AC 2012-4293: INCORPORATING AND ASSESSING RISK ANALYSIS IN UNDERGRADUATE ENGINEERING ECONOMY COURSES

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Incorporating and Assessing Risk Analysis in Undergraduate Engineering Economy Courses

Abstract

As spreadsheets have become commonplace in the teaching of engineering economics, it is time to adjust our curriculums to include more advanced material. Specifically, financial mathematics calculations can be reduced to teaching the meaning of ($^{P/F,i,N}$) and all other calculations can be eliminated, as they are unnecessary with the use of spreadsheets. Eliminating this material will allow more time to focus on tools for making good financial investment decisions, such as cash flow estimation, risk analysis and multi-attribute decision analysis. We report on how this material can be covered in a large-class setting, including how it can be examined. Our data suggests that spreadsheets must be incorporated into quizzes and or examinations in order to assess student abilities in these areas. Thus, while our teaching has evolved to include spreadsheets, so must our examination procedures.

Introduction

Capital investments require analyses by engineers with tools and insight into whether the investment is sound. The field of engineering economy provides these tools. In order to make a sound decision, a three-phase approach to evaluate the risk of a project is necessary:

1. Identify the risk, or risks, of an investment project.
2. Analyze the identified risk(s) of the project.
3. Assess how the identified risks impact the investment decision.

Of course, these steps must occur after an initial estimate of fiscal feasibility has been established, such as computing the net present value (NPV) or rate of return (IRR) from an initial estimate of project cash flows.

Unfortunately, most engineering economy courses at the undergraduate level focus their coursework on the financial mathematics and eventual computation of the NPV or IRR of a cash flow stream[1]. This is evidenced by the number of "fundamentals" or "essentials" textbooks on the market that generally have only one or two chapters dedicated to risk analysis.

With the use of spreadsheets becoming ubiquitous in practice and commonplace in teaching engineering economy, it is time to change the focus of our teaching practices to those techniques and tools that help in the evaluation of capital investment projects under risk and uncertainty and ultimately lead to engineers and others making better investment decisions. In terms of risk analysis, this requires more time to be focused on topics, at a minimum, such as sensitivity analysis, breakeven analysis and scenario analysis. Ideally, it would also include simulation analysis and decision trees.

To allow for these topics to be covered will most likely require a decrease in other topics commonly taught in engineering economy. The most obvious reduction should come in the derivation and teaching of financial mathematics calculations – namely the interest factors. Recently, Eschenbach and Lewis[1,3] called for a reduction in the use of tabulated factors which

was echoed by a number of engineering economy authors and teachers. They recommended the use of financial calculators and spreadsheets. This author is a proponent of using spreadsheets in the course as it is the industry standard.

The fundamental issue and motivation for this paper is summarized in the following two questions: Do we want "graduates" of an engineering economy course to be able to mathematically manipulate a given cash flow diagram into another diagram (such as an equivalent value at time zero)? Or do we want graduates to be able to examine an investment situation, estimate the cash flow diagram and all relevant information and then make a sound investment decision based on a thorough risk analysis? Previous work[4,9] has called for more risk analysis to be integrated into undergraduate courses. We illustrate how our presented framework can be used to guide teaching and also suggest methods for assessment.

Reducing the Teaching of Financial Mathematics Calculations

There appear to be three arguments against reducing content in engineering economy courses related to financial mathematics calculations (and the use of interest factors and interest factor tables):

1. Elimination of the ability to perform "back of the envelope" calculations in the field.
2. Loss of intuition gained from learning factors.
3. Coverage on the Fundamentals of Engineering exam.

These are addressed in turn and have also been discussed previously[7].

To the first point, field equipment has evolved to include notebook computers as well as powerful phones. A number of design-build firms have already developed in-house "apps" to help with cost estimates as well as common financial calculations such as payback periods. In this situation, the key skillsets required are being able to quickly estimate relevant input values (such as cash flows) and making a quick initial decision on viability given the output of the analysis. Time spent moving cash flows through time only detracts from these needs.

To the second point, is likely true that learning to use the interest factors can build intuition. The fact is, the intuition (or notion) is that under a common assumption of a positive interest rate, money grows to a larger value as it moves forward in time and shrinks as it moves back in time. This is reflected in the $(^{P/F,i,N})$ and $(^{F/P,i,N})$ factors which are generally introduced when discussing the notion of interest. As these serve as the basis for all other factors, they are the only factors that need to be explicitly covered in classroom material. Once understood, the mechanics of moving money through time can be easily illustrated on a spreadsheet, without the use of factors.

Furthermore, this author would argue that one can build intuition merely by working lots of problems – even if the actual calculations are performed on a spreadsheet. In terms of intuition, an engineer that can build intuition on the inherent risks of a given project (and thus understand where energy and funds should be funneled to reduce the risks) would be more valuable than one that could roughly estimate the NPV of a project given an initial cash flow diagram. Again, a spreadsheet would provide that answer in a timely fashion.

The final issue is hard to immediately overcome. At present, computers are not allowed during the exam and thus, students are currently forced to use tables or accepted financial calculators. The ultimate remedy would be that the exam questions would eventually change to reflect risk and decision analysis as opposed to common cash flow analysis calculations. However, as this is unlikely in the near future, it is suggested that this type of information be relegated to review or prep sessions for the test. The author runs these types of sessions each semester for students preparing for the exam. The argument here is that if students have successfully completed an engineering economy course that has pushed them to analyze the risk(s) of a project, they will find it easy to learn how to use the factors in a timely manner for an exam.

Curriculum Replacement

With the reduction of coverage of financial mathematics, time in the curriculum can be focused on tools for making good financial investment decisions, such as cash flow estimation, risk analysis and multi-attribute decision analysis. These topics should be presented in the previously identified three-step context:

1. **Identify the risk:** This is the task of sensitivity analysis, which measures the effect of changing values of input variables on some measure of project worth. Each variable should be tested over its viable range. The variables that result in the largest percentage change in the measure are identified as "key" variables.
2. **Analyze the risk:** Once the key variable or variables have been identified, the analysis must dig deeper. If there is only one key variable, then a breakeven analysis is prescribed to identify the minimum or maximum value to maintain fiscal feasibility (i.e., a net present value greater that is non-negative). If there are multiple values, then there are multiple approaches. One could perform breakeven analysis on each variable; a scenario analysis which looks at different cases in which each variable takes on a different value (perhaps pessimistic, average and optimistic); or a simulation analysis which can take a deeper look at the effect of changing variables simultaneously over their viable ranges. Depending on the problem complexity and decision setting, it may be appropriate to look at alternative investment strategies through decision trees.
3. **Assess the risk.** Once the risk has been analyzed, a judgment must ensue. In the case of a single key variable, it may be as straightforward as looking at the breakeven value and comparing it to historical values to make a judgment as to whether the risk is acceptable. For more complicated analyses where multiple techniques, and thus results, are utilized, some form of multi-attribute analysis may be required in order to combine this information in order to make one decision.

Note that these steps are to follow a baseline analysis of estimating a cash flow diagram and providing an initial estimate of some measure of worth. This should also include some basic risk analysis such as payback period.

Further note that there is *a lot* of information contained in the three above steps. At a minimum, students should be proficient at sensitivity analysis, breakeven analysis and scenario analysis. Time permitting, decision trees and simulation analysis would be welcomed. Software programs that interface well with spreadsheets make incorporating these topics into the curriculum much easier[2].

Assessment of Risk Analysis Ability

It is clear that it is easier to test, and thus, assess skills associated with financial mathematics calculations, as there are clear answers. While similar questions can be constructed for risk analysis, such as illustrating the effect of a change of a 10% increase in the investment cost on a project's present worth, they are clearly more involved and time consuming. Furthermore, breaking risk analysis down to these fundamental steps clouds the overall goal and point to risk analysis: making a good decision. To overcome this, case studies or projects may be assigned to help instill these skillsets and allow for practice in their application. However, as these are generally completed in teams, there may also be a need to devise individualized testing of this subject matter in an appropriate context.

For the past several years, the author[5,6] has employed a "one question" final exam in which the students are provided an investment scenario and background information from which they have two hours to make a compelling argument of whether the investment should be pursued or not. A university computer laboratory is reserved for this exercise. This past semester, two back-to-back sessions (different exam scenarios given) of roughly 70 students each were run where the students could access the exam material and a blank spreadsheet for use. The completed spreadsheet and associated write-up were turned in at the end of two hours.

The students were provided the grading rubric in advance such that they understood that the path of analysis and conclusions were to be graded closely. It was understood that given the time constraints, a good "write-up" would not be possible – rather the highlights (assumptions, quick analysis summary, and conclusions with discussion) would be expected. For the exam, four proctors were used to ensure that no other software programs or Internet capabilities were accessed.

An examination of the test results reveals how the student analyses in this format have changed over the years. This approach[7] was started in 2001 (at a different university). In that first semester (with 56 students), only 9% of the students performed sensitivity analysis while 27% performed payback period analysis. For this exam, students were only provided their textbook, notes and calculators. At that same institution in 2007, the percentages increased to 76% and 79%, respectively. However, the exam was strikingly different in that students were afforded the opportunity to use spreadsheets during the exam.

In 2007, the first year at this institution, the percentages were 42% and 62%, respectively, again without the use of computers. This past semester, the percentages grew to 84% and 65%, respectively, with 131 exams analyzed. Additionally, 44% performed breakeven analysis and a further 10% performed scenario analysis. These were with the use of spreadsheets.

This illustrates that, over time, students are responding to the change in direction of teaching engineering economy with a focus on decision and risk analysis and this is facilitated through the use of spreadsheets. Furthermore, it illustrates that these skills can be assessed in exam environments – although it is conceded that it takes more time to grade these solutions when compared to traditional computational problems.

Conclusions

This paper has called for the reduction in teaching financial mathematics calculations in engineering economy, instead relying on the use of spreadsheets to complete typical calculations. Time spent from the elimination of this material can be better used in the teaching of risk and decision analysis techniques. We have outlined approaches to assess this material, even in large class settings, and have shown that in our experience, student ability in risk analysis is growing and can be facilitated with spreadsheets.

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