

ECONOMICS FOR ENGINEERS: AN INTEGRATED APPROACH

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ABSTRACT

Engineers are the principal decision-makers who influence the profitability of firms, whether they are involved in manufacturing, construction or service industries. However, most conventional courses in engineering economy do not deal with the breadth of issues engineers will face in practice. This paper describes a revised approach to teaching Economics for Engineers rather than the more limited Engineering Economy. Case studies are used to teach the language and concepts of costs and the relationships between engineering decisions and the economic performance of the firm.

WHO REALLY DETERMINES COSTS?

A fundamental issue we must address as engineering educators is the vital role played by engineers in the economic performance of the firm for which they are employed. For, after all, it is the engineers who determine, through the nature and quality of their decisions, whether the firm will make money and stay in business or lose money and eventually go out of business.

I address this with the following parable, that I call the Parable of the X-Ray Vision.

Imagine that you and a friend are standing in the lobby of a manufacturing firm. Put on your Superman X-Ray vision glasses and look through the walls. As you examine all of the people at work in this firm, ask your friend “Who makes the decisions that determine whether this firm will stay in business, earning a profit and continuing to employ all of these people, or will lose money and go out of business, forcing these people into other jobs or into unemployment?”

Your friend might answer “Well, clearly, it is the Finance Office. The people in the Finance, Accounting or Comptroller’s Office, whatever they call it here, must be the ones who make those decisions.”

You would have to answer; “No, the Finance Office only keeps score. They are the ones who keep track of the firm’s performance and report it to the management, the owners and the government. Anything they do to influence profits could be illegal and send someone to jail!”

Then your friend might respond; “Well, it must be the workers on the assembly line. Yes, they are the ones who really determine the future of the firm.”

When you think for a minute, you have to say, “No, the workers do what they are trained to do, using the tools and procedures they are given within the time they are allotted

to accomplish their tasks. No. It can't be the decisions that they make."

"Well", your friend says, "then it must be the plant manager. She is the one paid the big bucks. She must be the one who really determines the success or failure of the firm."

To this, you respond, "In a sense, that is true. The plant manager provides the set of attitudes, through leadership that determine the level of spirit and enthusiasm within the firm. But, from a practical point of view, she operates within a set of constraints. The plant manager's job is to expand the profitability of the firm up to those constraints, and then to get the constraints expanded, so that the performance of the firm can continue to grow."

Your friend then asks, "Well, who are the people who set those constraints?"

Your answer, after you think for a minute, must center on the constraints. "To answer that," you say, "We have to determine who the people are who can expand those constraints. They must be the set of people who originally set the constraints."

"And, those people are the engineers. The product engineers, the process engineers, the materials engineers, the material handling engineers, the tooling engineers - these are the people who can expand those constraints and they are the ones who set the constraints."

Your friend looks at you curiously and asks, "Can you give me a clear example? How does all of this work?"

Your reflective reply goes something like this; "Well, if the product engineer selects a particular design that requires 12 bolts and nuts to assemble, it will have a particular cost. On the other hand, if she elects a design that can integrate the two parts into one piece, using some procedures such as those described by the researchers and writers on topics like "Design for Assembly", the cost may be substantially reduced. Thus, the cost to manufacture a particular part is a function of the decisions made by the engineers during the design process."

"OK", says your friend, "What is your message with all of this?"

Your response must be something like; "Well, we need to train the engineers to make the most cost effective decisions. However, we generally just teach them about present value. As I look through these walls, with my X-ray vision, I can see that the engineers must have a much deeper understanding of the economic consequences of their decisions."

This paper describes a course in engineering economics which has some very untraditional goals and which we believe, sets a new standard for the kind of education that engineers truly need to become effective in their professions. The goals of this course are:

- To learn how the firm's economic performance and profitability are measured and how costs are classified and reported within the firm. We use the firm's annual report as the basis for achieving this goal.
- To understand the product's Life Cycle costs and how these costs are influenced by engineering decisions,
- To explore how present value concepts are used to assess engineering decisions,
- To learn the tools and techniques of profitability analysis,
- To develop skills in cost estimating and,
- To understand the effects of engineering decisions on costs and profits.

This course is taught at the undergraduate level in all of our Engineering Technology majors and in Engineering programs in universities where I have been able to establish the

format. It requires background in several engineering courses, particularly Engineering Materials and Manufacturing Processes.

To begin the analysis of the course, we need to explore the morphology of the subject from an engineering point of view. We need to examine the structure of economics as experienced by practicing engineers. We make it a point to use case studies to illustrate the important concepts and to give students practice at dealing with the analysis of costs.

ECONOMICS FOR ENGINEERS

It is important to structure the course with several features including an understanding of the language of economics. Engineers must understand both the language and the concepts used by the firm's managers and the accounting specialists to describe the costs, and cost control systems. To accomplish this, we explore the major elements; how costs are incurred, recorded and reported, how engineers estimate costs, the notions of time value, product life cycles and how profitability is measured. All of this is taught with a continuing focus on the role played by the engineer in the decision making process. The following sections describe these elements and how they are addressed in the syllabus.

HOW COSTS ARE INCURRED, RECORDED AND REPORTED

The first set of concepts, with the accompanying terminology center on the ways in which costs are incurred by the firm, how they are recorded and how they effect the firm's financial position. I have found that examination of typical annual reports of publicly held companies can lead this discussion.

The Annual Report

Annual reports contain an excellent set of data to examine in class. Firms ranging from major manufacturers to food processors can be used effectively. The two major documents; the Income Statement and the Balance Sheet are the center of this discussion. It is easy to use these to trace the effects of engineering decisions. For example, the tradeoff between using human labor to perform some operation versus investing in automation shows up directly in both reports. It is essential that engineers understand how their decisions will be judged and how they will effect the firm's economic performance.

Cost Definitions

After an understanding of the basic concepts of cost flows has been reached, the instructor can then deal with more of the detail of the actual costs. This provides an opportunity to describe direct labor, indirect labor, direct materials and indirect materials, how they are related to decisions such as product design, process design, materials selection and so forth. This also provides a platform for understanding the cost effects of tooling and specification decisions. The cost effects of tolerance decisions for example, can be clearly shown in terms of process and tooling costs.

Overhead Costs

Overhead constitutes an ever increasing proportion of total product cost. The topic of overhead costs can be dealt with in any degree of detail needed. The concepts of Activity Based

Costing (ABC) are useful for describing the sources of overhead and illustrating how conditions such as environmental control efforts can have cost impacts. Following is a case example used to examine how environmental issues and process and materials decisions effect overhead costs.

Accurate Products manufactures small electronic devices. Some of the components in recent designs have been specified to include black paint. The plant has operated a paint spraying line but has recently been required to install upgraded filters to meet air quality requirements. The annual cost of disposing of the used filters was about \$10,000. The cost had been allocated through plant overhead along with the rest of the environmental compliance costs. Since the cost was relatively modest, that was not a bad decision. However, changes in hazardous waste disposal laws increased the cost to well over \$80,000. At that time, the overhead rate for the plant was adjusted from 400% to 410% of direct labor. Several other costs were adjusted at the same time. This increased the cost of the painting operation by only a fraction of a cent per part.

In fact, the increase in actual part cost was over \$0.25 on a fully accounted basis. The product engineering office, not being aware of the full incremental cost for painting, continued to specify painting for the parts and production volumes in the paint department continued to increase. At the same time, some other operations in the plant, which had large direct labor components, were judged to be non-competitive because of the increased overhead charges. Many of these parts were outsourced at considerable cost in the purchasing and engineering activities. Later examination showed that those parts were actually profitable for the firm but the profit margin was lost in the overhead allocation.

COST ESTIMATING METHODS

Another set of vital skills for the practicing engineer, regardless of area of specialty, is that of cost estimating. Engineers must be able to forecast the cost effect of their decisions at the time of the decision-making activity. To not have this skill means the engineer can not include cost in his decision making process and can never arrive at the correct decision by any circumstance other than luck.

It is also important to familiarize engineering students with the processes involved in cost estimating, as projects move from the concept stage to full production, or as the project takes form in design and then under on-site construction, for those in the civil engineering arena. The skills gained in cost estimating help students understand the process of convergence, during the evolution of the design. So much of the cost of a product or project is determined in the very early stage of engineering design that this understanding is essential to make progress in design improvements.

TIME VALUES AND RATES OF RETURN

It is important that students understand the fundamentals associated with time value. However, there are so many other topics that are equally important that they must be given appropriate weights. The principles are well presented in most engineering economy texts. And, many recent books take advantage of the computational power of spreadsheets.

Internal Rate of Return (IRR or TARR)

The notion of minimum acceptable rate of return or time adjusted rate of return is perhaps the most important outcome of the time value study. Most firms use IRR or TARR for analysis of engineering projects and it is essential that engineers understand both the principles and the practices of this concept. No set of engineering decisions should be made and presented to management without an appropriate analysis of rate of return and comparison with the firm's minimum level or MARR. Engineers should carry out this essential analysis

as part of the design task, and not be separated from it by the finance office.

Depreciation, Interest and Tax Effects

There is little to be gained by spending large amounts of time on depreciation, interest and tax issues. Depreciation is primarily a monetary policy decision, having little to do with engineering decisions. Tax matters, especially corporate income taxes, are another candidate for reduced treatment. Spreadsheet analysis can reduce most of the problem solving to simply setting up the case and understanding how the data must be translated from the case information to the problem analysis.

Case Study

The following is typical of the case studies used in this course to illustrate the application of present value analysis.

Club Paper Case

Club Paper Company specializes in manufacturing high quality art paper and stationery bond. They use large quantities of wood pulp and clean cotton rag waste. The firm has averaged \$8 mil in annual sales for the last several years. They are a privately held corporation with long term debt of \$1.5 mil at 10% interest rate. Paid-in capital totals \$5.6 mil and retained earnings are another \$1.2 mil. Annual dividends are \$340,000.

The firm employs four technical people in its R&D operation with another two as administrative support. Total cost for salaries in R&D is \$280,000 per year plus fringe benefits, estimated to be 38%.

Over the last several years, Club Paper has invested several millions in new equipment and processes, targeted at productivity improvements and environmental protection. IRR estimates for these projects averaged 23% but the actual returns are closer to 19%.

Club Paper invested \$200,000 at the end of 1996 for new wastewater treatment and control equipment. The equipment expected to last 15 years will have no salvage value and will require on-going maintenance costing \$500 per month. Operation of the equipment will result in recovery of paper pulp previously lost. The pulp is worth \$300 per ton. Every million cubic feet of water processed contains an average of 3 tons of pulp; recovery is 95% effective. Club Paper expects to process 6 million cubic feet of water each month for the next 15 years. Draw a cash flow diagram for this case, using an assumption of 10-year equipment on an MACRS schedule. Find the IRR and compare it with the firm's cost of capital. What is an appropriate MARR for this firm?

PRODUCT LIFE CYCLE CONCEPTS

Understanding of the notions of product life cycle and the technology life cycle are essential for understanding the evolution of product designs and the total cost effectiveness of a set of engineering decisions. Three tools are important for this understanding; product life cycle curves, S Curves and Learning Curves. These tools are well documented in the literature and can also be taught in terms of case studies.

PROFITABILITY ANALYSIS

The last topic for inclusion in an effective course in engineering economics is profitability analysis. Engineers must understand how the overall performance of the firm is measured and how their engineering decisions ultimately transfer through to the final profitability of the firm. The conventional ratios such as Return on Investment, Return on Sales and Return on Assets are generally used and should be familiar to engineers. This is also a good point to deal with the issues of productivity and productivity measures.

NEED FOR REVISIONS TO COURSES

The engineering economics course as described in this paper and as taught in our department represents a major departure from conventional courses taught in most engineering and engineering technology programs. However, to properly prepare engineers for the practice of their profession, we must make these changes.

The use of case problems provides an added benefit in that they give engineering students practice at analyzing highly disordered data, making the decisions as they go along, of what information is pertinent and what is extraneous. This tool is important in giving engineering and engineering technology students the insight they need to make cost effective engineering decisions.

STUDENT RESPONSES

The response by students has been uniformly good. They appreciate the very applied nature of the course, and understand how this approach helps them develop the insight required for good engineering decision making. Students who have had internships or other industrial experience find the course especially useful and beneficial. These students, exposed to the engineering workplace, find the case study approach very representative of the decision frameworks used in engineering practice.

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