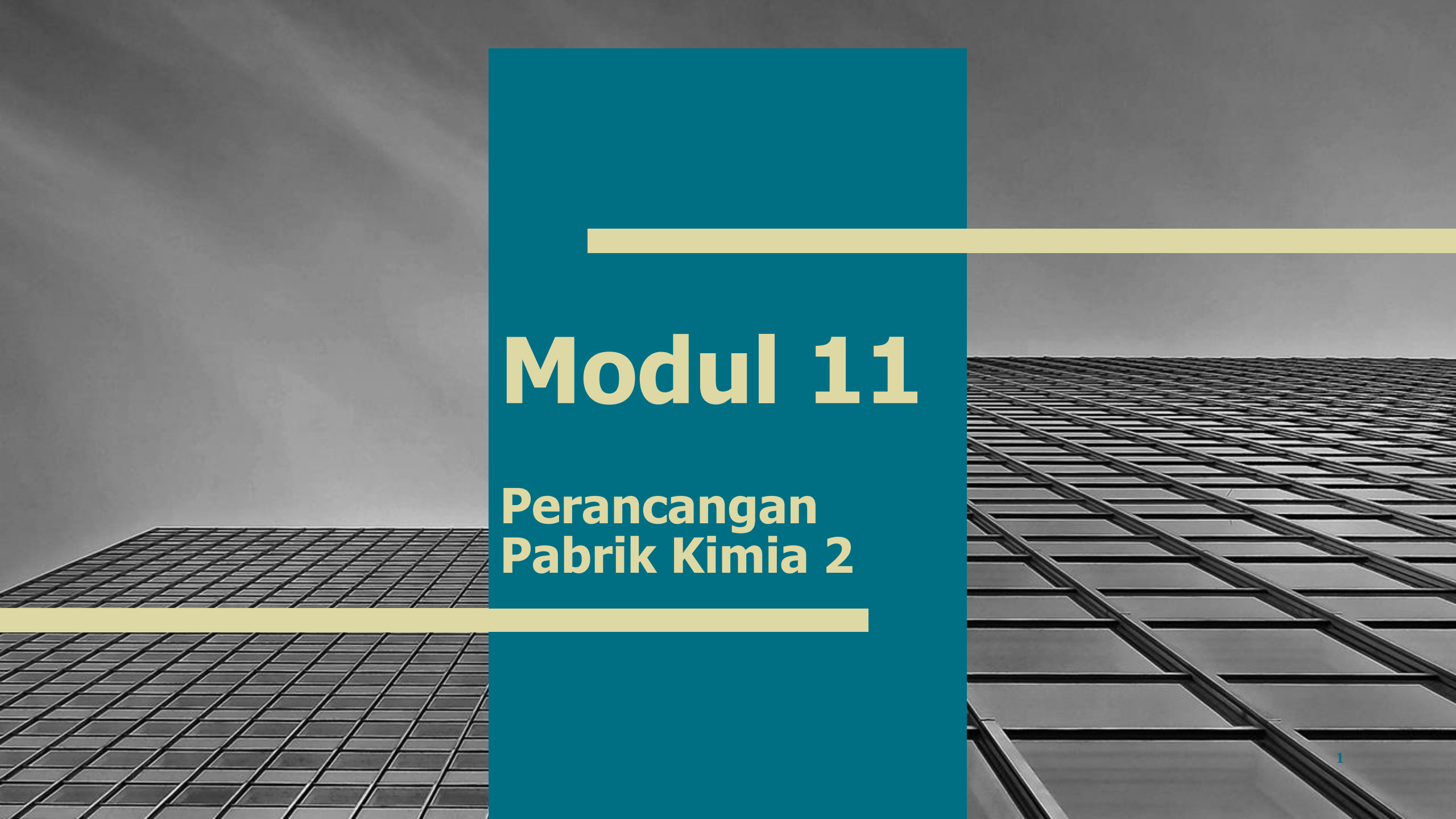

Modul 11

Perancangan Pabrik Kimia 2

Perancangan Estimasi Modal Investasi

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Capital Investment

- A capital investment is required for any industrial process, and determination of the necessary investment is an important part of a plant-design project.
- The total investment for any process consists of fixed-capital investment for physical equipment and facilities in the plant plus working capital which must be available to pay salaries, keep raw materials and products on hand, and handle other special items requiring a direct cash outlay.
- Thus, in an analysis of costs in industrial processes, capital-investment costs, manufacturing costs, and general expenses including income taxes must be taken into consideration.

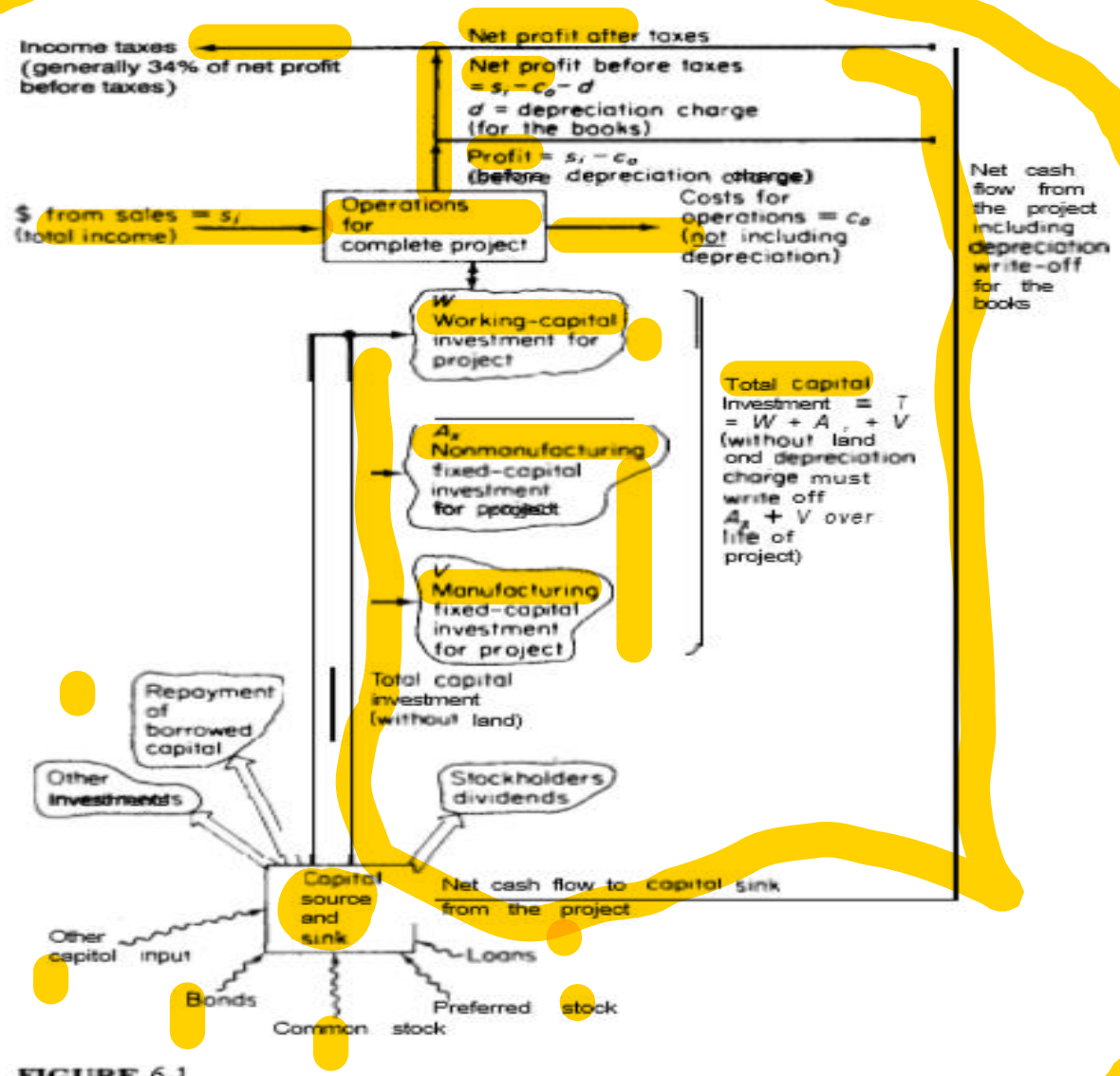

FIGURE 6-1
Tree diagram showing cash flow for industrial operations.

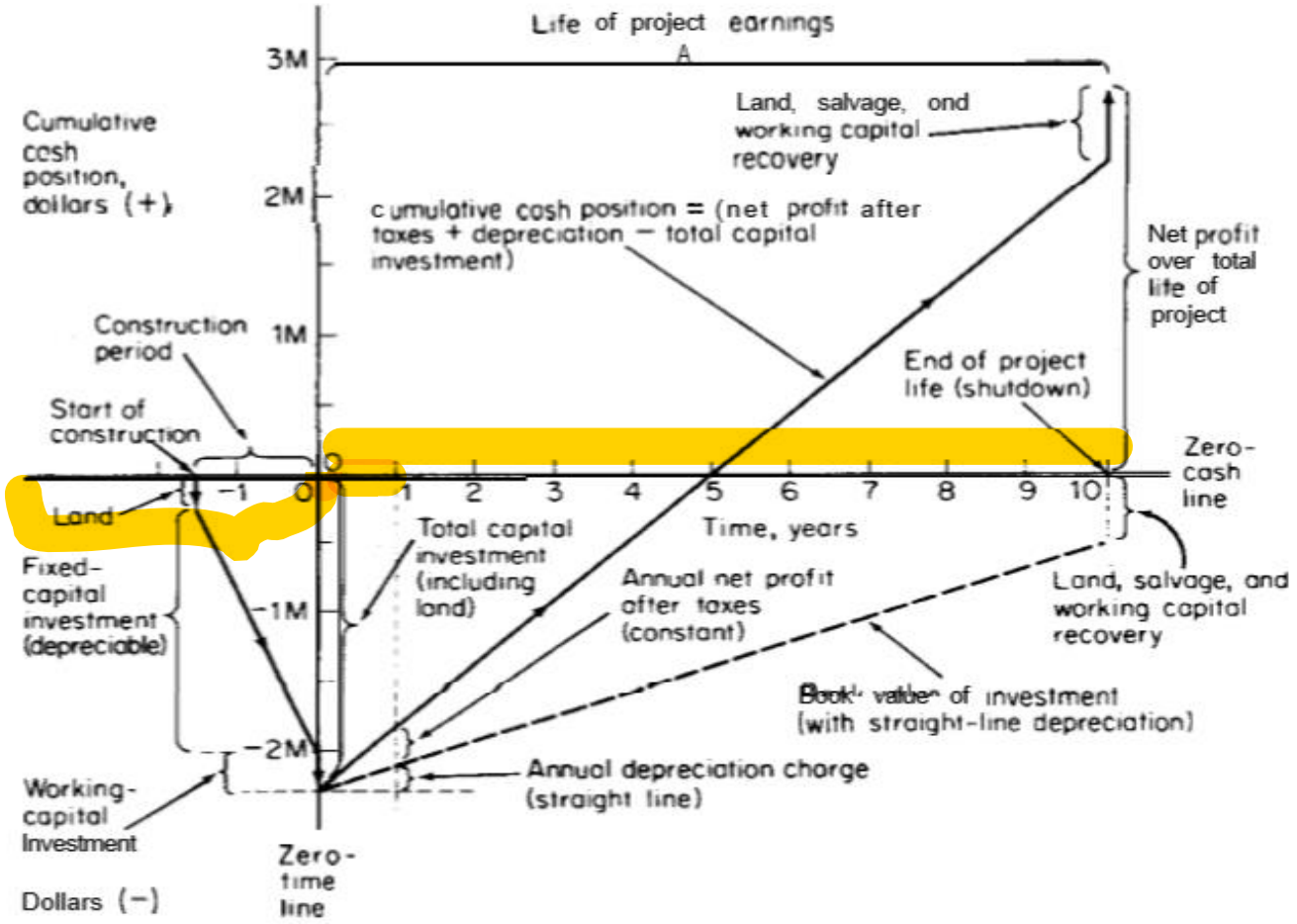

FIGURE 6-2
Graph of cumulative cash position showing effects of cash flow with time for an industrial operation neglecting time value of money.

FACTORS AFFECTING INVESTMENT AND PRODUCTION COSTS

- Sources of Equipment
- Price Fluctuations
- Company Policies
- Operating Time and Rate of Production
- Governmental Policies

Sources of Equipment

- One of the major costs involved in any chemical process is for the equipment.
- In many cases, standard types of tanks, reactors, or other equipment are used, and a substantial reduction in cost can be made by employing idle equipment or by purchasing second-hand equipment.
- If new equipment must be bought, several independent quotations should be obtained from different manufacturers.
- When the specifications are given to the manufacturers, the chances for a low cost estimate are increased if the engineer does not place overly strict limitations on the design.

Price Fluctuations

- In our modern economic society, prices may vary widely from one period to another, and this factor must be considered when the costs for an industrial process are determined.

- The chemical engineer, therefore, must keep up-to-date on price and wage fluctuations.

Company Policies

- Policies of individual companies have a direct effect on costs. For example, some concerns have particularly strict safety regulations and these must be met in every detail.
- The company policies with reference to labor unions should be considered, because these will affect overtime labor charges and the type of work the operators or other employees can do.
- Labor-union policies may even dictate the amount of wiring and piping that can be done on a piece of equipment before it is brought into the plant, and, thus, have a direct effect on the total cost of installed equipment.

Operating Time and Rate of Production

- One of the factors that has an important effect on the costs is the fraction of the total available time during which the process is in operation. When equipment stands idle for an extended period of time, the labor costs are usually low; however, other costs, such as those for maintenance, protection, and depreciation, continue even though the equipment is not in active use.
- Operating time, rate of production, and sales demand are closely interrelated. The ideal plant should operate under a time schedule which gives the maximum production rate while maintaining economic operating methods.

Governmental Policies

- The national government has many regulations and restrictions which have a direct effect on industrial costs.
- Some examples of these are import and export tariff regulations, restrictions on permissible depreciation rates, income-tax rules, and environmental regulations.
- Each company has its own methods for meeting these regulations, but changes in the laws and alterations in the national and company economic situation require constant surveillance if optimum cost conditions are to be maintained.

Capital Invesments

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 jked-capital investment and nonmanufacturing jked-capital investment.

Capital Investments

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.

Fixed-Capital Investment

The capital needed to supply the necessary manufacturing and plant facilities.

Divided into manufacturing fixed-capital investment and nonmanufacturing fixed-capital investment.

Working Capital Investment

The capital needed for the operation of the plant

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

Non Manufacturing 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.

Working Capital

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

(1) Raw materials and supplies carried in stock
(2) Finished products in stock and semifinished products in the process of being manufactured
(3) Accounts receivable
(4) Cash kept on hand for monthly payment of operating expenses, such as salaries, wages, and raw-material purchases
(5) Accounts payable
(6) Taxes payable

Working Capital

- The raw-materials inventory included in working capital usually amounts to a l-month supply of the raw materials valued at delivered prices.
- Finished products in stock and semifinished products have a value approximately equal to the total manufacturing cost for 1 month's production.
- Because credit terms extended to customers are usually based on an allowable 30-day payment period, the working capital required for accounts receivable ordinarily amounts to the production cost for 1 month of operation.
- The ratio of working capital to total capital investment varies with different companies, but most chemical plants use an initial working capital amounting to 10 to 20 percent of the total capital investment.

ESTIMATION OF CAPITAL INVESTMENT

Of the many factors which contribute to poor estimates of capital investments, the most significant one is usually traceable to sizable omissions of equipment, services, or auxiliary facilities rather than to gross errors in costing.

A check list of items covering a new facility is an invaluable aid in making a complete estimation of the fixed-capital investment. Table 1 gives a typical list of these items.

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.

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 f 10 percent.
5. Detailed estimate (contractor's estimate) based on complete engineering drawings, specifications, and site surveys; probable accuracy of estimate within +5 percent.

TABLE 1

Breakdown of fixed-capital investment items for a chemical process

Direct Costs

1. *Purchased equipment*
   - All equipment listed on a complete flow sheet
   - Spare parts and noninstalled equipment spares
   - Surplus equipment, supplies, and equipment allowance
   - Inflation cost allowance
   - Freight charges
   - Taxes, insurance, duties
   - Allowance for modifications during startup
2. *Purchased-equipment installation*
   - Installation of all equipment listed on complete flow sheet
   - Structural supports, insulation, paint
3. *Instrumentation and controls*
   - Purchase, installation, calibration, computer tie-in
4. *Piping*
   - Process piping-carbon steel, alloy, cast iron, lead, lined, aluminum, copper, ceramic, plastic, rubber, reinforced concrete
   - Pipe hangers, fittings, valves
   - Insulation-piping, equipment
5. *Electrical equipment and materials*
   - Electrical equipment -switches, motors, conduit, wire, fittings, feeders, grounding, instrument and control wiring, lighting, panels
   - Electrical materials and labor

6. *Buildings (including services)*

Process buildings-substructures, superstructures, platforms, supports, stairways, ladders, access ways, cranes, monorails, hoists, elevators

Auxiliary buildings-administration and office, medical or dispensary, cafeteria, garage, product warehouse, parts warehouse, guard and safety, fire station, change house, personnel building, shipping office and platform, research laboratory, control laboratory

Maintenance shops-electric, piping, sheet metal, machine, welding, carpentry, instrument

Building services-plumbing, heating, ventilation, dust collection, air conditioning, building lighting, elevators, escalators, telephones, intercommunication systems, painting, sprinkler systems, fire alarm

7. *Yard improvements*

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

8. *Service facilities*

Utilities-steam, water, power, refrigeration, compressed air, fuel, waste disposal

Facilities-boiler plant incinerator, wells, river intake, water treatment, cooling towers, water storage, electric substation, refrigeration plant, air plant, fuel storage, waste disposal plant, environmental controls, fire protection

Nonprocess equipment-office furniture and equipment, cafeteria equipment, safety and medical equipment, shop equipment, automotive equipment, yard material-handling equipment, laboratory equipment, locker-room equipment, garage equipment, shelves, bins, pallets, hand trucks, housekeeping equipment, fire extinguishers, hoses, fire engines, loading stations

Distribution and packaging-raw-material and product storage and handling equipment, product packaging equipment, blending facilities, loading stations

(Continued)

TABLE 1
Breakdown of fixed-capital investment items for a chemical process ***(Continued)***

Direct **Costs**

9. ***Land***
   Surveys and fees
   Property cost

Indirect costs

1. ***Engineering and supervision***
   Engineering costs-administrative, process, design and general engineering, drafting, cost engineering, procuring, expediting, reproduction, communications, scale models, consultant fees, travel
   Engineering supervision and inspection
2. ***Construction expenses***
   Construction, operation and maintenance of temporary facilities, offices, roads, parking lots, railroads, electrical, piping, communications, fencing
   Construction tools and equipment
   Construction supervision, accounting, timekeeping, purchasing, expediting
   Warehouse personnel and expense, guards
   Safety, medical, fringe benefits
   Permits, field tests, special licenses
   Taxes, insurance, interest
3. ***Contractor's fee***
4. ***Contingency***

TABLE 4

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	

Example

Estimation of fixed-capital investment using ranges of process-plant component cost

Make a study estimate of the fixed-capital investment for a process plant if the purchased-equipment cost is $100,000. Use the ranges of process-plant component cost outlined in Table 4 for a process plant handling both solids and fluids with a high degree of automatic controls and essentially outdoor operation.

Solution

Components	Assumed % of total	Cost	Ratioed % of total
Purchased equipment	25	$100,000	23.0
Purchased-equipment installation	9	36,000	8.3
Instrumentation (installed)	7	28,000	6.4
Piping (installed)	8	32, 000	7.3
Electrical (installed)	5	20,000	4.6
Buildings (including services)	5	20,000	4.6
Yard improvements	2	8,000	1.8
Service facilities (installed)	15	60,000	13.8
Land	1	4,000	0.9
Engineering and supervision	10	40,000	9.2
Construction expense	12	48,000	11.0
Contractor's fee	2	8,000	1.8
Contingency	8	32,000	7.3
		$436,000	100.0

Range will vary from $371,000 to $501,000 for normal conditions; if economy is inflationary, it may vary from $436,000–$566,000.

Methods for estimating capital investment

1. DETAILED-ITEM ESTIMATE
2. UNIT-COST ESTIMATE
3. PERCENTAGE OF DELIVERED-EQUIPMENT COST
4. “LANG” FACTORS
5. POWER FACTOR APPLIED TO PLANT-CAPACITY RATIO
6. INVESTMENT COST PER UNIT OF CAPACITY
7. TURNOVER RATIOS

1. DETAILED-ITEM ESTIMATE

- A detailed-item estimate requires careful determination of each individual item shown in Table 1.
- Equipment and material needs are determined from completed drawings and specifications and are priced either from current cost data or preferably from firm delivered quotations.
- Estimates of installation costs are determined from accurate labor rates, efficiencies, and employee-hour calculations.
- Accurate estimates of engineering, drafting, field supervision employee-hours, and field-expenses must be detailed in the same manner.
- Complete site surveys and soil data must be available to minimize errors in site development and construction cost estimates.
- In fact, in this type of estimate, an attempt is made to firm up as much of the estimate as possible by obtaining quotations from vendors and suppliers.
- Because of the extensive data necessary and the large amounts of engineering time required to prepare such a detailed-item estimate, this type of estimate is almost exclusively only prepared by contractors bidding on lump-sum work from finished drawings and specifications.

2. UNIT-COST ESTIMATE

- The unit-cost method results in good estimating accuracies for fixed-capital investment provided accurate records have been kept of previous cost experience.
- This method, which is frequently used for preparing definitive and preliminary estimates, also requires detailed estimates of purchased price obtained either from quotations or index-corrected cost records and published data.
- Equipment installation labor is evaluated as a fraction of the delivered-equipment cost.
- Costs for concrete, steel, pipe, electricals, instrumentation, insulation, etc., are obtained by take-offs from the drawings and applying unit costs to the material and labor needs.
- A unit cost is also applied to engineering employee-hours, number of drawings, and specifi t tions. A factor for construction expense, contractor’s fee, and contingency is estimated from previously completed projects and is used to complete this type of estimate.

2. UNIT-COST ESTIMATE

$$C_n = \left[\Sigma(E + E_L) + \Sigma(f_x M_x + f_y M'_L) + \Sigma f_e H_e + \Sigma f_d d_n\right](f_F) \qquad (2)$$

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

3. PERCENTAGE OF DELIVERED-EQUIPMENT COST

- This method for estimating the fixed or total-capital investment requires determination of the delivered-equipment cost.
- The other items included in the total direct plant cost are then estimated as percentages of the delivered-equipment cost.
- The additional components of the capital investment are based on average percentages of the total direct plant cost, total direct and indirect plant costs, or total capital investment

$$C_n = [\Sigma E + \Sigma(f_1 E + f_2 E + f_3 E + \ldots)](f_I) \qquad (3)$$

where $f_1, f_2 \ldots$ = multiplying factors for piping, electrical, instrumentation, etc.
f_I = indirect cost factor always greater than 1.

Example

Example 3 Estimation of fixed-capital investment by percentage of delivered-equipment cost. Prepare a study estimate of the tied-capital investment for the process plant described in Example 1 if the delivered-equipment cost is $100,000.

Solution. Use the ratio factors outlined in Table 17 with modifications for instrumentation and outdoor operation.

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

4. "LANG" FACTORS

- This technique, proposed originally by "Lang" and used quite frequently to obtain order-of-magnitude cost estimates, recognizes that the cost of a process plant may be obtained by multiplying the basic equipment cost by some factor to approximate the capital investment.
- These factors vary depending upon the type of process plant being considered. The percentages given in Table 17 are rough approximations which hold for the types of process plants indicated.
- These values, therefore, may be combined to give Lang multiplication factors that can be used for estimating the total direct plant cost, the fixed-capital investment, or the total capital investment.
- Factors for estimating the fixed capital investment or the total capital investment are given in Table 18. It should be noted that these factors include costs for land and contractor's fees.

Item	Percent of delivered equipment 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

TABLE 17
Ratio factors for estimating capital-investment items based on delivered-equipment cost

Values presented are applicable for major process plant additions to an existing site where the necessary land is available through purchase or present ownership.† The values are based on fixed-capital investments ranging from under $1 million to over $20 million.

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			
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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

TABLE 18

Lang multiplication factors for estimation of fixed-capital investment or total capital investment

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

5. POWER FACTOR APPLIED TO PLANT-CAPACITY RATIO

- This method for study or order-of-magnitude estimates relates the fixed-capital investment of a new process plant to the fixed-capital investment of similar previously constructed plants by an exponential power ratio.
- That is, for certain similar process plant configurations, 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.
- This power has been found to average between 0.6 and 0.7 for many process facilities. Table 19 gives the capacity power factor (x) for various kinds of processing plants.

5. POWER FACTOR APPLIED TO PLANT-CAPACITY RATIO

$$C_n = C(R)^{n} \tag{8}$$

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

$$C_n = f\left[D(R)^{x} + I\right] \tag{9}$$

6. INVESTMENT COST PER UNIT OF CAPACITY

- Many data have been published giving the fixed-capital investment required for various processes per unit of annual production capacity such as those shown in Table 19.
- Although these values depend to some extent on the capacity of the individual plants, it is possible to determine the unit investment costs which apply for average conditions.
- An order-of-magnitude estimate.of the fixed-capital investment for a given process can then be obtained by multiplying the appropriate investment cost per unit of capacity by the annual production capacity of the proposed plant.
- The necessary correction for change of costs with time can be made with the use of cost indexes.

7. TURNOVER RATIOS

- A rapid evaluation method suitable for order-of-magnitude estimates is known as the “turnover ratio” method.
- Turnover ratio is defined as the ratio of gross annual sales to the fixed-capital investment, where the product of the annual production rate and the average selling price of the commodities is the gross annual sales figures.
- The reciprocal of the turnover ratio is sometimes defined as the capital ratio or the investment ratio.
- Turnover ratios of up to 5 are common for some business establishments and some are as low as 0.2. For the chemical industry, as a very rough rule of thumb, the ratio can be approximated as 1.

Problems

- The purchased cost of equipment for a solid-processing plant is $500,000. The plant is to be constructed as an addition to an existing plant. Estimate the total capital investment and the fixed-capital investment for the plant. What percentage and amount of the fixed-capital investment is due to wst for land and contractor's fee?

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

- The total capital investment for a chemical plant is $1 million, and the working capital is $100,000. If the plant can produce an average of 8000 kg of final product per day during a 365-day year, what selling price in dollars per kilogram of product would be necessary to give a turnover ratio of l.O?

THANK YOU!

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