

AC 2008-905: REAL OPTIONS IN ENGINEERING ECONOMY EDUCATION

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Real Options in Engineering Economy Education

Abstract

This paper presents the results of a survey of engineering economy educators that service a wide variety of students across various disciplines and levels. We confirmed our hypotheses that real options are not being taught at the undergraduate level due to the material being advanced and that many engineering economy educators are not well prepared to teach the topic. We compare these results with those that teach traditional sequential decision-making techniques, such as decision-trees, and methods of dealing with uncertainty, such as sensitivity analysis and simulation. A recommendation is made regarding what methods should be included in undergraduate and graduate coursework in engineering economy.

Introduction

Real options analysis is a tool intended to value flexibility in future choices. The theoretical foundation for real options begins with options on financial securities. For example, a *call* (*put*) option gives the holder the right to buy (sell) a certain number of shares at a specified price within a specified period. The option *premium* is the price paid for the option. The extension into real options can be illustrated by an oil firm that continues to lease potential development tracts even though development is not currently economic. Paying for the real option can be the best choice, because of the possibility that improved technology, higher prices, or infrastructure extensions paid for by other prospects will make the development economic.

Real options analysis uses the mathematics of financial options to provide an Expanded Net Present Value (ENPV), which adds the value of the option to traditional NPV analysis. Thus, real options analysis is another tool in the engineering economic analysis set that has long included decision trees, sensitivity analysis, and simulation. The questions addressed in this paper focus on coverage of real options in engineering economy courses. This is intended to complement research on why the application of real options analysis has not been widely embraced. One reason is that many engineering managers are uninformed regarding the technique. We suggest that another reason is that real options add the most value when decisions are unclear (near-zero NPV), and the mathematics are supported by good data - that is the future benefit stream can be forecasted with identified sources of uncertainty. While options analysis has received wide attention in advanced finance coursework, its application to engineering economy and real engineering projects has been more limited. However, options analysis has been a significant issue in engineering economy research, and one that regularly appears in our literature. How familiar are we as engineering educators with real options analysis? Are we teaching real options to our students? We found no information in the literature regarding these questions.

Historical Development of Real Options

Financial options were developed in the early 1970s in academia. The famous Black-Scholes equation was developed by Fischer Black of the University of Chicago and Myron Scholes of MIT's Sloan School of Management¹. They worked closely with Robert Merton, also of MIT². Scholes and Merton were awarded the 1997 Nobel Prize in Economics for their work (Fischer Black had died in 1995). This work led to improved valuation for the trading of financial

options, and proved to be very timely with the 1973 opening of call options trading on the Chicago Board Options Exchange (CBOE).

Stewart Myers, also of MIT's Sloan School, explored the concept that financial investments generate options and it was he who coined the term "real options"³. Academic publications involving real options increased in the 1990s. Many continued to be generated in Finance departments, with the work demonstrating the applicability of financial options theory to real investment purposes. There was little effort to apply the theory to real world problems, and much of what was written was quite unreadable by managers in the industrial sector. The academic literature was largely dismissed by working managers, with the notable exception of Merck⁴.

Practitioner guides began to appear in the late 1990s, with the intent of bringing real options analysis to the financial manager in a useable form. The books explained the concept of viewing decisions as a set of options, and how the mathematics of financial options could be adapted to improve how managers valued strategic decisions. From a viewpoint of application, these books were a major step forward.

Real options analysis also began appearing in the engineering economics literature in the late 1990s. Many of the articles have been published in *The Engineering Economist*, and several in the *Engineering Management Journal*. Real options articles in engineering trade publications have not been wide spread, though there are some.

Thirty years after Stewart Myers coined the term, the use of real options still has not become widespread. In 2001, Tom Copeland⁵ predicted that real options would replace NPV as the central method for investment decisions. Reality appears to be falling far short of this prediction.

Real options analysis is being taught in a variety of ways in many universities in the United States. Most of these teaching applications are found in advanced finance courses in business schools. Examples of teaching real options analysis in engineering schools are more difficult to find, though they exist (such as Engineering Systems Analysis for Design at MIT, taught by Richard de Neufville).

The approach toward real options appears to be different in engineering economy than in finance. While the business schools tend to use examples of mergers and acquisitions, engineers tend to think more in terms of projects. The engineering examples tend to be more focused in scope, more application oriented, and more demanding in terms of meeting real world situations.

To better understand how real options analysis fits with current engineering curricula, a survey has been conducted among ASEE members. This survey addresses two main questions: 1) are engineering economics instructors familiar with real options analysis, and 2) to what extent are we teaching real options in US engineering schools.

A Real Options Example

In previous work⁶ we analyzed a more typical engineering project, where the value of waiting for more information to make a better decision (real option) is more than offset by the cost of not

immediately deciding (lost revenue). The example is of a drug company awaiting approval for a new drug from the Food and Drug Administration (FDA) with the decision expected in two years. The drug will have patent protection for ten years after FDA approval (the 20-year patent was applied for 8 years ago at an earlier stage of the development process). Once on the market, year-one net cash from sales is expected to be \$20M (million), year two cash flows are expected to be \$28M, and years three through ten are expected to be \$35M. Beginning construction of required facilities (\$38M over two years) now allows sales to begin immediately after the approval. However, delaying the build decision keeps the option open and avoids building facilities for a product that might not be approved.

The example uses a hurdle rate of 25%, and it includes salvage values at the project horizon and for the new facility if the 90% chance of FDA approval does not “come through.” Following the practice in much of the literature the volatility coefficient is assumed to be 0.40, which is typical for financial options for big pharmaceutical firms with volatility measured on an annual basis.

The question facing the firm is whether the facility should be built now or should they wait until after FDA approval? If the lost revenues are ignored (which matches the omission of waiting costs in the examples commonly found in the engineering economy research literature), then the value of the option to wait appears to make it the preferred choice. However, if the delay costs are included then beginning construction now is preferred.

Literature Review

The real options literature took a major step forward with the publication of the first book dedicated to real options, *Investment Under Uncertainty*⁷. This was soon followed by other influential books, including those by Trigeorgis^{8, 9}. The practitioner guides began appearing in the late 1990s, and included Amram and Kulatilaka¹⁰, Copeland⁵, Mun¹¹, and Brach¹². Copeland has published a revised edition¹³ and Mun has published a second edition¹⁴. Books have also been published for use specifically in the classroom, including Shockley¹⁵.

Looking more specifically at the engineering economy literature we examined both *The Engineering Economist* and textbooks. *TEE* has also published a number of articles on real options, starting in 1999. A bar chart showing the percentage of each year's articles that dealt with real options is shown in Figure 1. Three of the four issues in 2002 were special issues devoted to real options analysis.

Real options analysis is now appearing in engineering economy textbooks. A list of texts that were reviewed is shown in Table 1. Two of these texts have complete chapters devoted to options analysis. Park's 4th edition contains perhaps the best introduction to options analysis that we have seen. Canada et al. contains a reprint by T. A. Luehrman that was originally published in *Harvard Business Review*²⁵. The 10th edition of Newnan, Lavelle, and Eschenbach contains a brief conceptual section explaining that real options are a tool to deal with uncertainty and with some suggested guidelines for use of real options, and the text by Hartman contains a section regarding real options with the interesting example of “options on orders,” such as for aircraft.

Figure 1. Real Options Articles as a % of All Articles in The Engineering Economist.

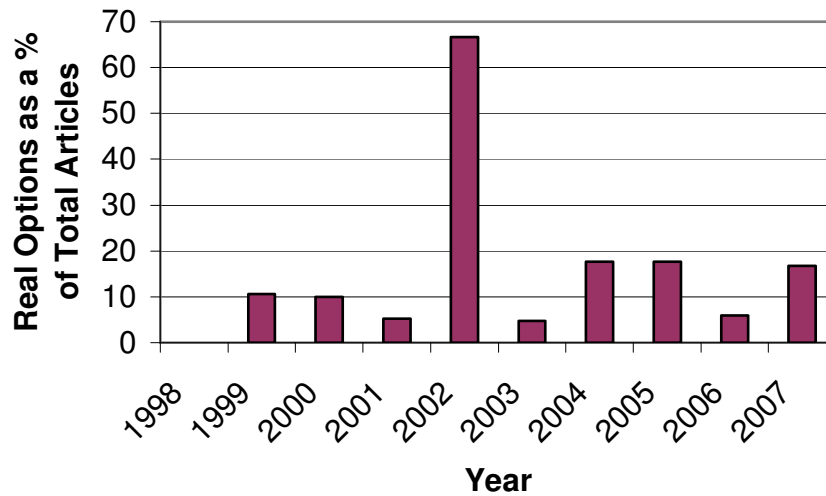


Table 1. Engineering Economy Texts.

<u>Title</u>	<u>Edition</u>	<u>Authors</u>	<u>Copyright</u>
<i>Engineering Economic Analysis</i> ¹⁶	10	Newnan, Lavelle, Eschenbach	2009
<i>Engineering Economy and the Decision-Making Process</i> ¹⁷	1	Hartman	2007
<i>Contemporary Engineering Economics</i> ¹⁸	4	Park	2006
<i>Engineering Economy</i> ¹⁹	6	Blank, Tarquin	2005
<i>Engineering Economy</i> ²⁰	13	Sullivan, Wicks, Luxhoj	2005
<i>Capital Investment Analysis</i> ²¹	3	Canada, Sullivan, Kulonda, White	2004
<i>Engineering Economy</i> ²²	2	Eschenbach	2003
<i>Engineering Economy</i> ²³	9	Thuesen, Fabrycky	2000
<i>Principles of Engineering Economic Analysis</i> ²⁴	4	White, Case, Pratt, Agee	1997

One of the first surveys regarding real options adoption was conducted in 2000, surveying 450 business executives regarding their use of a variety of management tools²⁶. In that survey, only about 11% of the respondents said that they used real options, and 32% of past real options users abandoned the technique. The author identified four major objections and viewpoints that must be overcome for real options to be widely accepted.

1. Real options analysis is a “black box.” The sophisticated math of real options and the lack of transparency and simplicity were real concerns.
2. Real options is a new economy tool. It did not help the cause that Enron was considered an innovative user of real options.
3. Real options only work for tradable assets. A common objection to options analysis was that it does not work when the underlying asset is not a tradable commodity.
4. Real options discount management realities. Critics said that because real options do not expire like financial options do, managers can not be counted on to abandon a project when they should.

Block²⁷ surveyed 1,000 companies to see if they had adopted real options. Of the 279 respondents, only 14% were currently using real options. Of the 40 users of real options, most came from technology, energy, and utilities. Block also identified four major reasons for not using real options.

1. Lack of top management support. Managers are not willing to make decisions based on techniques they do not fully understand.
2. Discounted cash flow is a proven method. The heavily favored methods in the literature are discounted cash flow techniques (NPV and IRR).
3. Real options require a high degree of sophistication. Real options tend to be used in industries where upper management tends to have engineering or technology backgrounds.
4. Real options tend to encourage excessive risk-taking. While NPV may underestimate project value, CFOs tend to believe that real options overestimate the value of uncertain projects.

Methodology

A brief survey was created using the internet site Survey Monkey (www.surveymonkey.com). A subscription was purchased and the survey was created using the tools available on the website. A copy of the survey is shown in Figure 2.

Arrangements were made for an email to be forwarded to the ASEE Engineering Economy Division (EED) list serve. This email contained a hyperlink, allowing people receiving the email to simply click on the link and participate in the survey. The survey was delivered to ASEE in early January 2008.

Figure 2. Survey Questionnaire

1. Do you teach Engineering Economics related courses?
 - Yes, regularly
 - Yes, occasionally (not every year)
 - No, but I could
 - No
2. Do you teach traditional sequential decision making techniques such as decision trees in your courses?
 - Yes
 - No
 - Don't know

3. Do you teach methods of dealing with uncertainty, such as expected value and sensitivity analysis?
 - Yes
 - No
 - Don't know
4. Do you teach simulation?
 - Yes
 - No
 - Don't know
5. What is your familiarity with real options analysis?
 - Highly familiar; I can teach the subject
 - Familiar: I can participate in conversations about the subject
 - Not familiar: I have read or heard about it, but am not familiar with the subject
 - Don't know the subject
6. Does your College/University offer at least one course that includes real options analysis?
 - Yes, we have a course devoted to the subject. How many credits?
 - Yes, we have a course that spends more than one week on the subject, but less than the entire course. How many weeks?
 - Yes, we have a course that spends less than a week on the subject, but more than a casual mention. How many hours?
 - Yes, we have a course that refers to real options analysis, but does not spend significant time on the subject
 - No, we don't teach real options analysis.
7. Is the course a graduate course or an undergraduate course?
 - We have one or more graduate course(s). How many?
 - We have one or more undergraduate course(s). How many?
8. Please provide the information below.

Name	City/Town
Position	State/Province
Institution/University	Country
City/Town	

Results

Responses to the survey began arriving within hours of the email being delivered to the EED list serve. Over the following 4 weeks, 41 responses were received from all parts of the country (including Puerto Rico) and the country of Columbia.

We wanted responses from engineering economics instructors, rather than business faculty for this particular survey. The first question confirmed that we were reaching the people we wanted. The results are shown in Figure 3.

Figure 3. Respondents teach Engineering Economics

1. Do you teach Engineering Economics related courses?

Yes, regularly	68%
Yes, occasionally (not every year)	20%
No, but I could	12%
No	0%

The next set of questions focused on whether other techniques focused on future uncertainties of engineering economics are being taught. In part, being able to learn real options depends on understanding these methods. For example, simulation is required to determine option volatility and decision trees are required in evaluating a compound option. Decision trees and simulation are not always taught, as shown in Figure 4.

Figure 4. Teaching of Related Topics

2. Do you teach traditional sequential decision making techniques such as decision trees in your courses? (Answers are shown of those who knew.)

Yes	65%
No	35%

3. Do you teach methods of dealing with uncertainty, such as expected value and sensitivity analysis? (Answers are shown of those who knew.)

Yes	90%
No	10%

4. Do you teach simulation?

Yes	56%
No	44%

While these results are self-explanatory, it is interesting to note that a real options course would likely need to begin with a foundation in decision trees and simulation.

Figure 5 shows how familiar that the respondents considered themselves with real options analysis. We found a wide range. It would appear that options analysis has not found wide support in engineering economics; more than half of the faculty in the survey was not familiar with the tool.

Figure 5. Familiarity with Real Options

5. What is your familiarity with real options analysis?

Highly familiar	15%
Familiar	29%
Not familiar	39%
Don't know the subject	17%

Most universities in our survey do not teach real options, though some do. While we realize that we have not surveyed all engineering schools in North America, the relatively low number of courses identified in the survey gives us some perspective regarding the number who might (not many). Real options courses are taught at Portland State, and we

already knew of courses at MIT. There are certainly others that we are not aware of. There are other universities that include options analysis in their more advanced courses that did not appear in the survey. Our database is not comprehensive. Details from the survey are shown in Figure 6.

Figure 6. Teaching of Real Options.

6. Does your College/University offer at least one course that includes real options analysis?

3% Yes, we have a course devoted to the subject.

1 University said yes; they have 3 graduate courses. Portland State

13% Yes, we have a course that spends more than one week on the subject, but less than the entire course. How many weeks?

5 Universities agreed. These include 6 graduate courses and 2 undergraduate courses at James Madison, Stevens, Texas A&M, the University of Arkansas, and the University of Tulsa. Time spent ranges up to three weeks.

5% Yes, we have a course that spends less than a week on the subject, but more than a casual mention. How many hours?

2 Universities said yes. These include 2 undergraduate and 1 graduate courses, with 2 to 4 hours spent on options. Univ. of Texas-Austin, and Universidad Icesi, Cali, Columbia.

8% Yes, we have a course that refers to real options analysis, but does not spend significant time on the subject

3 Universities agreed, including Univ. of Florida, Univ. of Texas – Austin, and Arizona State.

49% No, we don't teach real options analysis.

19 Universities answered this way.

28% of respondents did not know.

The majority of real options teaching occurs in graduate courses. One professor commented that he didn't think real options analysis was useful for an introductory [undergraduate] course; this appears to be widely shared.

As a group, the majority of engineering economics faculty in the survey consider themselves not familiar with real options analysis and most schools do not teach it. While this is not surprising, the information now exists to support the original hypothesis.

Recommendations

Most undergraduate engineering economics courses contain a full array of important, basic, proven tools. This is as it should be. Real options is an advanced tool that does not fit most introductory courses. At the undergraduate level, options analysis should probably be limited to making the student aware of its existence.

At the graduate level, we believe that traditional tools such as decision trees, sensitivity analysis, and simulation should be taught. The teaching of real options is better suited to graduate

courses, in intermediate or advanced economic analysis, or applied courses that focus on valuation or budgeting of advanced technology systems. The student of real options first needs to understand decision trees and simulation, as these tools are needed for the analyzing options.

Finally, the use of real options is still controversial. The engineering and the financial literature continues to question the true utility of this complex tool. However, as engineers, we must first understand options analysis if we are to join in the debate.

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