Engineering Economics for MBA Students

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Abstract
The purpose of this paper is to provide details on an Engineering Economy course offered to a part-time (evening) MBA program at William & Mary. The students included engineers and non-engineers. All students had taken multiple courses in accounting and finance prior to taking Engineering Economy. Thus, the focus of the course was on relevant applications of engineering economy through journal paper reviews, public media, traditional homework assignments, and the creation of a Social Security tool. The course was not focused primarily on typical time value of money concepts, since those concepts were well known from the finance courses.

The course included a project, which was completed in pieces. The project was to build an individual Social Security tool in Microsoft Excel. The tool incorporated the various breakpoints for when to claim and the risk of claiming early versus late, etc. The first stage of the tool was to complete the Microsoft Excel tool for just the basic breakpoints (i.e., earliest claiming age, full retirement age, and age 70) where month-by-month was the time frame; calculating the Net Present Value (NPV) for a given time value of money rate (8%) and age of death (85th birthday). The second stage of the tool was to determine the optimal claiming age given different ages of death. The third stage was to do a sensitivity analysis on the age of death, the time value of money rate, and whether or not Social Security "runs out of money" (i.e., drops benefits to 75%). This stage used a mortality calculator to assign a probability of death in any given month, and to calculate the NPV and the standard deviation of the various claiming scenarios (i.e., to measure risk).

The readers of this paper will benefit from learning about this course since it is an applied course with professional students. The students were fairly aware of the time value of money concepts, but were lacking in applications outside of their industry domain and the usage of Microsoft Excel to calculate these problems. Furthermore, using a project that impacts all (Social Security) sparked interest in the course and its material.

Introduction
The purpose of this paper is to provide details on an Engineering Economy course offered to a part-time (evening) MBA program at William & Mary. The MBA programs at the Mason School of Business at William & Mary are consistently ranked between 25 and 50 in the U.S. from various ranking organizations, and in the top 100 worldwide. The part-time (evening) MBA program has a concentration in Engineering Management, and the Engineering Economy course is an elective within that concentration. The business school does not offer a doctorate. The university overall is a top 10 public university in the U.S., and is a traditional liberal arts university. It does not currently have any engineering degree programs, although it did in the past.

Literature Review
There are many articles that discuss how to teach or integrate business topics to engineering students [1 - 3]. However, the opposite situation is not well covered in the literature for general business topics. With regards to Engineering Economy and as it relates to Finance, this has been evaluated by Ted Eschenbach [4], as it relates to encouraging change in the way Engineering

Economy is taught. Additionally, suggestions for how Engineering Managers should teach Engineering Economy has been surveyed and presented [5].

The project that is presented later in the paper follows the engineering economic evaluation of when to claim social security from both the NPV perspective and the risk perspective. For a full research review of such topics, the paper by Ted Eschenbach and Neal Lewis is suggested [6]. The design of a project for when to claim social security has been discussed and presented from both the individual perspective [7] and the couple's perspective [8].

Student Make-up

The course included 22 students, eight of which had an undergraduate engineering degree and worked in an engineering or technical capacity. Approximately half of the students took the course to satisfy an elective requirement without regard to the course topic (i.e., it fit their schedule), and the other half took the course to satisfy credits towards the Engineering Management concentration of the MBA program.

Course Structure

The course included 14 sessions, 11 face-to-face and 3 online. The sessions were approximately 2.75 hours each and the course met two or three times per week. The topical coverage of those sessions consisted of the following, in order:

1. Time Value of Money Calculations and Excel Review
2. Decision Making Process, Deferred Annuities, and Arithmetic and Geometric Gradients
3. Rate of Return and Breakeven Review
4. Problem Session
5. Mutually Exclusive Alternatives and Incremental Analysis
6. Replacement Analysis
7. Capital Budgeting and Mathematical Programming Approach
8. Sensitivity Analysis and Decision Trees
9. Cost Estimation and Learning Curves
10. Public Sector and Inflation
11. Multiple Criteria Decision Making and Analytic Hierarchy Process
12. Goal Programming
13. Real Options
14. Problem Session

Furthermore, the students were required to review 5 articles (one per week, starting in the second week). These articles were then discussed during the class case-study. The paper topics did not align directly with the subject topics for the 14 lessons. The following articles were reviewed (Lessons 4, 6, 9, 12, and 14):

1. R. Ries, M.M. Bilec, N.M. Gokhan, and K.L. Needy, "The Economic Benefits of Green Buildings: A Comprehensive Case Study," *The Engineering Economist*, 51, 259-295, 2006.

2. H-M.S. Wang, K.M. Spohn, L. Piccard, and L. Yao, "Feasibility Study of Wind Power Generation System at Arctic Valley," *The Engineering Management Journal*, 22, 21-33, 2010.

3. R.A. Followill and B.C. Olsen, "A Closed-Form, After-Tax, Net Present Value Solution to the Mortgage Refinancing Decision," *The Engineering Economist*, 60, 165-182, 2015.

4. B.C. Boehmke, A.W. Johnson, E.D. White, J.D. Weir, and M.A. Gallagher, "The influence of operational resources and activities on indirect personnel costs: A multilevel modeling approach," *The Engineering Economist*, 61, 289-312, 2016.

5. J.V. Farr, I.J. Faber, A. Ganguly, W.A. Martin, and S.L. Larson, "Simulation-based costing for early phase life cycle cost analysis: Example application to an environmental remediation project," *The Engineering Economist*, 61, 207-222, 2016.

The students did complete graded problem sets that included the traditional Engineering Economy applications and calculations. In addition, each week students submitted a one slide review of an article where Engineering Economy or the time value of money was discussed. A small sample of these were shared each week during class, with the students providing the overview while the instructor moderated.

Project *[Note, this section is verbatim; that is, exactly from the Project Assignments.]*:

Part 1:
Perhaps the most important individual decision with regards to the time value of money for a US worker is when to begin taking Social Security. For this question, we will assume it is a mutually exclusive decision (and "do nothing" is not a viable option). To make it a bit easier, we'll make some basic assumptions.

Date of Birth: May 31, 1960
Current Year Earnings: $100,000
Note: Values inputted into https://www.ssa.gov/oact/quickcalc/
Results below.
We will assume these values are valid for our analysis.

a) Compare the three alternatives based on Present Worth, Annual Worth, and Future Worth:
   62 and 1 month: $1642 per month
   67: $2418 per month
   70: $3057 per month

Assume the individual lives until they are 85 years old (i.e., they die on their 85th birthday).
Assume Social Security does not run out of money.
Assume an 8% MARR (i.e., time value of money interest rate).
Assume payments received at the end of the month (i.e., they get the last payment).

b) Use Excel to determine the "optimal" choices for a "death" at age 62 and 1 month until 100 years old. (I apologize for the morbidity of this question.)

Hint: It may be better to do this (visually) with a line graph, after creating a table of monthly cash flows and then calculating PWs based on ages.

Assume Social Security does not run out of money.
Assume an 8% MARR (i.e., time value of money interest rate).
Assume payments received at the end of the month.
Assume the individual dies at the end of a month (i.e., they get the last payment).

Figure 1: Calculations from the Social Security Quick Calculator [9]

Retirement

At right is the information you provided. Below that are estimated benefit amounts for retirement at 3 different ages, including your normal (or full) retirement age (67). We assume you will work every year up to the year in which you begin receiving benefits.

As shown in the table, you can receive a monthly benefit starting at age 62 and 1 month that would be reduced for life due to early retirement. If you choose to delay the start of benefits to a higher age, you can then receive a larger monthly benefit for the rest of your life.

For example, if you start taking benefits at age 62 and 1 month, you will receive $1,642 per month for the rest of your life. But if you wait until age 67 to start receiving benefits, you will get $2,418 for the rest of your life. So by waiting until age 67, you can then receive $776 more per month than if you started lower monthly benefits at 62 and 1 month. Remember, these estimated figures are in today's dollars.

Social Security benefits are the foundation on which to build a financially secure retirement. Savings and pensions also are key components of your retirement plan.

Information you submitted

Date of birth: **5/31/1960**
Current earnings: **$100,000.00**
Benefit in **year-2018** dollars

Retirement Benefit Estimates

Retirement age	Monthly benefit amount [1]
62 and 1 month in 2022	$1,642.00
67 in 2027	$2,418.00
70 in 2030	$3,057.00

[1] Assumes no future increases in prices or earnings.

We have calculated your benefits by making certain assumptions about your past earnings. Please look at these earnings to see if they appear reasonable to you. You can change them and see the effect on your benefit estimates!

See the earnings we used

Disability/Survivor

For disability and survivors estimates, we assumed that you became disabled or died **today**. We did not use future earnings in calculating those estimates.

Disability	Monthly benefit amount
You	$2,286.00

Your spouse and children may also qualify for benefits.

Survivors	Monthly benefit amount
Your child	$1,715.00
Your spouse caring for your child	$1,715.00
Your spouse at normal retirement age	$2,286.00
Family maximum	$4,001.20

Part 2:

Context and assumptions are the same as Part 1, unless otherwise specified.

I'm looking for you to answer and/or show the following from your analysis; using tables, charts, graphs, etc.; but you may still need to provide a short "write up" to explain your thoughts to go along with your figures:

a) Which assumption is most sensitive to small changes (-10% to +10%)?
b) Which assumption is most sensitive to large changes (-30% to +30%)?

c) If this was a friend who was healthy, what would you recommend he or she do? Alternatively, what would you tell him or her not to do?
d) Any other thoughts or comments as it relates to this question and your analysis?

Part 3:
Context and assumptions are the same as Parts 1 and 2, unless otherwise specified.

Assume an interest rate of 5% (note that this is a change from prior assignments).

Perform the following analysis:

a) Using some form of mortality calculator (or just make something up that is reasonable) assign a Probability of Death for each time period (make sure the probabilities sum to 1). [At minimum assume an equally likely death probability between 62 and 100.]

b) Calculate the Net Present Value (either at 62 and 1 month, or at the start of taking retirement payments) and Future Value (at time of death) for each of the three scenarios (62 & 1, 67, and 70). [Note, you should have this completed or partially completed from prior assignments.]

c) Calculate the Expected Value (i.e., the weighted average) of the Net Present Value and the Future Value using Part a and Part b (above) for each of the three scenarios.

d) Calculate the Standard Deviation of the Net Present Value and the Future Value using Parts a-c (above) for each of the three scenarios.

e) Using Expected Value (Part c) as the "Reward" (Maximize Reward) and "Standard Deviation" (Part d) as the "Risk" (Minimize Risk) – what is your suggestion to your friend?

Note, your spreadsheets should be created in such a way (i.e., absolute cell addressing) that you could change only a few cells and the analysis could be recalculated. That is, if you wanted to put in someone who was going to have three different payouts or a change in the interest rate; then it should take minimal effort to reconfigure the spreadsheet.

Project Discussion
It should be noted that the instructor did post a solution to Part 1, prior to Part 2 being due, and posted a solution to Part 2 prior to Part 3 being due. Thus, students were able to continue to build their own version or modify the instructor's interim solutions. Part 1 was reviewed during class prior to Part 2 being due, and Part 2 was reviewed prior to Part 3 being due. The most significant difficulty the students faced was spreadsheet organization (e.g., using a variable cell for interest rate, rather than hardcoding it into cells, and the use of arrays in Microsoft Excel).

The reason the Social Security simulation was selected was because it is perhaps the most personal time value of money application – except students and citizens are living the application. The students completed many applied Engineering Economy examples in the coursework and problem sets, encountered a few Engineering Economy examples in the journal articles, but this project assignment was personal. The student evaluation of teaching reflected that sentiment. All comments regarding the project were positive, with many of the students indicating that they are much more comfortable knowing how to plan for their Social Security retirement decision and how to advise others (e.g., parents, friends) on what the best economical decision is for them. While we do not know which student comments came from engineers or non-engineers, due to the number of positive comments it was a welcome project topic across-the-board.

The academic motivation for the case study included Ted Eschenbach and Neal Lewis's papers on the subject. The most recent paper showed that when to collect social security had small differences in NPV but large differences in risk (i.e., standard deviation). By completing Parts 1-3 of the project, the students reproduced many of the calculations of that paper and certainly came to similar conclusions [6].

Course Discussion

The instructor for this course had taught Engineering Economy in the more traditional sense to both undergraduate and graduate engineering students. In each of those cases the majority of the students had not taken finance nor accounting; thus, the time value of money calculations and principles were the focal point of the courses. In the undergraduate course the FE (EIT) Exam provided a good repository for questions. However, for an MBA class with students who have taken a core of classes which included accounting and finance, and all students having at least three years of work experience (and some with 20+ years), the course needed to take on a different structure.

The lectures and problem sets covered the foundation of Engineering Economy. The journal article reviews exposed the students to comprehensive studies and allowed them to understand the value that these students can bring an organization. The one slide reviews of contemporary topics allowed them to see where the time value of money was applicable in various aspects of daily life. The project gave them a personal real-world example that covered almost every course learning objective.

Due to the sample size of the class (22 students), distinguishing between the engineers and non-engineers is not possible quantitatively for any sort of statistical significant testing; thus, only qualitative observations are discussed. Of the 22 students, 20 students completed the course evaluation survey. Of those 20 students, 18 students had written feedback and/or comments regarding the course. All of those 18 comments were positive in terms of the course structure, coverage, and project scope.

Conclusions

The overwhelming conclusion of this paper is to consider using the Social Security decision as a project for Engineering Economy courses as indicated by the 18 students who were positive in terms of the course comments on the student evaluations. The project can be designed in such a way to include many of the course's learning objectives, including time value of money calculations, risk, and sensitivity analysis.

Minor contributions of this paper include course design suggestions for students who have already taken accounting and finance; thus, exposing them to actual examples of Engineering

Economy becomes a focal point of the course – rather than topical coverage of time value of money concepts. The course included those in a variety of ways – including review of journal articles, review of contemporary topics (prepared by students), and review of problems during lecture (prepared by faculty member).

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