Engineering Economics:
Comparing Financial Characteristics of Design Options

Massachusetts Institute of Technology
Department of Materials Science & Engineering

3.080 Econ & Enviro Issues In Materials Selection
Randolph Kirchain

Engineering Economic Analysis: Slide 1

Engineering Econ Example: Comparing Alternatives

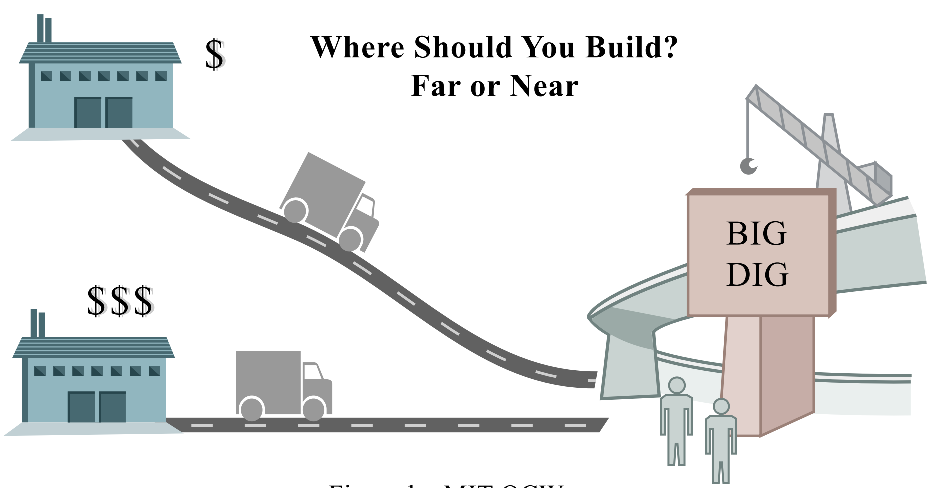

Figure by MIT OCW.

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Engineering Economic Analysis: Slide 2

Example: Comparing Alternatives

Cost	Site A	Site B	
Cost to build @ site	$250,000	$500,000	
Monthly Costs			
Average Hauling Distance	6	5	miles
Hauling Expense	$15	$15	/mile
Shipments	250	250	/month
Total Monthly Cost	$22,500	$18,750	

Monthly Savings	$3,750

Example: Comparing Alternatives

- **Simple payback:**
  - **Site B is preferred after 5 years**

$$\frac{(\$500{,}000 - \$250{,}000)}{\$3{,}750/month} \approx 67 months$$

- **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?**

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

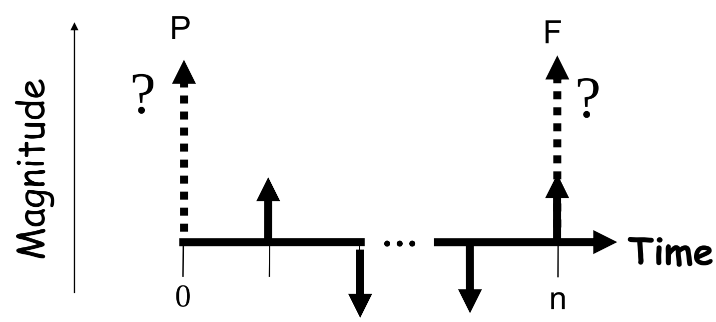
I_n (Interest in Period n) $= P_n i$

P_n = Principal in period n

i = interest rate per period

$$I = \sum_n I_n$$

Cash Flow Diagram



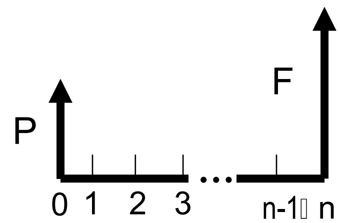
Formulae for N Periods –
Single Payments

Future Amount =

P (1 + *i*)^N =

P (caf)

caf ≡ **Compound Amount Factor**



Common notation:

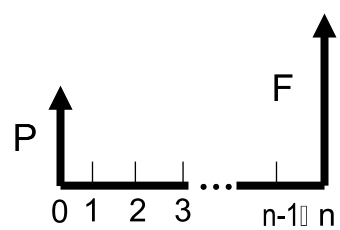
F = P(F/P, i%, N)

Formulae for N Periods –
Single Payments

Present Amount =

$$\frac{F}{caf} = \frac{F}{(1+i)^N}$$

1/caf ≡ **Present Worth Factor**



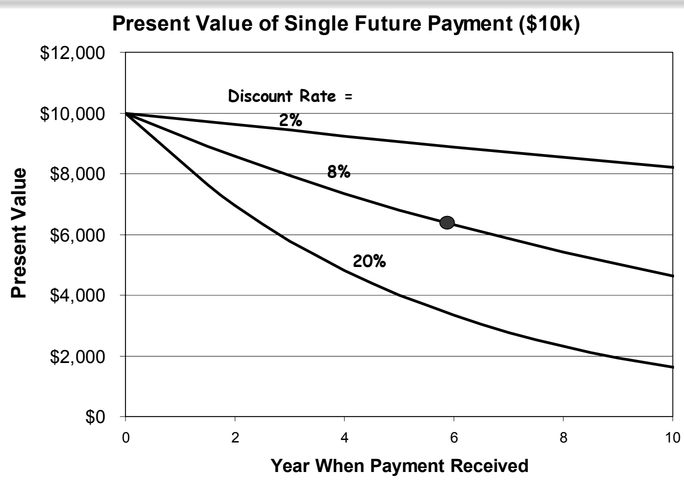
Common notation:

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?

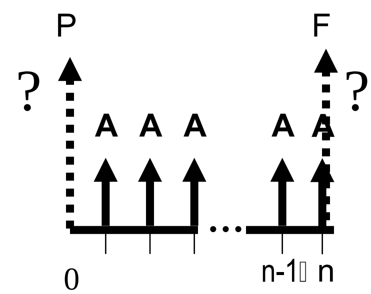
How Do Specific Parameters Effect the Result?



Relating a Uniform Series of Payments to P or F

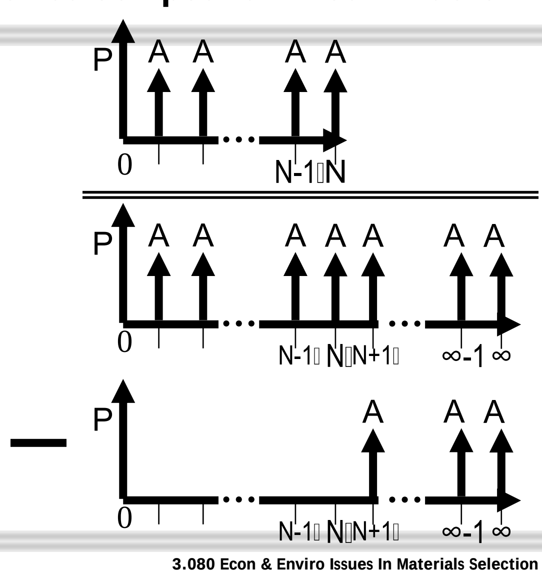
- **Uniform series of payments - often called an** *Annuity*
- **By convention:**
  - **P at time 0**
  - **A at end of period**
  - **F at end of period**

Therefore:
  - **1^{st} 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**



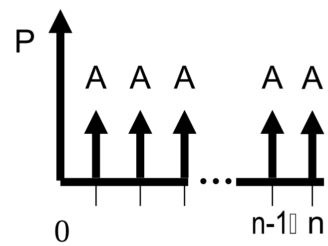
Formulas for N Periods

Finite Series of Equal Payments

a) Future Value (F)

$$= \sum_{i}^{N} A(1+r)^{i}$$

$$= A \frac{[(1+r)^{N} - 1]}{r}$$



b) Payment (A)

$$= P \times r \frac{[(1+r)^{N}]}{[(1+r)^{N}-1]}$$

$$= P\ (crf)$$

crf = Capital Recovery Factor