Engineering Economics:
Comparing Financial Characteristics of Design Options

Engineering Econ Example: Comparing Alternatives

Where Should You Build?
Far or Near

Figure by MIT OCW.
Example: Comparing Alternatives

<table>
<thead>
<tr>
<th></th>
<th>Site A</th>
<th>Site B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost to build @ site</td>
<td>$250,000</td>
<td>$500,000</td>
</tr>
<tr>
<td><strong>Monthly Costs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Hauling Distance</td>
<td>6 miles</td>
<td>5 miles</td>
</tr>
<tr>
<td>Hauling Expense</td>
<td>$15/mile</td>
<td>$15/mile</td>
</tr>
<tr>
<td>Shipments</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td><strong>Total Monthly Cost</strong></td>
<td>$22,500</td>
<td>$18,750</td>
</tr>
<tr>
<td><strong>Monthly Savings</strong></td>
<td></td>
<td>$3,750</td>
</tr>
</tbody>
</table>

• Simple payback:
  - Site B is preferred after 5 years
    \[
    \frac{($500,000 - $250,000)}{\$3,750/\text{month}} \approx 67\text{ months}
    \]

• Considering reasonable business assumptions
  (15% discount rate)
  - Site B is preferred after > 12 years

How do we come up with such a difference? ...
What is Engineering Economy?

• Engineering economy
  systematic evaluation of the economic merits of proposed solutions to engineering problems
• Principles:
  - Develop the alternatives
    • Alternatives need to be identified and defined.
  - Focus on the difference
    • Only the differences in expected future outcomes among the alternatives will effect the decision.
  - Use a consistent viewpoint
    • Prospective outcomes should be developed from a consistent, defined viewpoint.
  - Consider all relevant criteria
  - (try to) Use a common unit of measure
  - Make uncertainty explicit
    • Uncertainty is inevitable. Identify and explore it in analyses.
  - Revisit your decisions

Engineering Economy

• Objective - Evaluation
  - How to compare the economic value of alternative design options?
• Basis - Cash Flow Analysis
  - One is indifferent between investments with equivalent cash flows
    • Equivalence occurs when one is indifferent between two sets of cash flows
• Key issues
  - Time value of money
  - Cash flows occurring at different times
  - “Designs” with different durations
Cost Concepts: Nomenclature

• Capital
  - Wealth (money or property) that can be used to produce more wealth

• Sunk cost
  - Expense which has happened in the past. No relevance to alternatives being considered.

• Opportunity cost
  - Cost / value of the best rejected alternative

• Fixed cost
  - Magnitude does NOT vary with changes in level of activity (output) -- over some range of activity
    - Insurance
    - Management and administrative salaries
    - Licenses

• Variable cost
  - Magnitude DOES vary with level of activity (output)

Engineering Economy

• Objective - Evaluation
  - How to compare the economic value of alternative design options?

$20k vs $25k vs $350 / Month Lease

Figure by MIT OCW.
Determining Equivalence:
Issue - Value over time

- Money now has a different value than the same amount at a different date
  - Would you prefer $75 today or $80 in one year?
  - It depends - Rate of return on investment

- Proper name: Discount Rate, $i$ or $r$
  - Future benefits / costs are reduced (ie, “discounted”) to compare with present

Return on Capital

- Why consider return on capital?
  - For most engineering projects, capital must be tied up for some period of time
    - Purchase a piece of equipment
    - Fund a research project
  - Revenues from the use of capital
    - Provides incentive to forego using the capital today for consumption
    - Provides incentive to take on risk of losing capital

- Opportunity cost (of capital)
  - Profit available from the use of capital in some other alternative

- Frequent engineering economy question:
  Does the return on capital exceed the opportunity cost?
Notation

- \( i \) = effective interest rate per interest period
- \( N \) = number of compounding periods
- \( P \) = present sum of money (present value)
  - equivalent value of cash flows at a reference point in time called the present
- \( F \) = future sum of money (future value)
  - equivalent value of cash flows at a reference point in the time called the future
- \( A \) = end-of-period cash flows
  - in a uniform series of payments continuing for a specified time, starting at the end of the first period and continuing to the end of the last period

How does Capital Change in Value with Time?

Simple Interest

- **Simple interest** (infrequently used)
  - Total interest earned (charged) is linearly proportional to
    - the initial amount of principal (loan)
    - Interest rate
    - Number of time periods of commitment

\[
Total\ Interest = I = P \cdot N \cdot i
\]

- \( P \) = principal amount lent or borrowed
- \( N \) = number of interest periods
- \( i \) = interest rate per period
How does Capital Change in Value with Time?

Compound Interest

- Compound interest
  - Interest earned (charged) for a period is based on
    - Remaining principal plus
    - Accumulated (unpaid) interest at the beginning of the period

\[ I_n (\text{Interest in Period } n) = P_n i \]

\[ P_n = \text{Principal in period } n \]

\[ i = \text{interest rate per period} \]

\[ I = \sum_{n} I_n \]

Cash Flow Diagram
Formulae for N Periods - Single Payments

Future Amount =
\[ P \times (1 + i)^N = P \times (c_{af}) \]

\[ c_{af} \equiv \text{Compound Amount Factor} \]

Common notation:
\[ F = P(F/P, i\%, N) \]

Present Amount =
\[ \frac{F}{c_{af}} = \frac{F}{(1+i)^N} \]

\[ 1/c_{af} \equiv \text{Present Worth Factor} \]

Common notation:
\[ P = F(P/F, i\%, N) \]
Single Payment Example

- An investor can purchase land that will be worth $10k in 6 years
- If the investor’s discount rate is 8%, what is the max they should pay today?

How Do Specific Parameters Effect the Result?

The present value of a single future payment ($10k) decreases as the discount rate increases. The diagram shows how the present value changes with the year when the payment is received for discount rates of 2%, 8%, and 20%.
Relating a Uniform Series of Payments to P or F

- Uniform series of payments - often called an Annuity
- By convention:
  - P at time 0
  - A at end of period
  - F at end of period

Therefore:
- 1st A, 1 period after P
- Last A, coincident with F

Derive Uniform Series Compound Amount Factor

- How do we find the present value (PV) of N payments @ $A?
- Subtract the PV of an infinite series of payments starting at N+1 from the PV of an infinite series of payments starting at 1
### Formulas for N Periods

**Finite Series of Equal Payments**

<table>
<thead>
<tr>
<th>Formula</th>
<th>Description</th>
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</table>
| a) **Future Value (F)**<br>\[ F = \sum_{i=0}^{N} A(1+r)^i \]
| b) **Payment (A)**<br>\[ A = \frac{P \cdot (1 + r)^N - 1}{r} \]

\[
\text{Crf} = \text{Capital Recovery Factor}
\]