AC 2010-249: FUNDING DECISIONS FOR MULTI-STAGE PROJECTS

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Funding Decisions for Multi-Stage Projects

Abstract
Large industrial projects are generally organized and funded in stages, with each stage funded and executed sequentially. This is widely practiced with new product and new technology development projects, venture capital projects, and natural resource development projects. It is required and regulated for pharmaceutical projects. Continued funding of a project generally requires the successful completion of a stage.

The methods used to value multi-stage projects are derived from the fields of finance and engineering economics. Traditional valuation techniques for multi-stage projects are based on decision trees; this is the primary method taught to engineering students. Proponents of real options have suggested that options analysis more closely follows the assumptions used in actually funding a project, but these new methods have other, unresolved problems.

Introduction

Firms often undertake large investments in stages[1]. Rather than invest all required funds at the beginning of a large project, many firms will make a series of sequential investments based on the success of previous investments. Many projects involve multiple stages, and multi-stage economic analysis is often necessary. An example of a multi-stage project is pharmaceutical drug development, where new drug products must pass a series of clinical trials, and where successive clinical trials are performed (or not) depending on the success of the previous clinical tests. That is, Phase II tests are only performed if Phase I tests are successful, and Phase III testing is conducted only if Phase II is successful. Staged funding also occurs in many other large projects, where new ideas pass from concept development to product design and development to engineering, creation of manufacturing capacity, and product introduction into the marketplace. Each stage involves rapidly increasing monetary commitments, and each stage is funded only if the previous stage is successful — and not necessarily even then. For example changing markets, new drugs from competitors, and more promising drugs may stop a drug after a successful clinical trial. This paper is an initial analysis of stage-gate funding and it assumes that a successful clinical trial implies continuing with development. Staged funding is a method of managing the investment risk. While at each *passed* stage the probability of the drug reaching the market increases, the increasing financial stakes imply increasing amounts of risk.

Current methods for determining the value of staged projects use NPV analysis based on expected costs, expected revenues, and the probabilities of passing from one stage to the next. Decision trees are often used to organize the information and to calculate project value. Real options analysis can use compound options to determine an expanded net present value (ENPV) of a staged project. In high risk, high payoff projects, such as drug development, where the probabilities of moving forward are fairly low, options analysis may provide a different, and possibly more positive, project assessment. There is a possibility that options analysis will provide a more accurate project valuation than traditional methods if existing problems and concerns that exist with real options can be overcome.

In this paper, we examine the issue of staged funding. Engineering economics, finance, and project management textbooks are first reviewed to determine the extent to which we are

teaching staged funding. The past fifteen years of *The Engineering Economist* are also reviewed. A case study is analyzed using both traditional and real option techniques to demonstrate the different valuations that can result. We conclude with a discussion of what should be taught in undergraduate and graduate engineering economy courses.

Literature Review

Current engineering economy texts[2,3,4,5,6,7,8,9,10,11] were reviewed to determine whether they included material regarding staged funding. There were two ways that staged funding was discussed: as a part of decision trees, and as independent material. Table 1 shows the results in those texts where staged funding was discussed, whether there was a discussion of staged funding as part of decision tree analysis, and/or whether there was an independent discussion or use of staged funding.

While the use of staged funding is widespread within industry, it is not a significant part of our engineering economy textbooks. A survey of finance texts revealed much the same thing; some books discuss staged funding [1,12,13] while others do not[14,15,16,17]. Project management texts deal with the fact that many large projects are managed as distinct stages or phases[18,19,20,21], but few discuss how the stage-gate process includes project funding[22].

Table 1. Staged Funding Content

Authors	Copyright	Staged Funding included, part of Decision Trees	Staged Funding included, not part of Decision Trees
Newnan, Lavelle, Eschenbach	2009		X
Hartman	2007	X	
Park	2007	X	
Blank, Tarquin	2005	X	
Eschenbach	2003	X	X

Articles in *The Engineering Economist* over the past fifteen years (starting with 1995) were surveyed, searching for examples of staged or phased funding. Surprisingly, only six articles were found[23,24,25,26,27,28]. Even more surprising, all six articles had the common topic of real options analysis. Despite the large proportion of money that is managed using staged funding, the topic does not frequently appear in our literature.

Case Study

A drug candidate for treating hypertension (high blood pressure) has been identified and has completed initial (animal) testing. In order to develop the drug candidate for market, a series of clinical tests would need to be conducted, following established Food and Drug Administration (FDA) rules. Three clinical trials would be needed, followed by FDA approval and a launch phase. Each phase is increasingly more expensive, and each is dependent on the success of the previous phase.

As summarized in Figure 1, the testing and approval process is expected to take ten years. If all goes according to plan, the drug would have 10 years of exclusive marketing rights, beginning with FDA approval. In Phase I testing, the drug would be given to 20 – 80 healthy people to determine human safety. The testing is expected to cost $8 million (in year 2) and take two years to complete, with an estimated 70% chance of success. In Phase II testing, the drug would be given to 100 – 300 people to determine the efficacy for treating hypertension. The probability of success is estimated at 30%. Phase II testing is expected to require 2 years to complete, and would cost $30 million (in year 4). In Phase III clinical testing, the drug would be given to 1000 – 5000 people to determine safety and efficacy in a broad spectrum of the population. This testing is expected to take three years to complete and would start pending successful results from Phase II. The Phase III trials would cost $300 million (in year 7) and have an 80% chance of success. To obtain FDA approval, a new drug application would need to be written; this will require $10 million (in year 8) and one year to complete. FDA approval is expected to take two years, and there is a 90% probability of obtaining the needed approval. Successfully launching the product would require $350 million (primarily marketing costs) in year 10.

The hypertension drug has the potential of generating large profits, with net revenue of $450 million per year for ten years, starting in year 11. While the development costs are high and the chances of success are low, the potential payout is high if success can be achieved. The question therefore becomes: should the drug be developed? The minimum attractive rate of return is 20%. This information is summarized in Table 2.

Table 2. Hypertension product costs

	Year	Required Cost (EOY $ million)	Conditional Probability of Success
Phase I	2	8	70%
Phase II	4	30	30
Phase III	7	300	80
NDA	8	10	90
	10	350	

Traditional Valuation. Figure 1 illustrates a decision tree for the problem in terms of decisions and probability of success or failure in a given stage over the 10 year horizon. We examine the costs and revenues. To match published practice for sequential options, we assume that payments are made at the conclusion of each phase. Product launch and market introduction costs $350 million in year 10. As is normal with decision trees, the calculations start at the final stage and work their way backward to the initial decision point.

Cost @ year 10 = $350M

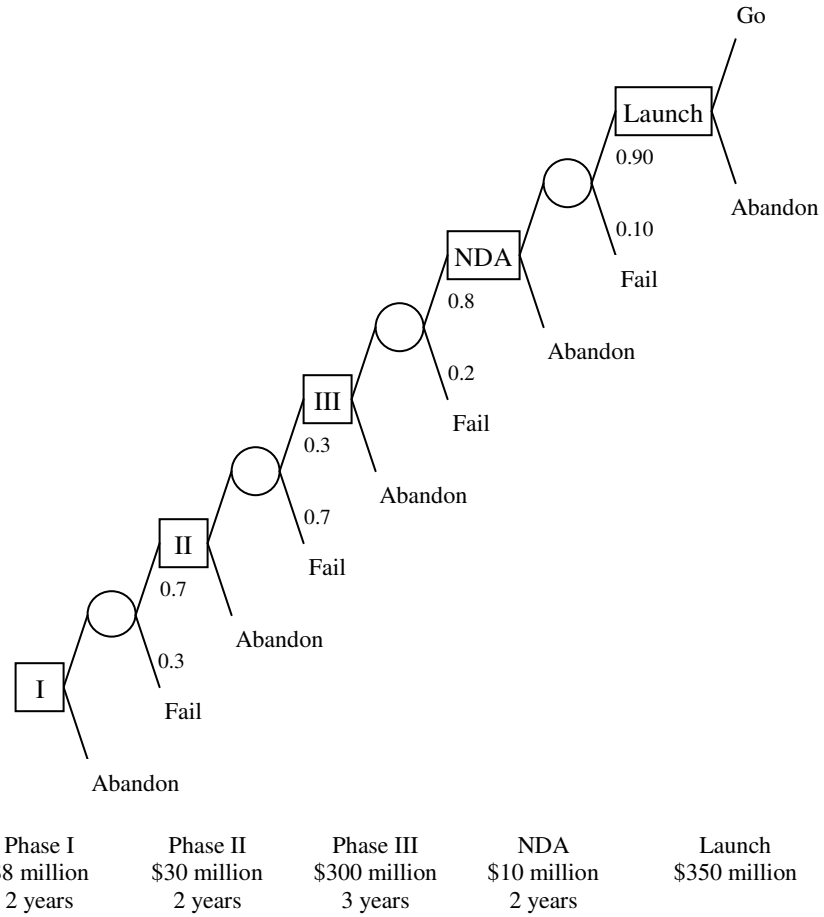
Revenue at year 10 = 450M(P/A,20%,10) = $1886.4M

NPV_{10} = 1886.4M – 350M = $1536.4M

The New Drug Application (NDA) will cost $10 million in year 8. To determine the likely costs in year 8, we add the NDA preparation cost to the probability weighted discounted cost from year 10. The MARR is 20%.

Expected Cost @ year 8 = 10M + (0.9)(350M)(*P*/*F*,20%,2) = $228.75M
Expected Revenue @ year 8 = 1886.4M(0.9)(*P*/*F*,20%,2) = $1179M
Conditional EV = 1179M – 228.75M = $950.25M

Figure 1. Hypertension Drug Decision Tree



In year 7, we need to pay for the Phase III testing and need to assume probability-adjusted costs of further testing.

Expected Cost @year 7 = 300M + (.80)(228.75M)(*P*/*F*,20%,1) = $452.5 million
Expected Revenue @ year 7 = 1179M(0.8)(*P*/*F*,20%,1) = $786.0M
Conditional EV = 786.0M – 452.5M = $333.5M

In year 4, we need to pay $30 million for Phase II tests.

Expected Cost @ year 4 = 30M + (0.3)(452.5M)(*P*/*F*,20%,3) = $108.6 million
Expected Revenue @ year 4 = 786.0M(0.3)(*P*/*F*,20%,3) = $136.5M
Conditional EV = 136.5M – 108.6M = $27.9M

In year 2, we need to pay $8 million for Phase I tests.

Expected Cost @ year 2 = 8M + (0.7)(108.56)(*P*/*F*,20%,2) = $60.77 million

Expected Revenue @ year 2 = 136.5M(0.7)(*P*/*F*,20%,2) = 66.35

Conditional EV = 66.35-60.77 = $5.58M

Discounting this to year 0, we have

Conditional EV = 5.58(*P*/*F*,20%,2) = $3.88M

The expected NPV of the project is $3.88 million. The project is worth pursuing, but the NPV is not particularly high given the long timeline and the many hurdles that need to be overcome.

Option Valuation Using Binomial Lattices. There has been a significant amount of literature in the past ten years concerning the development and use of real options for evaluating capital investment decisions under uncertainty. Real options methods are used to determine an option value, which is added to traditional net present value (NPV), creating an expanded net present value (ENPV). The argument for real options analysis is that it incorporates uncertainty when calculating the option value, unlike traditional measures of worth, and provides a value for management flexibility, such as the option to delay an investment, often improving the forecasted value of projects. The mathematical foundation for real options analysis is in financial option pricing methods. However, there are numerous problems in translating financial options into real options. Recent research has illustrated a number of pitfalls with the use of real options – especially with regards to volatility, which is the parameter that real options uses to describe the uncertainty in the data.

Staged funding can be viewed as a series of options. If the first stage is successfully passed, then management has the option, but not the obligation, to fund the second stage. This is also true of each succeeding stage. Successfully completing one stage creates further options: to abandon, to delay, and so on. A multi-stage project can be seen as a series of dependent options, also known as a sequential compound option. In theory, this approach accurately follows the actual decision making process regarding multi-stage project funding. Some real options proponents[29,30] have suggested that sequential compound options is a preferred method over decision tree analysis for determining the value of multi-stage projects.

The majority of work and the latest criticism regarding real options have been focused on the simple deferral (single stage) option. As with single stage analysis, an option value for a multiple stage project can be computed. However, there is significantly more complexity in evaluating a multi-stage project when compared to a single-stage project. Because of this complexity, closed form (and thus straightforward) solutions are generally not possible. Also, due to the complexity, many questions about multi-stage analysis remain open.

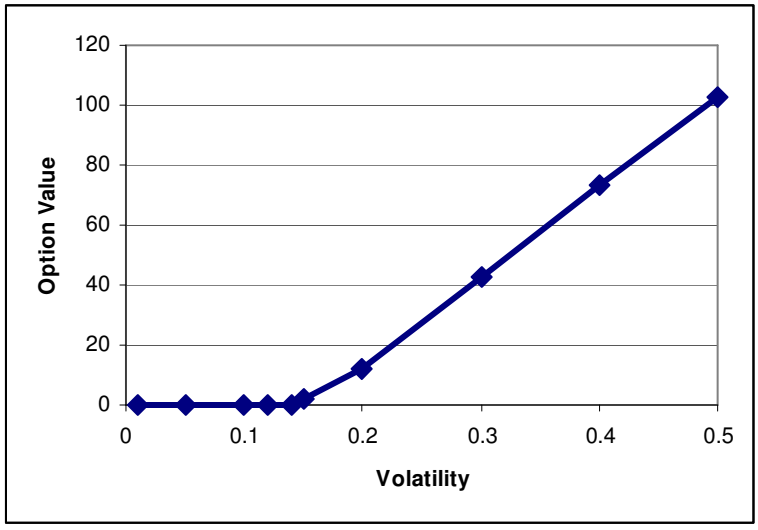
Binomial lattices were created to provide a simplified approach to option valuation that did not require calculus[31]. Lattices are more flexible and can be used to calculate more types of options than can be done with closed form equations. The Black-Scholes model is limited in how it can be applied; lattices are more flexible. However, the proof that lattices worked was that they would provide the same answer as Black-Scholes if enough time-steps were performed. For simple options, the methods are essentially the same. Lattices can be set up fairly easily as a discrete form of the continuous Black-Scholes model. However, for complicated options

including compound options, binomial lattices must be used because closed form equations generally do not exist.

While the real options literature claims that simple NPV undervalues the true value of many projects[32,33,34], there is feedback from industry that real options analysis overvalues projects[35]. There are a variety of concerns regarding the use of real options. A common problem is that most of the examples found in the literature are highly simplified compared to real problems found in practice[36]. In reality, problems are much more complex than most authors imply, making a complicated decision process much more difficult. Most companies have not adopted real options analysis[35,37]. This limited use may also be attributed to the fact that the results of the analysis are not significantly different than for traditional decision analysis (i.e., decision tree and utility theory) methods[36,38] when performed correctly.

The option value for the project may be determined using binomial lattices. The details of the calculation technique are outside of the scope of this paper, but are available in the literature[28,30]. Because there are five project stages, the value calculation consists of six lattices, each related to the previous one. The first lattice is the underlying lattice, starting with the present value of the predicted net revenues. This value is expanded over time, based on the project's estimated volatility and the length of each time step. Remaining lattices subtract the cost of each stage, and calculate an option value based on the risk-neutral probability (which is based on the volatility), the risk-free rate of return, and the length of each time step. The probability of passing each stage is incorporated into the volatility parameter, which is the estimated standard deviation of the project's projected rate of return. The option value is highly dependent on the volatility, as shown in Figure 2.

Figure 2. Effect of Volatility on Option Value, Hypertension Drug



Under typical published practice, a project of this type would likely have a volatility of at least 0.2, and likely 0.4 or more. However, it is unclear how much of this volatility would be

actionable which is discussed in the next section. The option value with a volatility of 0.40 is $73.7 million. Because the NPV is $3.88 million, options analysis provides an ENPV of 77.5 at 0.4 volatility. The large option value relative to the NPV is theoretically due to several factors[29]. First, the option approach identifies all of the opportunities that are available to the firm, including those that are not obvious from the decision tree (such as uncertainties regarding price, sales volume, and market conditions). Second, the option includes a value for managerial flexibility where uncertainty exists. The option value can increase, but never decrease, the project value relative to the NPV.

Problems with compound options. In previous work, we identified two significant reasons for inflated real options valuations. A common real option is the deferral option, where there is value in delaying (deferring) a decision to a later time when more information is known. Most authors ignore the fact that there is usually an associated cost of waiting, which decreases the expected net present value of cash flows of a project[39,40]. Merck's project Gamma, which has been used as a real options example, has also been criticized because they failed to consider a patent expiration, which led to overestimating the option value. This resulted in an incorrect decision to license another company's technology[41].

The second problem lies in estimating an overly high value for volatility. Many real options examples use multiple sources of volatility, including cash flows, hurdle rates, and time horizons. Only volatility that can be captured by exercising the option (termed *actionable volatility*) should impact the value of the option[42]. Volatility that comes from independent random variability cannot be captured and should not be used to value the option. Doing so leads to an inflated volatility parameter and an inflated option value.

In real multi-stage projects, the volatility is not constant. Each stage of a multi-stage project has a different level of risk, and in general, the probability of failure decreases over the life of the project as facts become better known, and early hurdles are overcome. As volatility decreases over time, project costs often increase dramatically, so the highest cost stages have lower probabilities of failure. Risk, however, is often viewed as the probability of failure times the potential loss, so risk does not necessarily decrease as the project progresses. This is not captured by traditional techniques nor is this addressed in most real options work. However, it is possible to capture this effect using real options tools. Changing volatility over time complicates the lattice, making valuation extremely difficult, but hopefully possible in future work.

If each stage of a project has its own volatility, how can we determine stage volatility? This is very difficult; estimating the volatility of a simple option is challenging. Uncertain variables contribute to project volatility. Accurately determining actionable volatility for each stage of a multi-stage project can be daunting, and has not been addressed by those who propose the use of compound options. The volatility of an individual stage is far smaller than the average project volatility. Some uncertainties will continue throughout the project, causing the values of some stages to be correlated to the values of other stages. The standard (published) compound option method uses the average project volatility at each stage. This difference should produce a significant change in the value of the option. To our knowledge, no one has explored the impact of correlated stage volatility.

The problems and the perceptions regarding real options need to be overcome before the tools can become widely accepted by industry. The problems have been very real, and the negative perceptions are directly related to these problems. The issues plaguing simple options are present in compound options, and the parameters under which compound options can be successfully applied are not yet understood.

What we should teach.

Staged funding is used extensively in industry as a means of funding large projects. This is widely practiced with new product and new technology development projects, venture capital projects, and natural resource development projects. The reason that staged funding is widely used is because it works as a hedge against risk. A large project may be kept alive with partial funding, accompanied by regular reviews. The firm does not need to commit to the entire project, only the next step. Decision trees help to organize the information and aid the decision making process by laying out the alternatives in a clear manner. These topics should be taught in the undergraduate course. Risk management is a necessary part of project funding, and this is appropriate for the undergraduate curriculum. Inclusion as an application of decision trees is a logical and worthwhile application, and we are pleased to see that most authors include the material in their texts.

Use of options analysis should be reserved for graduate courses. Use of options analysis in multi-stage project analysis is a fairly limited area, and is still not fully understood (although there is available literature that may allow you to calculate a project value). Where this is taught, the current methods need to be accompanied by the concerns and shortcomings of the current methods. Unfortunately, the engineering and the finance literature has plenty of content showing methods that either can not or should not be applied.

Conclusions

While staged funding is widely practiced in industry, it is not a significant part of our engineering economy textbooks, and so is not a significant part of what we teach. Finance and project management texts do no better (though most project management texts discuss risk management). Traditional methods of determining the value of a multi-stage project are based on decision trees, using NPV analysis. Decision trees help to organize information and aid the decision making process, and may be used to determine NPV, IRR, or other valuations. This is an important tool in industry, and should be taught at the undergraduate level.

Real options analysis may also be used to determine a multi-stage project value using sequential compound options. Options analysis assumes that the project moves forward only if the preceding stage was successful and includes a value for managerial flexibility which is based on the project's volatility. Including volatility usually provides a significantly higher value. There is a possibility that options analysis could provide a more accurate project valuation than traditional methods if existing problems and concerns that exist with real options can be overcome. However, in the near term, we believe that existing problems should preclude a firm from placing much emphasis on real options methods.

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