Profitability Analysis

Dr. Suverna Trivedi

Assistant Professor

Department of Chemical Engineering

IIT Kharagpur

Profitability analysis

Objectives

- To asses the potential investment opportunities.
- To evaluate the profitability of a project
- To compare investment opportunities
- To decide on replacements

Profitability Analysis

❑ **Profitability Analysis** is a method businesses use to evaluate how much **profit** they make from different products, services, customers, or business segments. It helps companies understand **what is making money and what is not**, so they can make smarter decisions.

- **Why Is It Important?**

✅ Identifies the most profitable products/services

✅ Helps reduce costs and improve efficiency

✅ Guides pricing and investment decisions

✅ Supports business growth by focusing on high-margin areas

Profitability Standards

- A profitability standard is a quantitative measure of profit with respect to the investment required to generate that profit.
- Any anticipated profit from an investment must be judged relative to some profitability standard.
- The profit must be judged relative to the investment.
- For any investment to be profitable, the investor (corporate or individual) expects to receive more money than the amount of capital invested.
- A fair rate of return, or return on investment, must be realizable.

Investment	Capital Investment (Rs.)	Profit per annum	Return on investment
A	1,00,000	10,000	10 %
B	10,00,000	30,000	3 %

Profitability Standards

- **Cost of capital**
- **Minimum Acceptable Rate of Return.**

- **Cost of capital**: The Cost of Capital is the amount paid for the use of capital from sources as bonds, stocks, and loans.
- **Minimum Acceptable Rate of Return (MARR)** is a reasonable rate of return established for the evaluation and selection of alternatives.
- A project is not economically viable unless it is expected to return at least the MARR.
- The MARR is also known as: The Hurdle Rate, The Cut-off Rate, The Benchmark Rate, and The Minimum Attractive Rate of Return

- MARR = Np,avg/TCI

Cost of Capital

- The Cost of Capital is the amount paid for the use of capital from such sources as bonds, stocks, and loans.
- A company generally use a balance of both debt financing (long-term bonds) and equity financing (shares/stocks).
- The overall cost of capital is the weighted average of the cost of debt and the cost of equity.

$$\mathbf{i_c = (DR \times i_d) + (1\text{-}DR)\, i_e}$$

i_c = Cost of capital

DR = Debt ratio = Total debt/Total asset

i_d = Interest rate due on debt

$\mathbf{i_e}$ = Cost of equity

Example :A company was financed 55% with debt at an average 8% interest and 45% with equity that carried an expectation of a 25% return.

The overall Cost of Capital would be:

$$i_c = (DR \times i_d) + (1\text{-}DR)\, i_e$$

$$= (0.55 \times 0.08) + (0.45 \times 0.25)$$

$$= 0.1565$$

$$= 15.65\ \%$$

Target: Achieve a profit which meets or exceeds this interest rate.

Suggested values for risk and minimum acceptable return on investment

Investment description	Level of risk	Minimum acceptable return m_{ar} (after income taxes), percent/year
Basis: Safe corporate investment opportunities or cost of capital	Safe	4–8
New capacity with established corporate market position	Low	8–16
New product entering into established market, or new process technology	Medium	16–24
New product or process in a new application	High	24–32
Everything new, high R&D and marketing effort	Very high	32–48+

Methods for Calculating Profitability

A. The methods that do not consider the Time Value of Money:

- Rate of Return on Investment (ROI)
- Payback Period (PBP)
- Net Return

B. The methods that consider the Time Value of Money:

- The Discounted Cash Flow Rate of Return (DCFROR)
- Net Present Worth/Value (NPW, NPV)

C. Annualized Cost Method

Calculating Profitability:

Rate of Return on Investment

- For those methods that do not consider the time value of money, it is not important what depreciation schedule is used in the evaluation.
- Therefore, straight-line depreciation is often used for convenience.
- Rate of Return on Investment (ROI):

$$\text{ROI} = \frac{Annual\ Net\ Profit}{Total\ Capital\ Investment}$$

Depending on corporate policy or decision maker:

- Gross Profit may be used in place of Net profit
- Fixed Capital Investment (FCI) may be used in place of TCI

Calculating Profitability:

Rate of Return on investment

- Net profit usually is not constant from year to year for a project. Total investment also changes if additional investments are made during project operation.
- In such a case, it is recommended to take the average ROI over the entire project life.

$$\mathbf{ROI} = \frac{1/N \sum_{j=1}^{N} N_{p,j}}{\sum_{j=-b}^{N} TCI_j} = \frac{N_{p,avg}}{\sum_{j=-b}^{N} TCI_j} = \frac{N_{p,avg}}{TCI}$$

- N = Evaluation period
- Np,j = Net profit in year j
- -b = The year in which first investment is made in the project with respect to zero as the start-up time
- TCIj = Capital investment in year j
- Np,ave == Average value of Net Profit per year

Calculating Profitability:
Rate of Return on investment

- An ROI calculated from any of these equations can be compared directly with an assumed MARR value to judge profitability.

- If ROI ≥ MARR, the project offers an acceptable rate of return.

- Otherwise, the project is not desirable for investment with respect to MARR.

Turnover Ratio

- Turnover Ratio represent the ratio of Gross Sales to the Fixed Capital Investment.

- Turn over ratio = $\frac{Gross\ sales}{Fixed\ Capital\ Investment}$

- Capital ratio = $\frac{1}{Turnover\ ratio}$

- For chemical industries the turnover ratio is about one. Values up to 5 are common for very efficient processes.
- More productive Fixed Capital can be obtained by more compact flow-sheet design and higher productivity of equipment by process intensification.

Payback Period:

- The Payback Period (or Payout Period) is the length of time necessary for the total return to equal the capital investment.

- Payback Period (PBP) = $\frac{TCI}{Annual\ cash\ Flow}$

- PBP= $\frac{FCI}{Annual\ cash\ Flow} = \frac{V+A_x}{A_i} = \frac{V+A_x}{A_{avg}}$

- V = Manufacturing FCI
- Ax= Non-manufacturing FCI
- Aj = Annual Cash Flow

- Then PBP represents the time required for the cash flow to equal the original FCI.
- If the the cash flow changes from year to year. average value cash can be used.
- Calculated PBP should be compared to a PBP obtained from the assumed MARR

Payback Period from MARR

Usually, Working Capital is 15% of TCI.

- PBP= $\frac{FCI}{Annual\ cash\ Flow} = \frac{V+A_x}{A_i} = \frac{V+A_x}{A_{avg}}$

- $V + A_x$ = 0.85 TCI

- A_{avg} = N p,avg + dj,avg
- = (MARR) (TCI) + $\frac{0.85(TCI)}{N}$ (since, MARR = Np,ave/TCI)

- PBP = $\frac{0.85(TCI)}{\frac{0.85(TCI)}{N}+(MARR)\ (TCI)} = \frac{0.85}{\frac{0.85}{N}+(MARR)}$

- To be acceptable, a project payback period should be less than or equal to the reference value given by the above equation.
- The shorter the Payback Time, the more attractive is the project.

Payback Period

- The payback time can be identified on a cash flow diagram as the time interval from the plant first production to the break-even point.
- By definition, this index cannot measure the performance of a project after paying the initial investment.
- For large plants, as in petrochemicals and refineries, the payback time should be between seven and ten years.
- This measure is much smaller for high-tech processes, as in speciality chemicals and biotechnologies.
- For small-scale projects, as revamping or energy saving, typical values for the payback time are 2 to 3 years, sometimes shorter

Example 2: A proposed chemical plant will require a fixed-capital investment of INR 10 crore. It is estimated that the working capital will be 25% of the total investment. Annual depreciation costs are estimated to be 10% of the fixed-capital investment. If the annual profit will be 3 crore, determine the percent return on the total investment and the payout period.

Solution:

Total Investment (TI) = FCI + Working Capital

$= 10 + 0.25\ (TI)$

$\Rightarrow TI(1 - 0.25) = 10$

Solving: $TI = 10/0.75 = 13.33$ crore

ROI = (Annual Net profit x 100) / TCI) $= 3 \times 100/13.33 = 22.5\%$

- Payback Period (PBP) = $\frac{FCI}{Annual\ cash\ Flow}$
- $= \frac{FCI}{Annual\ profit + Annual\ depreciation}$
- $= \frac{10}{3+(0.1)*10} = 2.5$

B. The methods that consider the Time Value of Money:

- Net Present Worth/Value (NPW, NPV)
- The Discounted Cash Flow Rate of Return (DCFROR)

These methods consider the Time Value of Money and account for the earning power of invested money by the discounting techniques.

- These methods are often used by large companies for economic analysis.
- The timing of cash flows is very important to investors because:

1. Not all of the capital must be financed immediately
2. Capital that is repaid sooner can be put back to work in another investment

Net Present Worth (Value)

- The Net Present Worth/Value (NPW or NPV) analysis evaluates projects by converting all future cash flows into their present equivalent.

- The NPV (NPW) is the total of the present worth of all cash flows minus the present worth of all capital investments.

- $CF_{n,0} = \frac{CF_n}{(1+i)^n}$ (similar to P = $\frac{F}{(1+i)^n}$)

- By Net Present Value (NPV) analysis, the cash flow CF_n earned in different years n is brought to the present value $CF_{n,0}$ by using a compound-interest factor.

Net Present Value

Net Present Value (NPV)

- **Definition**: NPV is the sum of the present values (PVs) of incoming and outgoing cash flows over a period of time.
- **Calculation**: It is calculated by subtracting the present value of cash outflows (investment costs) from the present value of cash inflows (revenue or savings).

$$NPV = \sum \left(\frac{C_t}{(1+r)^t} \right) - I_0$$

Where:

- C_t = Cash flow at time t
- r = Discount rate (or required rate of return)
- t = Time period (usually in years)
- I_0 = Initial investment

- **Interpretation**: If the NPV is **positive**, the project is expected to generate more value than its costs and is considered a good investment. If **negative**, the project is not expected to be profitable.

Net Present Worth (Value)

$$\text{NPV} = \sum_{n=1}^{N} \frac{CF_n}{(1+i)^n} - TCI$$

- A positive NPW (or NPV) means that the equivalent worth of the inflows is greater than the equivalent worth of outflows, so the project makes a profit.
- If NPW > 0, then the project provides a return at a rate greater than the MARR.
- If NPW = 0, then the project provides a return that matches the MARR.
- In either of these cases, the project is judged as favorable compared to the MARR selected in the calculations.
- If NPW < 0, the project is unfavorable with respect to MARR selected.
- While comparing multiple alternatives, compute the NPW for each alternative and select the one with the largest NPW.

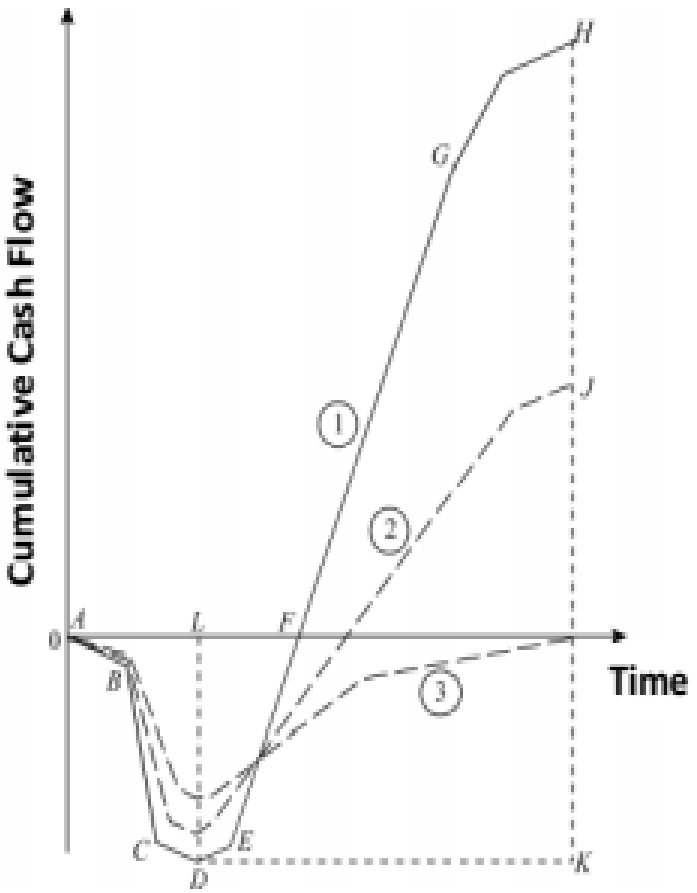
Net Present Worth: Cumulative Cash Flow Diagram

For given cash flows, higher interest rates (MARR) will tend to decrease the NPW (NPV) and vice-versa. Also, see the effect on Payback Time.

Curve 1 represents the case with no discounting (i = 0). The project NPV is equal to the final net cash position given by H.

Curve 2 shows the effect of discounting at a fixed rate of interest (i > 0). The corresponding project NPV is given by J .

Curve 3 shows a larger rate of inter but it is chosen such that the NPV is zero at the end of the project.



Net Present Worth (Value)

- The Net Present Value is always less than the total future worth of the project because of the discounting of future cash flows.
- Net Present Value is easily calculated using spreadsheets and most spreadsheet programs (such as MS Excel) have a NPV function.
- The Net Present Value is a strong function of the interest rate used and the time period studied. The time period is sometimes denoted by a subscript (NPVN).
- Thus, NPV10 would denote the NPV over a 10-year period.
- Net Present Value is a more useful economic measure than Simple Payback and ROI, since it allows for the Time Value of Money and also for annual variation in expenses and revenues.
- Large projects are neither completed in a single year nor do they immediately begin production at full capacity.

Net Present Worth (Value): Example-1

A proposed chemical plant is estimated to have a Fixed Capital (FC) of Rs 24 crore. Assuming other costs to be small, the total investment may be taken to be same as FC. After commissioning (at t = 0 years), the annual profit before tax is Rs. 10 crores/year(at the end of each year) and the expected life of the plant is 10 years. The tax rate is 40% per year and a linear depreciation is allowed at 10% per year. The salvage value is zero. If annual interest rate is 12%, what is the NPV (net present value or worth) of the plant in crores of rupees? **GATE 2015**

Solution:

Given Data:

- **Fixed Capital (FC) = Total Investment (TI) = ₹24 crore**
- **Annual Profit Before Tax (PBT) = ₹10 crore**
- **Plant Life = 10 years**
- **Tax Rate = 40%**
- **Depreciation Rate (Linear) = 10% per year**
- **Salvage Value = ₹0**
- **Interest Rate (Discount Rate) = 12%**

- The annual depreciation is:

$$d = \frac{V - V_S}{N} = \frac{24 - 0}{10} = 2.4\ Cr/Year$$

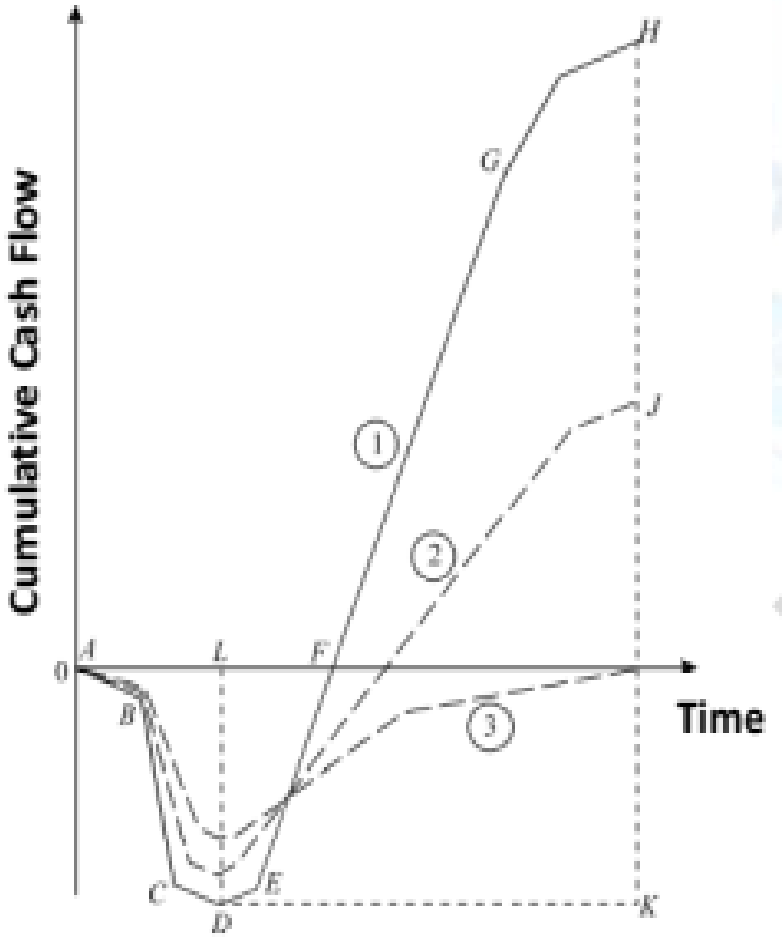
- Taxable profit = Profit before tax – Depreciation = 10 – 2.4 = Rs. 7.6 crore/year
- Amount of Tax = (0.40)(7.6) = Rs. 3.04 crore/year
- Profit after tax (Net Profit) = 10 – 3.04 = Rs. 6.96crore/year
- Annual Cash Flow = Net Profit + Depreciation = 6.96 + 2.4 = Rs. 9.36 crore/year
-

$$NPV = \sum_{n=1}^{N} \frac{\text{NCF}}{(1+i)^n} - \text{Initial Investment}$$

$$NPV = 9.36 \times \left(\sum_{n=1}^{10} \frac{1}{(1.12)^n} \right) - 24$$

Discounted Cash Flow Rate of Return (DCFROR)

- Discounted Cash Flow Rate of Return (DCFROR) is a measure of the maximum interest rate that a project could afford just by paying the TCI at the end of its life.
- Thus, the project breakevens at the end of project life (Curve-3 in the Figure).
- DCFROR can be determined as the interest (discount) rate for which the NPV at the end of the project lifetime becomes zero.
- DCFROR is also known as Internal Rate of return (IRR).



Discounted Cash Flow Rate of Return (DCFROR)

- Mathematically, DCFROR can be determined as the interest rate for which the Net Present Value at the end of the project lifetime becomes zero

- $\mathbf{NPV} = \sum_{n=1}^{N} \frac{CF_n}{(1+i)^n} - TCI = 0$

- Since the discount rate appears in many exponents, it is generally impossible to solve for the discount rate analytically .

- It can be determined graphically or numerically (iterative solution).

- Higher DCFROR means more profitable project.

Discounted Cash Flow Rate of Return (DCFROR)

- DCFROR provides a useful way of comparing the performance of capital for different projects, independent of the amount of capital used, the life of the plant, or the actual interest rates prevailing at any time.
- DCFROR is a more useful method than NPV when comparing projects of very different size.
- The NPV of large projects is usually greater than that of small projects, but then the investment is also much greater.
- DCFROR is independent of project size and higher DCFROR means more profitable project.
- When the NPW is favourable, the DCFROR will necessarily be favourable and will be the actual earning rate of the investment.
- The NPW and DCFROR are nearly always used together.

DCFROR: Example-2

A company has the alternative of investing in one of two projects, A or B. The capital cost of both projects is Rs. 10 million. The predicted annual cash flows for both projects are shown in the Table. Which project should be chosen on the basis of Discounted Cash Flow Rate of Return (DCFROR), based on a five-year lifetime?

	Cash Flows (Million Rs.)	
Year	**Project-A**	**Project-B**
0	**-10**	**-10**
1	**1.6**	**6.5**
2	**2.8**	**5.2**
3	**4.0**	**4.0**
4	**5.2**	**2.8**
5	**6.4**	**1.6**

Project-A:
Start with an initial guess for DCFROR of 20% and find NPV. NPV will be zero between 20 to 25%. Interpolating:
DCFROR = 23%

Project-B:
NPV will be zero between 35 to 40%.
Interpolating: DCFROR = 38%.

Project B is chosen for higher DCFROR.

Projet A:

$$\text{NPV} = \frac{-10}{(1+i)^0} + \frac{1.6}{(1+i)^1} + \frac{2.8}{(1+i)^2} + \frac{4}{(1+i)^3} + \frac{5.2}{(1+i)^4} + \frac{6.4}{(1+i)^5} - 1{,}00{,}00{,}000$$

AT i =0.23 NPV =0

Project B:

$$\text{NPV} = \frac{-10}{(1+i)^0} + \frac{6.5}{(1+i)^1} + \frac{5.2}{(1+i)^2} + \frac{4}{(1+i)^3} + \frac{2.8}{(1+i)^4} + \frac{1.6}{(1+i)^5} - 1{,}00{,}00{,}000$$

I = 0.38 for NPV = 0

Discounted Payback Period

- Simple Payback period = FCI/ Annual Cash flow
- Simple or Conventional Payback Period does not take into account the Time Value of Money—that is, the cost of funds (interest) used to support a project.
- The discounted payback period is modification to simple payback period so that the Time Value of money can be considered.
- We define the discounted payback period as the number of years required to recover the investment from discounted cash flows.

C. Annualized Cost Method

- The Annualized Cost Method, also known as the Equivalent Annual Cost (EAC) method, is used to compare the costs of assets with different lifetimes by converting their total costs into an equivalent annual expense. This helps in making decisions about whether to replace an asset or choose between alternatives.
- The total cost of owning and operating an asset consists of:
  1. Capital Recovery Cost (CRC) – Spreads the initial investment over its useful life.

2. Annual Operating & Maintenance Cost (AOMC) – The recurring cost of operating the asset.

$$CRC = P \times \frac{r(1+r)^n}{(1+r)^n - 1}$$

$$EAC = \left[P \times \frac{r(1+r)^n}{(1+r)^n - 1}\right] + \text{Annual Maintenance Cost}$$

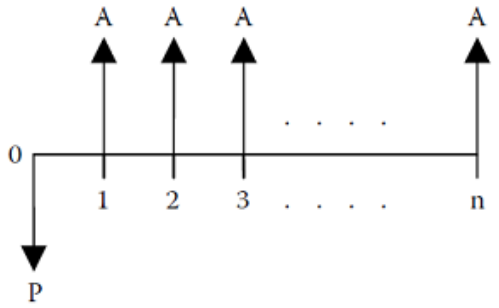
C. Annualized Cost Method

- A is the regular annual payment that must be made to generate the same amount of money over n years as would be earned by investing P at interest rate i for n years

$$P = A\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right]$$

- **The Annual Capital Charge Ratio (ACCR)** is the fraction of the Principal that must be paid out each year to fully repay the Principal and all accumulated interest over the life of the investment

- $\frac{A}{P} = \left[\frac{i(1+i)^n}{(1+i)^n - 1}\right]$



Example 1; A pump (PUMP-A) costs Rs. 1,40,000 and is expected to have a service life of 5 years before it requires replacement. Another pump (PUMP-B) is available at Rs. 1,82,000 and is expected to have increased service life of 10 years. Which pump is the most economical if the cost of capital is 12%?

Solution:

Annual Capital Charge Ratio

$$\frac{A}{P} = \left[\frac{i(1+i)^n}{(1+i)^n-1}\right] = \left[\frac{0.12(1+0.12)^5}{(1+0.12)^5-1}\right] = 0.27$$

The Annualized Capital Cost of PUMP-A = Rs. 140,000 × 0.277

= Rs. 38,780 per year

Pump B: With a 12% interest rate and 10 year life, the Annual Capital Charge Ratio is

$$\frac{A}{P} = \left[\frac{i(1+i)^n}{(1+i)^n-1}\right] = \left[\frac{0.12(1+0.12)^{10}}{(1+0.12)^{10}-1}\right] = 0.177$$

The Annualized Capital Cost of PUMP-B = Rs. 1,82,000 × 0.177
= Rs. 32,210 per year.

Annualized Capital Cost for Pump-A = Rs. 38,780
Annualized Capital Cost for PUMP-B = Rs. 32,210

Hence, it would be more economical to buy PUMP-B as it's yearly cost is lower

Example-2

	Equipment-A	Equipment-B
Initial cost	Rs. 10,000	Rs. 18,000
Estimated life	20 years	35 Years
Estimated salvage	0	Rs. 3,000
Annual cost of operation	Rs. 4,000	Rs. 3,000

Which equipment is the most economical if the rate of interest is 10%?

Solution:

Annual Capital cost of equipment- A = $P\left[\frac{i(1+i)^n}{(1+i)^n-1}\right]$ +4000

= $10000\left[\frac{0.1(1+0.1)^{20}}{(1+0.1)^{20}-1}\right]$ +4000

= Rs. 5,175

Annual Capital cost of equipment- B = $18000\left[\frac{0.1(1+.1)^{35}}{(1+0.1)^{35}-1}\right]$+3000-3000

= Rs. 4,855

Equipment- B is more economical

Annualized Cost of A Plant

Let, C = Annual Production Cost
C_{TCI} = Total Capital Investment
i_{min} = A Reasonable Return on Investment
C_A = Annualized Cost

$$C_A = C + i_{min}\, C_{TCI}$$

Example 3: The total fixed cost of a chemical plant is Rs. 10.0 lakh, the internal rate of return is 15% and the annual operating cost is Rs. 2.0 lakh. What is the annualized cost of the plant?

Solution:

Annualized Cost of the Plant (lakh Rs.):

$C_A = C + i_{min}\, C_{TCI} = 2 + 0.15*10 = 3.5$

Several Profitability Methods: How to Select One

- When we evaluate two or more proposals using all the available methods, the methods may not always provide the same conclusion, because different quantities are utilized in the definitions of the profitability measure.

- The methods that consider Time Value of Money give a more realistic picture of investment and the value of the earnings compared to those methods that do not consider the Time Value of Money.

- The Net Present Worth method, combined with the Discounted Cash Flow Rate of Return method, is strongly recommended for making economic decisions.

Alternative Investment: Incremental Analysis

- A general rule for making comparisons of alternative investments:
- The minimum investment which will give the necessary functional results and the required rate of return should always be accepted unless there is a specific reason for accepting an alternative investment requiring more initial capital.
- When alternatives are available, the base plan would be that one requiring the minimum acceptable investment.
- The alternatives should be compared with the base plan, and additional capital should not be invested unless an acceptable incremental return or some other distinct advantage can be achieved.

Alternative Investment: Incremental Analysis: Example

For an existing chemical plant, four different designs of heat exchangers are being considered to recover the heat that is being lost in waste gases.

	Design-I	Design-2	Design-3	Design-4
Fixed initial installed cost ($/)	10,000	16,000	20,000	26,000
Annual savings ($/Year)	2000	3000	3200	3550
Annual percent return (%)	20	18.8	16	13.7

Company policy demands at least a 15% annual return before taxes based on the initial investment for any unnecessary investment. Only one of the four designs can be accepted. Using before-tax return on investment as the basis, which design should be recommended?

Solution: Acceptable Designs: Design-1, Design-2, and Design-3 (> 15% return).

Which one to select among 3 alternatives?

Analyse by means of return on incremental investment. Take Design-1 as starting basis.

Comparing Design-2 to Design-1.

The return on incremental investment is

$$\frac{3000 - 2000}{16000 - 10000} \; x\, 100 = 16.7\ \%$$

Design-2 is acceptable by company policy in preference to Design-1.

Comparing Design-2 to Design-3. The return on incremental investment is

$$\frac{3200 - 3000}{20000 - 16000} \; x\, 100 = 5\ \%$$

Design-3 is not acceptable

Thus, Design-2 is the preferred alternative

Replacement Analysis

- Replacement analysis is an engineering economic analysis technique for determining when to replace assets (such as a piece of equipment).
- **Replacement** refers to new equipment or assets purchased and put into service in place of existing equipment or assets.
- The equipment or assets removed from service are used for other purposes, sold for a salvage value, or disposed of permanently.
- **Challengers**: When an engineering economic analysis is being performed to evaluate the possible replacements of equipment or other assets, the potential new equipment or assets (possible alternatives) are called Challengers.
- **Defenders:** The existing equipment or assets that are being considered for replacement, are known as Defenders.

Replacement Analysis

- **Augmentation** is the term for equipment or assets purchased and installed to increase (or change) the capacity of existing equipment.

- In order to augment existing equipment or other assets, the existing equipment or assets are kept in service.

- **Retirement** of equipment or assets occurs when they are removed from service and either repurposed to perform other operations, left idle and only used if other similar equipment or assets are temporarily removed from service for repairs or replacement, or disposed of without a new piece of equipment or other asset being purchased to replace them.

Replacement Analysis: When to Replace Equipment?

General Consideration:

- The process for determining when to replace equipment or assets is unique to each company.
- Some companies replace their equipment or assets based on obsolescence, especially if they operate in a cutting-edge profession.
- Other companies may keep their equipment or assets as long as they are able to depreciate it for tax benefit.

- **Engineering Economic Analysis:** If the defender proves more economical, it will be retained. If the challenger proves more economical, it will be installed.

The time when equipment or assets should be replaced occurs when:

1. New assets will generate a higher net present worth or equivalent uniform annual worth than the existing equipment or assets

OR

2. The net present cost or equivalent uniform annual cost of the proposed replacement is less than the existing facility.

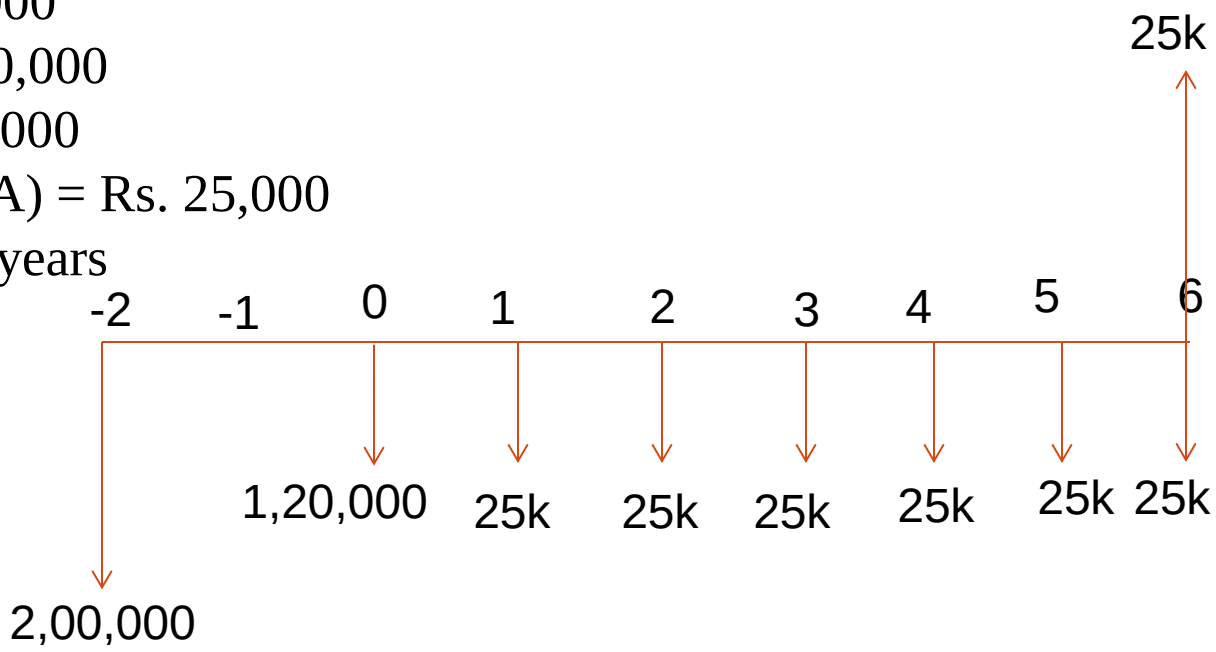
Example: When to Replace Equipment?

Two years ago, a machine was purchased at a cost of Rs. 2,00,000 to be useful for 8 years. Its salvage value at the end of its life is Rs. 25,000. The annual maintenance cost is Rs. 25,000. The market value of the present machine is Rs. 1,20,000. Now, a new machine to cater to the need of the present machine is available at Rs. 1,50,000 to be useful for 6 years. Its annual maintenance cost is Rs. 14,000. The salvage value of the new machine is Rs. 20,000. Using an interest rate of 12%, find whether it is worth replacing the present machine with the new machine.

Solution

Alternative 1: Present Machine (Defender)

Purchase price = Rs. 2,00,000
Present value (P) = Rs. 1,20,000
Salvage value (F) = Rs. 25,000
Annual maintenance cost (A) = Rs. 25,000
Remaining service life = 6 years
Interest rate = 12%



$$\frac{A}{P} = \left[\frac{i(1+i)^n}{(1+i)^n-1}\right]$$

$$A = F\left[\frac{i}{(1+i)^n-1}\right]$$

$$EUAC = -P\left(\frac{A}{P}, 12\%, 6\right) + F\left(\frac{A}{F}, 12\%, 6\right) - A$$

$$= -120000\left(\frac{A}{P}, 12\%, 6\right) + 25000\left(\frac{A}{F}, 12\%, 6\right) - 25000$$

$$= -29187 + 3081 - 25000$$

$$= -51,106$$

Alternative 2: New Machine (Challenger):

Purchase price (P) = Rs. 1,50,000
Salvage value (F) = Rs. 20,000
Annual maintenance cost (A) = Rs. 14,000
Service life = 6 years
Interest rate = 12%

$$\text{EUAC} = -P\left(\frac{A}{P}, 12\%, 6\right) + F\left(\frac{A}{F}, 12\%, 6\right) - A$$

$$= -150000\left(\frac{A}{P}, 12\%, 6\right) + 20000\left(\frac{A}{F}, 12\%, 6\right) - 14000$$

$$= -36484 + 2465 - 14000$$

$$= -48{,}019 \text{ Rs.}$$

New Machine: Rs. 48,019 Existing Machine: Rs. 51,106

EUAC_Challenger < EUAC_Defender. Recommendation: REPLACE

Sensitivity Analysis: What is it?

- The economic analysis of a project can only be based on the best estimates of the investment required and the cash flows.

- The actual cash flows achieved in any year will be affected by many factors:
  - Changes in raw materials costs
  - Other operating costs
  - Sales volume and price, etc.

- A sensitivity analysis is a way of examining the effects of uncertainties in the forecasts on the viability of a project.

Sensitivity Analysis: How to Perform?

- To carry out the analysis, the investment and cash flows are first calculated using what are considered the most probable values for the various factors.
- This establishes the base case for analysis.
- The base case uses the most likely values for each input.
- We then change each input variable in turn by several specified percentage points above and below the most likely values, while holding other variables constant.
- Next, we calculate a new NPW for each of the values we obtained.
- This analysis shows how sensitive the cash flows and economic criteria are to errors in the forecast figures.

Sensitivity Analysis:

Example

The project's NPW is:

(1) very sensitive to changes in product demand and unit price,
(2) fairly sensitive to changes in variable costs,
(3) Relatively insensitive to changes in the fixed cost and the salvage value.

Sensitivity Analysis

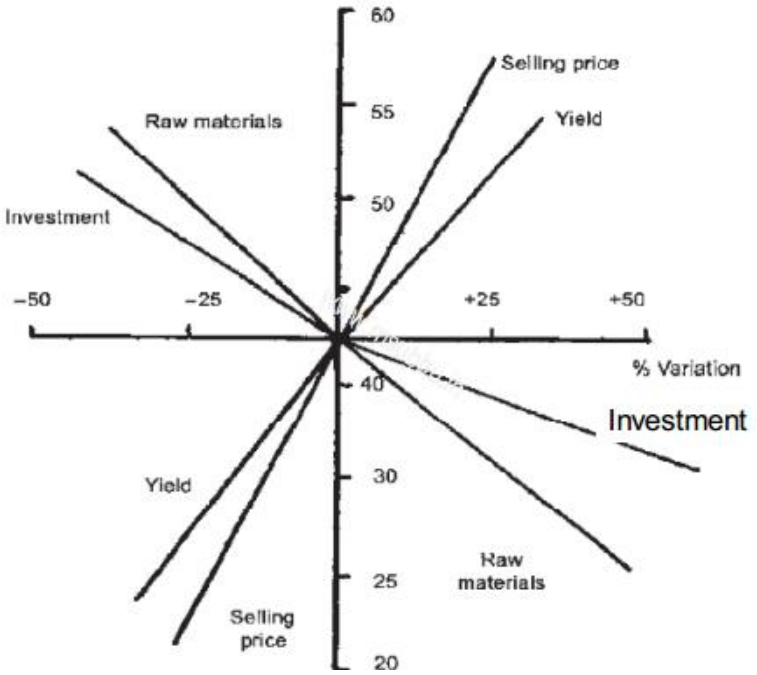
- Sensitivity analysis: is concerned with the extent of change in a cost analysis resulting from variations in one or more elements of a cost study.
- It shows the influence of possible changes of significant variables upon profitability.
- Using this, the variables that have a critical effect are identified.
- Profitability is assessed in number of ways varying each significant cost element over a range.

- **Single factor sensitivity analysis:** involves keeping all factors except one constant while varying the remaining cost factor through a range of percentage changes.
- The effect of cost factor changes on the worth is observed, to determine whether the alternative remains attractive under the evaluated changes and to determine which cost factor effects the measure of worth the most.

Strauss Plot

- Strauss plot or spider plot is used to plot the results of sensitivity analysis.

- In Strauss plot, the ordinate is the measure of profitability is plotted as ordinate and change in a variable percentage is plotted on abscissa.



Example1: Conduct a sensitivity analysis for the cash flow data as shown below. The sensitivity analysis should explore the sensitivity of present worth to changes in annual revenue over the range -10 to +10 %. Interest rate applicable is 8 %.

Initial investment = Rs. 1000

Cash flow = Rs. 600 per year at the end of each year

Project life = 4 years

Solution:

NPW of the project $= -1000 + \frac{600}{(1+0.08)} + \frac{600}{(1+0.08)^2} + \frac{600}{(1+0.08)^3} + \frac{600}{(1+0.08)^4}$

$= -1000 + 555.6 + 514.4 + 476.3 + 441.0$

$= 987.3$

The sensitivity of present worth to changes in annual revenue over the range of -10 to +10 %

Annual revenue for -10 % change = 600 - 0.1*600 = 540

Annual revenue for +10 % change = 600 + 0.1*600 = 660

NPW of the project for -10 change in annual revenue

$$= -1000 + \frac{540}{(1+0.08)} + \frac{540}{(1+0.08)^2} + \frac{540}{(1+0.08)^3} + \frac{540}{(1+0.08)^4}$$

$$= -1000 + 500 + 463 + 428.7 + 396.9$$

$$= 788.6$$

NPW of the project for + 10 change in annual revenue

$$= -1000 + \frac{660}{(1+0.08)} + \frac{660}{(1+0.08)^2} + \frac{660}{(1+0.08)^3} + \frac{660}{(1+0.08)^4}$$

$$= -1000 + 611.1 + 565.8 + 523.9 + 485.1$$

$$= 1185.9$$

The sensitivity of PW to changes in annual revenue over the range of -10 % to +10% is **Rs. 397.3** (Rs. 1185.9 – Rs. 788.6)

The sensitivity of present worth to changes in initial cost over the range of -10 to +10 %

Initial cost for -10 % change = 1000 - 0.1*1000 = 900

Initial cost for +10 % change = 1000 + 0.1*1000 = 1100

NPW of the project for -10% change in initial cost

$$= -900 + \frac{600}{(1+0.08)} + \frac{600}{(1+0.08)^2} + \frac{600}{(1+0.08)^3} + \frac{600}{(1+0.08)^4}$$

$$= 1087.3$$

NPW of the project for +10% change in initial cost

$$= -1100 + \frac{600}{(1+0.08)} + \frac{600}{(1+0.08)^2} + \frac{600}{(1+0.08)^3} + \frac{600}{(1+0.08)^4}$$

$$= -887.3$$

The sensitivity of PW to changes in initial cost over the range of -10 % to +10% is - **Rs. 200** (Rs. 1087.3 – Rs. 887.3)

The sensitivity of present worth to changes in interest rate over the range of -10 to +10 %

Interest rate for -10 % change = 0.08 - 0.1*0.08 = 0.072
Interest rate for + 10 % change = 0.08 + 0.1*0.08 = 0.088

NPW of the project for -10 % change in interest rate

$$= -1000 + \frac{600}{(1+0.072)} + \frac{600}{(1+0.072)^2} + \frac{600}{(1+0.072)^3} + \frac{600}{(1+0.072)^4}$$

$$= -1000 + 559.7 + 522.1 + 487 + 454.3$$

$$= 1023.1$$

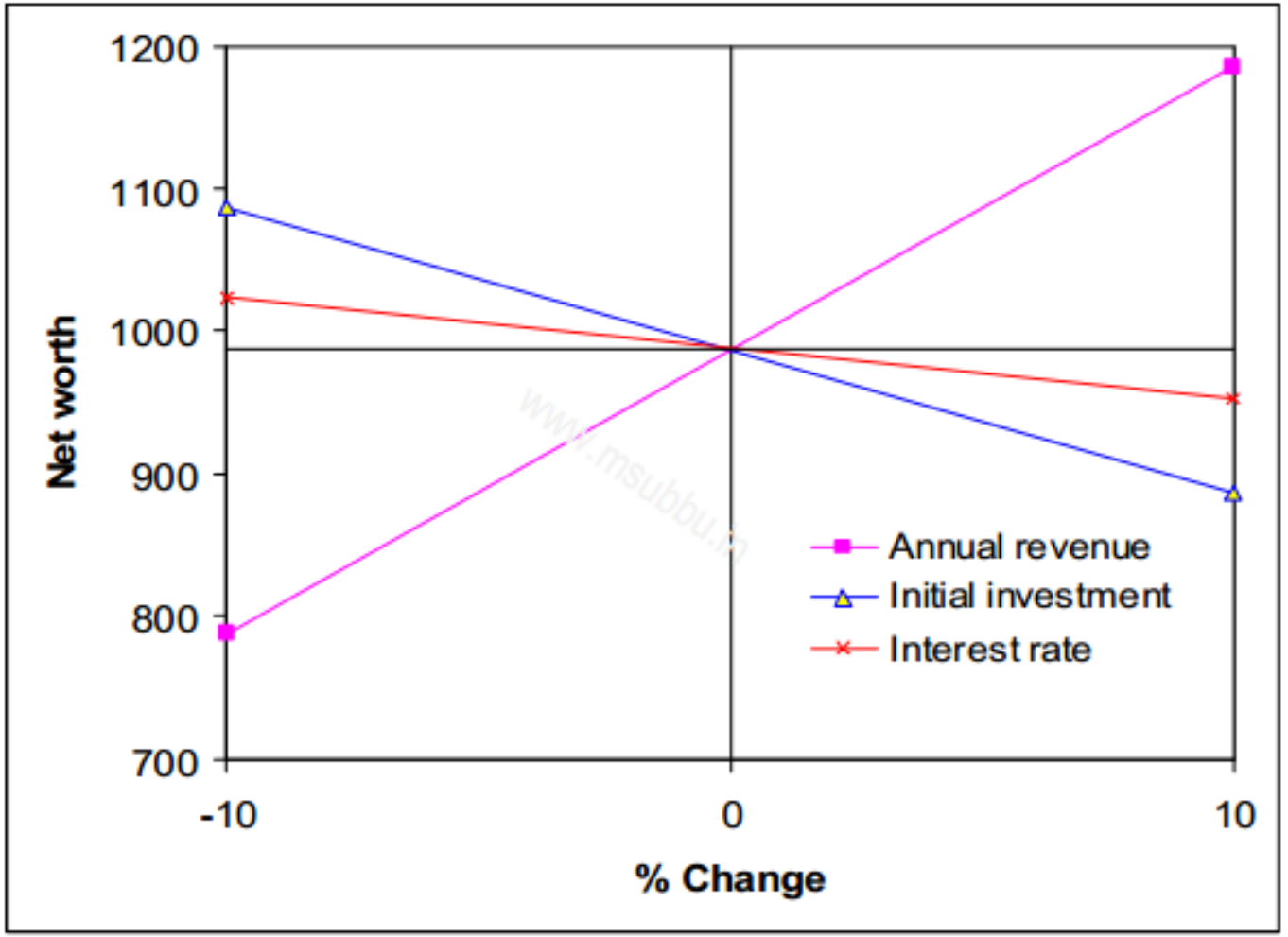
NPW of the project for +10 % change in interest rate

$$= -1000 + \frac{600}{(1+0.088)} + \frac{600}{(1+0.088)^2} + \frac{600}{(1+0.088)^3} + \frac{600}{(1+0.088)^4}$$

$$= -1000 + 551.5 + 506.9 + 465.9 + 428.2$$

$$= 952.5$$

The sensitivity of PW to changes in interest rate ver the range of -10 % to +10% is **Rs. 70.6** (Rs. 1023.1 – Rs. 952.5)


1200
1100
1000
900
800
700
Net worth
-10
0
10
% Change
Annual revenue
Initial investment
Interest rate

References

1. Max S. Peters, Klaus D. Timmerhaus, Ronald E. West, Plant Design and Economics for Chemical Engineers, 5th Ed, Mc Graw hill (2003).

2. G. Towler, R. Sinnot, Chemical Engineering Design, Principles, Practice and economics of plant and process design, Elsevier (2009).

Thank you