Engineering Economics

WHAT IS ECONOMICS ?

The study of how limited resources is used to satisfy unlimited human wants

Economics and Engineering

Economics is a big part of an engineer's job.

The engineer must translate scientific ideas in products and systems that better mankind.

Ideas need to make sense economically and the engineer must be able to convince others that this is so.

Accounting Vs. Engineering Ecom.

Evaluating past performance

Accounting

Evaluating and predicting future events

Engineering Economy

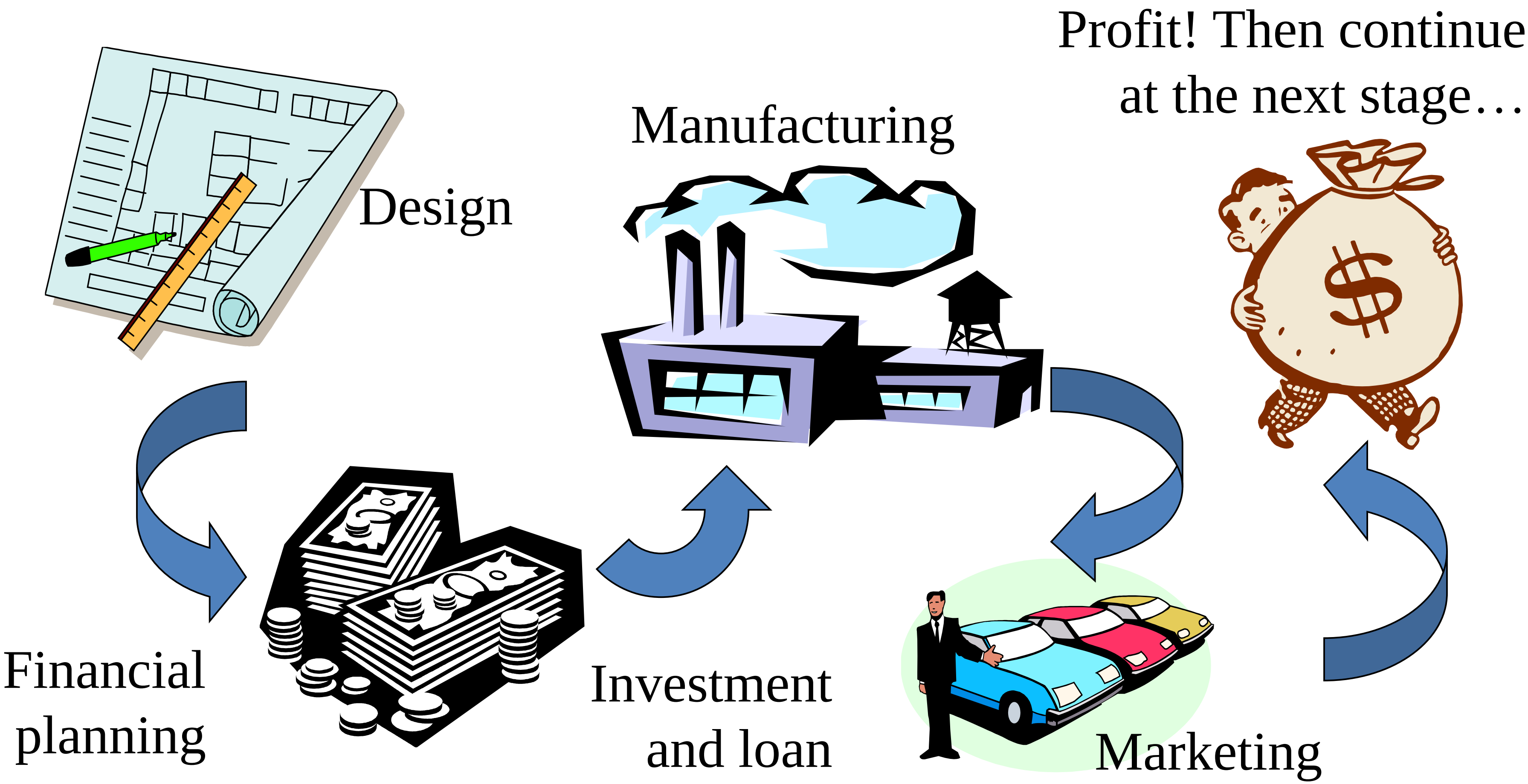
Past

Present

Future

Engineering Economic Decisions

Needed e.g. in the following (connected) areas:



syllabus

Process design development.

Cost estimation.

Factors affecting the production cost and investment.

Capital investment.

Cost index, Interest and investment cost. Depreciation calculation methods.

Optimum design, Cost of the mass and heat transfer equipments.

Chap. 1 Ec.

Process design development

Process design development

A principle responsibility of the chemical engineer is the design, construction and operation of chemical plants. In this responsibility, the engineer must continuously search for additional information to assist in these functions. Such information is available from numerous sources, including recent publications, operation of existing process plants, and laboratory and pilot-plant data.

DESIGN-PROJECT PROCEDURE

The development of a design project always starts with an initial idea or plan. This initial idea must be stated as clearly and concisely as possible in order to define the scope of the project. General specifications and pertinent laboratory or chemical engineering data should be presented along with the initial idea.

Types of Designs

The methods for carrying out a design project may be divided into the following classifications, depending on the accuracy and detail required:

1. Preliminary or quick-estimate designs
2. Detailed-estimate designs
3. Firm process designs or detailed designs

Preliminary designs are ordinarily used as a basis for determining whether further work should be done on the proposed process. The design is based on approximate process methods, and rough cost estimates are prepared. Few details are included, and the time spent on calculations is kept at a minimum.

If the results of the preliminary design show that further work is justified a ***detailed-estimate design*** may be developed. In this type of design, the cost and-profit potential of an established process is determined by detailed analyses and calculations. However, exact specifications are not given for the equipment and drafting-room work is minimized.

When the detailed-estimate design indicates that the proposed project should be a commercial success, the final step before developing construction plans for the plant is the preparation of a firm ***process design.*** Complete specifications are presented for all components of the plant, and accurate costs based on quoted prices are obtained. The firm process design includes blueprints and sufficient information to permit immediate development of the final plans for constructing the plant.

Feasibility Survey

Before any detailed work is done on the design, the technical and economic factors of the proposed process should be examined. The various reactions and physical processes involved must be considered, along with the existing and potential market conditions for the particular product. A preliminary survey for the

this type gives an indication of the probable success of the project and also shows what additional information is necessary to make a complete evaluation.

Following is a list of items that should be considered in making a feasibility survey:

1. Raw materials (availability, quantity, quality, cost)

2. Thermodynamics and kinetics of chemical reactions involved (equilibrium, yields, rates, optimum conditions)

3. Facilities and equipment available at present

4. Facilities and equipment which must be purchased

5. Estimation of production costs and total investment

6. Profits (probable and optimum, per pound of product and per year, return on investment)

7. Materials of construction

8. Safety considerations

9. Markets (present and future supply and demand, present uses, new uses, present buying habits, price range for products and by-products, character, location, and number of possible customers)

10. Competition (overall production statistics, comparison of various manufacturing processes, product specifications of competitors)

11. Properties of products (chemical and physical properties, impurities, effects of storage)

12. Sales and sales service (method of selling and distributing, advertising required, technical services required)

13. Shipping restrictions and containers

14. Plant location

15. Patent situation and legal restrictions

COMPARISON OF DIFFERENT PROCESSES

The following items should be considered in a comparison of this type:

1. Technical factors

a. Process flexibility

b. Continuous operation

c. Special controls involved

d. Commercial yields

e. Technical difficulties involved

f. Energy requirements

g. Special auxiliaries required

h. Possibility of future developments

i. Health and safety hazards involved

2. Raw materials

a. Present and future availability

b. Processing required

c. Storage requirements

d. Materials handling problems

3. Waste products and by-products

a. Amount produced

b. Value

c. Potential markets and uses

d. Manner of discard

e. Environmental aspects

4. Equipment

a. Availability

b. Materials of construction

c. Initial costs

d. Maintenance and installation costs

e. Replacement requirements

f. Special designs

5. Plant location

a. Amount of land required

b. Transportation facilities

c. Proximity to markets and raw-material sources

d. Availability of service and power facilities

e. Availability of labor

f. Climate

g. Legal restrictions and taxes

6. Costs

a. Raw materials

b. Energy

c. Depreciation

d. Other fixed charges

e. Processing and overhead

f. Special labor requirements

g. Real estate

h. Patent rights

i. Environmental controls

7. Time factor

a. Project completion deadline

b. Process development required

c. Market timeliness

d. Value of money

8. Process considerations

a. Technology availability

b. Raw materials common with other processes

c. Consistency of product within company

d. General company objectives

SPECIFICATIONS

Preliminary specifications for equipment should show the following:

1. Identification
2. Function
3. Operation
4. Materials handled
5. Basic design data
6. Essential controls
7. Insulation requirements
8. Allowable tolerances

GENERAL DESIGN CONSIDERATIONS

PLANT LOCATION

The geographical location of the final plant can have strong influence on the success of an industrial venture.

1. Raw materials availability

2 . Markets

3 . Energy availability

4 . Climate

5 . Transportation facilities

6 . Water supply

7 . Waste disposal

8 . Labor supply

9. Taxation and legal restrictions

10. Flood and fire protection

Chap. 2 Ec.

Cost estimation

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.

Classifications of costs:-

Fixed:

Typically includes building leases, equipment insurance, Management salaries and Taxes costs.

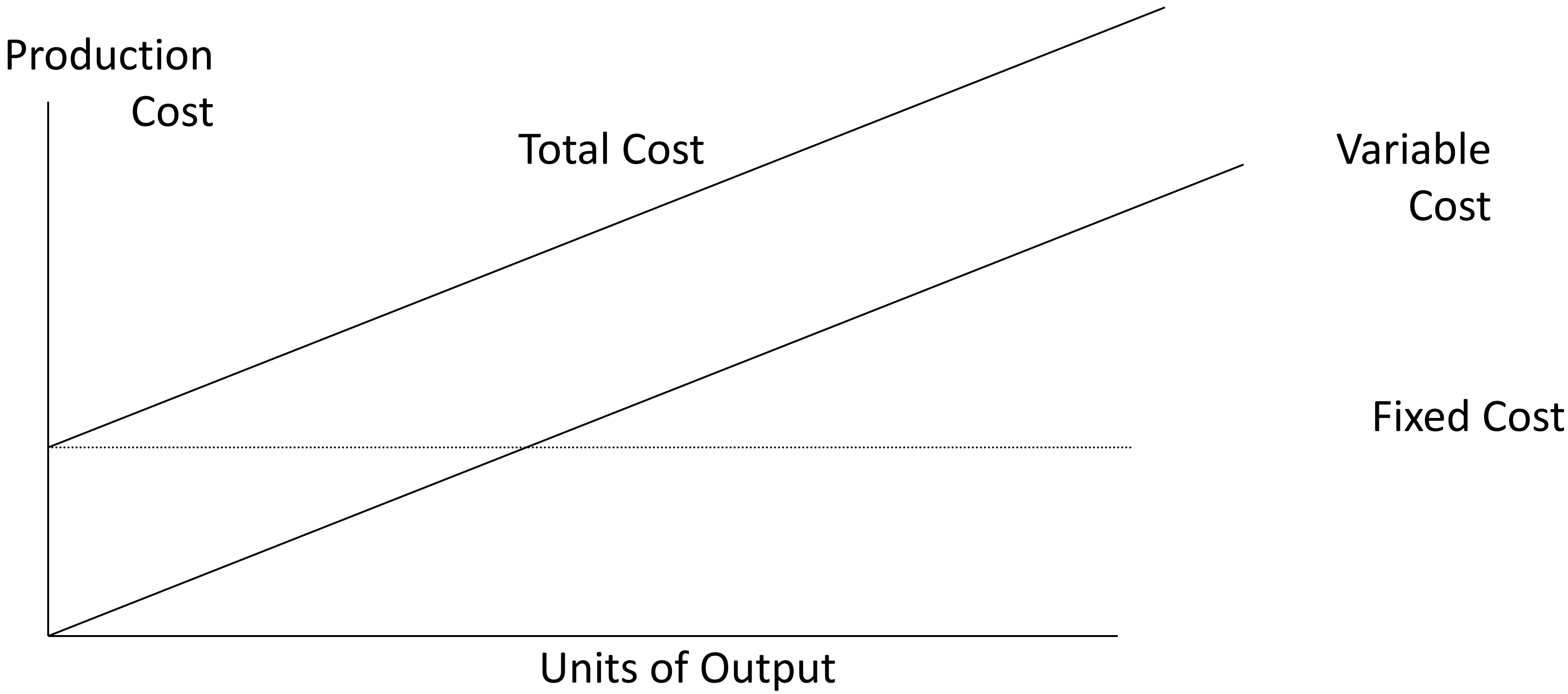
Variable:

Typically vary with the level of production.

like raw material, Labor salaries

and energy costs.

Costs- Fixed and Variable

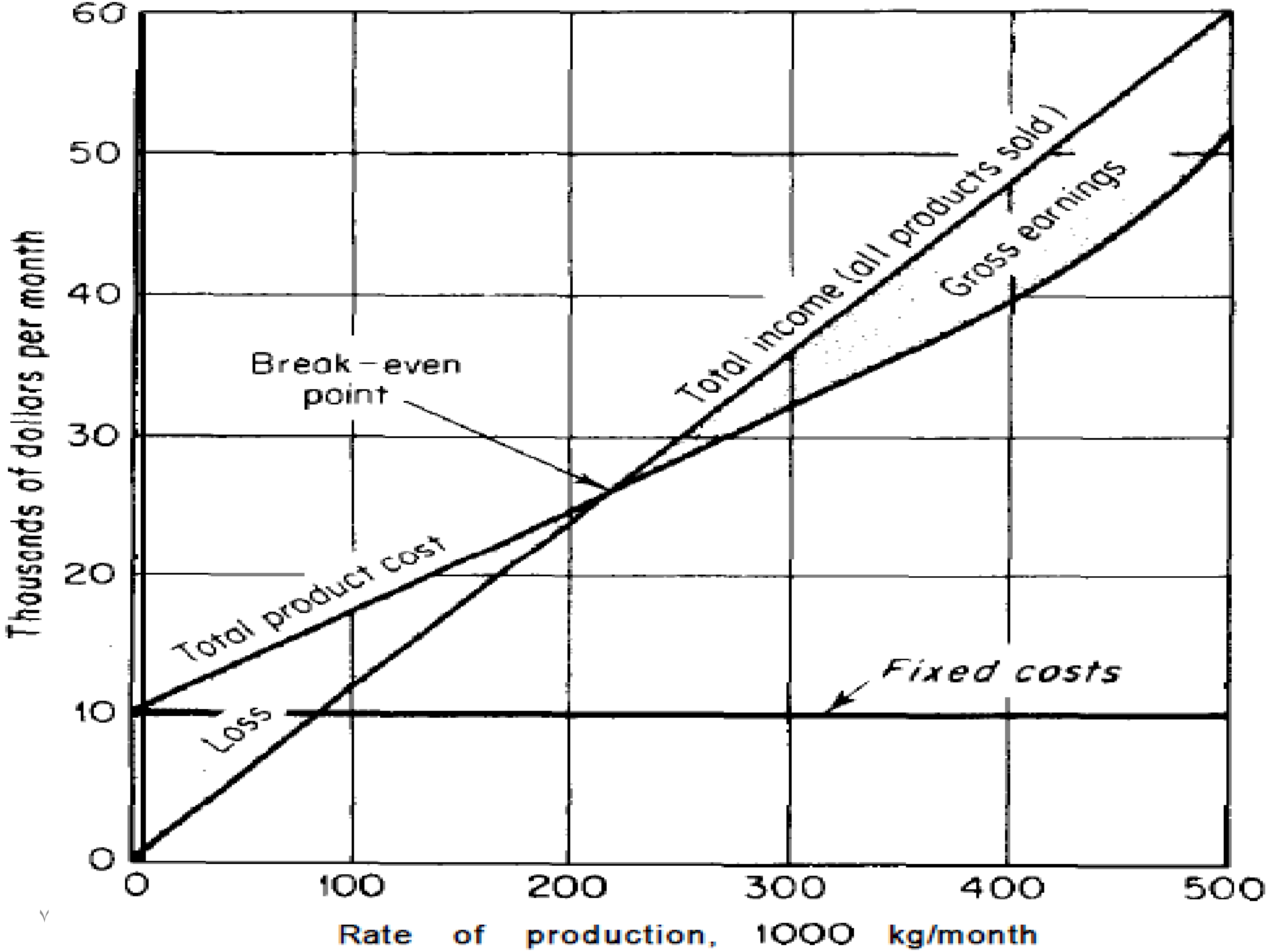


Fixed costs are constant and unchanging as volumes change, while variable costs change as output changes.

Fixed and variable costs are used to find the breakeven value between costs and revenues, as well as the regions of net profit and loss.

Profit and Loss Terms

- In terms of costs and revenues there are three possible profit and loss points for a business activity.
- **Breakeven**: total revenue = total costs
- **Profit region**: total revenue > total costs
- **Loss region**: total revenue < total costs



60
50
40
30
20
10
0
0
100
200
300
400
500
Thousands of dollars per month
Rate of production, 1000 kg/month
Total income (all products sold)
Gross earnings
Break - even point
Total product cost
Loss
Fixed costs

FACTORS AFFECTING INVESTMENT AND PRODUCTION COSTS

When a chemical engineer determines costs for any type of commercial process, these costs should be of sufficient accuracy to provide reliable decisions. To accomplish this, the engineer must have a complete understanding of the many factors that can affect costs.

FACTORS AFFECTING INVESTMENT AND PRODUCTION COSTS

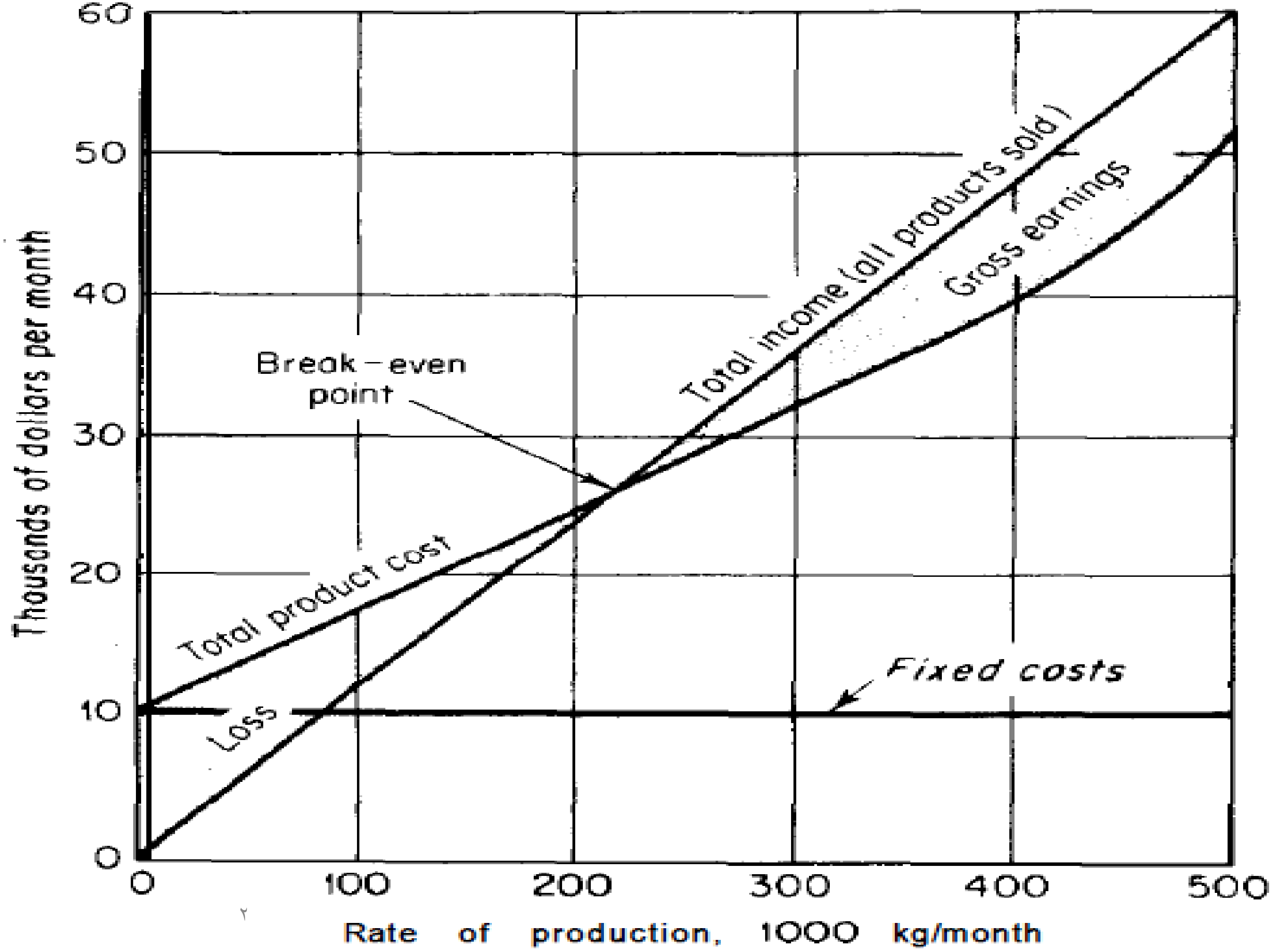
1- Sources of Equipment

2- Price Fluctuations

3- Company Policies

4- Operating Time and Rate of Production

5- Governmental Policies


Thousands of dollars per month
60
50
40
30
20
10
0
0
100
200
300
400
500
Rate of production, 1000 kg/month
Total income (all products sold)
Gross earnings
Break - even point
Total product cost
Loss
Fixed costs

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.

1- 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.

Fixed capital required for construction and for all plant components that are not directly related to the process operation is designated as the nonmanufacturing fixed-capital investment.

2- Working Capital Investment

The working capital for an industrial plant consists of the total amount of money invested in (1) raw materials (2) finished products (3) cash kept on hand for monthly payment of

operating expenses, such as salaries, wages, and raw-material purchases and (4) taxes payable.

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.

The **total capital investment** for any process consists of fixed capital investment plus working capital investment.

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.

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.

Chap. 3 Ec.

Cost index

A cost index is merely an index value for a given point in time showing the cost at that time relative to a certain base time.

If the cost at some time in the past is known, the equivalent cost at the present time 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.

$$\text{Present cost} = \text{original cost}\left(\frac{\text{index value at present time}}{\text{index value at time original cost was obtained}}\right)$$

Many different types of cost indexes are published regularly. Some of these can be used for estimating equipment costs; others apply specifically to labor, construction, materials, or other specialized fields. The most common of these indexes are the ***Marshall and Swif all-industry and process-industry equipment indexes,*** the ***Engineering News-Record construction index,*** the ***Nelson-Farrar refnev construction index,*** and the ***Chemical Engineering plant cost index.*** **cost indexes for materials and labor.**

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 = loo
	All-industry	Process-industry	1913 = 100	1949 = 100	1967 = 100		
1975	444	452	2412	464	207	576	182
1976	472	479	2401	503	224	616	192
1977	505	514	2576	540	241	653	204
1978	545	552	2776	582	259	701	219
1979	599	607	3003	630	281	757	239
1980	560	675	3237	679	303	823	261
1981	721	745	3535	741	330	904	297
1982	746	774	3825	802	357	977	314
1983	761	786	4066	852	380	1026	317
1984	780	806	4146	869	387	1061	323
1985	790	813	4195	879	392	1074	325
1986	798	817	4295	900	401	1090	318
1987	814	830	4406	924	412	1122	324
1988	852	870	4519	947	422	1165	343
1989	895	914	4606	965	429	1194	355
1990 (Jan.)	904†	924	4673	979	435	1203	356

† All costs presented in this text are based on this value of the Marshall and Swift index unless otherwise indicated.

Purchased Equipment

The most accurate method for determining process equipment costs is to obtain firm bids from fabricators or suppliers.

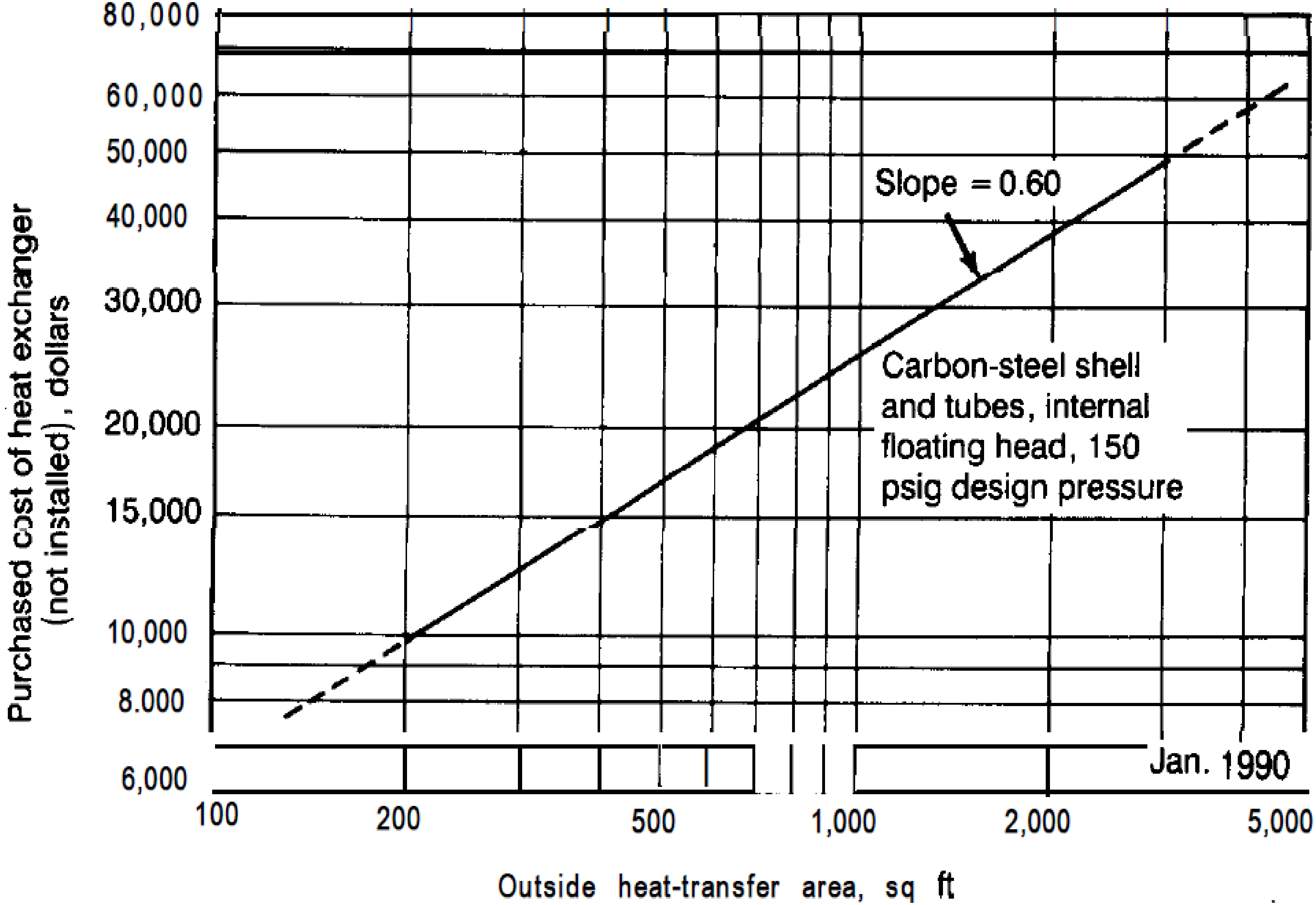
Second best in reliability are cost values from the file of past purchase orders. When used for pricing new equipment, purchase-order prices must be corrected to the current cost index.

Estimating Equipment Costs by Scaling.

Estimating Equipment Costs by Scaling

It is often necessary to estimate the cost of a piece of equipment when no cost data are available for the particular size of operational capacity involved. Good results can be obtained by using the logarithmic relationship known as the six-tenths-factor rule, if the new piece of equipment is similar to one of another capacity for which cost data are available.

$$\text{Cost of equip. a} = \text{cost of equip. b}\left(\frac{capac.equip.a}{capac.equip.b}\right)^{o.6}$$



Application of "six-tenth-factor" rule to costs for shell-and-tube heat exchangers.

The *power-sizing technique* (or *exponential model*) is frequently used for developing capital investment estimates for industrial plants and equipment.

$$C_A = C_B \left(\frac{S_A}{S_B} \right)^X$$

$C_A = \text{cost for plant A}$

$C_B = \text{cost for plant B}$

$S_A = \text{size of plant A}$

$S_B = \text{size of plant B}$

$X = cost - capacity factor$ to reflect economies of scale.

The actual values of the cost capacity factor vary from less than 0.2 to greater than 1.0.

Typical exponents for equipment cost vs. capacity

Equipment	Siie range	Exponent
Blender, double cone rotary, c.s.	SO-250 ft^3	0.49
Blower, centrifugal	10^3-10^4 ft^3/min	0.59
Centrifuge, solid bowl, c.s.	$10-10^2$ hp drive	0.67
Crystallizer, vacuum batch, c.s.	500-7000 ft^3	0.37
Compressor, reciprocating, air cooled, two-stage, 150 psi discharge	10–400 ft^3/min	0.69
Compressor, rotary, single-stage, sliding vane, 150 psi discharge	10^2-10^3 ft^3/min	0.79
Dryer, drum, single vacuum	$10-10^2$ ft^2	0.76
Dryer, drum, single atmospheric	$10-10^2$ ft^2	0.40
Evaporator (installed), horizontal tank	10^2-10^4 ft^2	0.54
Fan, centrifugal	10^3-10^4 ft^3/min	0.44
Fan, centrifugal	$2 \times 10^4-7 \times 10^4$ ft^3/min	1.17
Heat exchanger, shell and tube, floating head, c.s.	100-400 ft^2	0.60
Heat exchanger, shell and tube, fixed sheet, c.s.	100-400 ft^2	0.44
Kettle, cast iron, jacketed	250-800 gal	0.27
Kettle, glass lined, jacketed	200-800 gal	0.31
Motor, squirrel cage, induction, 440 volts, explosion proof	5-20 hp	0.69
Motor, squirrel cage, induction, 440 volts, explosion proof	20-200 hp	0.99
Pump, reciprocating, horizontal cast iron (includes motor)	2–100 gpm	0.34
Pump, centrifugal, horizontal, cast steel (includes motor)	10^4-10^5 gpm $\times$ psi	0.33
Reactor, glass lined, jacketed (without drive)	50–600 gal	0.54
Reactor, s.s., 300 psi	10^2-10^3 gal	0.56
Separator, centrifugal, c.s.	50-250 ft^3	0.49
Tank, flat head, c.s.	10^2-10^4 gal	0.57
Tank, c.s., glass lined	10^2-10^3 gal	0.49
Tower, c.s.	$10^3-2 \times 10^6$ lb	0.62
Tray, bubble cup, c.s.	3-10 ft diameter	1.20
Tray, sieve, c.s.	3-10 ft diameter	0.86

Example 1:-

The purchased cost of a 50-gal glass-lined, jacketed reactor (without drive) was \$8350 in 1981. Estimate the purchased cost of a similar 300-gal, glass-lined, jacketed reactor (without drive) in 1986. Use the annual average Marshall and Swift equipment-cost index (all industry) to update the purchase cost of the reactor.

Solution:- Marshall and Swift equipment-cost index (all industry)

(From Table) For 1981 721
(From Table) For 1986 798
From Table , the equipment vs. capacity exponent is given as 0.54:

$$\text{In 1986, cost of reactor} = (\$8350)\left(\frac{798}{721}\right)\left(\frac{300}{50}\right)^{0.54}$$

$$= \$24,300$$

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 = loo
	All-industry	Process-industry	1913 = 100	1949 = 100	1967 = 100		
1975	444	452	2412	464	207	576	182
1976	472	479	2401	503	224	616	192
1977	505	514	2576	540	241	653	204
1978	545	552	2776	582	259	701	219
1979	599	607	3003	630	281	757	239
1980	560	675	3237	679	303	823	261
1981	721	745	3535	741	330	904	297
1982	746	774	3825	802	357	977	314
1983	761	786	4066	852	380	1026	317
1984	780	806	4146	869	387	1061	323
1985	790	813	4195	879	392	1074	325
1986	798	817	4295	900	401	1090	318
1987	814	830	4406	924	412	1122	324
1988	852	870	4519	947	422	1165	343
1989	895	914	4606	965	429	1194	355
1990 (Jan.)	904†	924	4673	979	435	1203	356

† All costs presented in this text are based on this value of the Marshall and Swift index unless otherwise indicated.

Methods for estimating capital investment

METHOD A DETAILED-ITEM ESTIMATE

METHOD B UNIT-COST ESTIMATE

$$C_n = \left[\Sigma(E + E_L) + \Sigma(f_x M_x + f_y M_L') + \Sigma f_e H_e + \Sigma f_d d_n\right](f_F)$$

where C_n = new capital investment

E = purchased-equipment cost

E_L = purchased-equipment labor cost

f_x = specific material unit cost, e.g., f_p = unit cost of pipe

M_x = specific material quantity in compatible units

f_y = specific material labor unit cost per employee-hour

M_L' = labor employee-hours for specific material

f_e = unit cost-for engineering

H_e = engmeermg employee-hours

f_d = unit cost per drawing or specification

d_n = number of drawings or specifications

f_F = construction or field expense factor always greater than 1

METHOD C PERCENTAGE OF DELIVERED-EQUIPMENT COST

$$C_n = \left[\Sigma E + \Sigma(f_1E + f_2E + f_3E + \ldots)\right](f_I)$$

where $f_1, f_2 \ldots$ = multiplying factors for piping, electrical, instrumentation

f_I = indirect cost factor always greater than 1.

Example 2:- Prepare a study estimate of the tied capital investment for the process plant handling both solids and fluids with a high degree of automatic controls and essentially outdoor operation. If the delivered-equipment cost is $100,000.

Typical percentages of fixed-capital investment values for direct and indirect cost segments for multipurpose plants 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	4-16
Contractor's fee	2-6
Contingency	5-15
Total fixed-capital investment	

Item	Percent of deliveredequipment cost for		
	Solid-processing plant‡	Solid-fluid-processing plant ‡	Fluid-processing plant ‡
Direct costs			
Purchased equipment-delivered (including fabricated equipment and process machinery) §	100	100	100
Purchased-equipment installation	45	39	47
Instrumentation and controls (installed)	9	13	18
Piping (installed)	16	31	66
Electrical (installed)	10	10	11
Buildings (including services)	25	29	18
Yard improvements	13	10	10
Service facilities (installed)	40	55	70
Land (if purchase is required)	6	6	6
Total direct plant cost	264	293	346
Indirect costs			
Engineering and supervision	33	32	33
Construction expenses	39	34	41
Total direct and indirect plant costs	336	359	420
Contractor's fee (about 5% of direct and indirect plant costs)	17	18	21
Contingency (about 10% of direct and indirect plant costs)	34	36	42
Fixed-capital investment	387	413	483
Working capital (about 15% of total capital investment)	68	74	86
Total capital investment	455	487	569

Components	*cost*
Purchased equipment (delivered), E	$100,000
Purchased equipment installation, 39% E	39,000
Instrumentation (installed), 28% E	28,000
Piping (installed), 31% E	31,000
Electrical (installed), 10% E	10,000
Buildings (including services), 22% E	22,000
Yard improvements, 10% E	10,000
Service facilities (installed), 55% E	55,000
Land, 6% E	6,000
Total direct plant cost D	301,000
Engineering and supervision, 32% E	32,000
Construction expenses, 34% E	34,000
Total direct and indirect cost $(D+I)$	367,000
Contractor's fee, 5% $(D+I)$	18,000
Contingency, 10% $(D+I)$	37,000
Fixed-capital investment	$422,000

METHOD D "LANG" FACTORS FOR APPROXIMATION OF CAPITAL INVFSTMENT.

Factor x delivered-equipment cost = fixed-capital investment or total capital investment for major additions to an existing plant.

Type of plant	Factor for	
	Fixed-capital investment	Total capital investment
Solid-processing plant	3.9	4.6
Solid-fluid-processing plant	4.1	4.9
Fluid-processing plant	4.8	5.7

Method E: Estimating relative costs of construction labor as a function of geographical area.

Example 3:- If a given chemical process plant is erected near Dallas (Southwest area) with a construction labor cost of $100,000 what would be the construction labor cost of an identical plant if it were to be erected at the same time near Los Angeles (Pacific Coast Area)?

Relative labor rate and productivity indexes in the chemical and allied products industries for the United States (1989)†

Geographical area	Relative labor rate	Relative productivity factor
New England	1.14	0.95
Middle Atlantic	1.06	0.96
South Atlantic	0.84	0.91
Midwest	1.03	1.06
Gulf	0.95	1.22
Southwest	0.88	1.04
Mountain	0.88	0.97
Pacific Coast	1.22	0.89

Solution

Relative median labor rate-Southwest 0.88 from Table.

Relative median labor rate-Pacific Coast 1.22 from Table.

$$\text{Relative labor rate ratio} = \frac{1.22}{0.88} = 1.3864$$

Relative productivity factor-Southwest 1.04 from Table

Relative productivity factor-Pacific Coast 0.89 from Table

$$\text{Relative productivity factor ratio} = \frac{0.89}{1.04} = 0.8558$$

Construction labor cost of Southwest to Pacific Coast = (1.3864)/(0.8558) = 1.620

Construction labor cost at Los Angeles = (1.620x$100,000) = $162,000

METHOD F POWER FACTOR APPLIED TO PLANT-CAPACITY RATIO

the fixed-capital investment of the new facility is equal to the fixed-capital investment of the constructed facility C multiplied by the ratio R, defined as the capacity of the new facility divided by the capacity of the old, raised to a power X.

$$C_n = C\,(R)^x$$

This power has been found to average between 0.6 and 0.7 for many process facilities.

A closer approximation for this relationship which involves the direct and indirect plant costs has been proposed as

$$C_n = f\left[D(R)^x + I\right]$$

Capital-cost data for processing plants (1990)†

Product or process	Process remarks	Typical plant size, 1000 tons / yr	Fixed-capital investment, million $	$ of fixed-capital investment per annual ton of product	Power factor (*x*)‡ for plant-capacity ratio
		Chemical plants			
Acetic acid	CH_3OH and CO-catalytic	10	6	650	0.68
Acetone	Propylene-copper chloride catalyst	100	32	320	0.45
Ammonia	Steam reforming	100	24	240	0.53
Ammonium nitrate	Ammonia and nitric acid	100	5	50	0.65
Butanol	Propylene, CO, and H_2O—catalytic	50	40	800	0.40
Chlorine	Electrolysis of NaCl	50	28	550	0.45
Ethylene	Refinery gases	50	13	260	0.83
Ethylene oxide	Ethylene-catalytic	50	50	1000	0.78
Formaldehyde (37%)	Methanol-catalytic	10	16	1600	0.55
Glycol	Ethylene and chlorine	5	15	2900	0.75
Hydrofluoric acid	Hydrogen fluoride and H_2O	10	8	800	0.68
Methanol	CO_2, natural gas, and steam	60	13	200	0.60
Nitric acid (high strength)	Ammonia-catalytic	100	6	65	0.60
Phosphoric acid	Calcium phosphate and H_2SO_4	5	3	650	0.60
Polyethylene (high density)	Ethylene-catalytic	5	16	3200	0.65
Propylene	Refinery gases	10	3	320	0.70
Sulfuric acid	Sulfur-catalytic	100	3	32	0.65
Urea	Ammonia and CO_2	60	8	130	0.70

Capital-cost data for processing plants **(1990)** *(Continued)*

Product or **process**	**Process** remarks	**Typical** plant **size,** **1000 bbl / day**	**Fixed-capital investment, million $**	**$ of fixed-capital** investment per **bbl** / day	Power factor (*x*)‡ for **plant-capacity** ratio
		Refinery units			
Alkylation (H_2SO_4)	Catalytic	10	19	1900	0.60
Coking (delayed)	Thermal	10	26	2600	0.38
Coking (fluid)	Thermal	10	16	1600	0.42
Cracking (fluid)	Catalytic	10	16	1600	0.70
Cracking	Thermal	10	5	500	0.70
Distillation (atm.)	65% vaporized	100	32	3m	0.90
Distillation (vac.)	65% vaporized	100	19	200	0.70
Hydrotreating	Catalytic desulfurization	10	3	320	0.65
Reforming	Catalytic	10	29	2900	0.60
Polymerization	Catalytic	10	5	500	0.58

where f is a lumped cost-index factor relative to the original installation cost. D is the direct cost and I is the total indirect cost for the previously installed facility of a similar unit on an equivalent site. The value of x approaches unity

when the capacity of a process facility is increased by adding identical process units instead of increasing the size of the process equipment. The lumped cost-index factor f is the product of a geographical labor cost index, the

corresponding area labor productivity index, and a material and equipment cost index.

Example 4:- If the process plant was erected in

the Dallas area (Southwest area) for a fixed-capital investment of $436,000 in 1975, determine what the estimated fixed-capital investment would have been in 1980 for a similar process plant located near Los Angeles (Pacific Coast Area) with twice the process capacity but with an equal number of process units? direct and indirect plant costs are 308000$and 128000$.

Solution:-

with a 0.6 power factor and the Marshall and Swift all-industry index, the fixed-capital investment is:

$$C_n = Cf_E(R)^x$$

833,507 \$$C_n$= (436000)(560/444)$(2)^{0.6}$=

with a 0.7 power factor and the Marshall and Swift all-industry index, the fixed-capital investment is:

C_n= (436000)(560/444 $C_n = Cf_E(R)^x$ 1 \$

with a 0.6 power factor, the Marshall and Swift all-industry index and the relative labor and productivity indexes, the fixed capitalinvestment is:

$$C_n = f\left[D(R)^x + I\right]$$

Where: $f = f_E f_L e_L$

C_n= (560/444)(1.22/0.88)(1.04/0.89)[(308,000)(2)$^{0.6}$ + 128,000]

C_n= 1,215,419 $

with a 0.7 power factor, the Marshall and Swift all-industry index and the relative labor and productivity index, the fixed-capital investment is:

$$C_n = f\left[D(R)^x + I\right]$$

Where: $f = f_E f_L e_L$

$$C_n = (560/444)(1.22/0.88)(1.04/0.89)[(308,000)(2)^{0.7} + 128,000]$$

$$C_n = 1,283,882\ \$$$

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 = loo
	All-industry	Process-industry	1913 = 100	1949 = 100	1967 = 100		
1975	444	452	2412	464	207	576	182
1976	472	479	2401	503	224	616	192
1977	505	514	2576	540	241	653	204
1978	545	552	2776	582	259	701	219
1979	599	607	3003	630	281	757	239
1980	560	675	3237	679	303	823	261
1981	721	745	3535	741	330	904	297
1982	746	774	3825	802	357	977	314
1983	761	786	4066	852	380	1026	317
1984	780	806	4146	869	387	1061	323
1985	790	813	4195	879	392	1074	325
1986	798	817	4295	900	401	1090	318
1987	814	830	4406	924	412	1122	324
1988	852	870	4519	947	422	1165	343
1989	895	914	4606	965	429	1194	355
1990 (Jan.)	904†	924	4673	979	435	1203	356

† All costs presented in this text are based on this value of the Marshall and Swift index unless otherwise indicated.

Relative labor rate and productivity indexes in the chemical and allied products industries for the United States (1989)†

Geographical area	Relative labor rate	Relative productivity factor
New England	1.14	0.95
Middle Atlantic	1.06	0.96
South Atlantic	0.84	0.91
Midwest	1.03	1.06
Gulf	0.95	1.22
Southwest	0.88	1.04
Mountain	0.88	0.97
Pacific Coast	1.22	0.89

METHOD G TURNOVER RATIOS

Turnover ratio is defined as the ratio of gross annual sales to the fixed-capital investment,

$$\text{Turnover ratio} = \frac{\text{gross annual sales}}{\text{fixed-capital investment}}$$

For the chemical industry, as a very rough rule of thumb, the ratio can be approximated as 1.

The reciprocal of the turnover ratio is sometimes defined as the capital ratio or the investment ratio.

Chap. 4 Ec.

Interest and Investment Costs

interest is the money returned to the owners of capital for use of their capital. This would mean that any profit obtained through the uses of capital could be considered as interest.

Interest :- Fee charged for borrowing someone else's money.

Instead, they prefer to substitute the term ***return on capital*** or ***return on investment*** for the classical ***Interest.***

Engineers define interest as the ***compensation paid for the use of borrowed capital.*** This definition permits distinction between profit and interest.

TYPES OF INTEREST

1- Simple Interest

Simple Interest :- Fixed interest of the principal ($ borrowed)

$$Z = Pin$$

P represents the principal, n the number of time units or interest periods, and **i** the interest rate based on the length of one interest period,

Interest rate:- Percentage of money borrowed charged by lender.

the amount of simple interest Z. $1000 x 0.1 x 4 = $400

The principal must be repaid eventually; therefore, the entire amount S of principal plus simple interest due after n interest periods is:

$$S = P + Z = P(1 + in)$$

2- Ordinary and Exact Simple Interest

The time unit used to determine the number of interest periods is usually 1 year, and the interest rate is expressed on a yearly basis. When an interest period of less than 1 year is involved, the ***ordinary*** way to determine simple interest is to assume the year consists of twelve 30-day months, or 360 days. The ***exact*** method accounts for the fact that there are 365 days in a normal year.

d represents the number of days in an interest period.

$$\text{Ordinary simple interest} = Pi\frac{d}{360}$$

$$\text{Exact simple interest} = Pi\frac{d}{365}$$

Ordinary interest is commonly accepted in business practices unless there is a particular reason to use the exact value.

3- Compound Interest

If payment is not made, the amount due is added to the principal, and interest is charged on this converted principal during the following time unit.

Thus, an initial loan of \$1000 at an annual interest rate of 10 percent would require payment of \$100 as interest at the end of the first year. If this payment were not made, the interest for the second year would be (\$1000 + \$100)(0.10) = \$110,

and the total ***compound amount*** due after 2 years would be:

$$\$1000 + \$100 + \$110 = \$1210$$

Compound Interest Percentage interest applied to principal + previously accumulated interest.

The compound amount due after any discrete number of interest periods can be determined as follows:

Period	Principal at start of period	Interest earned during period (i = interest rate based on length of one period)	Compound amount S at end of period
1	P	Pi	$P + Pi = P(1 + i)$
2	$P(1 + i)$	$P(1 + i)(i)$	$P(1 + i) + P(1 + i)(i) = P(1 + i)^2$
3	$P(1 + i)^2$	$P(1 + i)^*(i)$	$P(1 + i)^2 + P(1 + i)^*(i) = P(1 + i)^3$
n	$P(1 + i)^{n-1}$	$P(1 + i)^{n-1}(i)$	$P(1 + i)^n$

Therefore, the total amount of principal plus compounded interest due after n interest periods and designated as S is:

$$S = P(1 + i)^n$$

The term $(1 + i)^n$ is commonly referred to as the ***discrete single-payment compound-amount factor.***

1	$1,000	$100	$1,100
2	$1,100	$110	$1,210
3	$1,210	$121	$1,331

NOMINAL AND EFFECTIVE INTEREST RATES

In common industrial practice, the length of the discrete interest period is assumed to be 1 year and the fixed interest rate ***i*** is based on 1 year. However, there are cases where other time units are employed. Even though the actual interest period is not 1 year, the interest rate is often expressed on an annual basis.

For example in which the interest rate is 3 percent per period and the interest is compounded at half-year periods. A rate of this type would be referred to as “6 percent compounded” Interest rates stated in this form are known as ***nominal interest rates***. The actual annual return on the principal would not be exactly 6 percent but would be somewhat larger because of the compounding effect at the end of the period. A rate of this type is known as the ***effective interest rate***.

In common engineering practice, it is usually preferable to deal with effective interest rates rather than with nominal interest rates. The only time that nominal and effective interest rates are equal is when the interest is compounded annually.

$100 invested at a nominal interest rate of 20 percent compounded annually would amount to $120.00 after 1 year; if compounded semiannually, the amount would be $121.00. The corresponding effective interest rates are 20.00 percent and 21.00 percent respectively.

$$S = P(1 + i)^n$$

Relationship between nominal and effective interest rates:-

$$S_{\text{after 1 year}} = P(1 + i_{\text{eff}})$$

$$\text{Effective annual interest rate} = i_{\text{eff}} = \left(1 + \frac{r}{m}\right)^{m} - 1$$

r : the nominal interest rate

m : interest periods per year

Example 1:- It is desired to borrow $1000 to meet a financial obligation. This money can be borrowed from a loan agency at a monthly interest rate of 2 percent. Determine the following:

(a) The total amount of principal plus simple interest due after 2 years if no intermediate payments are made.

(b) The total amount of principal plus compounded interest due after 2 years if no intermediate payments are made.

(c) The nominal interest rate when the interest is compounded monthly.

(d) The effective interest rate when the interest is compounded monthly.

Solution:-

(a) Length of one interest period = 1 month

Number of interest periods in 2 years = 24

periods at periodic :For simple interest, the total amount due after n interest rate *i* is

$$S = P(1 + in)$$

$$S = \$1000(1 + 0.02 \text{ x } 24) = \$1480$$

(b) For compound interest, the total amount due after n periods at periodic interest rate *i* is:

$$S = P(1 + i)^n$$

$$S = \$1000(1 + 0.02)^{24} = \$1608$$

(c) Nominal interest rate = 2 **X** 12 = 24% per year compounded monthly

(d) Number of interest periods per year = m = 12

$$\text{Effective interest rate} = \left(1 + \frac{r}{m}\right)^m - 1$$

$$\text{Effective interest rate} = \left(1 + \frac{0.24}{12}\right)^{12} - 1 = 0.268 = 26.8\%$$

4- Continuous Interest

The concept of continuous interest is that the cost or income due to interest flows regularly, and this is just as reasonable an assumption for most cases as the concept of interest accumulating only at discrete intervals.

$$S=Pe^{rn}$$

S: continuous interest compounding P: Initial principal

r: nominal annual interest rate n: no. of years

$$1-e^{rn}=i_{eff}$$

Example 2 : For the case of a nominal annual interest rate 20.00 percent, determine:

(a) The total amount to which one dollar of initial principal would accumulate after one year 365day with daily compounding.

(b) The total amount to which one dollar of initial principal would accumulate after one year with continuous compounding.

(c) The effective annual interest rate if compounding is continuous.

Solution:-

(a)P = $1.0, ***r = 0.20, m = 365,***

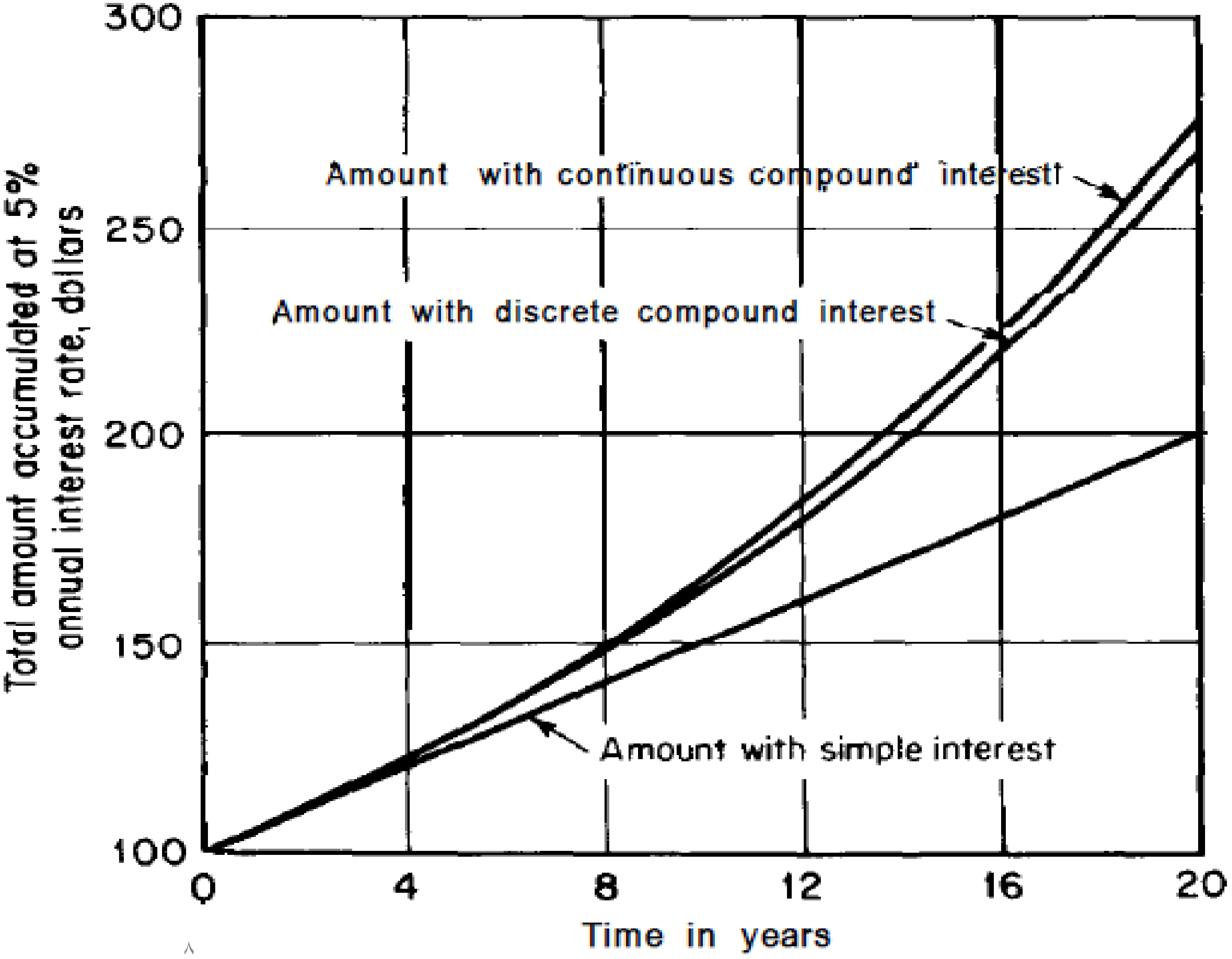
$$S_{\text{after 1 year}} = P\left(1 + \frac{r}{m}\right)^{m} = (1.0)\left(1 + \frac{0.20}{365}\right)^{365} = \$1.2213$$

(b)

$$S = Pe^{rn} = (1\ .0)(e)^{(0.20)(1)} = \$1.2214$$

(c)

$$1\text{-}e^{rn} = i_{eff} \quad = e^{0.2} - 1 = 0.2214 \quad \text{or } 22.14\%$$



Total amount accumulated at 5% annual interest rate, dollars
300
250
200
150
100
0
4
8
12
16
20
Time in years
Amount with continuous compound interest
Amount with discrete compound interest
Amount with simple interest

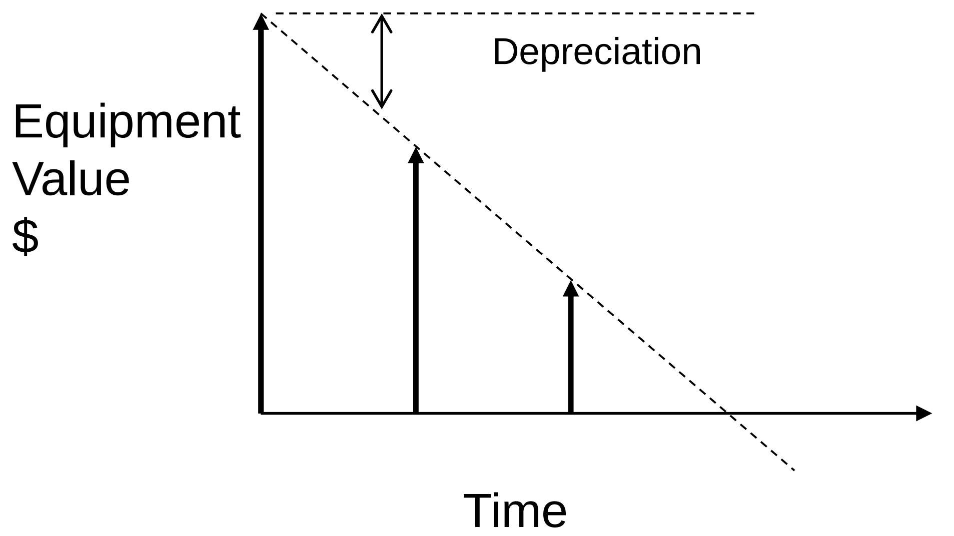
Chap. 5 Ec.

Depreciation calculation methods

An analysis of costs and profits for any business operation requires recognition of the fact that physical assets decrease in value with age. This decrease in value may be due to physical deterioration, technological advances, economic changes, or other factors which ultimately will cause retirement of the property. The reduction in value due to any of these causes is a measure of the ***depreciation.***

Because the engineer thinks of depreciation as a measure of the decrease in value of property with time, depreciation can immediately be considered from a cost viewpoint. For example, suppose a piece of equipment had been put into use 10 years ago at a total cost of $31,000. The equipment is now worn out and is worth only $1000 as scrap material. The decrease in value during the 10-year period is $30,000; however, the engineer recognizes that this $30,000 is in reality a cost incurred for the use of the equipment. This depreciation cost was spread over a period of 10 years, and sound economic procedure would require part of this cost to be charged during each of the years.

Depreciation – decrease in value of something over time.



TYPES OF DEPRECIATION

1-Physical depreciation: is the term given to the measure of the decrease in value due to changes in the physical aspects of the property. Wear and tear, corrosion, accidents, and deterioration due to age or the elements are all causes of physical depreciation.

2- Functional depreciation: one common type of functional depreciation is **obsolescence.** This is caused by technological advances or developments which make an existing property obsolete.

Other causes of functional depreciation could be (1) change in demand for the service rendered by the property, such as a decrease in the demand for the product involved because of saturation of the market, (2) shift of population center, (3) changes in requirements of public authority, (4) inadequacy or insufficient capacity for the service required, (5) termination of the need for the type of service rendered, and (6) abandonment of the enterprise.

METHODS FOR DETERMINING DEPRECIATION

In general, depreciation accounting methods may be divided into two classes: (1) arbitrary methods giving no consideration to interest costs, and (2) methods taking into account interest on the investment. Straight-line, declining-balance, and sum-of-the-years-digits methods are included in the first class, while the second class includes the sinking-fund and the present-worth methods.

SALVAGE VALUE:- is the net amount of money obtainable from the sale of used property over and above any charges involved in removal and sale. If a property is capable of further service, its salvage value may be high.

Salvage Value (V_s) -- Estimated value of property at the end of useful life.

Book Value:- The difference between the original cost of a property, and all the depreciation charges made to date. It represents the worth of the property as shown on the owner's accounting records.

Book Value (V_a)-- Worth of depreciable property as shown on accounting records.

Straight-Line Method

In the straight-line method for determining depreciation, it is assumed that the value of the property decreases linearly with time.

The annual depreciation cost may be expressed in equation form as follows:

$$d = (V - V_s)/n$$

where ***d*** = annual depreciation, $/year

V = original value of the property at start of the service-life period, dollars

Vs= salvage value of property at end of service life, dollars

n = service life, years

The asset value (or book value) of the equipment at any time during the service life may be determined from the following equation:

$$V_a = V - a\,d$$

where V_a = asset or book value, dollars

a = the number of years in actual use.

Declining-Balance (or Fixed Percentage) Method

When the declining-balance method is used, the annual depreciation cost is a fixed percentage of the property value at the beginning of the particular year.

The fixed-percentage (or declining-balance) factor remains constant throughout the entire service life of the property, while the annual cost for depreciation is

different each year.

Under these conditions, the depreciation cost for the first year of the property’s life is Vf, where f represents the fixed-percentage factor.

At the end of the first year

Asset value = V_a= V(1 - f)

At the end of the second year

V_a= V(1 - f)²

At the end of a years

$$V_a = V(1 - f)^a$$

At the end of n years (i.e., at the end of service life)

$V_a = V(1 - f)^n = V_s$

Therefore,

$$f = 1 - \left(\frac{V_s}{V}\right)^{1/n}$$

Example 1:-The original value of a piece of equipment is $22,000, completely installed and ready for use. Its salvage value is estimated to be $2000 at the end of

a service life estimated to be 10 years. Determine the asset (or book) value of the equipment at the end of 5 years using:

(a) Straight-line method.

(b) declining-balance method.

Solution:-

(a) Straight-line method:

$V = \$22{,}000$, $V_s = \$2000$, n = 10 years

$$d = \frac{V - V_s}{n} = \frac{20{,}000}{10} = \$2000/\text{year}$$

Asset valu

$V_a = V - ad = 22{,}000 - (5)(2000) = \$12{,}000$

(b) declining-balance method:

$$f = 1 - \left(\frac{V_s}{V}\right)^{1/n} = 1 - \left(\frac{2000}{22{,}000}\right)^{1/10} = 0.2131$$

Asset value after 5 years is

$$V_a = V(1 - f)^a = (22{,}000)(1 - 0.2131)^5 = \$6650$$

Sum-of-the-Years-Digits Method

In the application of the sum-of-the-years-digits method, the annual depreciation is based on the number of service-life years remaining and the sum

of the arithmetic series of numbers from 1 to n, where n represents the total service life. The yearly depreciation factor is the number of useful service-life

years remaining divided by the sum of the arithmetic series. This factor times the total depreciable value at the start of the service life gives the annual depreciation cost.

As an example, consider the case of a piece of equipment costing $20,000 when new. The service life is estimated to be 5 years and the scrap value $2000.

The sum of the arithmetic series of numbers from 1 to n is 1 + 2 + 3 + 4 +5 = 15. The total depreciable value at the start of the service life is $20,000 -$2000 = $18,000. Therefore, the depreciation cost for the first year is ($l8,000)(5/15)= $6000, and the asset value at the end of the first year is $14,000.

The depreciation cost for the second year is ($18,000)(4/15)= $4800. Similarly, the depreciation costs for the third, fourth, and fifth years, respectively, would be $3600, $2400, and $1200.

Sum of the years digits method

Depriciation for any year a.

$$Dep = \frac{n-a+1}{\Sigma n}(V-V_s)$$

when n is not given depriciation for 2nd year is given

$$Dep = \frac{n-2+1}{\frac{n(n+1)}{2}}(V-V_s)$$

a = Year in which depriciation is required.

For example If service life is 5 years. n = 5

$$\Sigma n = 1+2+3+4+5 = 15$$

For first year $Dep = \frac{5-1+1}{15}(V-V_s) = \frac{5}{15}(V-V_s)$

For 2nd year $Dep = \frac{5-2+1}{15}(V-V_s) = \frac{4}{15}(V-V_s)$

For 5th year $Dep = \frac{5-5+1}{15}(V-V_s) = \frac{1}{15}(V-V_s)$.