The Role of Engineering Economics in the Chemical Engineering Curriculum

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Abstract

Engineering economics is an integral part of the senior design course in all Chemical Engineering curricula. The main topics normally covered include cost estimation (focused on chemical process equipment), the time value of money, and profitability measures. This paper offers a commentary on the importance and future role of engineering economics. Many topics of engineering economics display the engineering problem-solving approach at its best, in a manner that is shared by all engineering disciplines. For example, the hierarchy of cost estimation techniques is typical of methods used in other quantitative engineering problems. In cost estimation, one must learn to devote the extra effort required for more accurate estimates only in those cases where the accuracy will ultimate matter. Most unprofitable alternatives should be screened out using only very coarse and quick cost estimates. A likely change as engineering curricula become more practice-oriented is a move of economy material from the senior level to the first or second-year level. The earlier exposure to engineering economics will allow economic studies to be integrated into many intermediate-level courses with engineering design elements.

INTRODUCTION

In most undergraduate Chemical Engineering curricula, engineering economics is covered in the senior-level capstone design course which is project-based and involves the design of a chemical plant. The early modules of the course include (Peters and Timmerhaus, 1991, Woods, 1994) the estimation of capital and operating costs, time value of money, and profitability analysis, so that the economics of various design options can be compared as the project is carried out. The topics of depreciation and taxes receive only brief coverage. Cost estimation is geared towards chemical process equipment, with most ancillary costs lumped into simple factors.

How important is engineering economics for the Chemical Engineering curriculum? In what ways does it enhance engineering problem-solving skills? What likely changes in the structure of the curriculum will involve engineering economics, and what are their consequences? This paper offers the author's view on these important questions.

IMPORTANCE OF ENGINEERING ECONOMICS

The primary role of engineering economics is the same in all engineering disciplines: It guides decision making. In the design of a process, the engineer makes a multitude of choices in process configurations, units, and materials, and economic factors are central in these decisions (Hazelberg, 1994). Economic considerations likewise guide the operation of an existing process.

Very often, these choices are guided by rules of thumb (Douglas, 1988) which summarize past experience, but the engineer must still contend with frequent exceptions and with choices not covered by such rules. Thus, the quantitative understanding of economic implications in the design and operation of a process is indispensable.

Engineering economics is among the course topics most likely to be used directly by students after graduation. It is sufficiently generic to be valuable in a large variety of chemical engineering jobs. It is also quite realistic (at least in some of its topics, such as the time value of money) so that the barriers between the course material and a practical application confronting a new engineer are quite low.

This set of direct benefits of engineering economy is sufficient to earn it a permanent role in the chemical engineering curriculum. Beyond these primary effects, engineering economy also has two indirect (yet, in the author's opinion, quite important) beneficial effects, discussed in the next section.

INDIRECT BENEFITS OF ENGINEERING ECONOMICS

Engineering economic analysis can demystify processing systems and units. The students are often puzzled about particular process arrangements. What is the rationale for a distillation column or a jacketed chemical reactor? The teacher could give explanations of how these processes work, but full assimilation and understanding of the material requires an answer to another question: Why is the arrangement desirable?

In most cases, there are direct economic reasons that lead to the evolution of a unit from simpler (i.e., more obvious), arrangements (Mavrovouniotis, 1995). For example, a distillation column is a less expensive alternative for a sequence of flash drums. The best way to get the point across to the students is to carry out a complete computation of costs.

The systematic economic analysis of standard yet complex process arrangements helps the students understand the rationale of the arrangements; the students are then better prepared to recognize when a process arrangement is useful and what its limitations are.

The second indirect benefit of engineering economy is that it exemplifies and cultivates problem-solving skills. For example, cost estimation can be done at different levels of detail - depending on what approximations one is willing to make and what accuracy is demanded of the result. Better accuracy requires more detailed, time-consuming analysis, and one should be careful not to expend effort if the final outcome (a decision to accept or reject a design alternative) is not sensitive to improved accuracy.

Some design alternatives have large cost differences; detailed cost computations for an alternative that will be rejected are unwise. The correlation between effort and accuracy creates the need to economize one's efforts and focus them in those sensitive areas of the problem where they will impact the solution the most. This applies to most engineering problem-solving but it is most apparent (and hence didactic) in design and in the associated economic evaluation of design alternatives.

Note also that, in profitability measures, we make assumptions that are valid in typical cases, but we must nevertheless watch out for the exceptions – a typical feature of engineering decision-making. With cash flows that have unusual variations with time, it is, for example, possible to have multiple solutions for the discounted cash flow rate of return. The interplay of assumptions and exceptions is present in most engineering problem-solving.

FUTURE CHANGES

Is there a more appropriate role and place for engineering economy in the Chemical Engineering curriculum? We have recently witnessed a trend of incorporating design earlier in the curriculum, with many new freshman-level design courses (Dym, 1994; Miller and Olds, 1994). Design has also been receiving renewed emphasis as a component of intermediate-level courses; McMasters and Ford (1990) argue that "design" and "engineering" are fundamentally synonymous, and design as a fully integrated part of the curriculum including the core engineering science courses. Engineering economy is an integral part of design (Hazelberg, 1994). Design is realistic decision making; without downplaying ethical and social issues that a mature and responsible engineer should also consider, it is clear that economic factors are always important and often central in realistic decision making. Thus, the expanded role of design in introductory and intermediate-level courses creates a need for additional attention to engineering economics in the earlier portions of the curriculum. It can be argued, in fact, that the core of engineering economics should be entirely shifted from the senior level to the freshman and sophomore levels. (This is certainly not going to be the case with design as a whole, since capstone design courses are rightfully receiving renewed, not diminished, emphasis.)

What form would a shift take, and what are its benefits?

Certain aspects of engineering economics require only minimal engineering science background. The time-value of money, profitability criteria, generic aspects of cost estimation (such as distinctions between capital and operating costs, or issues related to depreciation and taxes), the effective use of the literature in finding costs, and the use of indices to update costs can all be covered in introductory-level design courses. Economic computations are an excellent way to introduce computer tools (such as spreadsheets and graphics) in a unified manner for all engineering disciplines.

There are, of course, economic topics which require discipline-specific engineering science and design background. For Chemical Engineering, these involve primarily cost estimation for specific types of process equipment.

The author believes that the details of these topics rightfully belong to the corresponding engineering science courses. The reinforcement and application of engineering economics should also take place through examples in these courses.

This is such a natural structure for the intermediate courses that it is surprising it has not been implemented already. For example, the discussion of heat transfer fundamentals and equipment should be immediately followed by economic aspects: the estimation of equipment costs, the trade-off between capital costs (heat-exchange area) and operating costs (energy). Note that economic factors are not entirely missing in the present form of the courses; but they stop just short of direct monetary analysis. In heat transfer, the computation of heat-exchange surface area is already important; the relationship of this quantity to equipment costs is only a short yet significant step to take. This change can be applied to virtually all intermediate chemical engineering courses. Fluid mechanics can include the cost of piping; process control may cover the cost of instrumentation; reactor design should discuss the cost of reactor equipment.

In all of these cases, we are not advocating merely inclusion of cost-estimation but application of engineering economics to study trade-offs in the design and operation of processes. The student will thus understand why process control systems rely on certain measurements (temperature, flow, pressure) more commonly than others (composition) which are difficult and more expensive; why and when multi-stage compressors are used; or why a distillation column is preferable to a sequence of flash drums.

Does this mean that the first time students find out about the estimation of the cost of a particular equipment type will be in the corresponding engineering science course? Not necessarily y. It is in the nature of design and engineering, that in discussing each topic (such as a family of unit operations) it is useful to have a coarse understanding of other topics (whose detailed study may occur later in the curriculum. For example, in the study of vapor-liquid equilibrium separations, one cannot completely ignore the issue of heat exchange and its costs. Usually, an "Introduction to Chemical Engineering" course has among its goals the overview of chemical processes, precisely to meet this need.

With costs and economics brought into the picture for the intermediate courses, it is useful to make a similar inclusion of economic aspects into "Introduction to Chemical Engineering": Include an overview of process equipment and the simplified, approximate estimation of their costs.

Let us summarize the curricular proposal made here: engineering economics should be introduced at the freshman-level design course. "Introduction to Chemical Engineering" then includes an overview of process equipment and simplified cost estimation models. Each specific intermediate-level engineering course includes detailed cost-estimation and economic trade-offs for its technical topic. The capstone design course does not need to explicitly cover economic techniques, but uses them extensively in a major design project.

The author believes that this configuration is consistent with the increasing role of design and makes all the courses more cohesive and interesting to the students.

SUMMARY **AND CONCLUSIONS**

Engineering economics is currently an integral part of the senior design course in all Chemical Engineering curricula. The main topics normally covered include cost estimation, the time value of money, and profitability measures. Cost estimation is geared towards chemical process equipment, with most ancillary costs lumped into simple factors. This paper offers a commentary on the importance and future role of engineering economics in chemical engineering curricula.

Economic factors are central to engineering decision-making in designing or operating a process. One cannot imagine realistic design or problem solving without explicit analysis of the economics of the process. Furthermore, many topics of engineering economics display the engineering problem-solving approach at its best, in a manner that is shared by all engineering disciplines. For example, the hierarchy of cost estimation techniques is typical of methods used in other quantitative estimation problems engineering. With a more time-consuming and detailed cost-estimation approach we can usually obtain more accurate estimates. We gain accuracy by refining each cost component into its constituent parts. In the opposite direction, we gain convenience by estimating a cost component as an approximate multiple of another cost component. Engineering economics thus teaches and exemplifies engineering problem-solving skills.

Economic decision-making will always be a central component of engineering. Engineering economy will continue to play an important role throughout future curricular transformations. A likely change as engineering curricula become more practice-oriented is a move of economy material from the senior level to the first or second-year level. Students acquire the needed mathematical background for engineering economics sufficiently early, and economic computations are an excellent way to introduce computer tools in a unified manner for all engineering disciplines. The earlier exposure to engineering economics will allow economic studies to be integrated into many intermediate-level courses with engineering design elements.

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