D. Introduction to economics and cost

1. Introduction to engineering economics
2. Cost concepts and design economics
3. Cost-estimation technique

Intro to Engineering Economics

- Definition – Systematic evaluation of the economic merits of proposed solutions to engineering problems. Or restated – All problems have multiple solutions and we need a set of tools to pick the "right" solution

For example: a motel's water heater breaks and needs to be replaced

  - Solution 1 – new standard efficiency boiler
  - Solution 2 – new high efficiency boiler
  - Solution 3 – solar thermal boiler

Engineering Economics

- Principles in engineering economics are:

  1. Alternative solutions to the same problem e.g. a motel that needs to replace a boiler
  2. Consistency in assessment – “everything must be measured in the same way”
  3. Understand that uncertainty is always present i.e. energy prices could rise or fall or savings from efficient equipment could be higher or lower

Engineering Economics

- Applying the principles to the motel boiler replacement example:

  1. Each boiler option would provide the same amount of hot water to the motel, i.e. we need to compare “apples to apples”

  2. All boiler options would include equipment and installation labor. All options should use the same energy prices and assume the same base case usage

  3. Recognize that prices may rise and savings may be higher or lower than projected. If using price escalators (increases) make sure they are the same across the options. If accounting for variation in savings by sure to apply the changes (e.g. 20% less savings, 15% more savings) uniformly

Project Cost Concepts

- All costs need to be accounted for order to compare alternative solutions. Costs can be grouped into 3 major categories:
  - First cost: the costs associated with installing a project, e.g. the costs to install a high efficiency boiler
  - Operation and maintenance cost: the costs required to operate equipment and to keep it in good working order, e.g. cleaning burners for boiler or cleaning thermal panels to ensure good solar conductivity
  - Life cycle cost: Total costs over the life of a project/installation, e.g. life cycle costs for a high efficiency boiler would include the first cost plus operations and maintenance costs.

Design Economics

- Consideration of cost over the whole life of a project and not just the capital costs
- Consideration of capital/first cost against operations and maintenance (O&M) costs

Design Economics

- Boiler replacement example: High efficiency boilers have a higher first cost compared to standard efficiency boilers
  - Standard efficiency boiler:
    - Installation cost-$15,000, O&M costs – $228,800
  - High efficiency boiler:
    - Installation cost-$20,000, O&M costs – $214,175
  - Comparison Standard vs. High Efficiency:
    - Installation - $5,000 higher for high efficiency
    - O&M costs - $14,625lower for high efficiency
    - Do you tradeoff $5,000 in first cost for $14,625 in O&M savings over the life of the equipment?

Cost Estimation Technique

- The cost estimation approach depends upon the stage in the construction/implementation process and the project economics
- Cost estimation varies from detailed contractor bids through tools such as RS Means (www.rsmeans.com)
- Generally, more accurate bids are required when the project economics more restrictive or the project is complex – basically when the “cost” of missing the budget is high

Cost Estimation Technique

- *Example of need for accurate estimation due to high cost of missing the budget*: HVAC retrofits in hospitals or data centers where it is critical that facilities are operating. That is, these facilities will have to operate no matter what cost. Project cost over runs have huge effects on operations.

- *Example of less sensitive estimates and budgets:* In the case of a lighting, lamp and ballast, retrofit for an office building is relatively simple. In this simpler case if the project is costs are off, the cost of missing the budget is relatively low.

E. Basic project evaluation

1. The time value of money
2. Evaluating a single project
3. Comparison and selection among alternatives
4. Evaluating project with the benefit-cost ratio method

Time Value of Money

- Present value and the time value of money are acknowledgements that $100 today is worth more than $100 in the future. Further, the longer it takes to acquire $100, the less that money is worth
- Why?
  - Money can be invested today and earn a return in the future, or over time
  - Prices may rise in the future and $100 will buy fewer goods, therefore reducing the “value” of that money
  - Future money limits your spending in the present, requiring patience

Discount and Interest Rates

Discount rate – the percentage by which future amounts are discounted they can be compared with present amounts

Present Value – the value today of a future amounts that have been discounted

Net Present Value – the *Present Value* of a project less the project cost

Interest rate – the percentage of money charged for its use. If the interest rate is 10% then the borrower must pay $0.10 per every dollar borrowed

Discount and Interest Rates

- Recognizing that money today is more valuable than money in the future, when we look at possible projects we need means to compare them to each other

- Applying a ***discount rate*** allows comparison of two future amounts

  – *In other words:* Do you want $60 today or $70 in one year? It will depend on the return on investment, and how much you discount future benefits or monies.

Discount and Interest Rates

- Discount rates are based on a complex financial calculation
- Most spreadsheet software will perform discount rate calculations.
- *Example:* the NPV function in Excel will calculate the net present value of a project by considering the project costs and the subsequent savings over time.
  - For example consider a project costs $25,000 to install, yields $9,000 annually and has a 10% discount rate
  - The Excel NPV function is = *NPV (rate, value1, value2, value3,…)* where the *values* are the costs and all savings associated with the project.
  - =NPV(10%, -$25,000,$9,000,$9,000,$9,000,$9,000,$9,000…)
  - Answer – NPV = $27,546

Benefit Cost Ratio

- Benefit cost ratio is a measure of the proportion of benefits to costs
- B/C = Project benefits/Project costs
- Payback – the number years it takes for project savings to equal project costs
  - Payback = Total Project Cost/Annual Savings ($)
- Return on Investment – Measures financial benefits of an investment, usually compared to other potential investments

Benefit Cost Ratio Calculations

- Sample project – high efficiency boiler replacement that is expected to last 10 years
  - Costs $20,000 - Savings $5,000 over a standard boiler
- Payback = $20,000/$5,000 = 4 years
- Payback - the project will payoff the original investment and begin yielding savings in 4 years
- ROI = $\dfrac{(\text{Annual Savings} * \text{Number of Years}) - \text{Costs}}{\text{Costs}}$

$$\frac{(\$5{,}000 * 10) - \$20{,}000}{\$20{,}000} = \frac{\$30{,}000}{\$20{,}000} = 150\%$$

- ROI – by investing the high efficiency boiler will yield a 150% over the original investment

Benefit Cost Ratio Calculations

- Note the in the previous example the savings were $5,000 per year for 10 years
- Recognizing that the savings will come in the future over 10 years, we need to adjust the savings by a discount rate.
- A discount rate will be used to adjust the future savings into present value terms. Using the previous example, savings in each future year will worth less today as it will be received further in the future.
- The value of savings in Year 1 is worth less than Year 2, which is worth less than Year 3, etc. For example $5,000 discounted at 10% yields the following discounted value (i.e. present value)
  - $5,000 received in 1 Year is worth $4,545 today
  - $5,000 received in 2 Years is worth $4,132 today
  - $5,000 received in 3 Years is worth $3,756 today
  - $5,000 received in 10 Years is worth $1,928 today

F. Additional elements of project and asset evaluation

1. Depreciation and income taxes
2. Price changes
3. Replacement analysis

Depreciation and Income Taxes

What is Depreciation?

- **Long-lived assets** such as real property, equipment, vehicles are purchased with the intention of owning them and using them for many years to make money for your business.

- When you purchase a **long lived asset**, you may convert the cost of the asset to an expense over its useful life. This treatment is referred to as Depreciation.

Depreciation and Income Taxes

- *Example*: assume a business purchases a high efficiency boiler with a useful life of 30 years for $20,000. Rather than recording the total expense of the equipment in the initial year of purchase, straight line depreciation would allow you to recognize expense of $20,000/30 years or $667 per year for 30 years (the assets useful life).

- The appropriate depreciation methodology is determined using Generally Accepted Accounting Principles or GAAP. While the following options may be the most common treatment there are many other methodologies.
  - Option 1 - $20,000 expense in Year 1 and $0 for Year 2 to Year 30
  - Option 2 - $667 expense in Year 1 and in each subsequent year through Year 30

- The net effect of Option 1 is a reduction to taxable income of $20,000 in year one only while the net effect option 2 is a reduction to taxable income of $667 per year for 30 years.

Replacement Analysis

- As shown in the boiler example above, the replacement of equipment can vary from standard efficiency to high efficiency, to a hybrid of renewables and higher efficiency.

- When comparing replacement opportunities it is important to consider first costs (initial equipment costs) as well as operating costs. For example, standard efficiency equipment is likely to lower initial/first costs but higher operating costs relative to more efficient equipment.

- When comparing replacement alternatives it is also critical to keep the specifications and cost inputs consistent. For example when replacing a boiler one should ensure that all options have the same capacity and the energy prices (used to calculate savings) are the same across all options.

G. Risk, capital and decision making with other factors

1. Breakeven and sensitivity analysis
2. Probabilistic risk analysis
3. The capital budgeting process
4. Decision making considering multi-attributes

Breakeven Analysis

- Breakeven analysis refers to the point where **total revenue** equals **total costs**. This concept is widely used in production and tries to answer the question, at what level of production does **total cost** equal **total revenue**?

- From an energy efficiency perspective, we look at point where **total project cost** equals **total project savings**.

Breakeven Analysis

- As shown earlier the breakeven point is measured in time, the time it takes for accumulated savings to equal total project costs. This is the same concept as payback.

- Using an example from above, if a project costs $20,000 and saves $5,000 each year, at what point do the savings equal the costs?

  – $20,000/$5,000 = 4 years to breakeven

Sensitivity Analysis

- Using the previous example, we can question regarding the sensitivity of the breakeven analysis. For example what would happen to the breakeven analysis if:
  - Project costs were 25% or 50% higher?
  - Project savings were 50% of projections?
  - Energy prices went up 15%?
- Each of these changes will impact the breakeven point.

Sensitivity Analysis

- To conduct sensitivity analysis one should re-run the breakeven analysis, adjusting, for example energy prices (which impact savings), project costs, and project savings

- Using the above examples, the breakeven analysis can be recalculated
  - Initial analysis: $20,000 project costs/$5,000 project savings annually = 4 years
  - Project costs were 25% higher: $25,000/$5,000 = 5 years
  - Project savings were 50% of projections: $20,000/$2,500 = 8 years
  - Energy prices went up 15%: $20,000/$5,750 = 3.5 years. Note that increases in energy costs have a positive impact on the breakeven analysis since there will be more savings as prices rise.

Probabilistic Risk Analysis

- **Probabilistic risk assessment (PRA)** is a systematic and comprehensive methodology to evaluate risks associated with a complex engineered / technological entities.

- Risk in a PRA is defined as a feasible detrimental outcome of an activity or action characterized by two quantities:
  - the magnitude (severity) of the possible adverse consequence(s), and
  - the likelihood (probability) of occurrence of each consequence.

Probabilistic Risk Analysis

- Consequences are expressed numerically (e.g., the number of people potentially hurt or killed) and their likelihoods of occurrence are expressed as probabilities or frequencies (i.e., the number of occurrences or the probability of occurrence per unit time).

- The total risk is the expected loss: the sum of the products of the consequences multiplied by their probabilities.

- The spectrum of risks across classes of events are also of concern, and are usually controlled in licensing processes – it would be of concern if rare but high consequence events were found to dominate the overall risk, particularly as these risk assessments are very sensitive to assumptions (how rare is a high consequence event?)

Probabilistic Risk Assessment

- Probabilistic Risk Assessment usually answers three basic questions:
  - What can go wrong with the studied technological entity, or what are the initiators or initiating events (undesirable starting events) that lead to adverse consequence(s)?
  - What and how severe are the potential detriments, or the adverse consequences that the technological entity may be eventually subjected to as a result of the occurrence of the initiator?
  - How likely to occur are these undesirable consequences, or what are their probabilities or frequencies?

Capital Budgeting Process

- **Capital budgeting** is the planning process used to assess a company's choice to invest in various **long lived assets**. The process can be viewed as a budget for major capital, or investment expenditures.

- Methods employed in the decision analysis to purchase capital use incremental cash flows for each potential investment. Methods used range from Simple Payback calculations to more sophisticated Net Present Value (NPV) and Return on Investment (ROI)

- NPV and ROI are considered a more reliable method as they take into account the time value of money

- The example used in the previous "Benefit Cost Ratio Calculation" yields a non discounted ROI of 150%. When the time value of money is applied to the incremental cash flow the discounted ROI in today's dollars is 43%. Still a fairly robust return.

Capital Project Selection Example

- A company has allocated $350,000 for energy related capital projects.
- Site staff have identified the following projects:

		Savings			
Project	Costs	Energy	Labor	Total	Length
Exterior LED Retrofit	$ (150,000)	$ 15,000	$ 15,000	$ 30,000	20
Cooling Tower Replacement	$ (200,000)	$ 14,000	$ -	$ 14,000	15
Energy Management System Upgrade	$ (125,000)	$ 18,750	$ -	$ 18,750	15
Interior Lighting Retrofit	$ (35,000)	$ 11,000	$ -	$ 11,000	7
Retro-commissioning	$ (15,000)	$ 11,000	$ -	$ 11,000	5

- Given the budget which projects are selected?

Capital Project Selection Example

- Analysis of the projects is as follows:

	Project	Costs	Savings			Payback	ROI
			Energy	Labor	Total		
1	Exterior LED Retrofit	$ (220,000)	$ 15,000	$ 15,000	$ 30,000	7.3	31%
2	Cooling Tower Replacement	$ (200,000)	$ 14,000	$ -	$ 14,000	14.3	-37%
3	Energy Management System Upgrade	$ (125,000)	$ 18,750	$ -	$ 18,750	6.7	26%
4	Interior Lighting Retrofit	$ (35,000)	$ 11,000	$ -	$ 11,000	3.2	59%
5	Retro-commissioning	$ (15,000)	$ 11,000	$ -	$ 11,000	1.4	179%
	Total Portfolio	$ (595,000)	$ 69,750	$ 15,000	$ 84,750	7%	13%

- Based upon payback the projects are ranked as follows- 5,4,3,1,2
- Based upon ROI (and discounting for future savings) the projects are ranked as follows-5,4,1,3,2
- Note that by accounting for the time value of money we shift the order of the projects. With $350,000 to spend the firm would undertake projects 5, 4, and 1

Capital Project Selection Example

- While the financial analysis of projects uses the best available information, sometimes inputs may change, or perhaps not be known with certainty. Sensitivity analysis will help inform the decisions.

- How would the analysis be impacted by:
  – A 10% increase in energy prices?
  – A rise in labor rates?
  – A utility program offering $250,000 in no interest loans?
  – The likelihood that the cooling tower will fail soon and require emergency backup of $175,000 while it is being repaired?

Answers

- How would the analysis be impacted by:
  - A 10% increase in energy prices? Paybacks and returns would improve since the savings would be higher
  - A rise in labor rates? Paybacks and returns would be worse since project costs would be higher
  - A utility program offering $250,000 in no interest loans? Would allow the firm to do more projects, effectively increasing the capital pool to $600,000
  - The likelihood that the cooling tower will fail soon and require emergency backup of $175,000 while it is being repaired? Consider moving up the cooling tower project up

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