Cost Estimation & Economic Analysis

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Topic To be Covered

- Project cost estimation
- Cost indexes
- Net earning
- Interest and investment costs
- Depreciation

Cost Estimation

- The main motive of starting an industry is to make profits.

- Understanding of Process Economics or plant economics is crucial for process engineer.

- The role of Process Economics in chemical plant design involves

- **Evaluation of designs**
  - Cost data are required to evaluate process designs
- **Process optimization**
  - Optimizing the process variables plays an important role in minimizing cost or maximizing profits.
- **Overall Project Profitability**
  - The economics viability of the project should be assessed at various stages of the project design.

Engineering Economics

The decision to construct any plant depends on two major issues:

- Technical feasibility
- Economic feasibility

- **A cost-benefit analysis**, **rate of return, pay out period**, etc., must be performed before venturing into a project.
- The design engineer must be familiar with the terms like **cash flow, interest rates, depreciation rates, salvage values of equipment**, etc. in order to understand the economic viability of the project.

Cost estimation

Approximate estimation	Detailed cost estimation
In early stages of design (PFD)	After detailed plant design (design of equipment, PID diagram)
It is also called budget, preliminary estimate	Detail estimate is prepared with the help of complete set of contract documents
Quick and approximate estimates	Detailed and accurate estimate
Required for process evaluation and optimization procedures	Required for Project construction and commissioning before final tender.

Capital Investment

- Capital is "a stock of accumulated wealth."
- Capital is savings that may be used as the owner decides.
- One use of the savings is investment; to promote the production of other goods, to obtain an income or profit.“

- Before an industrial plant can be put into operation, a large sum of money must be available
  - ❑ To purchase Land
  - ❑ To buy required machinery and equipment
  - ❑ To pay for service facilities
  - ❑ To provide piping, controls, and services.
  - ❑ To pay the expenses involved in the plant operation before sales revenue becomes available

Capital Investment

- **<u>Fixed-capital investment (FCI):</u>**The capital needed to supply the required manufacturing and plant facilities is called the fixed-capital investment (FCI).
- **<u>Working capital (WC):</u>** The capital necessary for the operation of the plant is termed as the Working Capital.
- **<u>Total capital investment (TCI)</u>**

TCI = FCI + WC

The fixed-capital portion may be further subdivided into:

- Manufacturing fixed-capital investment (Direct cost)
- Non-manufacturing fixed-capital investment (indirect cost)

Fixed-Capital Investment (Direct cost)

- Manufacturing fixed-capital investment represents the capital necessary for the installed process equipment with all components that are needed for complete process operation.

- It includes expenses for :

- ❑ Equipment Installation
- ❑ Transportation And Local Taxes
- ❑ Instrumentation
- ❑ Packing Installation
- ❑ Electrical Assembly
- ❑ Building (Included Services)
- ❑ Cost of land
- ❑ Service facility

Non-manufacturing fixed-capital investment (Indirect Cost)

- Indirect cost represents the capital required for
- All plant components that are not directly related to the process operation like
  - ❑ Land; processing buildings
  - ❑ Administrative and other offices, Warehouses, laboratories
  - ❑ Transportation, shipping, and receiving facilities
  - ❑ Utility and waste disposal facilities,
  - ❑ Shops, and other permanent parts of the plant.
- The construction overhead cost includes
  - ❑ Field office. supervision expenses,
  - ❑ Home office expenses, engineering expenses,
  - ❑ Miscellaneous construction costs
  - ❑ Contractors' fees, and
  - ❑ Contingencies.
- In some cases, construction overhead is proportioned between manufacturing and nonmanufacturing fixed-capital investment

Total capital investment (TCI)

FCI = Direct cost + Indirect cost

TCI = Fixed capital Investment (FCI) + Working capital (WC)

Fixed Capital Investment

- The fixed capital investment is the total cost of designing, constructing, and installing a plant and the associated modifications needed to prepare the plant site.

- The fixed capital investment is made up of

- ❑ The inside battery limits (ISBL) investment—the cost of the plant itself;

- ❑ The modifications and improvements that must be made to the site infrastructure, known as offsite or OSBL investment;

- ❑ Engineering and construction costs;

- ❑ Contingency charges

Breakdown of fixed-capital investment items for a chemical process

Direct costs

1. **Purchased equipment** (15-40 % of FCI)
   - All equipment listed on a complete flowsheet
   - Spare parts and non- installed equipment spares
   - Surplus equipment, supplies, and equipment allowance
   - Inflation cost allowance
   - Freight charges
   - Taxes, insurance, duties
   - Allowance for modifications during start-up

2. **Purchased-equipment installation** (6-14 % of FCI)
   - Installation of all equipment listed on complete flowsheet
   - Structural supports
   - Equipment insulation and painting

3. **Instrumentation and controls** (2-12 % of FCI)
   - Purchase, installation, calibration, computer control with supportive software

Breakdown of fixed-capital investment items for a chemical process

4. Piping (4-17 % of FCI)

- Process piping utilizing suitable structural materials
- Pipe hangers, fittings, valves
- Insulation

5. Electrical systems (2-10 % of FCI)

- Electrical equipment switches, motors, conduit, wire, fittings, feeders, grounding, instrument and control wiring, lighting, panels
- Electrical materials and labor

6. Buildings and services (2-18 % of FCI)

- Process buildings,
- Auxiliary buildings
- Maintenance shops
- Building services

7. Yard improvements (2-5 % of FCI)

- Site development—site clearing, grading, roads, walkways, railroads, fences, parking areas, wharves and piers, recreational facilities, landscaping

Breakdown of fixed-capital investment items for a chemical process [Direct costs]

8. Service facilities (8-30 % of FCI)

- Utilities—steam, water, power, refrigeration, compressed air, fuel, waste disposal
- Facilities—boiler plant incinerator, wells, river intake, water treatment, cooling towers, water storage, electric substation, refrigeration plant, air plant, fuel storage, waste disposal plant, environmental controls, fire protection
- Non process equipment—office furniture and equipment, cafeteria equipment, safety and medical equipment, shop equipment, automotive equipment, yard material-handling equipment, laboratory equipment, locker-room equipment, garage equipment, shelves, bins, pallets, hand trucks, housekeeping equipment, fire extinguishers, hoses, fire engines, loading stations
- Distribution and packaging—raw material and product storage and handling equipment, product packaging equipment, blending facilities, loading stations

9. Land (1-2 % of FCI)

- Surveys and fees
- Property cost

Breakdown of fixed-capital investment items for a chemical process [Indirect costs]

1. Engineering and supervision (4- 20 % of FCI)

- *Engineering costs* —administrative, process, design and general engineering, computer graphics, cost engineering, procuring, expediting, reproduction, communications, scale models, consultant fees, travel
- Engineering supervision and inspection

2. Legal expenses (1- 3 % of FCI)

- Identification of applicable federal, state, and local regulations
- Preparation and submission of forms required by regulatory agencies
- Acquisition of regulatory approval
- Contract negotiations

Breakdown of fixed-capital investment items for a chemical process [Indirect costs]

3. Construction expenses (4- 17 % of FCI)

- Construction, operation, and maintenance of temporary facilities, offices, roads, parking lots, railroads, electrical, piping, communications, fencing
- Construction tools and equipment
- Construction supervision, accounting, timekeeping, purchasing, expediting
- Warehouse personnel and expense, guards
- Safety, medical, fringe benefits
- Permits, field tests, special licenses
- Taxes, insurance, interest

4. Contractor's fee (2- 6 % of FCI)

5. Contingency(5- 15 % of FCI)

Working Capital

The working capital for an industrial plant consists of the total amount of money invested in:

- Start up operation
- Raw materials and supplies carried in stock
- Finished products in stock and semi finished products in the process of being manufactured;
- Accounts receivable
- Accounts payable
- Cash kept on hand for monthly payment of operating expenses (such as salaries, wages, and raw material purchases)
- Taxes payable

Working Capital

- The raw material inventory included in working capital usually amounts to a 1-month supply of the raw materials valued at delivered prices.
- Finished products in stock and semifinished products have a value approximately equal to the total manufacturing cost for 1 month's production.
- The working capital required for accounts receivable ordinarily amounts to the production cost for 1 month of operation.
- The ratio of working capital to total capital investment varies with different companies, but most chemical plants , it varies from10 to 20 percent of the TCI.
- This percentage may increase to as much as 50 percent or more for companies producing products of seasonal demand.

Total product cost

Total product cost (TPC) = Manufacturing cost (MC)

+

General Expenses (GE)

Manufacturing cost =

Direct production cost + Fixed charges+ Plant overheads

S.No.	Direct production cost	Fixed charges	General expanses
1	Raw materials	Depreciation	Administrative costs
2	Operating labour	Local Taxes	Distribution and selling cost
3	Direct supervisory and clericial labour	Insurances	R &D
4	Utilities	Rent	
5	Maintainance and repairs		
6	Operating supplies		
7	Labour charges		
8	Patent		
9	Plant overhead costs		

Estimation of Total Income

Gross earnings/income = Total income – Total product cost(TPC)

Estimation of total income

Wholesale selling price of product per kg = Rs. X /kg

Annual working days = 300 days

The Production of product per day = Z tons/day

Total annual production of product = Z tons/day x 300days

= 300Z tons/ year

Total income = selling price x quantity of production

= X Rs/kg x 300 Z ton/year x 1000 kg/ton

= 300000*X*Z rupees/year

Gross income = Total income - Total product cost

= 300000*X*Z rupees/year- TPC

Numerical Problem 2

The purchased-equipment cost for a plant which produces pentaerythritol (solid fuel-processing plant) is $300,000. The plant is to be an addition to an existing formaldehyde plant. The major part of the building cost will be for indoor construction, and the contractor's fee will be 7 percent of the direct plant cost. All other costs are close to the average values found for typical chemical plants. On the basis of this information, estimate the following:

(a) The total direct plant cost.

(b) The fixed-capital investment.

(c) The total capital investment.

Given Data:

- Purchased-equipment cost=$300,000
- Contractor's fee = 7% of DPC.
- Typical chemical plant cost proportions are used:
  - Installation = 50% of equipment cost.
  - Piping = 25% of equipment cost.
  - Instrumentation = 15% of equipment cost.
  - Building = 20% of equipment cost (for indoor construction).
- Fixed capital indirect cost is 30% of Direct cost
- Working Capital is typically 15% of FC

Net Profit

Net Profit = Gross income – taxes

- **Rate of return(RoR) :** is the net gain or loss of an investment over a specified time period

$$ROR = \frac{\text{Net Profit}}{\text{Total capital investment}} \times 100$$

- **Pay back period**: The payback period refers to the amount of time it takes to recover the cost of an investment.

$$\text{Pay back period} = \frac{\text{Total capital investment}}{\text{Net Profit}}$$

Problem 3

A chemical plant has the following estimated costs for its project:

- Equipment cost (installed): ₹10 crore
- Piping, insulation, and electrical: ₹3 crore
- Land and building: ₹2 crore
- Engineering and contingency: ₹1 crore
- Working capital requirement: 20% of the fixed capital investment

Find:

1. Total fixed capital investment.
2. Total capital investment

Problem 4

A project involves a total capital investment of ₹20 crore. The annual net profit (after taxes and depreciation) is ₹4 crore.

Find: The rate of return on investment (ROI).

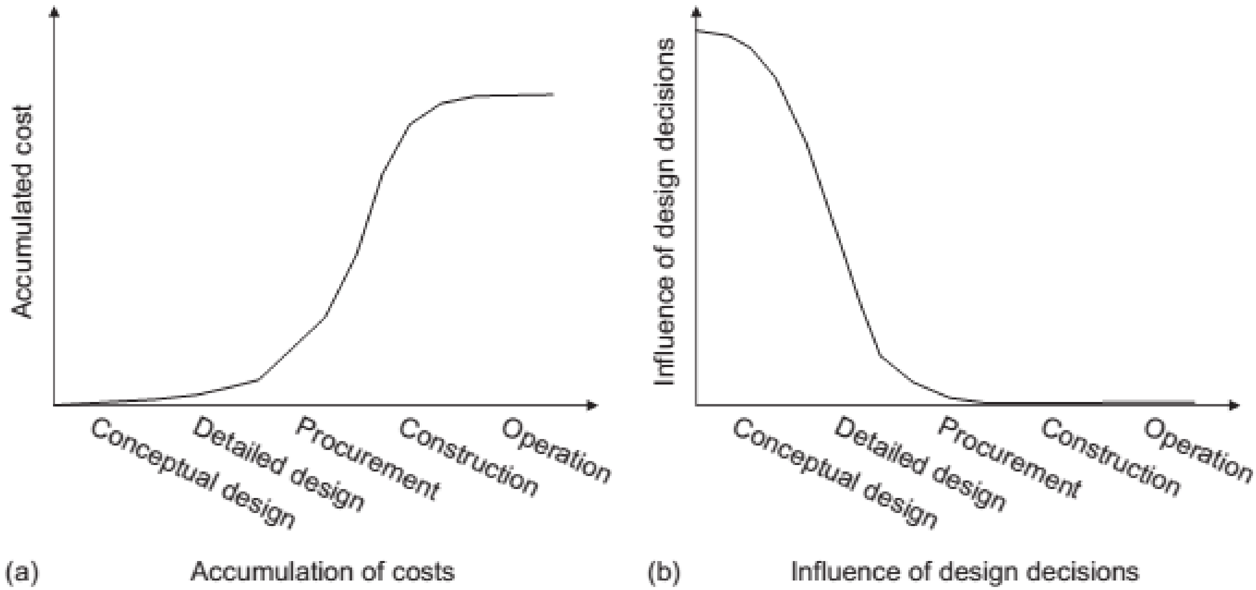
Problem 5

Problem 3:A company invests ₹15 crore in a new facility. The annual cash inflow (profit before depreciation) is estimated to be ₹3 crore. Find out the payback period.

Types of Capital Cost Estimates

1. Order-of-magnitude estimate {ratio estimate) based on similar previous cost data; probable accuracy of estimate over ±30 percent. (Initial Feasibility and concept screening)
2. Study estimate (factored estimate) based on knowledge of major items of equipment; probable accuracy of estimate up to ±30 percent. (To chosen design alternatives)
3. Preliminary estimate (budget authorization estimate or scope estimate) based on sufficient data to permit the estimate to be budgeted; probable accuracy of estimate within ±20 percent.
4. Definitive estimate (project control estimate) based on almost complete data but before completion of drawings and specifications; probable accuracy of estimate within ±10 percent. (baseline against actual costs and resources)
5. Detailed estimate (contractor's estimate) based on complete engineering drawings, specifications, and site surveys; probable accuracy of estimate within ±5 percent.

Influence Of Design Decisions On Project Cost



Cash Flow For Industrial Operations

Cash flow is the money that comes in and goes out of a business or person’s account.

•**Money coming in** is cash flow **in** (like sales or payments received).

•**Money going out** is cash flow **out** (like bills, salaries, or expenses).

Cash Flow For Industrial Operations

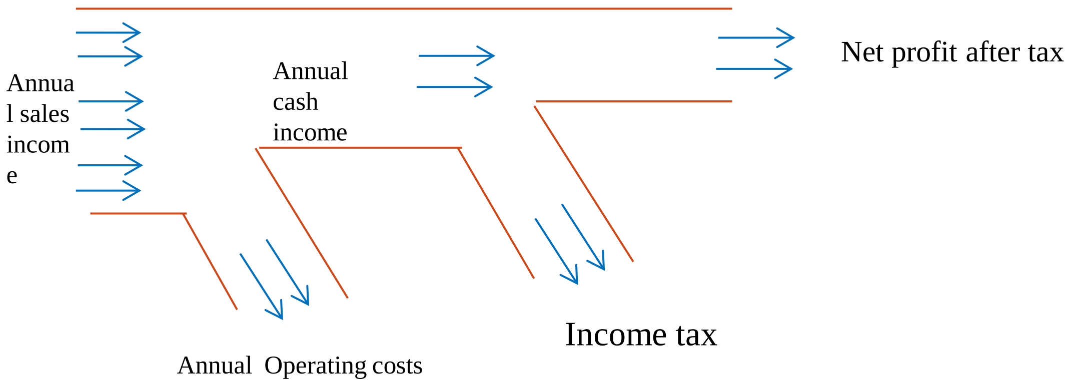


Fig 1. Flow scheme for a project resulting in a net profit

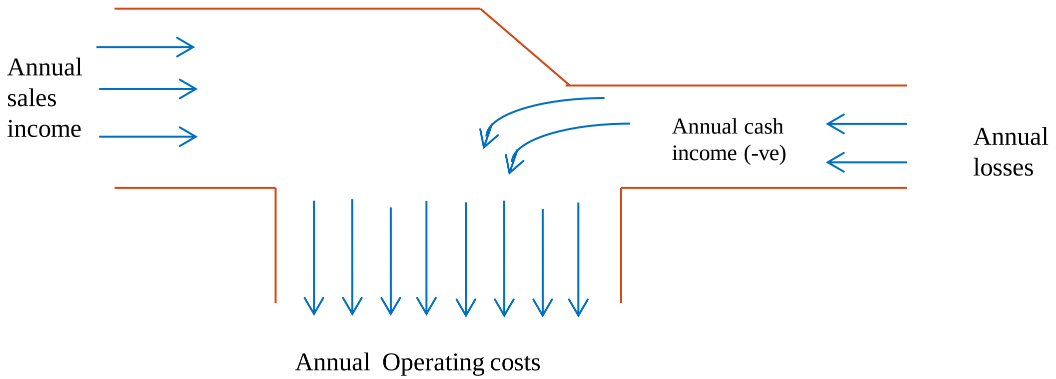


Fig 2. Flow scheme for a project resulting in a loss

Cash Flow For Industrial Operations

Reservoir and source of capital

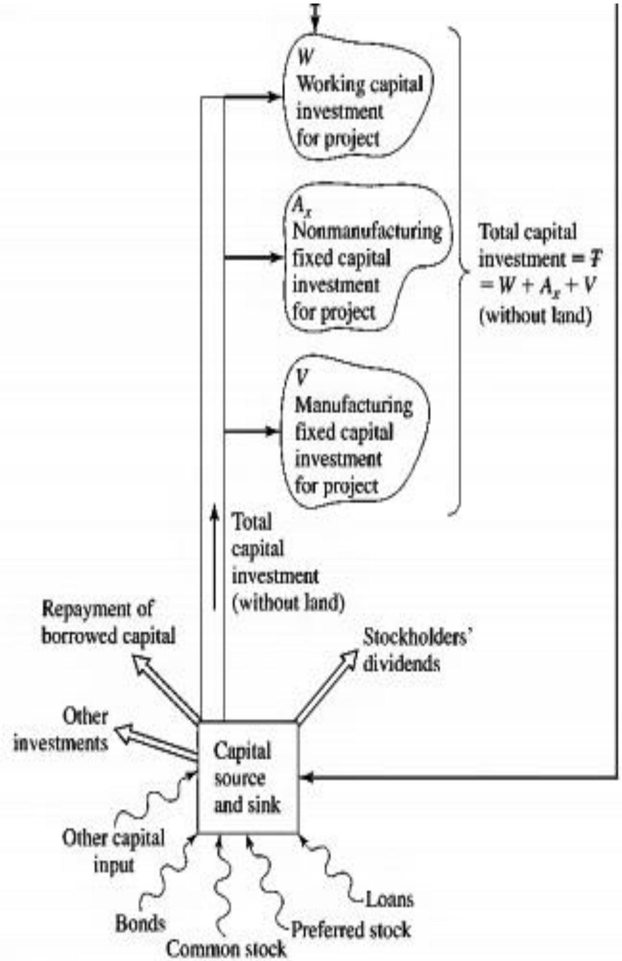
Inputs : Loans, stock issues, bond sales, and other capital sources, and the cash flow from project operations.

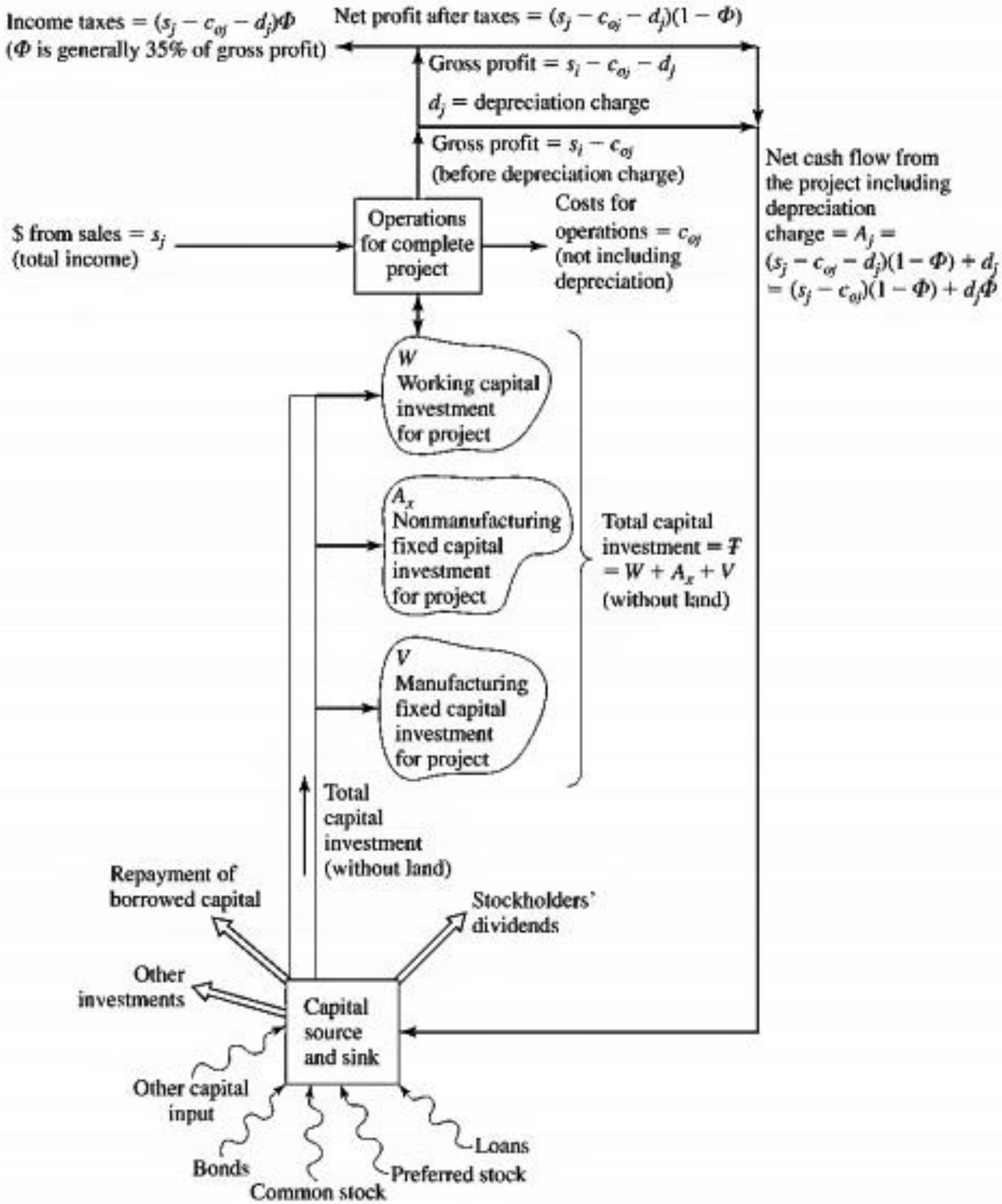
Outputs: Capital investments in projects, dividends to stockholders, repayment of debts, and other investments

Depreciation charge: Decrease in value of a facility with time.

Gross profit before depreciation = Income from sales- Operating costs

Gross profit after depreciation = Income from sales- Operating costs- depreciation charge




Income taxes = $(s_j - c_{oj} - d_j)\Phi$
(Φ is generally 35% of gross profit)
Net profit after taxes = $(s_j - c_{oj} - d_j)(1 - \Phi)$
Gross profit = $s_i - c_{oj} - d_j$
d_j = depreciation charge
Gross profit = $s_i - c_{oj}$
(before depreciation charge)
Net cash flow from the project including depreciation charge = A_j = $(s_j - c_{oj} - d_j)(1 - \Phi) + d_j$ $= (s_j - c_{oj})(1 - \Phi) + d_j\Phi$
\$ from sales = s_j
(total income)
Operations for complete project
Costs for operations = c_{oj}
(not including depreciation)
W
Working capital investment for project
A_x
Nonmanufacturing fixed capital investment for project
V
Manufacturing fixed capital investment for project
Total capital investment = T $= W + A_x + V$
(without land)
Total capital investment (without land)
Repayment of borrowed capital
Stockholders' dividends
Other investments
Capital source and sink
Other capital input
Bonds
Common stock
Preferred stock
Loans

Numerical Problem 6

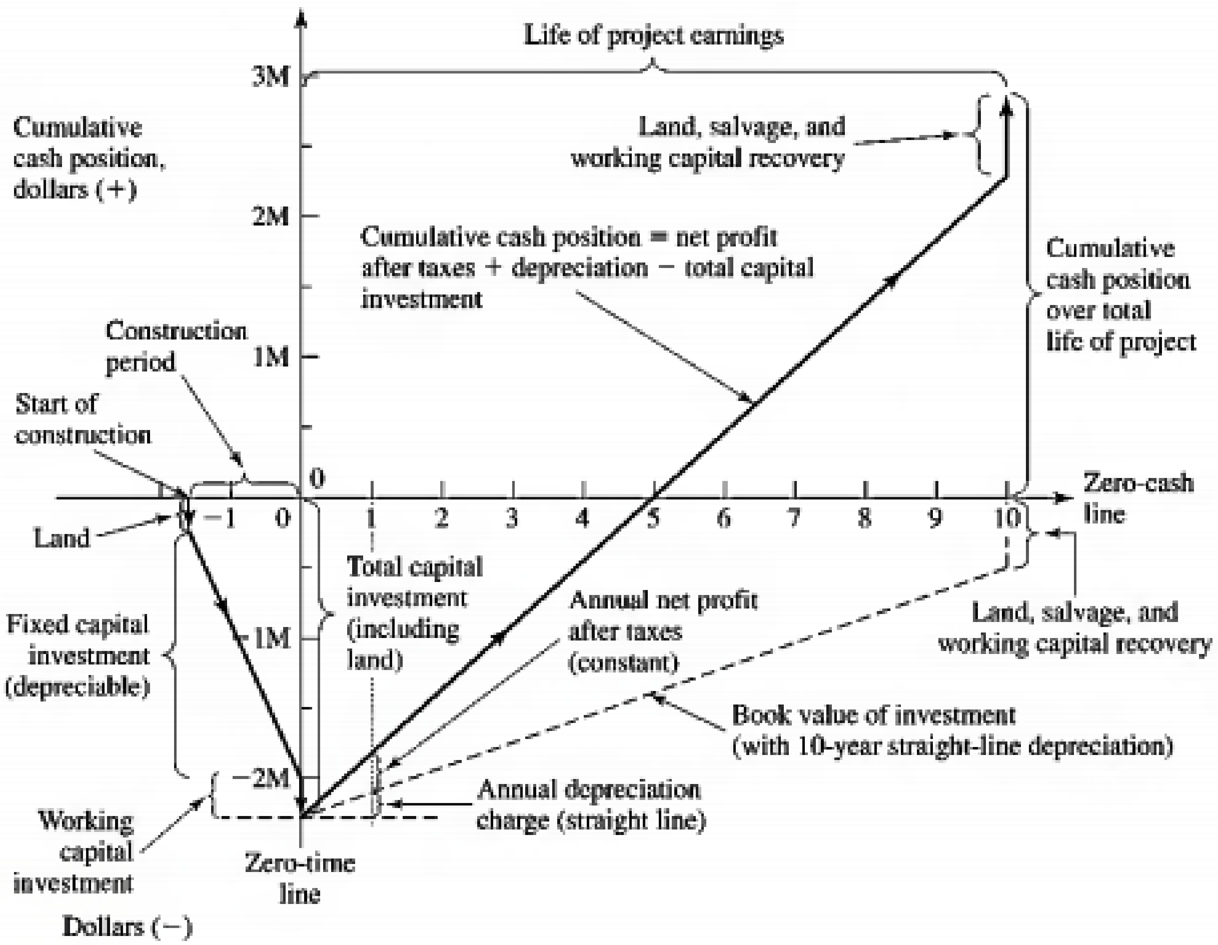
A company is working on a project with the following details:

1. **Total sales (S_y)**: \$1,000,000
2. **Operational costs (C_w)**: \$600,000
3. **Depreciation (d)**: \$100,000
4. **Income tax rate (Φ)**: 30% of Gross profit

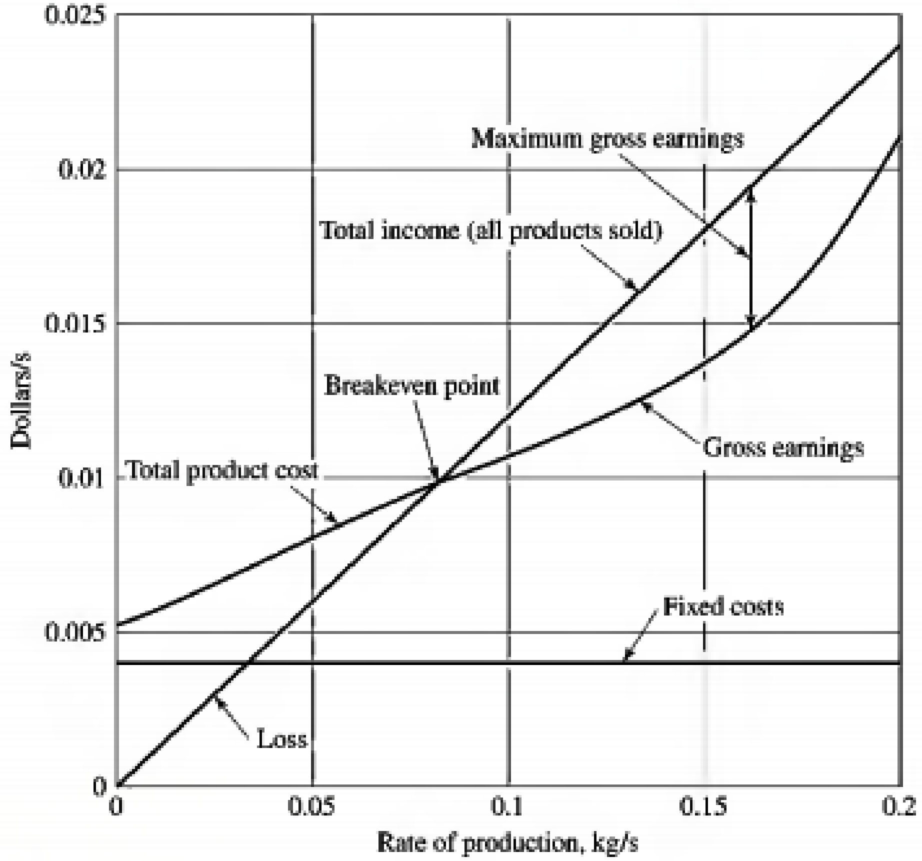
Questions:

1. Calculate the **gross profit** for the project.
2. Determine the **net profit after taxes**.
3. Compute the **net cash flow**, considering depreciation.

Cumulative cash position showing effects of cash flow over the full life cycle



Breakeven chart for chemical processing plant



Numerical Problem 7

The annual direct production costs for a plant operating at 70 percent capacity are $280,000 while the sum of the annual fixed charges, overhead costs, and general expenses is $200,000. What is the break-even point in units of production per year if total annual sales are $560,000 and the product sells at $40 per unit? What were the annual gross earnings and net profit for this plant at 100 percent capacity in 1988 when corporate income taxes required a 15 percent tax on the first $50,000 of annual gross earnings, 25 percent on annual gross earnings of $50,000 to $75,000, 34 percent on annual gross earnings above $75,000, and 5 percent on gross earnings from $100,000 to $335,000?

COST INDEXES

- Cost indexes allow engineers, economists, and project managers to estimate the current cost of a project or equipment by using past data. They help in comparing costs across different time periods.
- The prices may vary considerably with time due to changes in economic conditions.
- Therefore, some method must be used for updating old cost data
- This can be done by the use of cost indexes.
- A cost index is an index value for a given time showing the cost at that time relative to a certain base time.

COST INDEXES

- If the cost at some time in the past is known, the equivalent cost at present can be determined by multiplying the original cost by the ratio of the present index value to the index value applicable when the original cost was obtained.

- **Present Cost = Original Cost** $\left(\frac{\textit{Index value at present}}{\textit{Index value at the time originalcost was obatined}}\right)$

- **Cost in year A = Cost in Year B** $\left(\frac{\textit{Cost Index in Year A}}{\textit{Cost Index in Yeat B}}\right)$

- Cost indexes can be used to give a general estimate, but no index can take into account all factors, such as special technological advancements or local conditions.

- The common indexes permit fairly accurate estimates if the period involved is less than 10 years.

COST INDEXES

- Many different types of cost indexes are published regularly.
- Some can be used for estimating equipment costs; others apply specifically to labour, construction, materials, or other specialized fields.

The most common of these indexes are:

- The Marshall and Swift index [Equipment of Chemical industries]
- Engineering News Record Construction Index [cost of general construction projects, such as roads, buildings]
- The Nelson-Farrar Refinery Construction Index [**oil refining and petrochemical industries**.]
- The Chemical Engineering Plant Cost Index [chemical process industries]

Cost Indexes As Annual Averages

Year	Marshall and Swift installed-equipment indexes, 1926 = 100		*Eng. News-Record* construction index			Nelson-Farrar refinery construction index, 1946 = 100	*Chemical Engineering* plant cost index, 1957–1959 = 100
	All industries	Process industry	1913 = 100	1949 = 100	1967 = 100		
1987	814	830	4406	956	410	1121.5	324
1988	852	859.3	4519	980	421	1164.5	343
1989	895	905.6	4615	1001	430	1195.9	355
1990	915.1	929.3	4732	1026	441	1225.7	357.6
1991	930.6	949.9	4835	1049	450	1252.9	361.3
1992	943.1	957.9	4985	1081	464	1277.3	358.2
1993	964.2	971.4	5210	1130	485	1310.8	359.2
1994	993.4	992.8	5408	1173	504	1349.7	368.1
1995	1027.5	1029.0	5471	1187	509	1392.1	381.1
1996	1039.1	1048.5	5620	1219	523	1418.9	381.7
1997	1056.8	1063.7	5825	1264	542	1449.2	386.5
1998	1061.9	1077.1	5920	1284	551	1477.6	389.5
1999	1068.3	1081.9	6060	1315	564	1497.2	390.6
2000	1089.0	1097.7	6221	1350	579	1542.7	394.1
2001	1093.9	1106.9	6342	1376	591	1579.7	394.3
2002	1102.5‡	1116.9‡	6490‡	1408‡	604‡	1599.2‡	390.4†,§

†All costs presented in this text and in the McGraw-Hill website are based on this value for January 2002, obtained from the *Chemical Engineering* index unless otherwise indicated. The website provides the corresponding mathematical cost relationships for all the graphical cost data presented in the text.

Order of Magnitude Estimate

Several shortcut methods are available to estimate the total plant cost within $\pm$ 50% accuracy for preliminary studies.

Cost curve methods

- The quickest way to estimate an order-of-magnitude estimate of plant cost is to scale it from the known cost of an earlier plant that used the same technology or from published data.
- The capital cost of a plant can be related to capacity by the equation

$$C_2 = C_1 \left(\frac{S_2}{S_1}\right)^n$$

C_2 = ISBL capital cost of the plant with capacity S_2
C_1 = ISBL capital cost of the plant with capacity S_1

Example-1

If cost of an heat exchange in the year 2000 is Rs. 12,50,000 for 100 m^2. What is the cost of the heat exchange (200 m^2) in the year 2020.

Given the cost indices for the years 2000 and 2020 are 480 and 520, respectively.

Solution:

$$C_2 = C_1 \left(\frac{S_2}{S_1}\right)^n$$

Cost of 200 m^2 capacity Hex in 2000 $= 125000 \left(\frac{200}{100}\right)^{0.6}$

Cost in year 2020 = Cost in year 2000 $\left(\frac{\text{Cost index in year 2020}}{\text{Cost index in year 2000}}\right)$

$$= 125000 \left(\frac{200}{100}\right)^{0.6} \left(\frac{520}{480}\right)$$

$$= 13{,}54{,}166.66 = 20{,}5200$$

Order of Magnitude Estimate

Cost curve methods

$$C_2 = C_1\left(\frac{S_2}{S_1}\right)^n$$

C_2 = ISBL capital cost of the plant with capacity S_2
C_1 = ISBL capital cost of the plant with capacity S_1

Processes	n
Mechanical work or gas compression	**0.8 to 0.9**
Petrochemical processes	**0.7**
Small-Scale, highly instrumented processes	**0.4 -0.5**
Averaged across the whole chemical industry	**0.6**

- The averaged value (0.6) can be used to get a rough estimate of the capital cost if there are not sufficient data available to calculate the index for the particular process.
- It is commonly referred to as the "six-tenths rule

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