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A REAL OPTIONS APPROACH TO PROJECT MANAGEMENT

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ABSTRACT

When scheduling an uncertain project, project management may wait for additional (future) information to serve as the basis for rescheduling the project. This flexibility enhances the project's value by improving its upside potential while limiting downside losses relative to the initial expectations. Using traditional techniques such as net present value or decision tree analysis may lead to false results. Instead, a real options analysis should be used. We discuss the potentials of a real options approach to project scheduling with an example and highlight future research directions.

Keywords: *Project management; Real options; Flexibility; Uncertainty*

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1. Introduction

Most traditional investment decisions are characterized by irreversibility and uncertainty about their future rewards: once money is spent, it cannot be recovered if the payoffs hoped for do not materialize (Huchzermeier and Loch 2001). These decisions make implicit assumptions concerning an 'expected scenario' of cash flows and presume management's passive commitment to a certain operating strategy (Trigeorgis 1993). In the real world of uncertainty and competitive interactions, the realization of cash flows will probably differ from what management originally expected. As new information becomes available and uncertainty about market conditions and future cash flows is gradually resolved, management may depart from and revise the operating strategy it originally anticipated (Dixit and Pindyck 1994). As with options on financial securities, this flexibility to adapt in response to new information enhances the investment opportunity's value by improving its upside potential while limiting downside losses relative to the initial expectations under passive management (Trigeorgis 1996). Using the analogy with options on financial assets, such investment flexibility is often called a 'real option'.

The flexible decision structure considered in option theory is also valid in project scheduling. It may be uncertain whether a project will arrive or not, the processing time or the required resource capacity for the project may be undetermined yet, or other sources of uncertainty may occur when accepting a project. When scheduling such an uncertain project, project management may wait for more (future) information in order to reschedule the project as this new information becomes available. Using traditional techniques such as net present value or decision tree analysis may lead to false results. Instead, a real options analysis should be used.

In this paper, we will first give an overview of the different techniques and the appropriate methodology to value this flexibility. Next, we give a concrete example where a real options approach has to be used when it is uncertain whether a project will arrive or not. Finally, some topics for further research will be set forward.

2. Real options analysis: an overview

Real options are options on real assets, which can be defined simply as opportunities to respond to the changing circumstances of a project. These opportunities to change consist of rights but not obligations to take some action in the future (Dixit and Pindyck 1995). Many of these real options occur naturally, while others may be planned and built-in at some extra cost. The role of real options analysis is to quantify how much future opportunities are worth today. Using option pricing models, it is possible to quantify these opportunities and to indicate when these options should be optimally exercised (Botteron 2001).

Analogously to financial options, we can divide real options into call options and put options. A *call option* gives the holder the right, for some specified amount of time, to pay an exercise price (i.e. the investment price) and in return receive an asset (a project) that has some value. Consequently, the profit of the option at the time of exercise is the difference between the value of the underlying asset and the exercise price. An example of such a call option is the deferral option, which refers to the possibility to delay the start of a project until more information has become available. A *put option* is the opposite, i.e. the right to sell the underlying asset (project) to receive the exercise price. An example of a put option is the opportunity to abandon an uncertain project for a fixed salvage value.

In this section, we consecutively discuss the net present value method, decision tree analysis and real options analysis. To have a good understanding of the different valuation techniques, we will use a simple deferral option as an example. Copeland and Antikarov (2001, p. 87) describe a situation where you have the possibility to invest in a project that will cost *$115* million next year with absolute certainty, but will produce uncertain cash flows $c=(c_1,c_2)$ of either *$170* million or *$65* million, each with a probability of 50 %. The risk free rate in the example is 8 % and the project's specific cost of capital is 17.5 %.

2.1. Net present value analysis

Consider first the case without flexibility: we can only use the information that is available today and we have to decide now whether or not to invest. The *net present value* (NPV) method gives us the appropriate answer as follows:

The current gross project value is obtained by discounting the project's end-of-period values at the appropriate discount rate, i.e. $P(c) = [0.50*(\$170) + 0.50*(\$65)]/1.175 = \$100$.

After subtracting the current investment costs, the project's net present value is finally given by:

$$NPV = \$100 - \frac{\$115}{1.08} = -\$6.481$$

In the absence of managerial flexibility, we would decide not to invest in this project, based on its negative NPV.

Net present value based approaches provide an easy and instructive way to analyse the decision whether or not to commit resources to a new investment in a stable environment. They implicitly assume that a project will be undertaken now and operated continuously until the end of its expected useful life, even though the future is uncertain. Nevertheless, they fail in cases when markets move unpredictably and managers have the possibility to adapt their decisions in real-time: they ignore the upside potential of added value that could be brought to the project through the flexibility and innovations of management to alter the course of investment. Such interventions during the life of the project according to changes in market conditions over time provide companies with a better chance to reap higher returns or minimize losses in a volatile marketplace (Yeo and Qiu 2003).

This does not mean that traditional NPV calculations should be scrapped, but rather seen as a crucial and necessary input to an expanded, option-based analysis. The true value of the project with the option consists of two components: the traditional (static or passive) NPV of direct cash flows, and the option value of operating and strategic flexibility (Trigeorgis 1993).

2.2. Decision tree analysis

Suppose we allow for flexibility in our example. Instead of the now-or-never investment, we have the (unrealistic) option to wait until the end of the period and choose whether to spend $115 million based on the knowledge of the state of nature. Only in case the cash flows are $170 million, we decide to invest. When cash flows turn out to be only $65 million, we rather decide not to invest, instead of incurring a loss of $50 million. To obtain this right to defer the decision, we have to pay a certain price, since we eliminate the uncertainty and thus the risk of our investment. A frequently used method to capture the value of this flexibility is *decision tree analysis* (DTA). Here flexibility is modelled through decision nodes allowing future managerial decisions to be made and altered after some uncertainty has been resolved and more information has been obtained.

$$\begin{cases} \$170 - \$115 = \$55 \Rightarrow \textit{invest} \\ \$65 - \$115 = -\$50 \Rightarrow \textit{do not invest} \end{cases}$$

The expected return is estimated by discounting the expected cash flows of the project given the right to defer at the cost of capital of 17.5 %. The net present value of the project with this option now becomes

$$NPV = \frac{0.50*(\$55) + 0.50*(\$0)}{1.175} = \$23.40$$

Since the flexibility to defer increases the NPV of the project from -$6.48 million to $23.40 million, the value of the deferral option would be $\$23.40 - (-\$6.48) = \$29.88$ million.

At first glance, this seems to be a good approach, but on close reflection the DTA method is wrong. The presence of flexibility embedded in future decision nodes changes the payoff structure and the risk characteristics in a way that invalidates the use of the same constant discount rate. Since the risk profile has changed due to the changes in the cash flow pattern of the project, adjustment for risk should be done appropriately. Here is where the *real options analysis* comes in. The option approach can be interpreted in the decision tree context as modifying the discount rate to reflect the actual risk of the cash flows (Copeland and Keenan 1998).

2.3. Real options analysis

The real options method implicitly incorporates the correct cost of capital because the option flows are expressed as a linear combination of flows whose cost of capital is supposedly known correctly. To see how it works, we form a *replicating portfolio* composed of *m* shares of a twin security (which is a security having payoffs proportional to those of our project) and partly financed by borrowing an amount *B* at the risk free rate (Cox, Ross and Rubinstein 1979). The portfolio should be chosen such that it will replicate the payoffs of the deferral option. Because the replicating portfolio has the same payouts as the project with the deferral option, it should have the same present value in accordance with the 'no arbitrage' principle, or the *law of one price*. This law simply states that in order to prevent arbitrage profits, two assets that have exactly the same payouts in every state of nature are perfect substitutes and must, therefore, have exactly the same price (or value). Otherwise, arbitrageurs would buy the undervalued investment and sell the overvalued investment, making a risk-free profit (Grinblatt and Titman 2001).

The frustrating part of this twin security approach is that it is practically impossible to find a priced security whose cash payoffs in every state of nature over the life of the project are perfectly correlated with those of the project. Instead of searching in financial markets, Copeland and Antikarov (2001) recommend to use the present value of the project without flexibility as the twin security in valuing real options. This *Marketed Asset Disclaimer* (MAD) assumption (Copeland and Antikarov 2001) states that the present value of the cash flows of the project without flexibility is the best unbiased estimate of the market value of the project: 'What is better correlated with the project than the project itself'?

When we construct an equivalent replicating portfolio consisting of buying a number m of shares of the underlying asset, and borrow against them an appropriate amount B at the risk free rate, such that it exactly replicates the future payoffs of the project with the option in any state of nature, we can write the following equations for the payoffs in the up state and in the down state:

$$\begin{cases} m*(\$170) - B*(1.08) = \$55 \\ \\ m*(\$65) - B*(1.08) = \$0 \end{cases}$$

Solving the two equations for the two unknowns, we have $m = 55/105 = 0.52391$ and $B = (0.52381*65)/1.08 = \$31.5256$.

Because the replicating portfolio has the same payouts as the project with the deferral option, by the law of one price, it should have the same present value. The present value of this replicating portfolio is:

$$\begin{aligned} P(o) &= m*(\$100) - B \\ &= 0.52381*(\$100) - \$31.5256 = \$20.856 \end{aligned}$$

We can conclude that the deferral option is worth $20.856 million. Consequently, the value of flexibility is $27.337 million, which is the difference between $20.856 million and –$6.481 million.

A second method to value real options is similar to the replicating portfolio and is called the *risk-neutral probability* approach (Cox, Ross and Rubinstein 1979). In this approach, we construct a hedge portfolio, composed of the underlying project and a short position of h shares of the project with the option. If we can find a value of the hedge ratio h that equates the payoffs in both states, the portfolio will return exactly the same cash flows in either nature and thus will be risk free.

Equating the payoffs in the up state and in the down state $\$170 - h*(\$55) = \$65 - h*(\$0)$ gives us the hedge ratio $h = \dfrac{\$170 - \$65}{\$55 - \$0} = 105/55 = 1.9091$.

Since the hedge portfolio is risk free, it will earn a risk free rate and the resulting payoff is identical in either the up state or the down state:

$[\$100 - h^*P(o)]^*1.08 = \$170 - h^*(\$55)$ and

$[\$100 - h^*P(o)]^*1.08 = \$65 - h^*(\$0)$,

which gives us the value of the call option $P(o) = \dfrac{\left[\$100 - \dfrac{\$65}{1.08}\right]}{1.9091} = \$20.856$

Not only is the numerical result the same as that obtained using the replicating portfolio approach, but also, by denoting the uncertain cash flows as c_1 and c_2 and the corresponding payoffs of the deferral option as o_1 and o_2, we obtain that

$$P(o) = \frac{p_1 o_1 + p_2 o_2}{1 + rf} \text{ with } p_1 = \frac{P(c)(1+rf) - c_2}{c_1 - c_2} \text{ and } p_2 = \frac{c_1 - P(c)(1+rf)}{c_1 - c_2}$$

where p_1 and p_2 are the so-called 'risk neutral' probabilities. In other words, the present value of the project with the call option is equal to the expected payouts, multiplied by probabilities that adjust them for their risk. In this way, the numerator becomes a certainty-equivalent cash flow that can be discounted at the risk-free rate.

3. A project management example

Consider now a simple example of project management in a flexible environment, where a real options analysis is necessary to make a correct decision. Suppose for example a contractor who installs standard prefab holiday houses. The arrival rate of the projects is Poisson distributed with a mean of one project per month (equivalent to 0.25 per week in a 4-week month). To be able to fulfil a project, the contractor has to have a prefab house in stock and therefore makes an investment of $10,000 at the beginning of the month. If a project arrives within the month, the contractor earns $20,000 for installing the prefab house. However, there is also a chance that no project arrives within that month, which gives him no revenues. In any case, the fixed costs (such as personnel costs and holding costs) have to be paid, which amount to $5,000. Consequently, if no project arrives within the month, the underlying value is reduced from $10,000 to $5,000 (the prefab house of $10,000 remains in stock) and if a project does arrive within the month, the underlying value increases to $15,000 (the revenue of $20,000 minus the fixed costs of $5,000). In other words, an investment of $10,000 is made at the beginning of the month in order to have an uncertain payoff of $15,000 or $5000 at the end of the month. The probabilities of these payoffs can easily be derived. Since we assume a Poisson arrival process, the probability that no project arrives within the next four weeks is $P_0(1) = 1^0 e^{-1}/0! = 0.368$ and thus the probability that at least one project arrives by the end of the month is $P_{1^+}(1) = 1 - P_0(1) = 0.632$.

The cash flows of $15,000 and $5,000 have to be discounted to their present value by the firm's cost of capital or a discount rate that appropriately reflects the perceived investment risk. A conventional approach is to develop a project-specific, risk-adjusted discount rate based on the capital asset pricing model, which says that the cost of equity consists of the risk-free rate plus a risk premium that varies in direct proportion to the project's beta. This discount rate is also called the *opportunity cost of capital* because it reflects the return foregone by investing in the project rather than investing in securities (Brealey and Myers 2000).

The opportunity cost of capital is the return a company (or its owners) could expect to earn on an alternative investment entailing the same risk (Luehrman 1997). The risk of the investment in the above mentioned example depends on the uncertain demand of the prefab houses, which is a function of their selling price. This demand is reflected in the arrival rate of the projects. When the selling price of a prefab house goes down, more customers will be interested in buying one, which is equivalent to an increase in the arrival rate λ. Consequently, the chance for the contractor of having a prefab house sold by the end of the month increases, which implies a lower risk. A standard prefab house may be considered a generic product in a market with perfect competition. This means that the market price cannot be influenced by the contractor's decisions, or in other words the selling price is exogenously determined and thus the arrival rate corresponding to this equilibrium price is also fixed.

In order to prevent arbitrage, the expected rate of return offered by other assets equivalent in risk should be the same as the one in the prefab house investment. The current price of the investment is \$10,000 and it generates uncertain payoffs of \$15,000 or \$5,000 with respective probabilities of 0.632 and 0.368. Thus, the expected return is

$$\frac{0.632*(\$15{,}000) + 0.368*(\$5{,}000)}{\$10{,}000} - 1 = 13.21\%.$$

This is also the opportunity cost of capital for investments with the same degree of risk as the prefab house investment and therefore the correct rate at which to discount the expected cash flows to their present value.

Suppose now that the contractor has potential customers who want to buy a prefab house at a reduced price, say \$15,000, and he may try to reach them during the next x weeks. After subtracting the fixed costs of \$5,000 this gives a payoff of \$10,000. Intuitively, this offer seems worthless, since the contractor taking a risk demands a higher return on investment. However, we can recognize this proposal as a real (put) option on the underlying project with an exercise price of \$10,000. Without flexibility, the contractor invests \$10,000 in order to have a return of either \$15,000 or \$5,000. But the further he approaches the end of the month, the more information he has on the underlying stochastic process. If at some point in time no project has arrived, it becomes more uncertain (and thus more risky) that a project will arrive by the end of the month and thus more likely that the contractor will exercise his option. In short, he waits for additional information in order to reduce his uncertainty.

This flexibility to adapt in response to new information enhances his investment opportunity's value by improving its upside potential while limiting downside losses relative to the initial expectations. For that reason, the contractor is willing to pay additional costs to have this option, which increase the longer he is able to keep the option open. In the extreme case, the contractor waits until the end of the month and if he has no project, he exercises his option since he prefers installing a prefab house for \$15,000, rather than having no revenues and still having to pay the fixed costs of \$5,000.

To make an appropriate decision on the price the contractor is willing to pay for having this option, a real options analysis should be used. Moreover, we will show that applying a traditional net present value technique leads to an erroneous result. The real options methodology that is used depends on the characteristics of the underlying asset that needs to be modelled and on the features of the option that is contingent to it. Therefore, we first model the stochastic process of the underlying asset and then we value the put option on this underlying asset.

Assume that the contractor weekly reconsiders his option to install the prefab house at the reduced price of $15,000. In case he exercises his option, he abandons his chance for the $20,000 revenue. Every week, there is a non-negative probability that a project already arrived. If no project has arrived yet, we calculate the present value of the investment and compare it with the exercise price of the option.

Week 1: At the start of the month, there is 63.2 % chance that a project will arrive in the coming month, equivalently to a payoff of $15,000, and 36.8 % chance that no project will arrive by the end of the month, which corresponds to a payoff of $5,000. Consequently, the expected value of the project by the end of the month is $0.632*(\$15{,}000) + 0.368*(\$5{,}000) = \$11{,}321$. Since this expected value is only available at the end of the month, we have to discount at the opportunity cost of capital (the risk-adjusted discount rate calculated earlier) for four weeks. This leads us to a discounted expected value at week one of

$$\frac{0.632*(\$15{,}000) + 0.368*(\$5{,}000)}{1 + 0.1321} = \$10{,}000$$, which equals the original investment cost.

Week 2: The chance that a project already came in during the first week is 22.1 %, since

$$P_{1^+}(0.25) = 1 - P_0(0.25) = 1 - \frac{(0.25)^0 e^{-(0.25)}}{0!} = 0.221$$

If no project has arrived yet (which has a probability of 77.9 %), there is still a 52.8 % chance that a project will arrive by the end of the month. This can be seen from

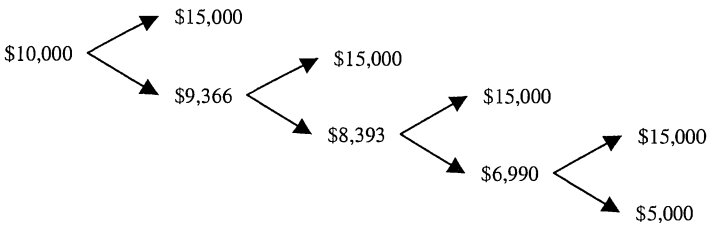
$$P_{1^+}(0.75) = 1 - P_0(0.75) = 1 - \frac{(0.75)^0 e^{-(0.75)}}{0!} = 0.528$$

The expected value foreseen at the end of the month is three weeks ahead and therefore has to be discounted at the cost of capital for three weeks:

$$\frac{0.528*(\$15{,}000) + 0.472*(\$5{,}000)}{(1 + 0.1321)^{3/4}} = \$9{,}366$$

We can apply the same approach to value the discounted expected value at weeks three and four. At the end of the month, we know with certainty whether a project came in or not. At that moment, all uncertainty is resolved.

We can model the stochastic process of the underlying asset as a tree with each upper arrow representing a probability of 22.1 % and each lower arrow as a 77.9 % probability:



Once we modelled the underlying risky project, we can calculate how much the put option is worth, or differently said, how much the contractor is prepared to pay for this option. It is intuitively clear that he is not going to exercise his option at the beginning of the first week. This would be useless, because no uncertainty has been resolved yet and thus the option has no value. But from the second week on, he already has more information concerning the uncertain process of his asset, and his expected return goes under the exercise price of the option of $10,000. Therefore the option has a positive value.

Suppose that no project has arrived during the first week. Then, the contractor has to decide whether to exercise his option at the start of week two or not. In this case, the uncertain payoffs of the underlying asset are $15,000 and $9,366 and the payoffs corresponding to the option are $15,000 and $10,000. Let us value this option by the replicating portfolio approach. We construct an equivalent replicating portfolio that is composed of *m* shares of the underlying asset, with a price of $10,000 per share, and *B* dollars of the risk-free bond whose present value is $1 per bond. The payouts of the replicating portfolio should be the same as the payouts of the project with the option. For the risk-free rate, we take the 3-month Treasury Bill (since this is virtually risk-free), which is around 1.20 % per annum nowadays. At the start of the second week, the replicating portfolio has the following payouts in the up state and in the down state:

$$\begin{cases} m*(\$15{,}000) + B*(1.012)^{1/52} = \$15{,}000 \\ m*(\$9{,}366) + B*(1.012)^{1/52} = \$10{,}000 \end{cases}$$

Solving these two equations for the two unknowns *m* and *B*, we find that $m = 0.887$ shares of the underlying project and $B = \$1{,}694$ invested in risk-free bonds. The present value of this replicating portfolio gives us the present value of the project with the option (by the law of one price):

$$P(o) = m*(\$10{,}000) + B = \$10{,}564$$

Consequently, the value of the option itself is $564. This means that the contractor is willing to incur some additional costs up to $564 to have this option in the second week.

It is intuitively clear that the longer the contractor waits, the more additional information he obtains and thus the more valuable the option will be. Suppose he decides to wait until the third week to decide whether to exercise his option or not. In this case, the chance that a project will arrive by the end of the month is only 39.3 % and his (discounted) expected return decreases to only $8,393. The replicating portfolio provides the following payouts after two weeks:

$$\begin{cases} m*(\$15{,}000) + B*(1.012)^{2/52} = \$15{,}000 \\ m*(\$8{,}393) + B*(1.012)^{2/52} = \$10{,}000 \end{cases}$$

With $m = 0.624$ and $B = \$5{,}631$ the net present value of the project including the option is $P(o) = m*(\$10{,}000) + B = \$11{,}871$. The value of the option itself is $1,871 and is indeed greater than the previous option.

Suppose the contractor has the option to extend his decision until the end of the month. At that time, all uncertainty is resolved. In case no project has arrived that month, he would be happy to install his prefab house for $15,000. Obviously, this is an optimal solution, since he limits all downside losses and consequently he has no risk anymore. The replicating portfolio approach indicates that after four weeks, he has payouts according to:

$$\begin{cases} m*(\$15{,}000) + B*(1.012)^{4/52} = \$15{,}000 \\ m*(\$5{,}000) + B*(1.012)^{4/52} = \$10{,}000 \end{cases}$$

The option value is then $P(o) - P(c) = [m*(\$10{,}000) + B] - \$10{,}000 = \$2{,}493$.

As mentioned earlier, a traditional discounted cash flow analysis would lead to an erroneous result and consequently the wrong decisions. To see this, let us have a look at the option that can be exercised until the end of the month. There is a 36.8 % chance that there is no project, in which case the contractor would exercise the option and hence have a payoff of $10,000 and a 63.2 % chance of having a project with payoff $15,000. The net present value of the decisions is estimated by discounting the expected payoffs of the project including the option at the risk-adjusted discount rate, as follows:

$\frac{0.632*(\$15{,}000) + 0.368*(\$10{,}000)}{1 + 0.1321} = \$11{,}624$ with an option value of $1,624.

When the contractor would use a decision tree analysis to decide how much additional cost he may pay for this option, he would be willing to pay only $1,624, while he may incur costs for $2,493.

4. Topics for further research

The real options theory aims to use recent option pricing developments to assist in making correct investment decisions. The objective of these techniques is to incorporate risk elements in the valuation of an investment strategy. Understanding and assessing these risks allows decision makers to permanently adapt their business strategies to changes in the market.

In this contribution, we showed how a real options approach should be used in case it is not certain whether a project will arrive or not. But there are other forms of uncertainty in project management, which should be valued with the same approach.

Suppose we have an arrival process of the projects, each with a different net present value. At each point in time we have a restricted resource capacity. When deciding to accept a project or not, we are uncertain whether or not a project with a higher NPV may arrive or a project which better fits the resource capacity. Also in this case, management may wait for more (future) information in order to make a better decision according to this new information and a real options analysis should be used as well.

In single-project scheduling, the number of the activities may vary, the duration of the activities can be stochastic or the required resource capacity for the activities can be uncertain. Also in this case, a real options analysis can be used instead of a net present value objective.

In our study, we have restricted ourselves to binomial decision trees. It would be interesting to extend our approach to multinomial trees, as in De Reyck, Degraeve and Vandenborre (2002).

5. Conclusion

The central paradigm for making decisions about investments is the net present value (NPV). Unfortunately, it is badly flawed because it is excluding any form of flexibility. Flexibility has a value in the context of uncertain projects, as management can repeatedly gather information about uncertain project and market characteristics and, based on this information, change its course of action. Decision tree analysis is a method to capture this flexibility, though it is inadequate because it assumes a constant discount rate even when uncertainty is clearly changing based on the changing payouts at various parts in the decision tree. Real options analysis corrects both deficiencies and should be the technique of choice for the modern project manager. In this case, we do not think there is any option.

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