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Practical Engineering Guidelines for Processing Plant Solutions

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GENERAL PROCESS PLANT COST ESTIMATING (ENGINEERING DESIGN GUIDELINE)

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Scope

Many engineering design projects are developed to provide sizing information from which estimates of capital and operating costs can be made. Chemical plants are built to make a profit, and an estimate of the investment required and the cost of production is needed before the profitability of a project can be assessed. Cost estimation is a specialized subject and a profession in its own right, but the design engineer must be able to make rough cost estimates to decide between project alternatives and optimize the design.

Cost estimation may be defined as the process of forecasting the expenses that must be incurred to manufacture a product. These expenses take into consideration all expenditures involved in design and manufacturing with all the related service facilities such as pattern making, tool making as well as portion of the general administrative and selling costs. Cost estimates are the joint product of the engineer and the cost accountant.

Estimating is of great importance to a concern because it enables the factory owner to decide about the manufacturing and selling policies. It is obvious that too high of an estimate will not get any jobs for the firm quoting higher rates. Under estimating will put the engineering firm owner with a loss and may lead the engineering firms failure. Therefore, estimation must be carried out accurately.

This design guideline covers the how to estimate capital investment, total product cost and economic and profitability analysis of cost estimating used in the typical process industries. It assists engineers to understand the basic design of cost estimation.

This design guideline covers the basic elements in the field of cost estimation in sufficient detail to allow an engineer to design a cost estimate with the suitable economic analysis; depreciation, net profit after tax, percentage of return of investment, payout period of project net present value with interest rate and cash flow, etc.

The design of cost estimation may be influenced by factors, including equipments size, process requirements, location, labor cost, and complexity level of process. .All the important parameters use in the guideline are explained in the definition section which help the reader more understand the meaning of the parameters or the terms utilized.

In the application section of this guideline, five case studies are shown and discussed in detail, highlighting the way to apply the theory for the calculation. Example Calculation

Spreadsheets are part of this guideline. This Example Calculation Spreadsheets are based on case studies in the application section to make them easier to understand.

INTRODUCTION

General Consideration

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. Capital must be allocated for direct plant expenses, such as those for raw materials, labor, and equipment. Besides direct expenses, many other indirect expenses are incurred, and these must be included if a complete analysis of the total cost is to be obtained.

A. Sources of Price Data

The revenues and variable costs of production are obtained by multiplying the product, feed, or utility flow rates from the flowsheet by the appropriate prices. The difficult step is usually finding good price data.

In many large companies the marketing or planning department develops official forecasts of prices for use in internal studies. These forecasts sometimes include multiple price scenarios, and projects must be evaluated under every scenario. Company forecasts are occasionally made available to the public.

Other sources of price data are based on trade journals. Other companies also can be hired as consultants to provide economic and marketing information or contact online brokers and suppliers directly and last source, get price data from reference books[9].

B. Capital Requirement

The cost of capital is what it costs a company to borrow money from all sources, such as loans, bonds, and preferred and common stock. It is an important consideration in determining a company's minimum acceptable rate of return on an investment. A company must make more than the cost of capital to pay its debts and make a profit.

From profits, a company pays dividends to the stockholders. If a company ignores the cost of capital to increase dividends to the stockholders, then management is not meeting its obligations to pay off outstanding debts. The following explanations are principal to build cost estimating of a plant.

C. Capital Investments

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.

I. Fixed Capital Investment

About 85 to 90 percent of total capital is comprised generally of fixed capital. Fixed capital may be defined as the total cost of processing installations, buildings, auxiliary services, and engineering involved in the creation of a new plant. Several methods to obtain fixed capital investment can be described as follow.

i. Method 1

This method requires the cost factors by consider the proportional costs of each component. The cost factors presented are based on modern industrial experience. The typical variation in component costs as percentages of fixed capital investment for multiprocess grass-roots plants or large battery limit additions are summarized in table 1. A grass-roots plant is defined as a complete plant erected on a new site.

Table 1: Percentage of Fixed capital Invesment (Peters, 1990)

Typical percentages of fixed-capital investment values for direct and indirect cost segments for multipurpose plant or large additions to existing facilities	
Component :	Range, %
Direct costs	
Purchased equipment	15-40
Purchased equipment installation	6-14
Instrumentation and controls (installed)	2-8
Piping (installed)	3-20
Electrical (installed)	2-10
Buildings (including services)	3-18
Yard improvements	2-5
Service facilities (installed)	8-20
Land	1-2
Total direct costs	
Indirect costs	
Engineering and supervision	4-21
Construction expense	4-14
Contractor's fee	2-6
Contingency	5-15
Total fixed-capital investment	

ii. Method 2

This method looks like first method but, there is contained difference in the application. The used of this method requires initially that the cost of purchased process equipment. All components of direct cost are then estimated individually as equivalent to precentages of the equipment cost.

iii. Method 3

A simple technique to estimate the capital cost of a chemical plant is the Lang Factor method. The Lang factor method has a tendency to produce high results. The total cost is determined by multiplying the total purchased cost for all the major items of equipment by a constant. The multipliers, depending on the type of plant are given in table 2[10].

Table 2: Lang factor

Type of chemical plant	Lang factor, F_{lang}
Solid processing	3.10
Solid – fluid processing	3.63
Fluid processing	4.74

The capital cost calculation is determined using Equation 1.

$$C_T = F_{Lang} \sum_{i=1}^{n} C_{p,i} \qquad \text{Eq (1)}$$

Where,

C_T = Capital cost of the plant
$C_{p,i}$ = Purchased cost for the major equipment units
n = Total number of individual units
F_{Lang} = Lang Factor

II. Working Capital

Working capital is the amount of capital required to start up the plant and finance ordinarily amounts to the production cost for 1 month of operafion before revenues from the process start. In general it will be found to be amount equal to 15 to 20% of the fixed capital investment or 25% of annual product sales value[3].

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 semifinished 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[7].

D. Total Production Cost

Important part of a complete cost estimate besides capital investment is the estimation of costs for operating the plant and selling the products. Capital expenditures occur once during the life of a project but operating expenses are recurring expenses and, as such, significantly affect the cash flow and profitability of a venture. These costs can be grouped under total production cost. Total production cost is generally divided into the categories of manufacturing costs and general expenses.

I. Manufacturing Costs

The manufacturing expense will be interpreted to mean all expenses required to make a product and to ready it for shipment. These expenses, as considered here, are divided into three classifications as follows: direct production costs, fixed charges, and plant-overhead cost.

II. General Expenses

In addition to the manufacturing costs, other general expenses are involved in any company's operations. These general expenses may be classified as administrative expenses, distribution and marketing expenses, research and development expenses, and financing expenses.

E. Classification of 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. The American National Standards Institute (ANSI) defines five categories represent the accuracy range and designation normally used for design purposes:

Table 3 : Classification of Cost Estimates[11]

Phase of estimating cycle	Typical process industry accuracy range and contingency	Typical data input available	Typical end uses	Typical techniques
Class V (Order of magnitide, guessestimate)	-30% to +50% before contingency Typical contingency : 15 – 40%	Engineering <2% complete; general fuction; rough capacities and outputs	Project screening; brain-storming	Judgement or parametric including : capacity factoring, parametric cost models, gross unit costs/ratios
Class IV (Study, conceptual)	-15% to +30% before contingency Typical contingency : 10 – 20%	Engineering 1-5% complete; capacities and outputs; block layouts and diagrams; preliminary equipment list; soils data assumed	Project screening; concept evaluation; feasibility studies; budget previews	Parametric including : equipment factored,gross unit costs/ratios, parametric cost models
Class III (Preliminary, budget autorization)	-10% to +20% before contingency Typical contingency : 8 – 12%	Engineering 10-40% complete; preliminary layouts and diagrams; equipment list and specifications; partial soils data	Design development; cost control; detailed feasibility	Mixed parametric and unit: battery limit, cascading; parametric unit cost models; some unit costs

Continue from table 3

Phase of estimating cycle	Typical process industry accuracy range and contingency	Typical data input available	Typical end uses	Typical techniques
Class II (Definitive, project control)	-5% to +15% before contingency Typical contingency : 5 – 10%	Engineering 30-60% complete; final layouts and diagrams; final equipment list and quotes; preliminary design drawings; complete soils data	Check or comparison; bid or tender (soft $); detail cost control	Unit cost or line item with minor parametric application
Class I (Detailed, firm)	-5% to +5% before contingency Typical contingency : 3 – 5%	Engineering >90% complete; design essentially complete; approved for construction; full quantity take off	Bid or tender (hard $), material procurement	Unit cost or line item

It should be noted that the predesign estimates may be used to provide a basis for requesting and obtaining a capital appropriation from company management. Later estimates, made during the progress of the job, may indicate that the project will cost more or less than the amount appropriated. Management is then asked to approve a variance which may be positive or negative.

F. Estimating Procedure

Committees within the firm are formed to plan for the future and prepare capital budgets. The economic evaluation of a process proceeds in several steps. These are:

1. preparing a process flow diagram
2. calculating mass and energy flows
3. sizing major equipment
4. estimating the capital cost
5. estimating the production cost
6. forecasting the product sales price
7. estimating the return on investment

The difficulty in a process evaluation is not the computations, but the variability in the terminology that appears in the literature, which is a result of differences in company practice[8].

DEFINITION

After-tax cash flow - the net profit after taxes plus depreciation.

Breakeven point the operating - condition, such as output, at which two alternatives are equal in economy.

Cost estimating - A predictive process used to quantify, cost, and price the resources required by the scope of an asset investment option, activity, or project**.**

Cost index (price index) - a number that relates the cost of an item at a specific time to the corresponding cost at some arbitrarily specified time in the past.

Direct costs - the portion of the operating costs that is generally assignable to a specific product or process area.

Escalation - the provision in actual or estimated costs for an increase in the cost of equipment, material, labor, etc., over that specified in the purchase order or contract due to continuing price level changes over time.

Indirect costs - costs not directly assignable to the end product or process, such as overhead and general purpose labor, or costs of outside operations, such as transportation and distribution.

Interest rate - the ratio of the interest payment to the principal for a given unit of time, usually expressed as a percentage of the principal.

Operating cost (or manufacturing cost) - the expenses incurred during the normal operation of a facility, or component, including labor, materials, utilities, and other related costs.

Overhead - a cost or expense inherent in the performing of an operation, plant overhead is also called factory expense.

Payout period - the time required to recover the original fixed investment from profit and depreciation.

Present value - the value of the asset in its condition at the time of valuation.

Profit – the excess of income over expenditure

Royalty - compensation for the use of a property, usually a patent, copyrighted material, or natural resource; often expressed as a percentage of receipts from using the property.

Salvage value - the market value of a capital asset at the time it is retired (often assumed to be zero in economic analysis).

Service life - the useful life of an asset.

Stockholder - an investment group or individual holding legal ownership of a business by virtue of investing equity capital and entitled to any profits generated.

Straight line (SL) depreciation - provides that an asset be depreciated in equal annual installments over its usehl (book) life or its tax life.

Taxable income - cash earnings minus cash expense minus noncash expenses for depreciation, depletion, or amortization.

Taxes - cash payments to governmental agencies, including excise taxes, property taxes, capital gains taxes, and income taxes.

Time value of money - recognizes that money shifts in purchasing power over time to reflect inflation and uncertainty in investment returns.

Time zero - a single reference point in time set by the analyst as a starting point for economic analysis.

Working capital - cash that is tied up in an operation in addition to capital invested in facilities. Includes cash cost of inventories, net accounts receivable, spare parts or supplies, and cash-on-hand.

NOMENCLATURE

A	Uniform end-of-period payment or receipt, dimensionless
C_1	Estimated cost at previous time, $
C_2	Cost at expected time, $
c_a	Capacity of equipment a
c_b	Capacity of equipment b
CF_n	Cash flow in year n
D	Depreciation, $
E_a	Purchased cost of equipment a, $
E_b	Purchased cost of equipment b, $
F	Future sum of money at the end of period, dimensionless
F_{DB}	Factor of declining-balance depreciation, dimensionless
F_{DDB}	Factor of double-declining-balance depreciation, dimensionless
i	interest rate per period
I_1	Index value at expected time, dimensionless
I_2	Index value at previous time, dimensionless
L	Salvage value, $
n	Depreciable life in years, year
N_{OL}	Number of operators per shift, dimensionless
N_{np}	Number of nonparticulate processing steps (compressors, towers, reactors, heaters, and exchangers) , dimensionless
P	Present value, a single amount (may be used fixed capital investment)
P	Number of processing steps involving the handling of particulate solid (e.i distribution, particulate size control, and particulate removal). In general, the value of P is zero, dimensionless
t	Project life in years, year
T_b	Thickness of the shell at the bottom, in
T_p	Thickness required for the operating pressure, in
W	Weight of towers, lb

THEORY

A. Cost Indexes

Most cost data which are available for immediate use in a preliminary or predesign estimate are based on conditions at some time in the past. Because prices may change considerably with time due to changes in economic conditions, some method must be used for updating cost data applicable at a past date to costs that are representative of conditions at a later time. This can be done by the use of cost indexes.

Cost indexes are numerical values that reflect historical change in engineering costs. The cost index numbers are dimensionless, and reflect relative price change in either individual cost items such labor, material, utilities; or groups of costs such consumer prices, producer prices. Indexes can be used to update historical costs with the basic ratio relationship as follows[6].

$$C_2 = C_1\left(\frac{I_2}{I_1}\right) \qquad \text{Eq (2)}$$

where,
C_1 = Estimated cost at previous time
C_2 = Cost at expected time
I_1 = Index value at expected time
I_2 = Index value at previous time

There are several cost indexes used by the chemical industry to adjust for the effects of inflation.

Several of these cost indices are shown in Table 4.

Table 4: Cost Indexes

Year	Chemical Engineering Plant Cost 1957-1959 = 100	Eng.News-Record Construction Cost index 1967 = 100	Marshall and Swift Equipment Cost Index 1926 = 100	Nelson-Farrar refinery Cost index 1946 = 100
1995	381.1	5471	1027.5	1392.1
1996	381.8	5620	1039.2	1418.9
1997	386.5	5826	1056.8	1449.2
1998	389.5	5920	1061.9	1477.6
1999	390.6	6059	1068.3	1497.2
2000	394.1	6221	1089.0	1542.7
2001	394.3	6343	1093.9	1579.7
2002	395.6	6538	1104.2	1642.2
2003	401.7	6694	1123.6	1710.4
2004	444.2	7115	1178.5	1833.6
2005	468.2	7446	1244.5	1918.8
2006	499.6	7751	1302.3	2008.1
2007	525.4	7967	1373.3	2106,7
2008	575.4	8310	1449.3	2251,4
2009	521.9	8570	1468.6	2217.7
2010(midyear)	555.3	8837	1461.3	2337.6

Current and past values of several of the indexes may be obtained from each published sources, as such the Marshall & Swift Index (M&S) and the Chemical Engineering (CE) Index is found in *Chemical Engineering* under Economic Indicators; Nelson Farrar (NF) index is published in the first issue each month of the *Oil and Gas Journal* quarterly; and the Engineering News Record (ENR) Index may be found weekly in *Engineering News Record*.

The choice of the index to use is based upon the industry in which the person works. If it is general construction, the ENR Index is the best. An engineer in the petroleum or petrochemical business might find the NF Index suitable. In the chemical process industries, either the CE or the M&S are adequate. Although these latter two indexes have different bases, both of these give similar results[3].

As a rule of thumb, cost indexes permit accuracy may be limited by applying indexes over a 4 to 5 year period at best. The development of the cost index requires the actual cost at different times for a prescribed quantity and quality of the item. The base period is a selected time when the index is defined with a basis value of 100. The index each year (period) is determined as the cost divided by the base year cost and multiplied by 100. Future index values may be forecast using simple extrapolation by plot historical cost index trends[5].

B. Fixed Capital Investment

I. Component of Fixed Capital Investment

i. Estimation of Purchased Equipment Costs

To obtain an estimate of the capital cost of a chemical plant, the costs associated with major plant equipment must be known. The most accurate estimate of the purchased cost of a piece of major equipment is provided by a current price quote from a suitable vendor. The next best alternative is to use cost data on previously purchased equipment of the same type[10].

a. Six-Tenths Factor

Six tenths factor rule is given when the estimator is faced with the problem of determining the cost of a piece of equipment at a capacity for which has no cost data immediately available. This rule states that if the new piece of equipment is similar to one of another capacity for which cost data are available. According to this rule, if the cost of a given unit at one capacity is known, the cost of a similar unit with X times the capacity of the first is approximately $X^{0.6}$ times the cost of the initial unit.

$$E_b = E_a \left(\frac{c_b}{c_a} \right)^{0.6} \qquad \text{Eq (3)}$$

where,

ca = Capacity of equipment a
cb = Capacity of equipment b
Ea = Purchased cost of equipment a
Eb = Purchased cost of equipment b

ii. Equipment Instalation

Analyses of the total installed costs of equipment in a number of typical chemical plants indicate that the cost of the purchased equipment varies from 65 to 80 percent of the installed cost depending upon the complexity of the equipment and the type of plant in which the equipment is installed. The installation cost of process equipment may be estimated as being an amount equivalent to 43 percent of the purchased equipment cost. Futher detail may be made based upon the listing in table 5[1].

Table 5 : Installation cost

Parameter	Material, %	Labor, %	Total, %
Foundations	4	3	7
Platforms and supports	7	4	11
Erection of equipment	-	25	25
Total installation	11	32	43

iii. Piping

The cost for piping covers labor, valves, fittings, pipe, supports, and other terms involved in the complete erection of all piping used directly in the process. The cost of piping depending upon the type of process involved, may be estimated at amounts equal to percentages of the purchased equipment value.

Table 6: Piping cost

Type of process plant	Percent of purchased equipment			Percent of fixed capital investment
	Material	Labor	Total	Total
Solid	9	7	16	4
Solid-fluid	17	14	31	7
Fluid	36	30	66	13

iv. Instrumentation

Instrumentation is the major part of the capital investment which actually includes not only the instruments but also all auxiliries for a complete system. There are three parameters depend required of automatic controls which are installed in equipments. Instrumentation costs may be calculated from the purchased equipment as equivalent percentages that shown in table 7.

Table 7: Instrumentation cost

Parameter	Material, %	Labor, %	Total, %
Few or no controls	4	1	5
Some specific controls	12	3	15
Extensive controls	24	6	30

v. Insulation

Insulation factors can become important when temperature of equipment changes very high, and it may be necessary to estimate insulation costs with a great deal of care. The total cost for the labor and materials required for insulating equipment and piping in ordinary chemical plants is approximately 8 percent of the purchased equipment cost which each of their percentages is 5 and 3 percent.

vi. Electrical

In ordinary chemical plants, the electrical installation consists of four major components. those are power wiring, lighting, transformation and service, and instrument and control wiring. The complete installed cost of electrical may be estimated as being equivalent to 10 to 15 percent of the purchased equipment value.

vii. Buildings

In estimating the cost for buildings, depend construction and existence of plant site. Costs for plumbing, heating, lighting, ventilation, and similar building services are list the erected unit costs of buildings and building components and the installed cost of service. The cost of buildings, including services for different types of process plants, is shown in Tables 8 as equal to a percentage of the purchased equipment price.

Table 8 : Cost buildings include services

Type of process plant	Percentage of purchased equipment cost		
	New plant at new site (Grass roots)	New unit at existing site (Battery limit)	Expansion at an existing site
Solid	68	25	15
Solid – fluid	47	29	7
Fluid	45	5 – 18	6

viii. Yard Improvements

The yard improvements costs consist of constructions for fencing, grading, roads, sidewalks, railroad sidings, landscaping, and similar items. The cost of yard improvements for chemical plants may be estimated as an amount equivalent to 10 to 20 percent of the purchased equipment price.

ix. Service facilities

Service facilities include such as utilities for supplying steam, water, power, compressed air, and fuel in an industrial plant. Waste disposal, fire protection, and miscellaneous service items also are included under the general heading of service facilities cost. The total cost for service facilities in chemical plants may be determined as amounts equivalent to presentages of the purchased equipment cost in table 9.

Table 9: Total installed utility cost

Type of services	Installed cost, %
Minimum additional services	25
Average services	40
Complete new services	75

x. Land

The value of land is a highly fluctuating item. It will vary extensively with so many factors that it should be checked for each location of the property and may vary by a cost factor per acre as high as thirty to fifty between a rural district and a highly industrialized area. As a rough average, land costs for industrial plants amount to 4 to 8 percent of the purchased equipment cost. Because the value of land usually does not decrease with time, this cost should not be included in the fixed capital investment when estimating certain cash flow, such as depreciation.

xi. Engineering and Supervision

The engineering costs, sometimes referred to as home office costs or contractor charges, include the costs of detailed design and other engineering services required to carry out the project construction design and engineering, drafting, purchasing, accounting, construction and cost engineering, travel, reproductions, communications. This cost is normally considered an indirect cost in fixed capital investment and is approximately 30 percent of the purchased equipment cost or 8 percent of the total direct costs of the process plant.

xii. Construction

Construction is the item else that is included into indirect plant cost and consist temporary construction and operation, construction tools and rentals, home office personnel located at the construction site, construction payroll, travel and living, taxes and insurance, and other construction overhead. This expense item is occasionally included under equipment installation, or more often under engineering, supervision, and construction. If construction or field expenses are to be estimated separately, the construction expenses average roughly 10 percent of the total direct costs for ordinary chemical process plants.

xiii. Contractor's fee

The contractor's fee depends upon the size, complexity, and location of the plant. It may be estimated as being equivalent to 2 to 8 percent of direct plant cost, which is the sum of the physical plant cost and engineering and construction expense.

xiv. Contingency

Contingency charges are extra costs added into the project budget to allow for variation from the cost estimate. In order to compesate for unpredictable expense, minor process changes, price changes, and estimating errors, a contingency charge is applied against the direct plant cost. It may be estimated as shown in table 10 as equivalent to a percentage of the direct plant cost. A new development where there is no previous similar experience and rather limited information will carry a high contingency, whereas a simpler installation similar to other construction will need only a minimum contingency.

Table 10: Cost of contingency

Contingency level	Contingency cost, %
Low	10
Average	15
High	25

C. Total Production Cost

The costs associated with the day-to-day operation of a chemical plant must be estimated before the economic feasibility of a proposed process can be assessed. Production costs are generally expressed in term of cost per unit of output. Inasmuch as many oh the articles of manufacturing expense are calculated on basis of occuring over given intervals of time, the production rate must be know determine the unit cost.

There are many elements that influence the cost of manufacturing chemicals. A list of the important costs involved, including a brief explanation of each cost, is given in Table 11.

Table 11 : Total production cost

Component	Description		Basis	Percentage
Manufacturing Cost				
Direct cost : These costs include expenses directly associated with the manufacturing operation.				
Raw material	Costs of chemical feed stocks flowrates required by the process.		Material balance	
Operating labor	Costs of personnel required for plant operations.		Itemize	
Direct Supervisory and Clerical Labor	Cost of administrative, engineering, and support personnel.		Operating labor	15%
Utilities	The cost for utilities depending on the amount of consumption		Process requirement	
Maintenance and repairs	Costs of labor and materials associated with maintenance based on :	Simple chemical processes	Fixed Capital Investment	2 – 6 %
		Average process		5 – 9 %
		Complicated processes		7 – 11 %

Continue from table 11 (1)

Component	Description	Basis	Percentage
Operating supplies	Costs of miscellaneous supplies that support daily operation not considered to be raw materials. Examples include chart paper, lubricants, miscellaneous chemicals, filters, respirators and protective clothing for operators, etc.	Maintenance an repairs	15 %
Laboratory charges	Costs of routine and special laboratory tests required for product quality control and troubleshooting.	Operating labor	10 – 20%
Patents and royalties	Cost of using patented or licensed technology.	Sales	1 – 5%
Fixed charges : Expenses which remain practically constant from year to year and independent of changes in production rate.			
Depreciation	Costs associated with ihe physical plant (buildings, equipment, etc.). Legal operating expense for tax purposes.	Life period and salvage value	
Local taxes	Cost depends on the particular locality of the plant and the regional laws.	Fixed Capital Investment	1 – 2 %
Insurance	Costs depend on the type of process being carried out in the manufacturing operation and on the extent of available protection facilities.	Fixed Capital Investment	1%
Plant overhead costs : These costs are purposed for payroll overhead			
Plant overhead costs	Catch-all costs associated with operations of auxiliary facilities supporting the manufacturing process. Costs involve payroll and accounting services, pensions, fire protection and safety services, medical services, cafeteria and any recreation facilities, payroll overhead and employee benefits, general engineering, etc.	operating labor + supervision + maintenance	50 – 70 %

Continue from table 11(2)

Component	Description	Basis	Percentage
General Expenses			
Administration costs	Costs for administration; includes salaries, other administration, buildings, and other related activities.	Operating labor	20 – 30%
Distribution and selling costs	Costs of sales and marketing required to sell chemical products; includes costs for sales offices, salesmen, shipping, and advertising	Sales	0 – 7%
Research and development	Costs of research activities related to the process and product.	Sales	2 – 5%
Financing	Costs considered to be the compensation paid for the use of borrowed capital.	Total Capital Investment	0 – 10%

i. Operating Labor Cost

Operating labor is usually the second largest direct expense item on the manufacturing expense. Almost all plants are operated on a shift-work basis (even batch plants), with typically 4.8 operators per shift position with five 8-hour shifts a week. This gives a four-shift rotation with allowance for weekends, vacations, and holidays and some use of overtime. More shift positions are needed when handling highly toxic compounds and using more mechanical equipment.

Operating labor can be estimated by multiplying number of operators per shift with 4.8 operators per shift. The following technique used to estimate number of operating labors for chemical processing plants is given by[10]

$$N_{OL} = \left(6.29 + 31.7P^2 + 0.23N_{np}\right)^{0.5} \qquad \text{Eq (4)}$$

Where,

N_{OL} = number of operators per shift

P = number of processing steps involving the handling of particulate solid (e.i distribution, particulate size control, and particulate removal). In general, the value of P is zero.

N_{np} = number of nonparticulate processing steps (compressors, towers, reactors, heaters, and exchangers)

To estimate the cost of operating labor, the average hourly or yearly wage of an operator is required. Chemical plant operators are relatively highly paid, and data from the Bureau of Labor and Statistics give the hourly rate for miscellaneous plant and system operators.

ii. Utility Costs

The utility requirements for a process are obtained from material and energy balances then translated into expected demands natural gas or heating oil for fired heat, steam, electricity, cooling water, and refrigeration. In addition to the utilities required for heating and cooling, the process may also need process water and air for applications such as washing, stripping, and instrument air supply.

The cost of utilities can vary widely with the location, with the size of the service required, with the national and local economy, and even with the season. Generally utility pricing is regulated and the approved tariffs are readily available from the utility company or the cognizant regulatory agency.

D. Economic analysis

i. Margins

The sum of product and byproduct revenues minus raw material costs is known as the gross margin (or sometimes product margin or just margin). It is defined as

$$\text{Gross margin} = \text{Revenues} - \text{Raw materials costs} \qquad \text{Eq (5)}$$

Gross margin is a useful concept, as raw materials costs are almost always the largest contributor to production costs (typically 80 to 90% of total cost of production). Raw materials and product prices of commodities are often subject to high variability and can be difficult to forecast, but margins suffer less variability if producers are able to pass feedstock price increases on to their customers.

ii. Interest factor

Economic analysis begins with the definition of compound interest factors. Most interest tables in engineering economics textbooks are divided into two patterns of cash flow, those are single payment and uniform series.