HYBRID REAL OPTIONS VALUATION OF RISKY

PRODUCT DEVELOPMENT PROJECTS

By

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James E. Neely and Richard de Neufville

ABSTRACT

Managers and designers for technological systems face a common difficulty: new projects or products are inherently risky, both technologically and financially, especially given the rate of change in the high technology, deregulated economy. Consequently, they need solid methods for valuing prospective investments, so that they can justify their development strategies.

Their fundamental problem is compounded by two methodological difficulties: (a) traditional net present value (discounted cash flow) evaluations are inadequate for many risky projects, and (b) the available methods for valuing these projects are limited and often impractical.

This paper identifies practical solutions to this problem. Conceptually, it is crucial to focus on dynamic strategies of development, rather than on specific projects or products. Planners need to understand that they are consciously managing risk, and will do so most effectively by developing options they can exploit or abandon depending on future events. Methodologically, it is useful to combine the best of the alternative approaches to valuing risky projects, to achieve a practical and effective means of valuation.

Hybrid real options valuation combines the best features of decision and options analysis. The paper describes this new approach and illustrates it with an application to a portfolio of technological developments of a major automobile company. The example demonstrates the effectiveness of the new method.

Real options valuation has the further advantage that it rightfully increases the assessed value of risky projects, once we see them as options that can be abandoned in the context of a long-term development strategy. This increase is greatest for projects that are particularly risky or expensive to implement over time.

Key words: Real options, decision analysis, risk management, dynamic strategic planning, technology management

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The Basic Issue

Managers and designers for technological systems face a common difficulty: new technology and product development projects are inherently risky. Given the rate of technical change, the industrial restructuring associated with globalization, and the long time horizons associated with significant investments, it is simply impossible to forecast future conditions accurately. (See for example Ascher, 1978) Technology planners thus need solid methods for valuing prospective investments, so that they can justify their development strategies.

Two methodological difficulties have, unfortunately, compounded their fundamental problem:

1.   traditional approaches to project evaluation (variants of net present value or discounted cash flow analyses) are inadequate for many risky projects, and

2.   available methods for valuing these projects (decision analysis and financial options analysis) are limited and often impractical.

The question is: How should managers and designers evaluate risky projects? This paper suggests that using Hybrid Real Options analysis is both reasonable conceptually, and a practical, efficient way to value risky projects whenever these are particularly risky or expensive to implement over time.

Real Options Concept

The real options approach frames the valuation process differently from the traditional methods. It views a project as a process that managers can continually reshape in light of technological or market changes. For example the opening of a new oil field involves a series of decisions about whether to lease an area, how to explore it, what wells and pipelines to build, and so on. This perspective contrasts with the traditional view of a project as set of decisions made once at the beginning and unchanged during the life of the project. Some small projects do fit this scheme, for example the choice of a heating system for a

building. In general however, projects do not correspond to the situation assumed by traditional analyses, and the options view is much more realistic.

Because real options approach recognizes that risks can be managed, to avoid bad outcomes or take advantage of good ones are they become apparent, the use of real options practically always leads to higher values for the same project than the traditional methods, precisely because the options perspective recognizes that managers make future decisions about a project as uncertainties become resolved. They will terminate projects that are not working out, and expand on those that are performing well. Real options methods incorporate this avoidance of losses and exploitation of gains in the analysis and therefore necessarily lead to a higher perception of value of risky projects. This recognition and exploitation of the value of flexibility "unlocks" fundamental value in risky projects. The real options approach uncovers the contributions of active management, which is a commonly overlooked source of value.

Formally, "options" involve the "right but not the obligation" to take a course of action. A financial option might allow an investor to buy a stock at a set price (this call option might be to buy AT&T stock at $X per share, for example) should it be favorable to do so (when the share price is above $X), but does not obligate the owner of the option to buy the stock (if the price stays below $X). A "real option" deals with investments with options-like characteristics that are not traded as securities in financial markets. For instance, the capability to bring a new product to market (based on having invested in the necessary research and development) is a "real option". This capability enables a company to produce the new product if the market is favorable, but does not obligate the company to do so if the market is unattractive.

Managers of physical projects or products deal in real options all the time, even if they do not realize it. Real options are part of any development of a project or a product. They exist wherever and whenever investments involve strategic choices over time that managers can actively direct. For example:

- The roll-out of new manufacturing capacity can be staged at different times or in varying increments -- each of these is an option to build one way or another (Trigeorgis, 1996);

- Ownership of a research activity, either inside the company or in a partnership with others, implies the possibility of bringing new products to market (Neely, 1998);

- A license to do something, for example a lease on an oil field, involves a series of options to develop specific areas or products whenever the market is favorable (Paddock et al, 1988; Siegel et al, 1987).

In short, whenever managers have the choice between different lines of development, and select one rather than some other, they are exercising a "real option". Most importantly, real options can be designed into projects and products. This can be done either conceptually, by realizing that a project can be staged; or physically, by building in flexibilities that enable managers to exercise options.

Conceptually building in flexibility is comparatively simple -- it requires management to recognize that a specific project, such as the construction of a power plant or the development of an oil field, can be decided upon in stages at different times. In practice the conceptual changes may have to overcome significant institution traditions, as designers and project planners are not used to thinking in terms of flexibility. For example:

- The New England Electric System recast a project to build some new power plants (which looked favorable on the basis of discounted cash flow) in terms of an option to build the plants if new environmental regulations evolved favorably. In retrospect the application is obvious, but a significant innovative effort was necessary to effect this change in perspective (Kaslow and Pindyck, 1994);

- The development of a major marine oil field can be seen as a decision either to build platforms of specified capacity, or to implement variable amounts of capacity through the use of Floating Production Storage and Off-loading facilities (basically, tanker factory ships). Given the volatility of oil prices (about +/- 30% over the past decades), it would seem obvious to stage production capacity, but major oil companies have been reluctant to do so (Smets, 1998).

- The approval of a research program can be recast from a decision to develop and implement a product, the traditional perspective of many corporations, to one of having an option to implement it, should the research be successful and if the market seems favorable (Nichols, 1994).

Designers can also physically build real options into projects and products, giving managers options -- and the capability to improve performance -- they otherwise would not have. For instance:

- Engineers can build power plants to use several types of fuel, for example oil or natural gas. This flexibility costs money, but provides the potentially valuable option to switch from one source of supply to another according to relative fuel prices. (Kulatilaka, 1993)

- Manufacturers can build product platforms that can support many different models, or flexible manufacturing facilities that can switch rapidly from one type of product to another. This requires careful design, but gives management the opportunity to follow markets and orders as they develop, rather than run the risk of over or under producing their products.

The bottom line is that managers of risky projects and projects are surrounded by real options. These may simply exist or, under active management, can be created.

The essential advantages of options, both financial and "real", are that they:

- embody flexibility, and

- permit managers to achieve favorably biased returns.

By contrast, the traditional approach to project valuation does not account for flexibility, leaves no room for dynamic strategic planning and management, and fails to incorporate improved returns.

Inadequacy of Traditional Valuation Methods for Risky Projects

Traditional methods for project valuation (variants on net present value or discounted cash flow analysis) focus on a single stream of income and expenses (See de Neufville, 1990, for example). They are therefore inadequate for risky projects both mechanically and conceptually. Mechanically, they are in error because, by assuming a single cash flow, they also assume that the value of this average cash flow equals the average value of a range of cash flows. This assumption is false whenever the probability distribution of the returns is asymmetric, as is typically the case. In general, losses can be limited (if only by bankruptcy), while gains can be unlimited. Running multiple analyses for different cash flows, and then averaging the results according the estimated probabilities might overcome this difficulty. However, this is not done in practice, and does not adequately address financial risks for reasons that are

discussed shortly. Net present value assessments are thus inadequate mechanisms for evaluating risky projects.

Net present value assessments are wrong conceptually because they assume that initiation of a project entails a complete commitment to the cash flow specified. They assume that implementation always occurs, even when the early results are not promising. They ignore the reality of management control. Managers can initiate projects and then decide whether to carry them to completion. For example, they may undertake research for a new product, and then choose whether to build a plant and start production. Net present value schemes ignore such options.

Most projects involve options. Figure 1 illustrates this as a simple, two-stage decision tree. The first decision is about starting a project; the later choice is about completing development. In between these choices, the managers can observe the resolution of uncertainties such as the success of the initial research. They can then choose to continue with the second stage if the initial results are promising, or otherwise drop the project. Therefore, the cash flows from a properly managed project are not the same as those of a project in which initiation mindlessly entails implementation. In the properly managed project, managers will avoid the downside situation. The cash flows are consequently biased upwards with the low ones truncated, and the overall expected value of the project will be superior to that of a traditionally valued project.

[Figure 1 about here]

Alternatives for Valuing Risky Projects

Decision analysis is the obvious engineering approach to evaluating risky situations. It is the now classical paradigm for evaluating the kind of risky, asymmetric situations Figure 1 illustrates. It has the great virtue that it deals effectively with multiple scenarios and management decisions to truncate specific lines of development. It is widely presented in operations research areas as the preferred form of analysis (see Keeney and Raiffa, 1993, for example).

However, decision analysis has a great problem from the perspective of the evaluation of major projects and products. It cannot deal effectively with major projects that have financial implications over extended time. This is because the decision analysis must in practice assume that the discount rate is the same over the entire life of the project. Yet, discount rates should depend upon the relative risk associated with a situation, according to standard finance theory summarized in the Capital Asset Pricing Model (CAPM) (see Brealey and Myers (1991) for example). If the decision analysis of discounted cash flows were to be done correctly, it would have to alter the discount rates every time a decision could be made, and moreover would have to do so for all possible outcomes. This is simply not practical. Purely decision analytic estimates of the discounted cash flow values of risky projects are thus inherently flawed (see Trigeorgis, 1996, for example). Decision analysis approaches need to be supplemented or amended if they are going to give fully accurate valuations.

The correct valuation of risky projects with options will manage to account for the constant variation in the level of risk as it changes through time. Discovering ways to do this was the genius of Merton, Black and Scholes, whose Nobel prize-winning work developed the basic techniques for the correct valuation of options. (Merton, 1973; Black and Scholes, 1973). These are based on the statistical measurement of historical risk associated with the underlying assets associated with the project, specifically on their performance in the market and their volatility compared to the overall market. The Black-Scholes and related techniques apply immediately to financial assets or commodities for which analysts have extensive records over time.

Although economic purists suggest that options analysis can be applied in almost all circumstances (see Trisgeorgis, 1996, for example), this does not seem practical. The standard financial tools for valuing real options are generally inadequate for many new risky projects and products because the right data are not available. In some exceptional situations, for example, in the pharmaceutical industry in which large numbers of prospective new drugs must pass through standard procedures, the kind of statistical information needed may be available (Nichols, 1994). Generally, the data necessary for a standard

valuation of a real option cannot be found. For example, Kodak recognized that its new products are unique and normally have no comparable antecedents; it therefore used decision analysis to estimate the value of flexibility. (Faulkner, 1996) For the practical effective valuation of many projects, the options analysis must also be somehow complemented.

In short, neither of the two obvious alternatives for valuing risky projects is really appropriate as a general method. Decision analysis cannot deal with the fact that the discount rate ought to reflect the changing levels of risk over time. Options analysis requires data that are rarely available for major technological systems, especially for innovations for which there cannot be a meaningful historical record. How should this dilemma be resolved?

Concept for Effective Valuation of Risky Projects

Careful examination of the risks associated with major projects leads to a practical means of project assessment: hybrid option valuation. Risks are of two different kinds. One kind can be dealt with effectively and properly by decision analysis, the other through options analysis. The entire set of risks can then be evaluated realistically and accurately using the proposed hybrid real options method. This is the approach developed by Neely (1988) in his doctoral research, and presented here.

One kind of risk concerns the uncertainties associated with the project itself. How will its actual costs compare to estimates? How will performance compare to forecasts? For example, what will be the actual cost of constructing an oil platform and how much oil is there in the field? These are the project risks. The other kind of risk concerns the uncertainties in the value of the product when it is brought to market, for example with the uncertainties in the market price for the oil when it is sold. These are the market risks. The distinction between project risks and market risks is crucial. Each has quite different implications for the discount rate that should be used in the valuation of the project.

Project risks are unique to the project by definition. Managers and investors can thus guard against them by diversifying their investments so that unexpected losses in one project are compensated on average

by unexpected gains in others. Project risks do not require a discount rate adjusted to reflect unavoidable risk. They can be properly analyzed through an expected value decision analysis using a constant discount rate. This rate represents the return expected on investments that have no uncertainty. Most financial analyses use the U.S. Treasury rates as the standard benchmark on this risk-free rate.

Market risks require a different treatment. They stem from external markets and cannot be avoided by diversification. Oil companies can protect themselves against project risks by investing in oil platforms in Malaysia, Mexico and Nigeria and elsewhere, but they cannot protect themselves against a crash in the worldwide market for oil. Market risks thus require a higher discount rate as extra compensation, since they are unavoidable. The level of these market risks moreover changes when a project is actively managed. Choices about exercising options to enter a market change the perspective risk and the associated level of discount rate. Only options analysis is equipped to treat these market risks properly.

Options analysis deals with the issue of constantly varying discount rates through a process whose net effect is to adjust the project outcomes so that the risk-free rate can be applied. Technically, this process is known as "risk-neutral" valuation (see Hull, 1989). This process requires detailed statistical information on the price and volatility of an asset that is closely related to the project or product at hand. For example, when evaluating a power plant that might use different fuels, the underlying asset might be the price of fuel. Identifying an appropriate underlying asset is key to carrying out the options analysis.

Practical Hybrid Real Options Evaluation of Risky Projects

A practical approach to valuing real options combines options methods for the market risks, and decision analysis for the project risks. Paraphrasing King James, it renders onto the financial analyst what is driven by the market risks, and onto the decision analyst what is driven by project risks.

A main advantage of the hybrid approach is that it effectively and simply combines the best of the decision analysis and the options analysis into a practical means of accurate valuation of projects. Although the hybrid lacks elegance from a purely theoretical point of view, it is simple enough to be

applied in a broad range of situations by the persons in charge of the projects -- as demonstrated by the example analysis at the end of this paper. This simple effectiveness is a real, practical advantage over the realistic alternatives of either not valuing or systematically undervaluing the real options associated with new products and projects.

A second advantage of the hybrid method is analytical. It permits a consistent choice of discount rate for the valuation, the risk-free rate. This is possible because:

- the project risks can be diversified and therefore require no compensation for risk, and
- the market risks are transformed by the options analysis so that no further compensation for risk is required in the discount rate.

The result is that once project outcomes have been transformed by the options analysis, both the project and the market risks can be properly analyzed through standard decision or expected value analysis using a consistent discount rate.

A third major advantage is organizational. The hybrid approach to the evaluation of real options divides the valuation process into a technical and a financial part, associated with the project and market risks. Technical and financial experts can handle each of these independently, separately applying their knowledge to the technical and financial aspects of the evaluation. This separability can facilitate the implementation of a systems approach that joins distinct kinds of knowledge.

The division of the analysis into financial and technological parts is the crucial difference between the hybrid process and conventional approaches to project valuation. As with any good evaluation of major projects, the overall process begins with a set-up phase and ends with a sensitivity analysis of the results of the evaluation to many assumptions associated with any significant investment. The crux of the evaluation is the analysis in the middle of the process. This is the portion that is split into financial and technological parts. (See Figure 2)

[Figure 2 and Table 1 about here]

The crucial analysis phase of the evaluation involves two elements. The first is the collection of appropriate data. The second is the processing of this information in standard methods appropriate to the expertise of the departments involved. Financial analysts handle the options analysis concerning market risks, and engineers handle the decision analysis concerning project risks (See Table 1)

The financial side of the evaluation first identifies comparable assets that can be used to benchmark the flexibility represented by the options open to the managers and investors. It then assembles data on these assets and calculates their volatility. Finally it uses options analysis to develop the risk neutral probabilities of the prospective cash flows.

The technological side of the evaluation assembles estimates of the project risks from comparable developments. For example it might estimate the probability of success of a research effort or the likelihood of cost overruns from previous experience on similar projects in similar situations. It then uses decision analysis (in conjunction with the risk neutral outcomes calculated financially) to obtain the value of the proposed investment in a new project or product.

Details of Hybrid Real Options Valuation Method

The overall valuation method consists of the usual three elements: set up, analysis, and examination of the sensitivity of the results to the assumptions made. The first and last are fairly standard and are described for completeness. The crux of the proposed practical process for valuing flexible projects is in the novel way it deals with the analysis.

Set Up Phase: Definition of the Scope of Assessment.

In any valuation process, it is first necessary to identify the number of different uses of a project, and the range of uncertainties to be considered. For real projects this is not a trivial task. Defining the nature of the flexibility and the available options for projects is more difficult than it is for financial options whose flexibility is specified up front by a contract. Research programs, new production facilities and product

platforms can each lead to many different kinds of final developments and are certainly neither limited nor specified by contract.

For example, the proper valuation of the investment by Ford Motor Company into research on methanol fuel cells is not a simple options analysis of the value of investing in fuel cells as possible economic replacements for the conventional gasoline engines. The valuation of this investment, at Ballard with DaimlerChrysler, must also consider the different markets for fuel cells (as an engine for cars, for portable use or in fixed installations). It must also account for the uncertainties associated with new environmental regulations on automotive emissions or the possible drying up of sources of gasoline. (Oueslati, 1999)

The proper valuation of major projects also must identify the managerial decision points in the development process. This step is normally overlooked in cash flow analyses, which assume that projects proceed along a specified path and forget that project and product development pass through a number of crucial decision points. These managerial reviews embody the flexibility in the investment, the opportunity to abandon or modify a project. Specifically, the valuation process must identify the opportunities to change the development of a project, for example to delay it until more favorable circumstances, to slow it down or even abandon it, or to speed it up. These opportunities to choose are the valuable options associated with the project.

Analysis Phase: Data Collection and Analysis

The analysis phase requires both the collection of relevant data, and its processing. Analysts must specify the costs, benefits, and uncertainties associated with the decision opportunities. Then they need to combine them in the relevant option or decision analysis framework.

What is necessary from the financial perspective on market risks is almost totally different from that of the technological perspective on project risks. Thus Ford's investment in research at Ballard represents a set of opportunities to develop different fuel cells for distinct applications. To analyze the value of the real options associated with this research, the evaluation needs to assemble data on the costs of these

developments, on their potential profits, and on their technical and market risks. These costs and

benefits look very different from the perspective of the design engineer measuring success in terms of

performance and energy economy, than they do from the perspective of the financial analyst focussed on

profits in volatile markets.

Financial Perspective: This focuses on the risks broadly affecting a market, those that investors cannot

avoid by diversification within that market. For stocks traded on major stock exchanges, these are the

risks associated with the overall rise and fall of the major stock indices.

Identifying the market risks associated with projects and products is more difficult. There often is no

financial market for the results of the development project. As a practical matter, financial analysts need

to identify underlying assets that mimic the volatility of the project reasonably if not perfectly. For

example, in decisions involving the development of oil fields the market risk is ultimately associated with

the overall market for oil. In earlier phases of the process such as that of exploration, however, it would

more appropriately concern the product of that process, such as the market for proven oil leases -- but

information about these trades may not be readily available (Siegel et al., 1987; Paddock, et al., 1988). In

designing electric power plants that might incorporate burners with the flexibility to use different fuels, the

underlying assets defining the market risks would concern some ratio of the costs of these fuels that has

to be constructed. (Kulatilaka, 1993)

To carry out the options analysis, the financial analysts need to calculate the statistics of the underlying

assets and apply standard risk-neutral valuation procedures to adjust the potential future outcomes. (See

Hull, 1989) These transform the market risks into risk-neutral quantities that can be evaluated using the

risk-free rate of return. The result is input into the decision analysis that also incorporates the project

risks.

Technological Perspective: This focuses on the project risks, those uniquely associated with the specific

investment under consideration. These can usefully be associated with three aspects of the project:

- The likelihood of success,

- The possibility of cost overruns, and

- The influence on the available market.

Analysts can estimate the likelihood of successful development of a project or a product from statistics on similar projects when these are available. In the ethical drug industry for example, they can derive statistics from the thousands of prospective new drugs that go through clinical trials. (Nichols, 1994) Otherwise, they can obtain the probability of success from experts, which is perhaps the more typical process in practice.

Analysts can usually obtain the distribution of cost overruns from experience. Organizations normally have substantial data on their past costs that can be analyzed to estimate the probability of different levels of project costs.

Thirdly, managers need to consider the degree to which the new project or product could expand the overall market. In some cases there may be no effect. For example, the development of ceramic valves to replace steel valves in a car is unlikely to affect the market for cars or its demand for valves. On the other hand, some developments might have considerable effect on the overall market (as distinct from the variability of the market captured by the market risks). The development of cell phones, for instance, created a whole new market that could not exist when telephones had to be connected to a wire.

Technical analysts also need to develop data on the costs and benefits of the new project or product. Most obviously, they estimate them directly in financial terms. The building of an oil field platform or the creation of flat panel displays has a cost. However some benefits are not directly financial. For example, car manufacturers recognize that weight reductions have significant value in terms of meeting environmental regulations, and these benefits should be transformed into monetary equivalents (see Neely, 1998).

Decision analysis can then estimate the combined effect of the project risks, costs and benefits. This should use a standard risk-free discount rate without extra compensation for risk, since investors can diversify their investments across many projects. The decision analysis will also incorporate the market outcomes that have been converted to risk-neutral equivalents by the options analysis.

The decision analysis in the hybrid method unites the financial analysis of the market risks with the technical analysis of the project risks. The decision analysis can do this in the hybrid case, while it cannot in the stand-alone version, because in the hybrid case the outcomes have been adjusted using the options analysis, so that there is no further need to change the discount rates as the risk content varies. The genius of the options analysis is precisely that it contributes this element to the analysis, enabling what is known as the "risk neutral transformation". The hybrid method combining the decision analysis with the options analysis thus leads to an overall accurate assessment of the value of flexibility in a proposed investment in a new project or product development. (Figure 3)

[Figure 3 about here]

This value of flexibility, the option value, is always positive or zero -- even if the investment itself is not worthwhile. The value of flexibility increases, as do options, when there is more risk. This is because the ability to avoid unfavorable circumstances or to take advantage of favorable opportunities is more valuable when there are greater prospects of using this flexibility.

The hybrid real options method of valuation thus inevitably increases the perceived and actual value of prospective projects and products, once flexibility has been introduced into the design or the development process. This is a great plus for managers seeking to justify financing for their projects!

Sensitivity Phase: Assessment of importance of key assumptions

Any evaluation process should incorporate a sensitivity analysis. The results obtained from any analysis of real projects involve many assumptions. Good practice requires that their implications be tested.

A key assumption of any option analysis is that the past statistical record is a good guide to future performance. This is frequently but not necessarily so. For example, the massive collapse of the Long Term Capital Management company in 1998, was apparently due to options analysts assuming that certain relationships between the yields on government bonds would be stable over the long term. Unfortunately, this assumption turned out to be incorrect, and the company lost billions of dollars. Good managers will not want to be blind-sided by over reliance on speculative assumptions. They will instead subject their analyses to various scenarios to test their results.

Application to a Major Manufacturer

An application of the hybrid real options valuation method to the Research and Development (R & D) program of a major automotive manufacturer illustrates the procedure. Neely (1998) conducted this assessment cooperatively with the company as part of an extensive review of their procedures for selecting and justifying major new product development projects.

Set Up Phase: Definition of the Scope of Assessment.

The R & D project concerned a major effort to optimize the design of engine parts and reduce their failure rate and weight. In this case, managers estimated that all benefits and costs could be reasonably expressed in dollars. They also believed that the project was applicable to their entire fleet of passenger vehicles.

This R & D project appeared to be promising. The managers expected that its annual benefits, if successful, would be about $35 million a year for 5 years. They estimated that its probability of success was high, about 80%. Their preliminary evaluation using discounted cash flow analysis indicated that the net present value of the entire project was $85.5 million.

The conventional analysis assumed that the project would be carried through to completion once initiated. It did not explicitly recognize that the project might be cancelled, although R & D projects do get shelved

and this particular project had an estimated 20% chance of failing. The discounted cash flow analysis

certainly did not recognize the value of flexibility.

The case study focused on a single decision in addition to the initial choice to begin the project. It

evaluated the option to implement a successful technical development. This decision occurs at the end of

the R & D phase of the project as in Figure 1. If the company implements the technology it pays the

associated costs in exchange for the future benefits. If the company decides not to implement the

technology (either because the research was unsuccessful or the market for cars was poor) it avoids the

implementation costs and any possible market losses.

Analysis Phase: Data Collection and Analysis

Financial Perspective: The market for the new product lies in the engines of cars and light trucks that the

manufacturer sells in the United States. The market risk reflects the considerable variability in the size of

this market. Its annual size has been (Neely, 1998; Ward's Automotive Yearbook):

Company Annual Market$_t$, (in millions of cars) = 2.78 + 0.0159 t   (where t = year index, e.g., 1 for

1973)

With a variability described by:

Standard Error = 0.573

To obtain the value of the option on participating in this market, it is necessary to correlate this market

with some underlying asset that can be priced. The benchmark used in this case is the price of the stock

in the company. For the purpose of this analysis we used a model of the form:

Market Size$_{t+n}$ = Market Size$_t$ * EXP(A + B * LN(Stock Price$_{t+n}$/Stock price$_t$))

Assuming that the price of the stock in the company captures all the market risks of the project, as is the

accepted practice in financial analysis, it is possible to use standard options analysis techniques. This

process transforms the actual distribution of the stock prices to an equivalent distribution appropriate for

evaluation using the risk-free rate. This equivalent distribution can then drive the estimates of the future

market sizes in terms of vehicle production.

As an aside for those that are not familiar with financial analysis, it is important to stress two concepts. The first is that the price history of a stock determines its volatility and risk vis-à-vis the overall market for stocks. Thus rapidly appreciating stocks, such as those in information technology for example, have high degrees of volatility (high Betas) with respect to the market and are riskier. These volatile stocks should then, consistent with the standard financial Capital Asset Pricing Model (CAPM), call for higher discount rates reflecting their larger risk.

Historically, this company's stock has yielded 13.2% total return with a volatility of 20.7% (Neely, 1998, Appendix B). To obtain an equivalent distribution that can be used in the options analysis, a standard binomial approach was used. (Dixit and Pindyck, 1994) This distribution for the outcomes of the market risks can then be inserted in the overall decision analysis of the project. This calculation determines the content of the market uncertainties in the right hand side of the decision tree of Figure 3.

Technological Perspective: The technological analysis focuses first on the costs of the R & D effort and of the implementation of the project. The researchers know these quantities relatively well from experience. They also understand the probability of success for projects close to implementation (in contrast to those in an exploratory phase), at least to a first approximation. In this case, the probability of success was taken to be 0.8. This estimate might appear high to those who think of the uncertainties of pure research. However, for projects that have been screened for the most promising projects based on considerable prior work, this number is reasonable.

It is easiest to estimate the benefits of a successful product when it replaces an existing device and does not change the overall expected market. This was the situation in this case. The savings in making engine parts were about $30 per engine, and were not expected to lower the price of the cars sold or increase their market. The manufacturer's benefits could then be calculated as the savings per part times the expected number of passenger vehicles sold.

If the successful product actually increases the market substantially, as cell phones expanded the total market for telephones; this phenomenon should be incorporated into the analysis. In general, this would involve calculations of the expected increase in the market and the profit margins of these incremental products.

The final step of the analysis incorporates all the above technical and financial information into a decision tree similar to that in Figure 3. This is conveniently done using decision analysis software (such as Tree-Age©) or a spreadsheet that can feature decision trees (for example Excel© with a Treeplan© macro). (see Neely, 1998, Appendix C, for details).

Using hybrid real options valuation of the project, its overall value was over $114 million. This is nearly 30% higher than the $85.5 million obtained from the previous standard discounted cash flow analysis. The difference lies in the value of the flexibility. In this case the value derives from the option of dropping the implementation of the project in the 20% of the cases in which the R & D phase is not successful.

Sensitivity Phase: Assessment of importance of key assumptions

With the evaluation in a spreadsheet it is easy to examine the sensitivity of the results to changes in assumptions. For this project we examined the sensitivity of the valuation to the:

- Estimates of the benefits;

- Probability of success of the research and development effort;

- Cost of implementation;

- Market Uncertainty;

- Volatility of the Market; and

- Expiration of the Option.

The results demonstrated the pervasive strong value for the flexibility associated with the concept that the implementation is not set once managers approve the R & D project, but can be decided upon later.

Hybrid Real Options Valuation Most Effective for Large, Risky Projects

The increased value of projects due to hybrid real options valuation is greatest for risky projects, especially when later implementation costs are relatively large. As a general rule, the value of flexibility -- and thus the increased value of a project -- is greatest when the risk is largest. The larger the risk, the greater the possibility of exploiting flexibility and avoiding poor outcomes. As an extension of the general rule, flexibility also has more value when the size of downstream costs is relatively large. In this case, the exercise of the option has more leverage and is thus larger.

The work with the R & D portfolio of the major automobile manufacturer documented these trends. In a separate series of analyses, Neely (1998) compared the improvements in value associated with real options analyses over that obtained using a traditional, net present value perspective. Specifically he plotted the percentage improvement in the value estimate obtained from real options instead of NPV against project risk and the size of implementation costs (using a logarithmic scale for clarity). Figure 4 shows the increase in value as the project risk increases (that is, as the probability of success of Stage 1 decreases). Figure 5 shows the increase in value as the relative cost of the implementation in Stage 2 becomes larger compared to Stage 1. The trends are clear in both cases.

[Figures 4 and 5 about here]

Summary

This paper presents hybrid real options valuation as a practical and effective way to evaluate projects and products accurately. The procedure has several advantages. Conceptually, it clearly recognizes the value of management control and the exercise of choices at key decision points -- as traditional valuation procedures do not. Financially, it permits a consistent choice of the risk-free discount rate for the valuation, because the project risks can be diversified and the market risks are accounted for by the options analysis. Organizationally, it applies the knowledge of the technical and financial experts to their elements of the evaluation.

An application of hybrid real options valuation to the R & D program of a major manufacturer illustrates the procedure. This example demonstrates both how the approach works and its consequences. As the case study suggests, the implementation of this method is straightforward. Most importantly, this approach leads to significant improvements in the value of projects by recognizing the value of flexibility either inherent in a project or that can be built in. These improvements are greatest when the proposed project is most risky, and when the downstream costs are relatively large. The improvements in project or project value can be used to justify additional funding or finance for these ventures.

Acknowledgements

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Table 1: The practical process for evaluating the development of projects and products divides the responsibility for the analysis among the groups most knowledgeable about the project and market risks.

|	Assignment of Responsibility	
	Engineering	**Finance**
Data Collection	Project Risks • Success of research • Cost of implementation • Etc.	Market Risks • Identification of underlying assets • Price volatility of these assets
Analysis	Decision Analysis • Places project costs, benefits, and uncertainties into a decision tree • Uses market outcomes from financial analysis • Applies the risk-free rate to obtain a present value	Option Analysis • Correlation of project outcomes to underlying asset prices • Risk-neutral transformation of project outcomes • Transfers outcomes to engineering team
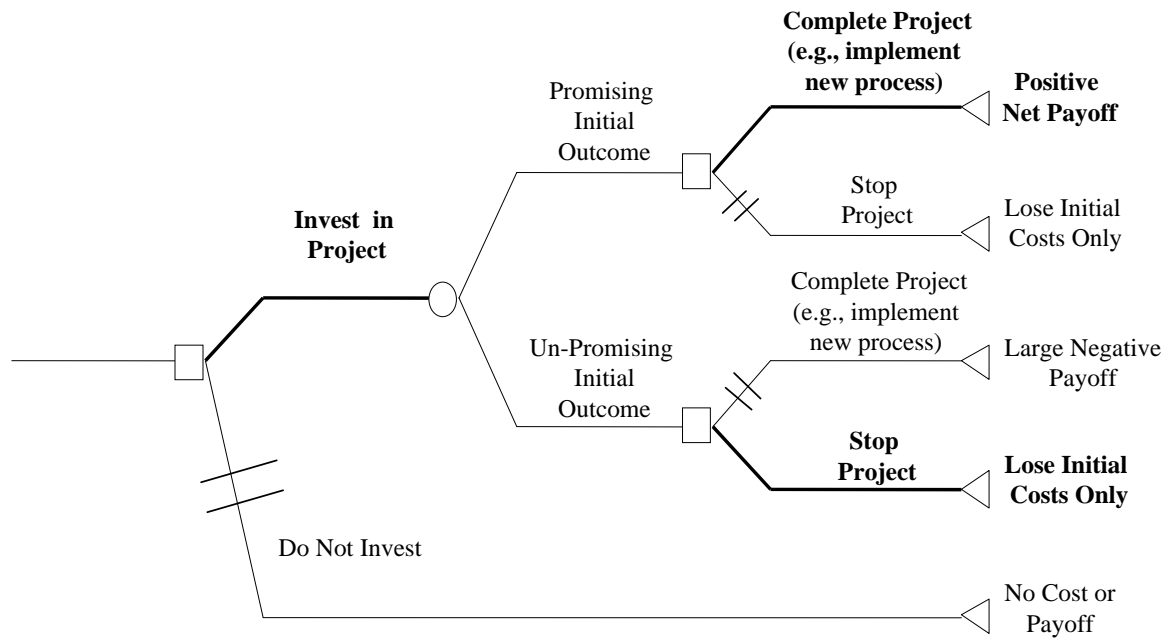
Figure 1: Example of Product Development Involving An Option: the initial decision to do R&D provides the Option to Invest in Completing Development, for instance by building a plant.

| Set-up	►	• Decision Analysis for Project Risk • Options Analysis for Market Risk	→	Sensitivity Analysis
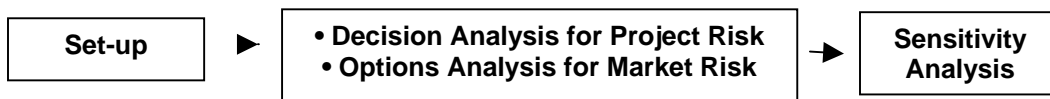
Figure 2: Splitting the analysis into financial and technological parts is the key feature of the hybrid real options process for valuing the development of projects and products.
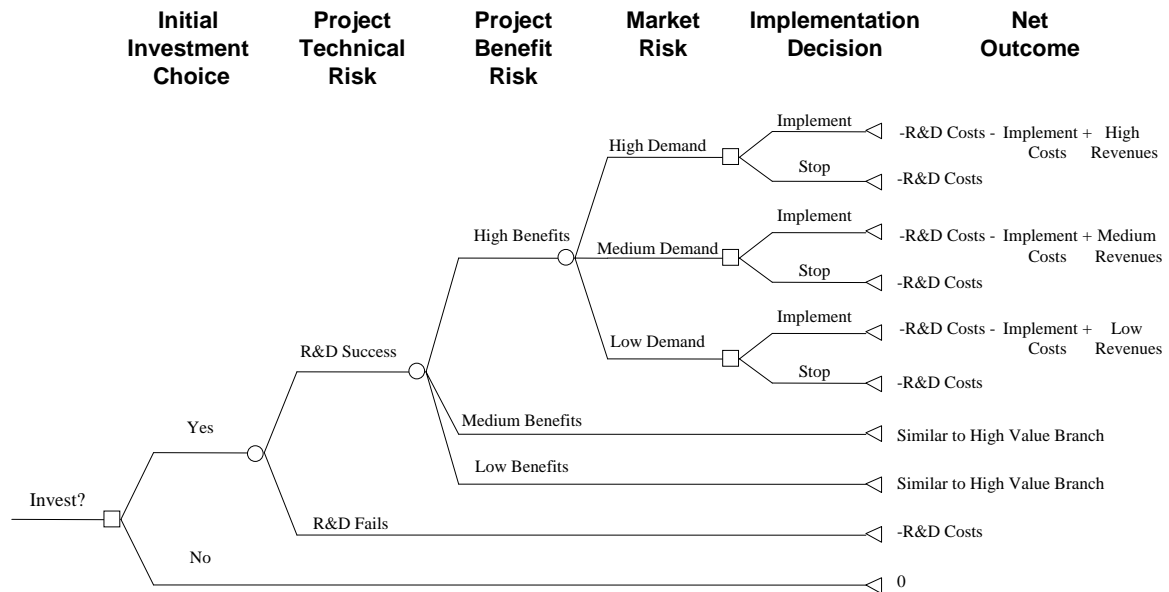
Figure 3: Hybrid Real Options Valuation in practice -- The Market Risks, once the outcomes are adjusted to allow for risk-neutral valuation, are integrated with the Project Risks into the decision analysis.
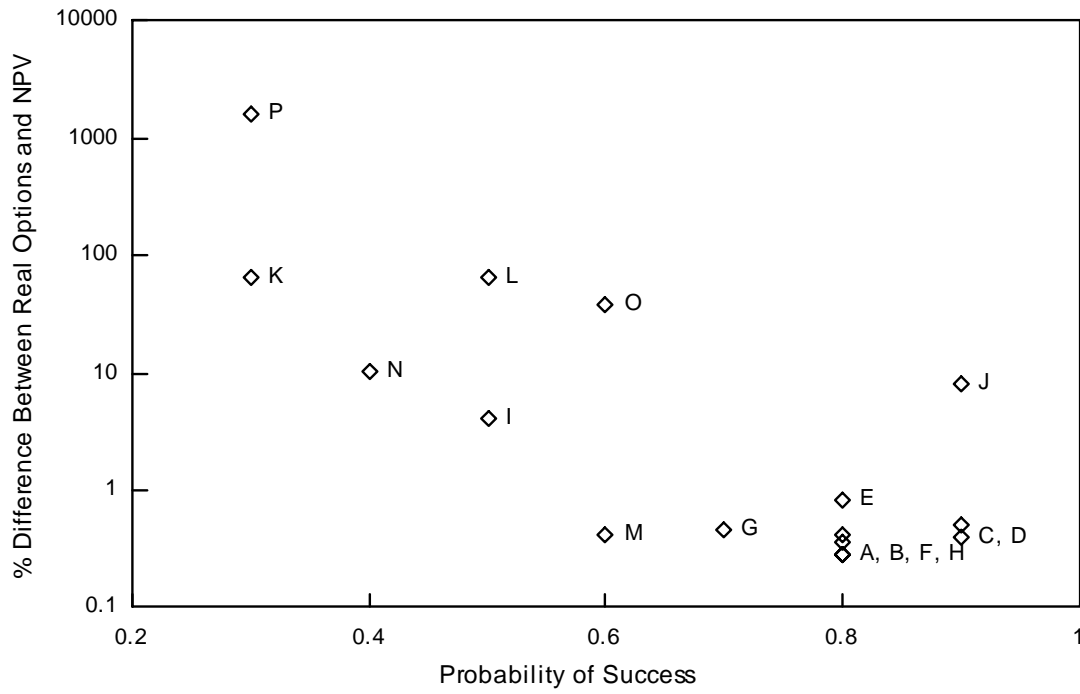
Figure 4: Flexibility in Product development, specifically the option to drop a project, increases in value as the project risk increases (i.e., as the probability of success of Stage 1 decreases).
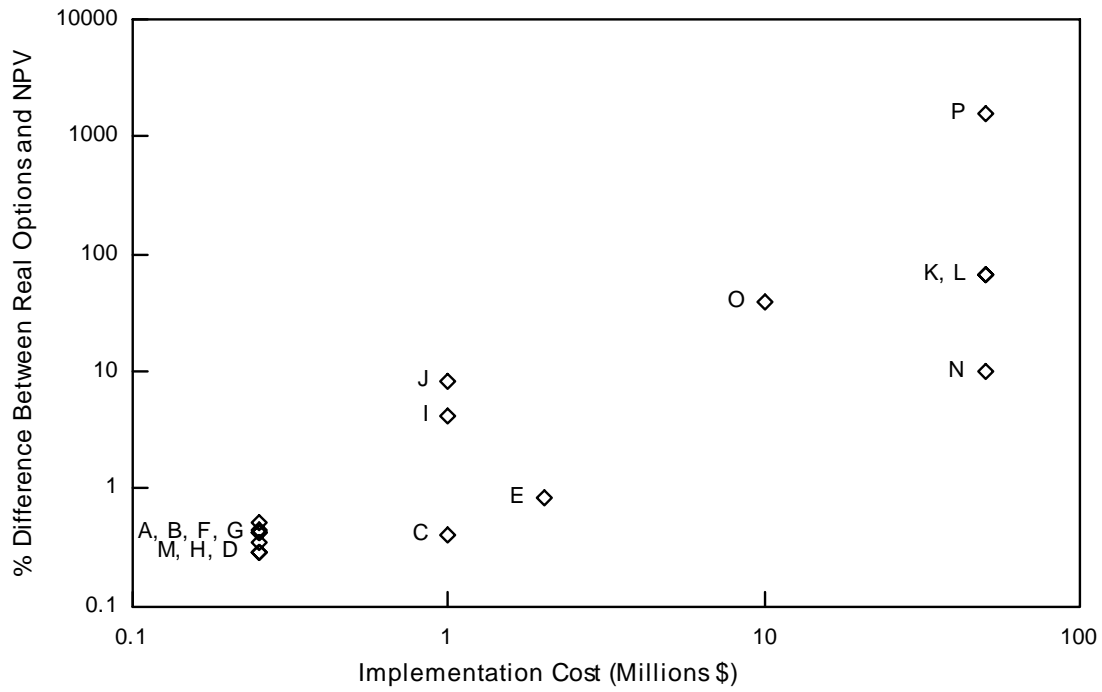
Figure 5: Flexibility in Product development, specifically the option to drop a project, increases in value as the relative cost of the implementation in Stage 2 becomes larger compared to Stage 1.