Blending Scenarios into Real Options: Relevance of the Pay-off Method to Management Investment Decisions

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Abstract This paper aims to demonstrate the relevance of the pay-off method to making management investment decisions under uncertainty. The success of the pay-off method as a replacement for the currently used option pricing algorithms was demonstrated by informing thirteen option pricing models with the same basic inputs and by comparing the mean option price obtained with the pay-off value. Everything else equal, the pay-off method demonstrated to be a useful tool to management uncertainty due to its mathematical simplicity and the possibility to embed scenario planning into the real option valuation. These benefits should make the use of real option thinking more relevant to management investment decisions under uncertainty.

Keywords: pay-off method, real options, pricing, scenarios, investment, decisions

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1. Introduction

The term "real options" refers to the application of option pricing theory to the valuation of investments in non-financial or "real" assets where much of the value is attributable to flexibility and learning over time [1]. This means that the opportunity inherent in a capital project can be viewed as implied contracts that allow management to choose only those actions that have positive cash flow effects. Where a difference arises, however, is that the underlying assets of the options in a capital investment decision are real assets like the development of a new plant, rather than financial assets, like stocks and shares. As a consequence, the options imbedded in the investment decisions are referred to as "real options" as opposed to financial options.

Research undertaken in the last two decades has shown that managers in diverse fields tend to make the same kind of decision-making mistakes. Of these, the single most common decision trap is what is referred to as "frame blindness"[2]: setting out to solve the wrong problem because a mental framework has been created for a decision that causes the best option to be overlooked. The alternative options embedded in the discounted cash flow models need to be considered explicitly because their value can be substantial.

To date, options literature has had relatively little influence on management practices. Attention to real options has been scant partly because modelling investments as options is a highly complex subject that is generally presented in a technical fashion. However,

options have great potential relevance to managers, given that the manager's role is to use uniqueskills to maximise shareholder wealth. Ownership and control of an investment project can often generate follow-on opportunities which are additional to the project's cash flows and, therefore, traditionally ignored in management decision making.

Although the general concept of real options is clear, their specific benefits for individual investment decisions are not. The development of the classical Black and Scholes equation [3] probably did not help executives to employ real options in practice. Academics felt that the early attempts to apply real options to the business world had been too simplistic to reflect the complexity of actual investment decisions. Theoretical research took the direction of searching for more "realistic" statistical models, increasing the complexity of calculus instead of focusing on management relevance. A number of sophisticated models were rapidly introduced and, over the years, real options never left the territory of applied mathematics to move to the desk of management practitioners.

There appears to be a paradox, with increasingly advancedlevels of calculus being used to try and help managers to understand the intricacy of what is already a difficult mathematical model. Options are still an obscure mathematical tool and the partial differential equation at the core of the option pricing model leaves management with a blank face. The complexity of the stochastic calculus is preventing practitioners to see the new "decision space" created by real options and to move inside this space at ease.

Common experience is that investment decisions spanning over long time periods are influenced by many

factors unknown at the present, so managers are not overly concerned by false precision. What they really need is a flexible valuation tool that is easy to understand and which can be played with at any time after the decision is made, when new information become available and the investment scenario consequently changes. Since management were unlikely to fully understand and put into practice the initial Black and Scholes model, the chances that they will use more sophisticated models based on a concept which is still unclear are actually marginal. Real options thinking should be developed towards the direction to make its core concept accessible and relevant to everybody.

In the late 1970s, parallel to the development of real option pricing theory, scenario planning gained prominence as a strategic management tool. It encourages managers to envision plausible future states of the world and consider how to take advantage of opportunities and avoid potential threats. Through scenario planning, the contingencies, uncertainties, trends and opportunities that are often unanticipated can be identified. While Scenario Planning is primarily a qualitative method of analysis used to identify risk, when combined with the real options approach it takes on a more quantitative identity, able to be used effectively in assessing value creation under conditions of uncertainty [4]. Eventually quantitative values have to be assigned to the probability and impact of each scenario on the critical factors determining investment outcomes.

Scenarios are not predictions or preferences but speculative descriptions of pathways in the future for a business unit or project. They operate with a minimum of two scenarios, often with four drawn from a two-dimensional matrix, and can, of course, grow to a large number of alternatives. Many scenario users are familiar with the terms "worst case", "best case" and "base case". The point is that if scenarios are not plural, the sole so-called scenario is in effect a prediction. A key reason for using scenarios is the fallibility of predictions. In advance of the developments which they depict, scenarios carry no guarantees to validity, but they widen the range of possible pathways and outcomes. Such widening increases the chances of capturing the salient future developments compared with single-line predictions.

Although scenarios and real options are both tools for dealing with uncertainty that can be used to complement one another, there is no evidence that they have been combined in management practice, although Miller and Waller [5] have proposed combining the two approaches into an integrated risk management process.

The objective of this paper is to bridge this gap, by evaluating a single analytical tool, the pay-off method, to blend scenario planning into the real option pricing model.

1.1. The Pay-off Method

Among the numerous option pricing algorithms available, the recently developed pay-off method has the potential to offer new insights into the field of decision-making, due to the intuitive logic and the simple math underlying its development [6].

The method, used in healthcare research (ref) utilises fuzzy sets to determine the possibilistic, as opposed to the probabilistic, expected value of a given activity. A fuzzy set is a class of elements with a continuum of grades of membership, characterised by a membership function which assigns to each element a grade of membership ranging between zero and one. The pay-off method derives the real option value from the pay-off distribution of the project's Net Present Value (NPV), which is treated as a fuzzy set. The pay-off distribution is created by using three NPV scenarios:

1.   A base case scenario with the estimations of the most likely values for cost and benefits;

2.   A worst case scenario, based on the lowest credible estimates for cost and benefits;

3.   A best case scenario, based on the highest credible estimates for cost and benefits.

The pay-off method will not consider outcomes outside the minimum and maximum scenarios, therefore the values included define the pay-off distribution of the project's NPV, which is treated as a fuzzy set. The pay-off method replaces the probability distribution of an NPV outcome with a simpler triangular distribution. The fuzzy set A is defined by three values: a (the best-case scenario NPV), α (the difference between the minimum and the best-case scenario NPV) and β (the difference between the maximum and the best-case scenario). The area between a-α represents the distribution of all possible negative NPV values while the opposite side, between 0 and a + β, shows the distribution of positive NPV values. The possibilistic mean value of the positive fuzzy NPV values E(A+), is the fuzzy mean value of the NPV.

The highest possibility (fully possible) is assigned to the base case and the lowest (near-zero) possibility to the minimum and maximum values of the distribution. The result is thus a triangular fuzzy distribution (A) that is equivalent to the fuzzy NPV of the project. The fuzzy NPV of a project is equal to the pay-off distribution of a project value that is calculated with fuzzy numbers.

The mean value of the positive values of the fuzzy NPV, E(A+), is the possibilistic mean value of the positive fuzzy NPV values, as shown graphically in Figure 1.
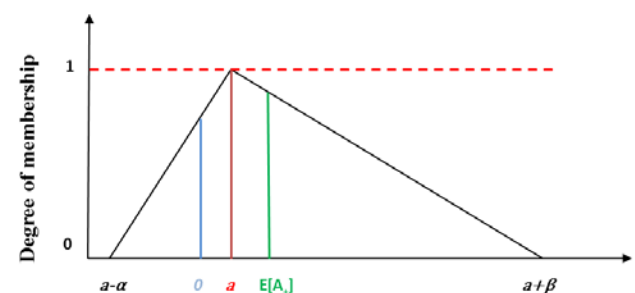

Figure 1. Triangular distribution of the fuzzy set A

The merit of this integrated approach to risk is appealing: while scenario planning turns managers' attention toward the external environment, an assessment of potential real options available provides an effective tool to evaluate the possible responses to create value under uncertainty. Furthermore, beyond this role, Real Options analysis can be quantitatively robust and its application, not only its underlying logic, can be achieved by practising managers.

1.2. Formulation of Hypothesis

In order to demonstrate the relevance of the pay-off method to management investment decisions, the accuracy of its outcomes must be tested:

H_1: the option price calculated with the pay-off method is within two standard deviation points from the mean option price calculated with a number of existing option pricing algorithms.

2. Materials and Methods

To avoid methodological bias, the Authors used a published biotechnology investment decision [7]. The case was related to a stop/go development decision of an experimental drug at the beginning of its clinical phase of development (Phase III). Biotechnology R&D is an ideal field for demonstrating the application of Real Options, because in this industry value is maximised by a series of discrete stop/go decisions on product development and the discontinuities in clinical research can create significant volatility in the value of project assets.

In the case that follows, reference will be made to the real option pricing algorithm, where the following five factors are used to determine the project's option value:
1. *Exercise value*
2. *Current value of the asset*
3. *Time to expiration*
4. *Project volatility*
5. *Risk-free rate*

A specific illustration of the inputs chosen to inform the real option modelling is reported in Table 1. A biotech company is developing a drug which is currently in Phase II stage of development. The probabilized expected Discounted Cash Flow (DCF) is $42.7 million (current value of the asset). The expected cost of the next stage of development (Phase III) is $70.0m (exercise value). The duration of Phase III clinical trials is expected to be 3 years (time to expiration). No pay-out was assumed before the expiration of the project. The volatility of the project has been estimated at 30%, based on industry data. The risk free rate has been set at 5% per year.

Table 1. Inputs to inform the Real Option pricing models

Inputs	Values
Expected probabilized DCF from marketed product	$42.7M
Expected cost of R&D Phase III development	$70.0M
Dividends pay-out	None
Volatility of Phase III	30%
Expected length of Phase III	3 years
Risk free rate	5%

We used the inputs reported in Table 1 to inform 13 different real option pricing models. Models, including European Options, American Options and Exotic, were chosen among the most commonly used algorithms to calculate the value of options embedded in real investment decisions [8]. Table 2 reports a brief description of the real option pricing models used to obtain 13 real options values for the project and to calculate the mean option value and its standard deviation.

A fuzzy pay-off distribution was created by using three DCF scenarios derived from the same biotech investment case [7]. Table 3 reports the main inputs used to inform

the pay-off model used to calculate the possibilistic option value of the project.

Table 2. Pricing models used to calculate the mean Option Value.

Option pricing model	Version	Reference
European BS with no dividends	Black-Scholes	[3]
European BS Monte Carlo (5,000 simulations)	Boyle	[9]
European BS quasi Monte Carlo (5,000 simulations)	Fang et al.	[10]
European binomial (100 steps)	Cox et al.	[11]
European trinomial (100 steps)	Boyle	[9]
Jump diffusion (50% vol. expl.): 1 jump	Merton	[12]
Jump diffusion (50% vol. expl.): 2 jumps	Merton	[12]
Jump diffusion (50% vol. expl.): 3 jumps	Merton	[12]
American binomial	Cox et al.	[11]
American trinomial	Boyle	[9]
American finite difference	Broadie and Glasserman	[13]
Exotic Up&In (100 it.5,000 simulations): continuous	Broadie et al.	[14]
Exotic Up&In (100 it.5,000 simulations): discrete	Broadie et al.	[14]

Table 3. Inputs to inform the pay-off Real Option pricing model

Inputs	Values ($ mill)
Best case scenario (DCF if the drug will receive marketing approval)	42.70
Base case scenario (DCF at Phase II of development)	-1.80
Worst case scenario (DCF if drug fails to enter Phase III of development)	-15.00
a (base case)	-1.80
α (distance between worst and base case scenario)	57.70
β (distance between best and base case scenario)	44.50

Based on the triangular fuzzy numbers, E(A+) was calculated as shown below [15]:

$$E(A_+) = a + \frac{\beta - \alpha}{6}, \ if \ 0 < a - \alpha \ 'all \ NPV \ Positive' \quad (1)$$

$$E(A_+) = \frac{(\alpha - a)^2}{6\alpha^2} + a + \frac{\beta - \alpha}{6}, \quad (2)$$

if $a - \alpha < 0 < a$ *'some negative NPV*; *positive peak'*

$$E(A_+) = \frac{(\alpha + \beta)^3}{6\beta^2}, \quad (3)$$

if $a < 0 < \alpha + \beta$ *'some positive NPV*;*negative peak'*

$$E(A_+) = 0, \ if \ \alpha + \beta < 0 \ 'all \ NPV \ negative' \quad (4)$$

The real option value calculated from the fuzzy NPV is the possibilistic mean value of the positive fuzzy NPV values E(A+) multiplied by the positive area of the fuzzy NPV over the total area of the fuzzy NPV.

$$Real \ option \ valuation = \frac{\int_0^\infty A(x)dx}{\int_{-\infty}^\infty A(x)dx} E(A_+) \quad (5)$$

In this equation A represents the fuzzy NPV, E(A+) is the possibilistic mean of the positive area of the pay-off

distribution, $\int_0^\infty A(x)dx$ is the positive area of the pay-off distribution and $\int_{-\infty}^\infty A(x)dx$ is the whole area of the pay-off distribution. This method of calculation is aligned with the real option valuation logic, which implies that management will interrupt or modify a project when its pay-off becomes negative.

3. Results

A set of 13 option prices was obtained from the pricing models as described in Table 4, with a mean value of $3.9192 million and a standard deviation of $.0.037215 million. The distribution of prices did not fundamentally violate normality, although both skewness (-1.352) and kurtosis (2.618) values indicated a certain difference from central tendency. In 95% of the results, option prices calculated with the 13 models would fall in between 2 standard deviation points from the mean value.

The real option value calculated according to the pay-off method was $3.9747m, falling within the 2 standard deviation price range of $3.844778m to $3.993637m obtained with the option pricing algorithms. The results from the pay-off method have been shown to converge to the results from the analytical Black-Scholes methods, hence the research hypothesis can be accepted.

Table 4. Summary of results

Option pricing models	Real Option value ($ mill)
European BS with no dividends	3.9357
European BS Monte Carlo	3.9012
European BS quasi Monte Carlo	3.8862
European binomial (100 steps)	3.9394
European trinomial (100 steps)	3.9412
Jump diffusion (1 jump)	3.8896
Jump diffusion (2 jumps)	3.9147
Jump diffusion (3 jumps)	3.9233
American binomial	3.9390
American trinomial	3.9412
American finite difference	3.9409
Exotic Up&In (continuous)	3.9726
Exotic Up&In (discrete)	3.8247
Mean	3.9192
Standard deviation	0.037215
Pay-off method	3.9747

4. Discussion

All the option prices calculated with the Black-Scholes models and the pay-off method fall in between 2 standard deviation points from the mean value. In other words, the choice of the model had a +/- 2% impact on the option value.

The t test of the sample (379.712 – sig .000) confirmed that the sample prices difference from the mean is statistically significant.

However, although a 2% difference may be statistically significant, is it really relevant from a management point of view? To answer this question, the Authors proceeded to verify the sensitivity of all the option models to inputs, calculating option prices for inputs changing one at a time by an interval of 1% (from +5% to -5%). These values were then compared to the ones obtained from the base case, to measure the magnitude of difference. All the models behaved very consistently. The correlation between the sensitivity paired outcomes for all models was always very high, with the exception of the models based on Monte Carlo simulations which showed a lower degree of correlation; but always significant at different levels, with just one exception. The correlation table reported below (Figure 2) provides additional evidence that all models move in synchrony, and their outcomes were concordant.
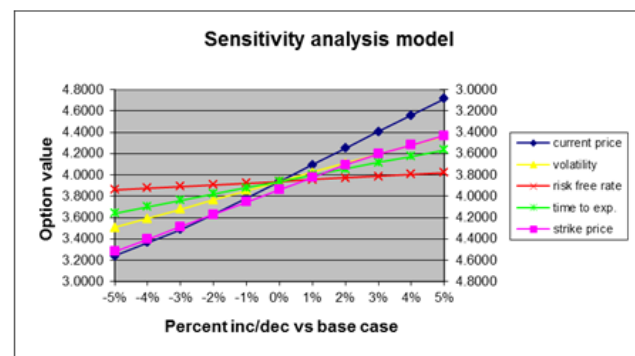

Figure 2. Sensitivity analysis model (all option pricing models included)

As it was demonstrated that all option pricing models outcomes by input change were correlated, the regression slope would define the sensitivity to each variable. The Authors selected the American binomial model as a base case, as it better reflected the decision tree often used in pharmaceutical R&D. The linear regression equations related to a one percent change of each single input at a time are reported in Table 5.

Table 5. Linear regression equations related to a one percent change of each single input at a time

Input	Regression equation	R-square
Value of the asset	y=14.942x + 3.952	0.999
Option price	y=-11.043x + 3.951	0.998
Volatility	y= 8.578x + 3.3937	1.000
Time to expiration	y= 5.919x + 3.3938	1.000
Risk free rate	y= 1.605x + 3.940	1.000

Hence, a one percent change in inputs would have an impact on the base case option price as reported in Table 6.

Table 6. Change in Real Option value as a consequence of a one percent change in main inputs, changed one at a time

Input change	Real Option value change vs. base case	Change %
+1% value of the asset	0.1494	3.50%
+1% option price	-0.1140	-2.59%
+1% volatility	0.8578	2.01%
+1% time	0.5919	1.39%

The choice of real option pricing model had an impact (+/-2%) lower than a 1% change in future value of the asset, option price and volatility.

All else equal, the application of pay-off model is feasible and useful without the necessity to engage in high-level and daunting mathematics; indeed the rescue of real options from the rarefied heights of mathematical calculations was a key motivation for this paper... Managers should no longer perceive real options as an arcane subject. The accessibility of the technique underpinned by the pay-off model means that the combination lends itself to "learnability" in terms of clear statement as to how the combination of scenarios and real options analysis works.

The most important challenge is to define the options available by correctly using scenario thinking. In the authors' experience this is a seriously neglected area and one requiring much more attention. Second, with the definition and consistency in assumptions clarified, values can be established and last, but not least, effort should be expended to understand the impact of changes in input assumptions on option values so as to ensure that the chances of making mistaken investment decisions is minimized.

The combination of the two types of analyses constitutes an integrated decision-making process for management and it yields opportunities for flexibility in the way management approaches strategic decisions changes in the way management approaches strategic decisions. It makes strategy an evolutionary process, flexibly moving from one choice point to the next through time.

The merit of the pay-off method is appealing: while scenario planning turns managers' attention toward the external environment, an assessment of potential real options available provides an effective tool to evaluate the possible responses to create value under uncertainty. Furthermore, beyond this role, real options analysis can be quantitatively robust and its application, not only its underlying logic, can be achieved by practising managers.

Many scenario users are familiar with the terms "worst case", "best case" and "base case". The danger implicit in using such labels is to draw conclusions before detailed impact analysis is undertaken, and to close mental doors as to the application of real options. Furthermore, as the "base case" steers between best and worst, it seems more comforting and even more probable.

Whilst scenario analysis initially focuses on the impacts of external factors that are usually beyond management's control, real options analysis creates a "space" for decision-making choices. It engages management in understanding the value consequences of different networks of choice than would be afforded by NPV analysis.

Instead of the unilinear pathway of value determined at any given time by DCF, which fixes the mind on whether to go or not go, by contrast real options analysis shows there are value-improving and real-protecting points of choice created by such thinking.

Whilst there are decision-tree models through which, in advance of implementing a strategy one can try to anticipate which decision will be more and which will be less positive for value, these calculations are not entirely fixed in advance. Hence "active management" means that at every choice-point or "node" there is an opportunity to calculate the value of each alternative strategy going forward from the next expected point in time. The decision-tree therefore evolves as assessments change – because with further knowledge the scenarios can change.

The support of scenario analyses for real options obliges the whole process to become intensely time sensitive. Precisely because scenarios do not come with built-in clocks, the decision maker has to make judgments as to the timelines on which different causes and effects may operate, affecting the value of the choices previously made and in prospect. This necessitates meticulous and imaginative attentiveness to the scenario-based factors that could impact on the value of choices.

This paper both argues the advantages of real options thinking and, by means of examples, exhibits the types of decision-making calculations that are distinctive to real options.

However in the process of clarifying the application of real options analysis to real decision making, a strong dependency upon scenario thinking is established. The value to decision makers of real options depends crucially on the substance and use of the scenarios on which it rests. The distinctive contribution of this paper consists in substantiating this view.

By forging a critical link between real options analysis and scenario thinking, the pay-off method brings capital investment decisions down from the esoteric heights of mathematics, converts it into an intuitive process readily accessible to managers and qualifies it for inclusion in the curriculum of management education.

5. Conclusions

This paper introduces an approach to managing uncertainty that provides a tool to support management decisions without relying on the intricacies of sophisticated quantitative models. Furthermore, it introduces a certain degree of discipline into real options decision making by challenging managers to develop coherent scenarios about the future and to make explicit their assumptions about the contingencies affecting real options.

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