Engineering Economy: Suggestions to Update a Stagnant Course Curriculum

Joseph C. Hartman
Industrial and Manufacturing Systems Engineering
Lehigh University

Abstract

Examining engineering economy textbooks from earlier this century and today reveals that the curriculum appears to be stagnant. This is supported by the fact that the material is virtually unchanged and in a variety of cases, the number of topics covered has actually declined. This may be attributed to an emphasis on economic equivalence and a de-emphasis on the decision process. Unfortunately, this is seen as a disservice to a student that will eventually perform engineering economy studies. This paper suggests ways in which to enhance the curriculum, including teaching engineering economy in the context of decision and design processes and integrating research advances into course material.

Introduction

If one compares an engineering economy textbook from early in this century[3,7,11] with a new edition from today,[4,8,10] they may be shocked to notice that the material has not really changed. Rather, in some cases, the amount of material has declined. It can be argued that the only innovation in engineering economy has been the utilization of spreadsheets to perform mundane calculations. Topics such as cost estimation have been virtually eliminated while relevant research breakthroughs from the past fifty years have not found their way into textbooks, and presumably, the classroom. The reduction in material may be attributable to an emphasis on time value of money fundamentals and a movement away from decision analysis.

For economic analysis, the decision process may be summarized in the following six steps:

1. Problem recognition and definition.
2. Generation of solution alternatives.
3. Development of feasible solution alternative cash flows.
4. Economic evaluation of alternative cash flows.
5. Selection and implementation of best solution alternative.
6. Post-implementation analysis and evaluation.

Despite these six steps, engineering economy courses tend to narrowly focus on Steps 4 and part of 5. That is, students are provided with cash flows and are taught to perform an evaluation (present worth, internal rate of return, etc.), selecting the best alternative from the given choices. Some texts provide methods in which to develop cash flows, however, the estimation means are quite simplified.

It is argued here that engineering economy is a vital part of a decision process and thus should be taught in this context. The entire process of evaluating a project, from its inception (Step 1) to its completion (Step 6), should be emphasized. In this context, the principles of engineering economy provide the foundation for these decisions. Associations with the design process, which is closely related, are also addressed in this paper.

In addition to a re-emphasis of the decision process, it is also argued that engineering economy educators must integrate research advances into the curriculum. While a variety of breakthroughs have occurred with relevant applications in replacement analysis and capital budgeting, it appears that these advances do not make it into the classroom. College and university educators have the responsibility to disseminate the important advances of our field.

The goal of this paper is to provide both motivation and a procedure in which to revitalize the engineering economy curriculum. Teaching engineering economy principles in the context of decision and design processes is discussed and a general course outline is presented. Additionally, some research advances are highlighted for integration into curriculums emphasizing the most advanced solution procedures available.

It should be noted that the author teaches "Engineering Economy and Decision Analysis" as a 3-hour, semester course usually consisting of second semester juniors, which may bias the views of the author. Engineering economy is taught earlier in the curriculum at a majority of institutions, however, it is believed that the suggestions in this paper should be valid nonetheless. Also, the author is an avid researcher and educator in the area of replacement analysis, further motivating this discussion.

Engineering Economy and the Decision Process

The fundamentals of engineering economy allow one to analyze and prioritize projects according to cash flows. Unfortunately, teaching these fundamentals overshadow defining the problem, possible solutions, and their implementation. While cash flow analysis is important, one must consider each step in the decision process when performing an engineering economy study. With this motivation, the six steps presented earlier are reviewed and discussed here with relevant topics for an undergraduate engineering economy course. The desire here is to emphasize engineering economy fundamentals in a decision-making context.

1. *Problem recognition and definition.* A considerable amount of time is not required on this subject, however, it should not be ignored. Most engineering courses (problem solving courses) generally assume that the problem is "a given." Since this is not a trivial step in the process, students must learn to recognize problems and formulate definitions, including understanding the difference between "problems" and "symptoms."

2. *Generation of solution alternatives.* This step is very germane to human decision making. Techniques such as brainstorming, the nominal group process and/or the Delphi method, may be discussed to illustrate methods for developing solution alternatives. It must be emphasized that this is a solution generation step and not an evaluation or elimination step.

3. *Development of feasible solution alternative cash flows.* This section is concerned with the estimation of costs and their associated cash flows. Traditional methods, such as indexing, should be covered but additionally, the application of forecasting tools (i.e. exponential smoothing or regression) should be mentioned. Fabrycky et al.[5] present simplified estimation

tools based on fitting curves to data which may be suitable for engineering economy. Inflation and taxes should also be considered here, as they are integral components of cash flows and influential in nearly all decisions.

4. *Economic evaluation of alternative cash flows.* This step is traditionally covered in detail in textbooks and would still constitute a majority of the course. Different evaluation methods, including PW, IRR, payback period, etc., should be discussed.

5. *Selection and implementation of best solution alternative.* This step is also generally considered in traditional engineering economy courses, however, it should be expanded in this context. While the best alternative may be selected according to economic criteria, discussions should also include non-traditional factors with costs and benefits that are not easily quantified. Ranking methods, AHP and/or utility theory may be discussed in order to evaluate these considerations. Canada and Sullivan[2] provide an excellent reference for these topics. Following these evaluation methods, alternative analyses such as breakeven, optimization or cost-benefit may be taught. Finally, methods to compensate for uncertainty or risk in decisions should be incorporated, including discussion of variance in estimates, sensitivity analysis, and/or decision trees, etc.

6. *Post-implementation analysis and evaluation.* This final step, which is generally ignored, plays a vital role in engineering economy for three reasons. First, a good engineering economy study needs data, which requires maintenance of a cost database. As with the cash flow estimation part of the course, this section should review the necessary costs that should be tracked over time. Second, costing practices, including traditional accounting practices and activity based costing should be emphasized here while stressing data collection methods. Finally, engineering reports, common with evaluations, may be discussed here.

As discussed, these decision steps provide an outline for a course in engineering economy where fundamental concepts are not sacrificed. For application to the classroom, the initial weeks can be spent on introductory cost concepts and time value of money calculations. This introductory material can then be followed by the decision process context in the order presented. Towards the end of the course, case studies or projects may be assigned to reiterate the process of taking a project from its inception to its completion.

Relation to Engineering Design Process

The engineering design process is closely related to the decision process presented here. Its steps include problem recognition and definition, generation of possible solutions, analysis, evaluation and selection of the preferred alternative. Due to these similarities and its inherent relationship with all engineering disciplines, there has been a movement to integrate design issues into the engineering economy curriculum.[12]

The author has been fortunate in having taught classes using this methodology and strongly encourages and supports its continuance. In light of this statement, it is believed that the design process should not replace the decision process, but rather, complement it. Consider the following problem: A shipping company is running short on dock space due to a recent surge in demand, causing delays to customers and lost revenues. There are a variety of solutions, but for simplicity, consider the following options: (1) Build a new dock at the current facility, (2) Extend the current dock with a permanent dock structure, (3) Extend the current dock with a temporary dock structure, (4) Purchase another dock, (5) Lease another dock, or (6) Do nothing but continue operations at current capacity. These options, may also be explored simultaneously, such as expanding a current dock while also building a new dock. Regardless of the options, the cash flows of these alternatives must now be estimated for analysis. For the temporary dock, this entails designing the structure and its construction and installation processes. Several designs may be evaluated before selecting the “best,” according to economic or engineering reasoning. Design issues may also be prevalent in other options.

The point here is that design issues are generally integrated into decision processes. Design issues should be considered when generating feasible solutions and generating their cash flows, as these are highly dependent on the chosen design. However, the design process cannot replace the decision process because engineering economy deals with additional problem scenarios. Consider the evaluation of options (4) and (5). This purchase versus leasing decision is not common to the design process but is very common in engineering economy. Thus, teaching engineering economy in a design context may be too narrowly focused when compared to a decision context. Rather, the design issues should be integrated into the presented decision process framework.

Dissemination of Engineering Economy Research

In addition to re-emphasizing the decision process in engineering economy courses, research advances must also be incorporated into the curriculum to assure that students are provided the best tools when analyzing problems. There are a number of journals, most notably *The Engineering Economist* and more recently *The Journal of Engineering Valuation and Cost Analysis*, which are devoted to research in the area of engineering economy with applications including capital budgeting and replacement analysis. As educators, it is our responsibility to move these advances into the classroom. While Park and Sharp[9] present a number of these advances for a graduate course, it appears that the advances are not moving to the undergraduate level over time.

Consider the subject of replacement analysis. A typical analysis, which can be found in nearly all textbooks, projects cash flows for the defender and a challenger over some common horizon. Cash flow analysis then leads to a decision to retain or replace the defender. As noted by Fleischer[6] at a recent conference, this analysis is incorrect. The reasons are numerous, including: (1) No challengers available between the current period and the final period are considered and (2) Truncating the horizon may alter the analysis. As educators, we dance around these issues with arguments that the analysis should take place every period and to only be concerned with the time zero decision. While true, what has been ignored is that this is a well-studied problem with a wealth of research available to solve it optimally under a variety of conditions.

Bellman[1] developed a dynamic programming solution to the equipment replacement problem with one challenger over a finite horizon over 40 years ago. Yet, the solution procedure is rarely mentioned in textbooks and most certainly not taught to undergraduates. This question is “Why?” It is true that sophomores or juniors have generally not been exposed to dynamic programming. However, it is believed that drawing the associated network representation (attributed to Wagner[13]) and solving it through shortest path analysis (complete enumeration) or an iterative procedure, without teaching the fine points of dynamic programming, is very possible. This explanation would provide the students with the necessary tools to solve the problem correctly. Additionally, if interested, they could pursue further topics in this area, as a number of variations have been developed to handle different equipment replacement scenarios. The fact is, capital assets are so expensive and critical to operations, that teaching an incorrect or incomplete procedure tends to diminish the solution's importance.

Replacement analysis is not the only field that has seen advances, as additional arguments can be made with capital budgeting. As educators, it is our responsibility to be aware of the latest advances and when appropriate, disseminate the information to our students. Obviously, many advances are not immediately suited for undergraduates, however, over time, advances should move to the undergraduate level. The decisions associated with capital assets are far too important and costly to justify ignoring the latest advances in our field.

Conclusion

Capital investments have large financial implications and impacts on operations. Engineering economy plays a vital role in industry and organizations and is a critical component of the industrial engineering curriculum. Unfortunately, the subject seems to be stagnating. In order to enrich the curriculum, this paper suggests re-emphasizing teaching engineering economy in a decision process context and disseminating research advances.

While engineering economy fundamentals may provide the tools for economic analysis, it is believed that their presentation in a decision/design process will lead to better decisions and decision-makers. As opposed to strictly teaching cash flow analysis, the presented context illustrates true decision making in taking a project from its inception to completion. In addition to fundamentals of economics and finance, the process illustrates the need for a variety of industrial engineering skills, including human decision making (problem definition), engineering design (solution generation), statistics (forecasting) and information systems (data collection and maintenance). While these courses may be taught individually in an industrial engineering curriculum, they must be highlighted here to illustrate their role and importance in making capital investment decisions. As a result, we can prepare engineers with the ability and the tools to make these vital decisions.

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Author Biography

JOSEPH C. HARTMAN is an Assistant Professor in the Department of Industrial and Manufacturing Systems Engineering at Lehigh University. He received his Ph.D. and M.S. in Industrial Engineering from the Georgia Institute of Technology and B.S. in General Engineering from the University of Illinois at Urbana-Champaign. He is a member of ASEE, IIE, INFORMS and NSPE and currently serves as director-elect of the EED of IIE.