Engineering Economics for Freshmen Engineers

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Freshmen are usually considered to be lacking in the mathematical skills and sophistication required to perform an economic analysis of an engineering proposal. However, operating under the theory that everyone is an economist of sorts, making shrewd economic choices daily in their personal lives, the teacher can pose a problem of sufficient complexity to introduce the students to the basic economic analysis thought processes that will be used throughout their careers as engineers.

Leading into an assignment to evaluate the economics of an engineering problem I usually start with an easy question, "It is four years in the future and you have graduated and are offered two jobs; one at a salary of $54,000 per year and the other is a salary of $64,500 per year. The location of each job is within four miles of each other in the northeast United States of America. The benefits are so similar that there is effectively no difference. Which job do you accept?" Most students ask additional questions about the work hours (day job or night shift), total hours worked per week, the financial history of the two companies, etc. Eventually, they select the job that pays $200 more per week. Then I introduce the proviso that the higher paying job pays its salaried workers once a year, at the end of a full year of employment. We then explore how, if, and why they might select one job over the other. It is an opportunity to introduce the time value of money, what it means, and what it costs to live off one's credit card while waiting for that giant payday. Given that each employee is likely to receive a pay raise at the end of a year, we also introduce the concept of a widening pay gap due to the effect of compound interest. The whole example is geared towards explaining the time value of money and showing the students how to use simple arithmetic (not mathematics, such as present value and future value equations) to evaluate the economic worth of a dollar today and compare it to a dollar at a specific time in the future. At the age of eighteen, five years in the future is an eternity so it takes some time for their personal time and planning horizon to stretch out five years.

The key to introducing the concepts of engineering economic analysis is to lay out the evaluation steps and to lead the students through each step, in sequence, and develop the mathematical tools (and thinking process) to complete each step. Although engineering economic analysis for public and private projects often employ complicated analytical techniques to buttress the decision to proceed or to discard them, the underlying principles are easily understood and absorbed by freshmen.

The problem I selected this year was the case of a small municipality (similar to the size and population of the town where the university is located – about 23,000 residents) deciding to replace its current sodium vapor street lights heads with LED street light heads. The impetus for this was an article published by a firm (LEOTEK, Light-On Group[1]) on how to evaluate replacement street lighting for municipalities. Of course, the analysis suggested is slanted

1 ftp://ftp02.portlandoregon.gov/PBOT/Chi/COP%20Signal%20&%20St%20Lighting%20Reference/COP%20St%20Lighting%20Reference/LED%20Lights/Leotek.LED.Streetlight.Guide.V7-101613.pdf

toward their LED product but the analysis steps are a fair representation of how one might analyze the decision at the city engineer level.

The basic decision is, do we spend money now to put a more expensive (purchase price) cobra style street light head with LEDs on the existing poles? As part of the process the problem was divided into four parts; 1) gathering data on representative costs of purchasing commercial street light heads (both sodium vapor and LED), 2) determining the installation costs of removing existing streetlight heads after deciding on two of each type from the data gathered in the first step (labor and equipment), 3) estimating the life-cycle costs from the data collected in step 1, of the newly installed street light heads, and 4) determining the payback period and financing alternatives for the project.

The first step was accomplished by gathering data from four models of sodium vapor street light heads and four LED street light heads. The data included purchase price, electrical feed requirements, lumens emitted, and electricity consumed in operation.

The second step was accomplished by introducing the cost of an employee to the employer, in this case the fictional municipality. The costs introduced were salary, payroll taxes borne by the city, health care insurance, workers compensation insurance, vacations, and retirement systems costs. This introduced the students to the cost of employment of a workforce. In addition, the support equipment costs were estimated to include the cost of purchasing, maintaining, and operating the hydraulic lift trucks required for replacing the street light heads. Along the way, mandatory crew size and safety considerations were added to the mix. Exact numbers were not obtained but representative costs were provided. The main thrust of this part of the exercise was to introduce the freshmen to the concept of assembling the costs for staff and support equipment and reducing those costs to an hourly rate of operations for a crew and its equipment. Also stressed was setting up the cost analysis so all inputs were identified and entered once and only once to enable the student to revise the analysis as new information was discovered without searching through each calculation to change the inputs.

The third step was to generate a time-cost profile for removing and replacing the street light heads. Two situations were considered, 1) replacing the existing street light heads with similar sodium vapor heads and 2) replacing the existing street light heads with LED heads. The concept of fitting the remove and replace schedule into the annual budget of the city was discussed and investigated to see the effect on the city-wide project if removal and replacement was limited to the expected expiration of the existing light heads. Comparisons of the illumination provided at street level by each streetlight head were calculated, also.

The fourth step was to calculate the operating costs of each alternative (sodium vapor street light heads v. LED street light heads) and to develop a time cost profile. During this phase the operating costs of the LED street light heads was shown to overcome the difference in installation costs of the two proposed solutions. This difference was investigate three ways; 1) assuming all funds were independent of the time they were spent and calculating the payback time for the more expensive LED street light head, 2) introducing the cost of capital for the fictional city using its various borrowing mechanisms and calculating the time value of the funds spent on the project to calculate an effective payback time for the installation, and 3) adding a "sinking fund" created by the fictional city's tax collections to fund the project. The sinking fund analysis included interest paid on the money collected and invested before payout.

The four steps were offered over a period of three weeks to give the concepts time to sink in. Most students (freshmen) were unacquainted with the concept of maintaining a checkbook register or tracking their credit card accounts. Matching expenditures with time and within a budget were all part of the process of learning about engineering economics. While we were pursuing the problem the Project software from Microsoft office was being exercised in the class and the connection between activities, project costs, and project cost curves concepts were introduced. This segment of the course was designed to introduce the topics to the freshmen with the anticipation that the concepts would be reinforced during the subsequent three and a half years of their education in construction management.

How did it work?

The results were varied but worth the effort. The benefits were:

1) Development of facility with Excel (the workhorse of any economic analysis).

2) Exploding the myth that one does not need to know facts, it is all on the internet. Actually it is, but one has to know a few things to be able to mine the data that are out there.

3) Development of an appreciation of designing, equipping, and funding small teams of technicians to accomplish a well-defined, finite task.

4) Learning to work in small teams (3-4 students) to capture data and to perform analyses.

Taking the project on in four steps worked well. It provided the time to grade the submissions, to return them to the students, to discuss the solutions in class, and to increase the concept of analyzing a project in terms of its economic payback over the life of the project. This last point is crucial for the future analyses the students will be required to do in supporting their analyses of life-cycle cost analysis (particularly in the area of "green" buildings) during the next three years of their education. The performance of the class was heartening with class averages of B, A-, B and B for the four parts. Taking it slowly seemed to afford the students the luxury of pondering what they were doing and absorbing the process. The payback analysis was particularly enlightening.

The first order analysis for evaluating the competing cost streams associated with the sodium vapor lamp heads and the LED lamp heads involved applying the difference in operating cost to the difference in installation costs to determine the period of time to pay for the difference in installation costs. After completing that analysis, the concept of cost of capital was introduced and estimates of the municipality's borrowing costs were obtained from the internet. This cost of capital was then used to develop a longitudinal estimate of the flow of funds to install and to operate the streetlights. We avoided using the canned formulae available in Excel. These shortcuts are covered thoroughly in a future course in Engineering Economics. Doing the analysis in an Excel spreadsheet, with costs compared on a monthly basis, requires little more than arithmetic and the ability to structure a spreadsheet of monthly costs for the two options. Add in a dash of graphics and the analysis becomes apparent to the student. This approach equips the students to understand the magic of Internal Rate of Return, Net Present Value, Present Value, and Future Value when they encounter them in later courses.

The students do not understand all that is presented during the exercise. The fact that the students do not have a comprehensive understanding on the first attempt is not a detraction from the process. It is only important that they start on the road to understanding economic analyses of engineering projects. Their next encounter with cost-benefit analysis will come in follow-on courses in Construction Project Control and Engineering Economic Analysis. We have qualitative data (end of course surveys) and quantitative data (grades) for the performance of the past ten classes who had no introduction to cost-benefit analysis in their freshmen year. This is the first step in a longitudinal study of early introduction of various topics covered (and found wanting) in later years of the program. The variable measured will be the efficacy of early introduction of the engineering economics topic to produce better understanding and performance in the later phases of the program.

Bibliography

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