# Engineering Economics

## Overview and Application in Process Engineering Industry

10.490 ICE
Kangyi MAO
02 OCT 2006

## WHAT IS ECONOMICS?

**"Economics is the study of how people and society choose to employ scarce resources that could have alternative uses in order to produce various commodities and to distribute them for consumption, now or in the future, …"**

from Paul Samuelson and William Nordhaus, *Economics*, 12th Ed., McGraw-Hill, New York, 1985.

## WHAT IS ENGINEERING ECONOMICS?

**The application of economic principles to engineering problems, for example in comparing the comparative costs of two alternative capital projects or in determining the optimum engineering course from the cost aspect.**

## WHY DO WE NEED TO KNOW ABOUT THIS?!

- Optimal cost-effectiveness
- Alternative possibilities (Cal Tech Industries!)

## WHAT DO WE NEED TO KNOW?

- Time value of money
- Estimation of cash flows
- Quantitative measurements of profitability
- Systematic comparison of alternatives

# Time Value of Money

**The fundamentals underlying all financial activities!**

## TIME VALUE OF MONEY

- **Why does money have time value?**

  – **The owner of the money must defer its use. Thus, the person using the money must pay for deferring the benefits.**

  – **An alternative use of the money could have generated other benefits, e.g. interests.**

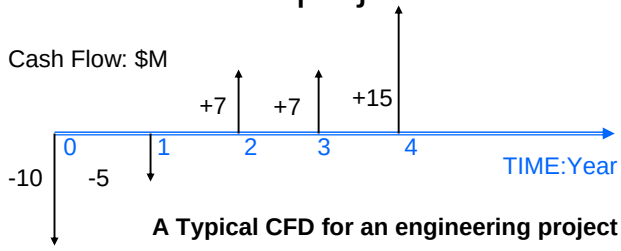
- **How do we characterize time value?**

  –**We use an interest rate, so that the effect of time is proportional to the total amount of money involved and positively related with the length of time.**

$$PV = \frac{FV}{(1+r)^n}$$

## CASH FLOW DIAGRAM

- Cash flow diagram is adopted to show the cash flows for a project over time.




**A Typical CFD for an engineering project**

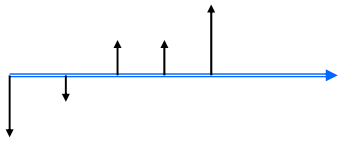
- How to project cash flows?
  - Cost estimation (the task of engineers!)
  - Product pricing and sales projection (Mutual efforts of S&M dept., consulting, engineers, and project managers)

# Quantification of Profitability

**The central target of most projects!**

## NET PRESENT VALUE (NPV)

$$NPV = \sum_{n=1}^{N} C_n (1+i)^{-n}$$



Examines the total value of all cash flows at time 0.

"i" is defined as the rate of return that could be achieved otherwise, or cost of capital.

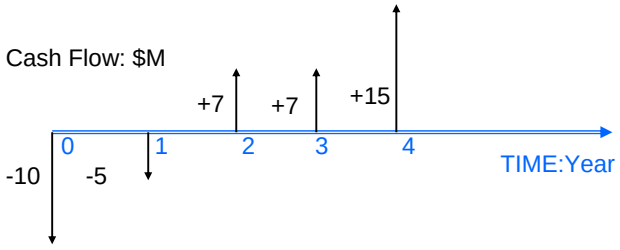
If NPV>0, the project is acceptable.

For our sample CFD

- The expected rate of return (cost of capital) is 10%
- The present value of C(0): PV[C(0)] = -$10M
- The present value of C(3): PV[C(3)] = 7/(1+10%)^3 = $5.23M
- The net present value of the project: SUM{PV[C(i)]} = $6.74M
- Project accepted!

## PAYBACK PERIOD

- **This measure is often used as a "quick and dirty" measure of profitability**
- **Also called Payout Time**
- **Defined in units of time (months or years)**
- **The time for the cumulative cash flow to achieve a value of 0.0. Usually, payback time does not consider interest.**




- **For our sample CFD, the payback period is approximately 3.1 years.**

## RETURN ON INVESTMENT (ROI)

- A comparison of the money earned (or lost) on an investment to the amount of money invested.

$$ROI = \frac{Annual\ Average\ Profit}{Total\ Investment}$$

- Generally does not calculate time value.
- In the example, if we assume cash flows at year 1&2 are total investment, we have ROI=(7+7+15-10-5)/4/(10+5)=~24%

## INTERNAL RATE OF RETURN (IRR)

- The IRR is defined as any discount rate that results in a net present value of zero, and is usually interpreted as the expected return generated by the investment.
- In general, if the IRR is greater than the project's cost of capital rate, the project will add value for the company.

$$NPV = \sum_{n=1}^{N} C_n (1 + IRR)^{-n} = 0$$

- In our example, IRR is calculated to be 26%

## RECOMMENDATION?

- Use NPV and IRR
- The others neglect the time value of money!
- Microsoft Excel have a group of functions designed to calculate these values.
- Don’t forget about the soft benefits and the requirements from other perspectives!

## TYPICAL ACCOUNTING TOOLS

- Income Statement is prepared on an accrual basis. It records expenses when the cost is incurred, not when the bill is paid. It gives an overview about how much the project is actually gaining during individual years.

- Project Cash Flow Statement is similar to the project checkbook. It shows the exact time that the checks are written and the savings are received. Compared with income statement, the cash flow statement does not include depreciation expense. Instead, the cost of the system is a cash outflow in the initial period, when the check is written.

## Example: Income Statement

| Year | 1 | 2 | 3 | 4 | 5 | **Total** |
|---|---|---|---|---|---|---|
| Implementation Costs | | | | | | **-22,000** |
| System Depreciation | -400 | -400 | -400 | -400 | -400 | **-2,000** |
| Service Contract | -1,750 | -1,750 | -1,750 | -1,750 | -1,750 | **-8,750** |
| Supplies & Miscellaneous | -250 | -250 | -250 | -250 | -250 | **-1,250** |
| Modification of the LIMS | -10,000 | 0 | 0 | 0 | 0 | **-10,000** |
| Installation | 0 | 0 | 0 | 0 | 0 | **0** |
| Labor Savings | | | | | | **153,880** |
| Salary | 21,650 | 21,650 | 21,650 | 21,650 | 21,650 | **108,250** |
| Tax | 1,660 | 1,660 | 1,660 | 1,660 | 1,660 | **8,280** |
| Benefits | 6,500 | 6,500 | 6,500 | 6,500 | 6,500 | **32,480** |
| Viariable Costs | 970 | 970 | 970 | 970 | 970 | **4,870** |
| Material Savings | | | | | | **10,400** |
| Label | 1,720 | 1,720 | 1,720 | 1,720 | 1,720 | **8,600** |
| Ink | 360 | 360 | 360 | 360 | 360 | **1,800** |
| Net Income* | 20,460 | 30,460 | 30,460 | 30,460 | 30,460 | **142,280** |

*: The net income here is actually net savings, so there is no income tax associated.

## Example: Project Cash Flow Statement

| Year | 0 | 1 | 2 | 3 | 4 | 5 | Total |
|---|---|---|---|---|---|---|---|
| Implementation Costs | | | | | | | **-$22,000** |
| System Cost | -2,000 | 0 | 0 | 0 | 0 | 0 | **-2,000** |
| Service Contract | 0 | -1,750 | -1,750 | -1,750 | -1,750 | -1,750 | **-8,750** |
| Supplies & Miscellaneous | 0 | -250 | -250 | -250 | -250 | -250 | **-1,250** |
| Modification of the LIMS | -10,000 | 0 | 0 | 0 | 0 | 0 | **-10,000** |
| Installation | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| Labor Savings | | | | | | | **153,880** |
| Salary | 0 | 21,650 | 21,650 | 21,650 | 21,650 | 21,650 | **108,250** |
| Tax | 0 | 1,660 | 1,660 | 1,660 | 1,660 | 1,660 | **8,280** |
| Benefits | 0 | 6,500 | 6,500 | 6,500 | 6,500 | 6,500 | **32,480** |
| Viariable Costs | 0 | 970 | 970 | 970 | 970 | 970 | **4,870** |
| Material Savings | | | | | | | **10,400** |
| Label | 0 | 1,720 | 1,720 | 1,720 | 1,720 | 1,720 | **8,600** |
| Ink | 0 | 360 | 360 | 360 | 360 | 360 | **1,800** |
| Net Cash Flow* | -12,000 | 30,860 | 30,860 | 30,860 | 30,860 | 30,860 | **142,280** |
| Accumulative Cash Flow | -12,000 | 18,860 | 49,710 | 80,570 | 111,420 | 142,280 | **142,280** |

*: The Net Cash Flow here is actually net savings, so there is no income tax associated.

# Cost Estimation

**Task of Engineers!**

## TYPES OF COSTS

**Capital Costs**

- **Fixed equipment**
- **Working capital**

**Operating Costs**

- **Direct costs**
- **Fixed costs**
- **General costs**

**Evaluating rough cost estimates for both using the same approach:**

**Use historical data to develop correlations and apply corrections for unique factors in specific situations.**

## HOW ACCURATE DO YOU WANT IT TO BE?

**We must balance the needed accuracy with the cost to perform.**

**(See Peters and Timmerhaus, Pg 160-162)**

| Name | Accuracy | Application | Process detail |
|---|---|---|---|
| Order of magnitude | -30 to +50% | Screen investments | Block flow diagram |
| Study | -15 to +30% | Finalize major choices | PFD + rough design of major equipment |
| Definitive | -5 to +15% | Control costs | P&I Drawing, detailed M&E balances, equipment specifications |

Where we are!

Rather overestimate than underestimate

**No shortcut: A flowsheet simulation (e.g., ABACUSS) is required when developing a definitive cost estimation. The information is required for accurate estimates of both capital and manufacturing costs.**

## ESTIMATION OF CAPITAL COSTS

- **A couple of very rough methods (initial screening)**
  - **Turnover Ratio**
  - **Lang's Factor**
- **Bare Module method**
  - **The primary method used in process industry**
  - **First calculate the cost of individual equipment**
    - Specific equipment type
    - Material of construction
    - Operating pressure
  - **Estimate other indirect costs with appropriate factors**
  - **See Guthrie (1974) and Ulrich (1984) for further details**

## TURNOVER RATIO

- **Values of 0.2 to 8.0; usually 1.0 to 1.25 in process industries**

$$TR = \frac{(\text{gross annual sales})}{(\text{fixed capital})}$$

We can use this to estimate the fixed capital costs for a plant making a known quantity for sales.

## LANG'S FACTOR

$$LF = \frac{(\text{Total capital cost})}{(\sum \text{Delivered cost of major equipment})}$$

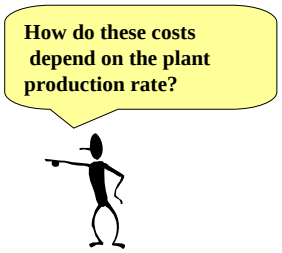
We use this as a guideline for the ratio of major equipment to total capital costs.

**VERY ROUGH CAPITAL COST ESTIMATION**
**(Use this with caution!)**

## OPERATING COSTS

**These are incurred with every unit of production and do not include capital items.**

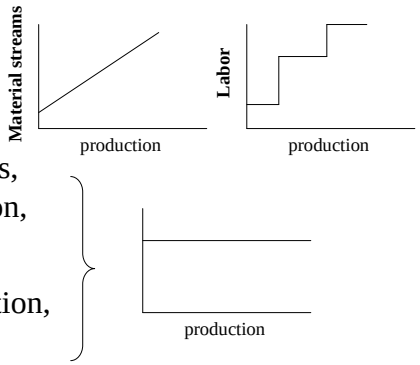
- **Direct** - Materials, labor, utilities, supplies, waste treatment, etc.
- **Fixed (indirect)** - Land taxes, insurance, plant administration, etc.
- **General expenses** - Corporation, sales&marketing, R&D, etc.




## OPERATING COSTS

**These are incurred with every unit of production and do not include capital items.**

- **Direct** - Materials, labor, utilities, supplies, waste treatment, etc.
- **Fixed (indirect)** - Land taxes, insurance, plant administration, etc.
- **General expenses**- Corporation, sales&marketing, R&D, etc.



## HINTS FOR ESTIMATION OF OPERATING COSTS

- **Do not use standard inflation for energy or raw materials costs.**
  - ***These can change rapidly + and - due to international incidents.***
- **Account for all shifts and overhead when estimating labor costs**
  - ***Overhead is about 40% of salary***
- **Personnel do not scale with production when equipment size can be increased.**

## REQUIREMENT OF ICE PROJECT?

- Categorized cost estimation
  - Equipments (Assuming no other capital costs)
    - Rental or purchase?
    - Piece-wise calculation
  - Raw materials
  - Utilities
    - Heating/Cooling/Pressure&Vacuum Supply
  - Waste treatment
    - Wastes in various phases
- Target?
  - Cost per pound
  - Campaign time

## SUMMARY

- Time value of money
  - Why does money have time value?
  - How to calculate?
- Quantification of profitability
  - NPV / Payback period / ROI / IRR
- Typical accounting tools
  - Income statement and cash flow statement
- Cost estimation
  - Capital costs and operating costs
  - Requirement of ICE project