Ministry of Higher Education and Scientific Research

Al-Mustaqbal University College

Chemical Engineering and Petroleum Industries Department

Chemical Engineering Economics
Fourth Stage
Lecture No.3

Ass. Lec. Zahraa Abdulelah Hadi

Estimation of Capital Costs

An acceptable plant design must present a process that is capable of operating under conditions which will yield a profit. Since net profit equals total income minus all expenses, it is essential that the chemical engineer be aware of the many different types of costs involved in manufacturing processes.

Before an industrial plant can be put into operation, a large sum of money must be supplied to purchase and install the necessary machinery and equipment. Land and service facilities must be obtained, and the plant must be erected complete with all piping, controls, and services. In addition, it is necessary to have money available for the payment of expenses involved in the plant operation.

The capital needed to supply the necessary manufacturing and plant facilities is called the **fixed-capital investment**, while that necessary for the operation of the plant is termed the **working capital**. The sum of the fixed-capital investment and the working capital is known as the **total capital investment**. The fixed-capital portion may be further subdivided into manufacturing fixed-capital investment and nonmanufacturing fixed-capital investment.

Capital Investments

1. Fixed-capital investment

- Manufacturing Fixed-capital investment
- Nonmanufacturing Fixed capital investment

2. Working capital

- Raw materials and supplies carried in stock

- Accounts payable, taxes payable. accounts receivable
- Cash kept on hand for monthly payment of operating expenses, such as salaries, wages, and raw-material purchases,
- Finished products in stock and semi-finished products.

Fixed-Capital Investment

Manufacturing fixed-capital investment represents the capital necessary for the installed process equipment with all auxiliaries that are needed for complete process operation. Expenses for piping, instruments, insulation, foundations, and site preparation are typical examples of costs included in the manufacturing fixed-capital investment.

Fixed capital required for construction overhead (general) and for all plant components that are not directly related to the process operation is designated as the **nonmanufacturing fixed-capital investment**. These plant components include the 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 consists of field-office and supervision expenses, home-office expenses, engineering expenses, miscellaneous construction costs, contractor's fees, and contingencies. In some cases, construction overhead is proportioned between manufacturing and nonmanufacturing fixed-capital investment.

Working Capital

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

- raw materials and supplies carried in stock;
- finished products in stock and semi-finished products in the process of being manufactured;
- accounts receivable;
- cash kept on hand for monthly payment of operating expenses, such as salaries, wages, and raw material purchases;
- accounts payable; and
- taxes payable.

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 semi-finished products have a value approximately equal to the total manufacturing cost for 1 month's production. Because credit terms extended to customers are usually based on an allowable 30-day payment period, the working capital required because of 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 use an initial working capital amounting to 10 to 20 percent of the total capital investment. This percentage may increase to as much as 50 percent or more for companies producing products of seasonal demand, because of the large inventories which must be maintained for appreciable periods.

Types of Capital Cost Estimates

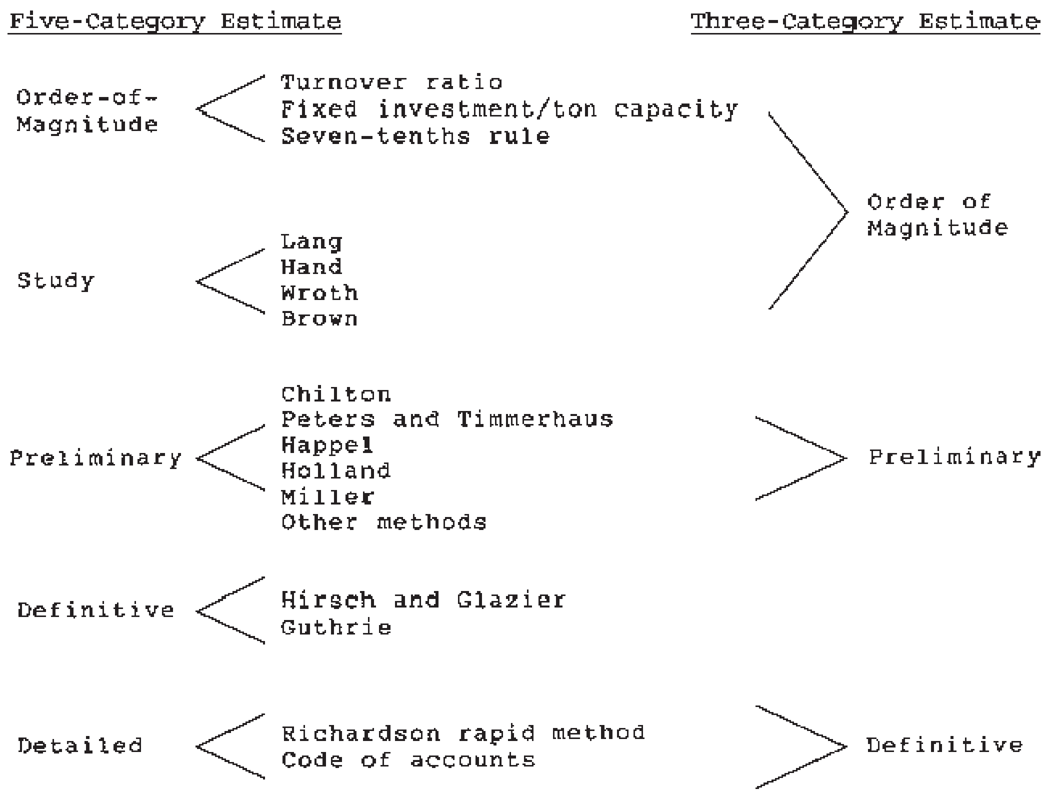
An estimate of the capital investment for a process may vary from a predesign estimate based on little information except the size of the proposed project to a detailed estimate prepared from complete drawings and specifications. Between these two extremes of capital-investment estimates, there can be numerous other estimates which vary in accuracy depending upon the stage of development of the project. These estimates are called by a variety of names, but the following five categories represent the accuracy range and designation normally used for design purposes:

1. Order-of-magnitude estimate (ratio estimate) based on similar previous cost data; probable accuracy of estimate over ± 30 percent.
2. Study estimate (factored estimate) based on knowledge of major items of equipment; probable accuracy of estimate up to ± 30 percent.
3. Preliminary estimate (budget authorization estimate; 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.
5. Detailed estimate (contractor's estimate) based on complete engineering drawings, specifications, and site surveys; probable accuracy of estimate within +5 percent.

Cost of Preparing a Capital Cost Estimate

Type of estimate	Cost (% of capital cost)
Order of magnitude	0.01–0.05
Study	0.10–0.20
Preliminary	0.20–0.50
Definitive	0.40–1.50
Detailed	1.00–5.00

Predesign cost estimates (defined here as order-of-magnitude, study, and preliminary estimates) require much less detail than firm estimates such as the definitive or detailed estimate. However, the predesign estimates are extremely important for determining if a proposed project should be given further consideration and to compare alternative designs.



In this study, we will use the tree category method.

1. Order-of-Magnitude {OOM}

This estimate is generally used by management for feasibility studies, for evaluating the best process, the establishment of plant size, and the economic feasibility of the project.

Turnover Ratio

This is a rapid, simple method for estimating the fixed capital investment but is one of the most inaccurate. The turnover ratio is defined as

$$\text{Turnover ratio (TOR)} = \frac{\text{annual gross sales}}{\text{fixed capital investment}}$$

The annual gross sales figure is the product of the annual production rate and the selling price per unit of production. A basic assumption is that all product made is sold. For a large number of chemical processes operating near ambient conditions, the turnover ratio is near 1.0. These ratios may vary from 0.2 to 5.0. Values less than 1.0 are for large volume, capital-intensive industries and those greater than 1.0 are for processes with a small number of equipment items. A list of turnover ratios is found in Table 1.

Example 1

Estimate the fixed capital investment for a 1500 ton/day ammonia plant using the turnover ratio. The current gross selling price of ammonia is \$150/ton. The plant will operate at a 95% stream time.

Solution:

$$\text{TOR} = \frac{\text{annual gross sales}}{\text{fixed capital investment}}$$

Solution:

The TOR for ammonia plant is 0.65

$$\text{Annual gross sales} = \$150/\text{ton} \times 365 \times 0.95 \times 1500\ \text{ton/day}$$

$$= \$78{,}000{,}000$$

$$\text{FCI} = \frac{\text{annual gross sales}}{0.65} = \frac{\$78{,}000{,}000}{0.65} = \$120{,}000{,}000$$

Table:1 Turnover Ratio

Product	TOR
Acetic acid	1.70
Acrylonitrile	1.55
Ammonia	0.65
Ammonium sulfate	3.82
Benzaldehyde	1.00
Benzene	8.25
Butadiene	1.68
Butanol	1.10
Carbon tetrachloride	1.00
Ethylene dichloride	0.51
Ethylene glycol	1.10
Ethyl ether	6.05
Methanol	1.00
Methyl chloride	2.95
Methyl isobutyl ketone	2.10
Maleic anhydride	4.82
Nitric acid	3.95
Phthalic anhydride	3.12
Polyethylene	0.40
Polypropylene	0.35
Sodium carbonate	0.39
Styrene	5.21
Sulfuric acid	0.63
Urea	2.36
Vinyl chloride	3.40

Seven-Tenths Rule

The cost of the plant can be determined by the ratio method by adjusting the capacity by using the 7th rule. It has been found that cost-capacity data for process plants may be correlated using a logarithmic plot similar to the 0.6

rule. Remer and Chai have compiled exponents for a variety of processes and most are between 0.6 and 0.8. The use of an average value 0.7 is the name of this method. In order to use this method, the estimator must have the fixed capital investment for another plant using the same process but at a different capacity. Cost indexes may be used to correct costs for time changes.

Table 1 contains appropriate data. The equation is

$$\text{Cost plant } B = \text{cost plant } A \left(\frac{\text{capacity plant } B}{\text{capacity plant } A} \right)^{0.7}$$

Table 2: Seven-Tenths Rule

Compound	Process	Size range	Unit	Exponent
Acetaldehyde	Ethylene	25–100	1000 tons/yr	0.70
Acetylene	Natural gas	4–37	1000 tons/yr	0.73
Ammonia	Natural gas	37–110	1000 tons/yr	0.63
Benzene				0.61
Cyclohexane	Benzene, H_2	15–365	1000 tons/yr	0.49
Ethanol	Ethylene by direct hydration			0.72
Ethylene	Refinery gas or hydrocarbons			0.71
Ethylene oxide	Direct oxidation of ethylene			0.67
Methanol	Natural gas			0.71
Phthalic anhydride	Naphthalene or *o*-xylene	21–365	1000 tons/yr	0.72
Propylene				0.70
Sulfuric acid	Contact, sulfur	7–256	1000 tons/yr	0.63
Urea		20–200	1000 tons/yr	0.70
Vinyl chloride	Ethylene, Cl_2 or HCl	27–365	1000 tons/yr	0.88

Example 2 :

A company is considering the manufacture of ethylene oxide as an intermediate for its polymer division. The process to be used is the direct oxidation of ethylene. The company built a similar unit in 1997 that had a rated capacity of 100,000 tons annually for $60,000,000. The projected production of the new facility is to be 150,000 tons annually. Estimate the fixed capital investment in late 2001 dollars to produce the required ethylene oxide.

Solution:

CE Index for 1997 = 386:5

CE Index for late 2001 =396:8

The equation can be modified to include the cost indexes. So,

$$\text{Cost}_{150}(2001) = \text{cost}_{100}(1997)\left(\frac{\text{capacity } 150}{\text{capacity } 100}\right)^{0.67}\left(\frac{\text{CEI } 2001}{\text{CEI } 1997}\right)$$

$$\text{Cost}_{150}(2001) = (\$60{,}000{,}000)\left(\frac{150}{100}\right)^{0.67}\left(\frac{396.8}{386.5}\right)$$

$$\text{Cost}_{150}(2001) = (\$60{,}000{,}000)(1.31)(1.027)$$

$$= \$80{,}722{,}000, \text{ say } \$80{,}700{,}000$$