomes. Section 2 outlays their results and their calculation method with a description of their chosen option for calculation. Section 3 establishes a profound analysis of their reasoning and identifies its major gaps. After, Section 4 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. Existing model of the infrastructure project

2.1 Context and data of the project

According to Kmad & al. [3], 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.

2.2 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 1 gathers the input parameters of this application.

Table 1. Input parameters (Kmad & al. 2011) [3].

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, 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 2. Option's parameters (Kmad & al. 2011) [3].

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. Figure 1 represents the binomial tree and their obtained results according to this application of the abandonment option. The construction of this tree begins with the end: it is positioned at the option's maturity, at year 9. In the case of the American option, it is necessary for

each node to arbitrate the maximization between the gains that would be realized by exercising the option in advance and the value of the option if it is maintained in the future life. If the value of the underlying asset at that time is less than the value of the option, then the option is exercised, and the benefit is the difference between the value of the underlying and the value of the the option.

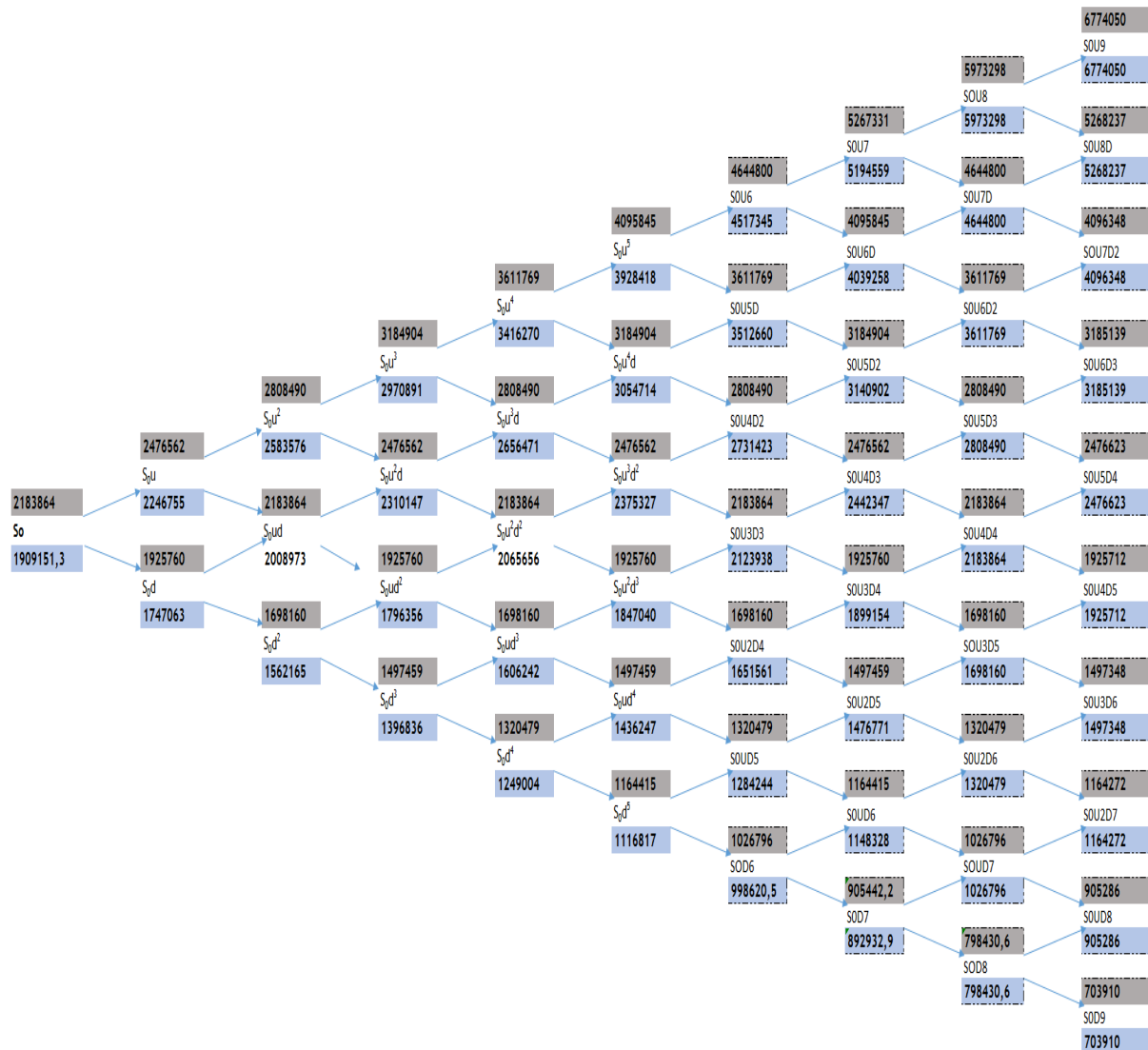


Figure 1. The binomial tree of the study [1].

Thus, the results obtained in Figure 1 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 & al [3] not to be exercised and the project profitable.

2.3 Results and Gaps Analysis

In order to quantify the uncertainties and the flexibilities embedded in this project, the choice of [1] 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. It's an American put option, where you can exercise the option on or before its expiration date by selling your project's assets [4]. 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 [5]; 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 [6]. 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 [5]. 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 [7].

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, and so on ... 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 (NPV) 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 [4]. 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 (ie the project) 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.

3. 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.

3.1 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 (salvage assets) 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.

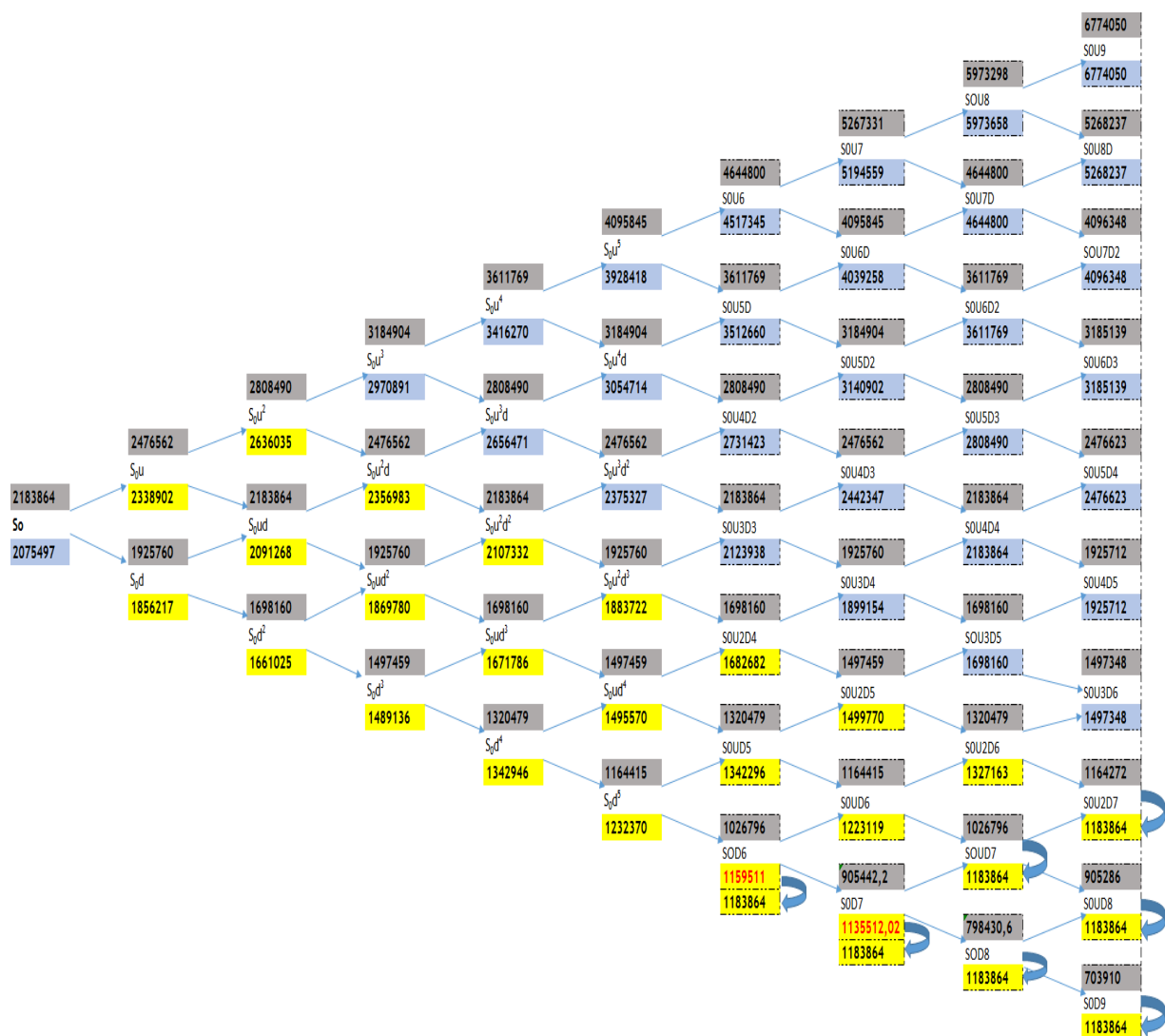


Figure 2. The adjusted binomial tree with abandon option

The results of this correction, represented in figure 2 where the yellow case are indeed the nodes of the tree that have had different values compared to the earlier results of [1], 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.

3.2 Proposed corrected model using new options

The previous correlations brought some relatively improved values to the desalination plant project and adjusted some calculations. Nevertheless, it didn't quite exactly assess the inherent flexibilities that might have been available to decision-makers, and have been neglected by using a passive option as the abandon one.

Therefore, 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, we 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

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 [4].

- 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 [4]. 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 [4]. 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 (buy) in the project.

4. Application, Results & 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 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.

What is the value of the chooser option for the sea water desalination plant in Agadir? What is the best strategy to take over? We'll address this questions in these next sections.

4.1 Building the binomial tree and calculating latter nodes

The projects inputs are still the same as the ones available in section 2, and the up and down factors as well as the risk-neutral probability are unchangeable. Therefore, we build a binomial tree following the decision model established in our earlier work [8] & [9], as shown in figure 3, 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} ($2183864 \text{ MAD} * 1.134055 = 2476562 \text{ MAD}$) and S_{0d} ($2183864 \text{ MAD} * 0.881791 = 1925760$), 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 3 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 $S_{0u}^4d^5$, $S_{0u}^3d^6$, $S_{0u}^2d^7$, $S_{0u}d^8$ 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.

4.2 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:

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

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 3, 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.

4.3 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 3 below.

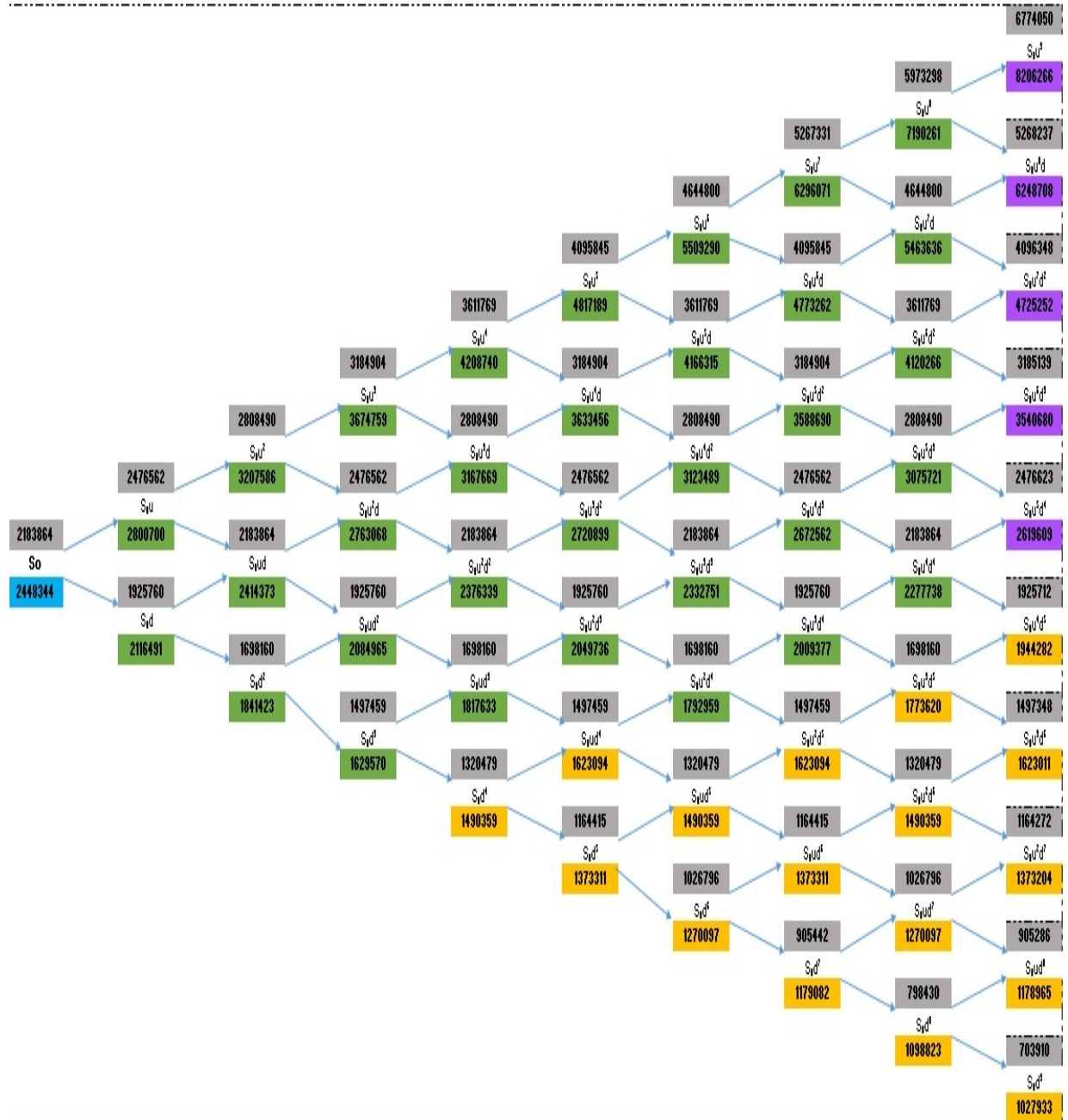


Figure 3. The binomial tree of the proposed corrected model

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.

Additional information on the probability of the survival of the desalination plant also can be of use to the portfolio manager in making the investment decision. That information can be obtained easily from the binomial lattice used in solving the options problem. An examination of Figure 3's 9-years recombining binomial lattice reveals ten possible asset values at the end nodes of the nine-time-step binomial lattice. Of the ten, 5 nodes are expand options and hence will trigger the option's exercise, the latter five are contract options. At the surface, it may seem, therefore, that the probability of exercising the option to expand the project is that is, at the end of the option life is 5/10 or 50%, and respectively, the option to contract's probability of exercise is 5/10 or 50%. This in fact is not always true. Since the binomial tree in this example is recombining, there are many different paths leading to each node. The number of paths contributing to each node must be calculated first before estimating the probability of exercising the option at the end of the option life.

The verifications of those probabilities can be done using Pascal's triangle (named after the discoverer), as shown in Figure 4. If the triangle is rotated 90 degrees counterclockwise, it will represent a binomial lattice showing the number of paths each node represents. Each node's value in this triangle is the sum of the values of the two nodes that lead up to that node. This shows the total number of paths for all the end nodes combined in a nine-step binomial lattice to be 512.

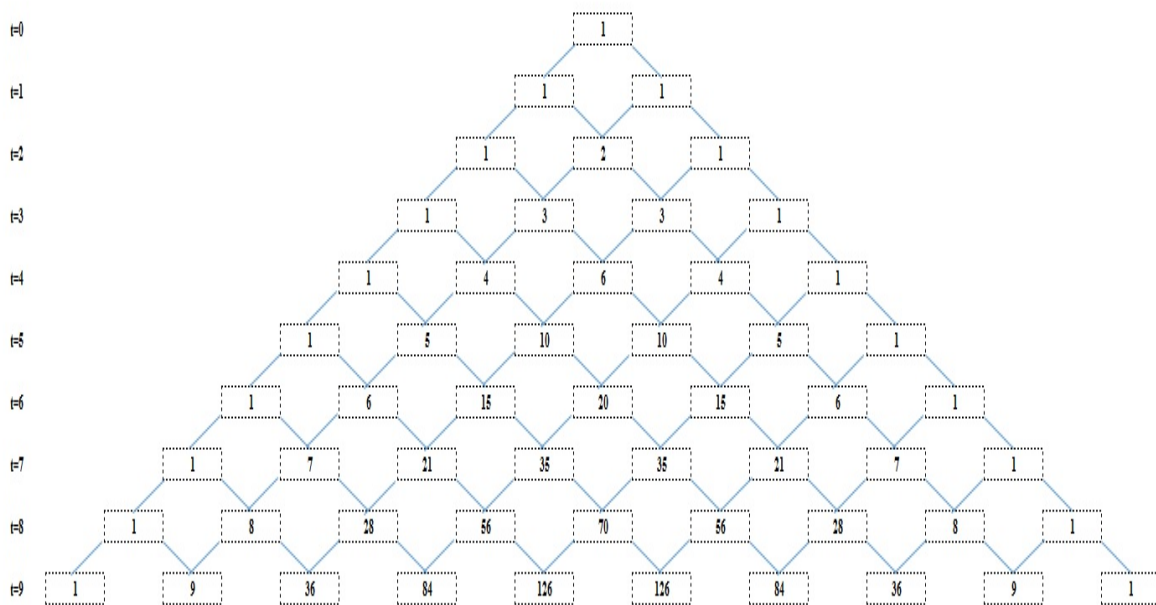


Figure 4. Pascal's triangle of the binomial tree

The total number of paths corresponding to the five bottom end nodes where the expand option option will be exercised in our example is 256. Therefore, the probability that the project will be expanded at the end of the option life is 50%. Similarly, the probability that the project will be contracted at the end of the option life is equal to 50%. Conversely, this information can be helpful in making decisions in a project portfolio context when projects with similar NPVs

and even similar option values are compared. We strongly advise to expand this project due to its prominent socioeconomic impact.

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 [4].

5. Conclusion

Real options are a way of valuing infrastructure projects, which involve irreversible investment decisions subject to uncertainty. Whereas discounted cash flow analysis is based on fixed estimates of costs and revenues and a predetermined development scenario, real options focus on project flexibility (e.g., being able to defer starting a project, or conversely, to accelerate its development, to contract ...). Early applications concentrated on flexibility to overcome uncertainty on financial parameters and tended to ignore uncertainty on technical parameters (such as recoverable reserves) [10]. The flexibility to revise managerial and operational decisions over time in response to uncertain market conditions can significantly increase the value of a project [11].

Thus, an option has value because there is market uncertainty related to the underlying asset. The idea is that once the uncertainty clears, the option may be exercised and the project initiated, expanded, scaled down, or contract accordingly. The option lets us take advantage of the upside while avoiding the downside [4].

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 [12]. 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 need 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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