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Cost Estimation

All capital cost estimates of industrial process plants can be classified as one of four types:

1. Rule-of-thumb estimates
2. Cost-curve estimates (this book)
3. Major equipment factor estimates
4. Definitive estimates

RULE-OF-THUMB COST ESTIMATES

- The rule-of-thumb estimates are only an approximation of the order of magnitude of cost.
- Assumes straight line relation between capacity and cost.
- These estimates are simply a fixed cost per unit of feed or product. Some examples are:

  Complete coal-fired electric power plant: $1,500/kW
  Complete synthetic ammonia plant: $120,000/TPD
  Complete petroleum refinery: $15,000/BPD
- These rule-of-thumb factors are useful for quick "ball-park" costs.
- The average deviation from actual practice can be more than 50%.
- Its ok to use rule of thumb estimates for estimating utility requirements but not prices

COST-CURVE ESTIMATES

- The cost-curve method of estimating corrects for the major deficiency of the rule of thumb method by Reflecting the effect of capacity on cost.
- The curves do not include utilities, storage, offsite facilities, and location cost differentials, which is calculated separately.
- Some of the plots show a curvature in the log–log slope which indicates that the cost exponent for these process units varies with capacity.
- Variations in the log–log slope (cost exponent) range from about 0.5 for small capacity units up to almost 1.0 for very large units.
- This curvature is due to paralleling equipment in large units and to disproportionately higher costs of very large equipment such as vessels, valves, pumps, etc.
- The cost-curve method of estimating, if carefully used and properly adjusted for local construction conditions, can predict actual costs within 25%.
- Except in unusual circumstances, errors will probably not exceed 50%.

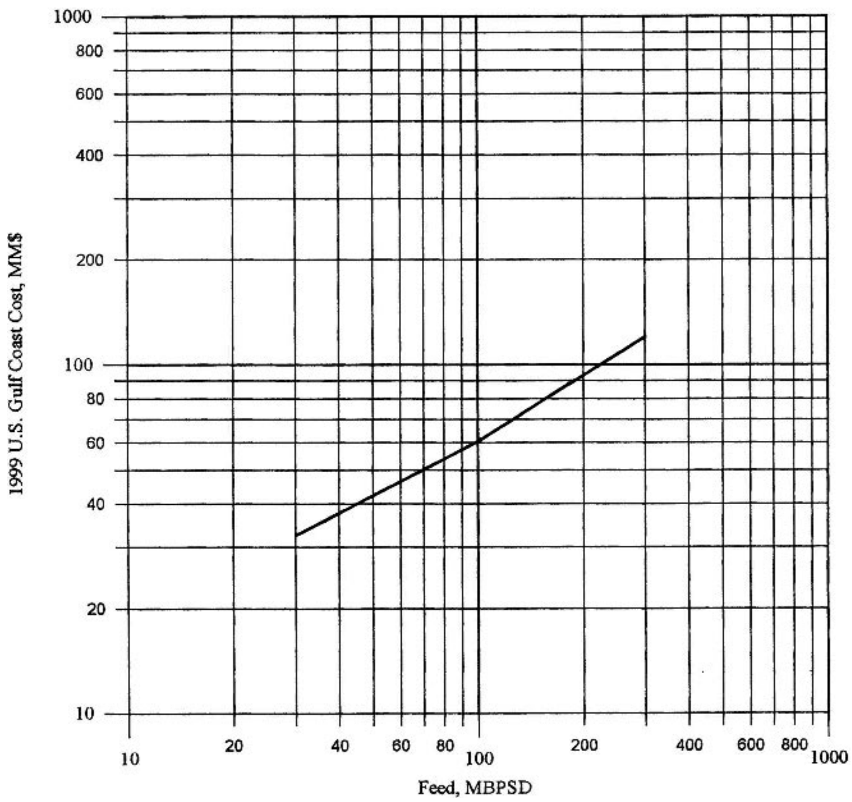

Figure 4.9 Atmospheric crude distillation units investment cost; 1999 U.S. Gulf Coast. (See Table 4.4.)

The following power relation relates the costs of similar process units or plants to capacity:

$$\frac{Plant\ A\ cost}{Plant\ B\ cost} = \left(\frac{Plant\ A\ capacity}{plant\ B\ capacity}\right)^X \qquad \text{Where, X = 0.6} \qquad (1)$$

Example:
According to Figure 4.9, a 100,000 BPD crude unit will cost 60 million $US in 1999. Find the price of the same unit with 200,000 BPD capacity using cost-capacity curve, rule of thumb, and power relation (Equation 1).

Solution:
From the same figure, 200,000 BPD crude unit will cost 92.5 million $US in 1999.

If we use the rule of thumb it will give an estimated price of = 60 million (200,000/100,000) = 120 million $US for a 200,000 BPD crude unit which represents an error of 29%.

If we use equation (1) the estimated price of the 200,000 BPD will be 60 $(200{,}000/100{,}000)^{0.6}$ = 91 million $US which represents an error of only -1.6% which is much more accurate.

MAJOR EQUIPMENT FACTOR COST ESTIMATES

- Prices of major equipment must first be obtained.
- Heat and material balances as well as the size and basic specifications for the major equipment must be established.
- Major equipment factor estimates are made by applying multipliers to the costs of all major equipment required for the plant.
- Different factors are applicable to different size and types of equipment (such as pumps, heat exchangers, pressure vessels, etc.).
- This method of estimating, if carefully followed, can predict actual costs within 10 to 20%.
- A shortcut of this method uses a single 4.5 factor for all equipment. The accuracy in this case is of course less.

DEFINITIVE COST ESTIMATES

- The most time-consuming and difficult to prepare but are also the most accurate.
- Require preparation of plot plans, detailed flow sheets and preliminary construction drawings.
- All material and equipment are listed and priced.
- The number of man-hours for each construction activity is estimated.
- Indirect field costs, such as crane rentals, costs of tools, supervision, etc., are estimated.
- This type of estimate usually results in an accuracy of ±5%.

SUMMARY FORM FOR COST ESTIMATES

- The items to be considered when estimating investment from cost-curves are:

Table 15-1

Item	Cost
Process units Storage facilities Steam systems Cooling water systems	
Subtotal A	
Offsites (Table below)	
Subtotal B	
Special costs (≈ 4% of Subtotal B)	
Subtotal C	
Location factor (Table below)	
Subtotal D	
Contingency (احتياط) usually ≈ 15%	
Total	

STORAGE FACILITIES "the tank-farm"

- The cost of storage facilities is very significant.
- Storage capacity for feed and products varies widely at different refineries depending on the number and type of products, method of marketing, source of crude oil, and location and size of refinery.
- Installed costs for "tank-farms" vary from $40 to $60 per barrel of storage capacity. This cost includes tanks, piping, transfer pumps, dikes, fire protection equipment, and tank-car or truck loading facilities. The value is applicable to low vapor pressure products such as gasoline and heavier liquids.
- Installed costs for butane storage ranges from $75 to $100 per barrel, depending on size.
- Costs for propane storage range from $90 to $120 per barrel.

LAND AND STORAGE REQUIREMENTS

- Each refinery must have its own land and storage requirements.
- Three types of tankage are required: crude, intermediate, and product.
- If the refinery receives the majority of its crude by pipe line and distributes its products in the same manner, about 13 days of crude storage and 25 days of product storage should be provided.
- The 25 days of product storage is based on a three-week shutdown of a major process unit. This generally occurs only every 18 months or two years, but sufficient storage is necessary to provide products to customers over this extended period.
- A rule-of-thumb figure for total tankage (including intermediate storage) is approximately 50 barrels of storage per BPD crude oil processed.
- Producing many types of gasolines and oxygenated components can increase blending and thus product storage requirements by about 50%.
- In 1992 the average refinery must have about 25 to 90 days of total storage capacity.
- The land necessary for operational and storage facilities is about 4 acres per 1,000 BPCD crude capacity (1acre= 4046.856 m^2).
- Land actually purchased is usually much more than this, and varied from 8 to 30 acres per 1,000 BPD. This additional land provided a buffer zone between the refinery and adjacent property and allowed for expanding the capacity and complexity of the refinery.

STEAM SYSTEMS

- A preliminary estimate of investment cost is $80 per lb/hr of total refinery steam-generation capacity.
- This represents the total installed costs for (gas or oil fired, forced draft) boilers, operating at 250 to 300 psig and all associated items such as water treating, deaerating, feed pumps, yard piping for steam, and condensate.
- Total fuel requirements for steam generation can be assumed to be 1,200 Btu (LHV) per pound of steam.
- A contingency of 25% should be applied to preliminary estimates of steam requirements.
- Water makeup to the boilers is usually 5 to 10% of the steam produced.

COOLING WATER SYSTEMS

- A preliminary estimate of investment cost is $100 per gpm of total refinery water circulation.
- This represents the total installed costs for a conventional induced-draft cooling tower, water pumps, water treating equipment, and water piping (Special costs for water supply and blowdown disposal are not included).
- The daily power requirements (kWh/day) for cooling water pumps and fans is estimated by multiplying the circulation rate in gpm by 0.6. This power requirement is significant and should not be ignored.
- The cooling tower makeup water is about 5% of the circulation which is also significant and should not be overlooked.
- Contingency of 15% should be applied to the cooling water circulation requirements.

OTHER UTILITY SYSTEMS "Offsites"

- Some utility systems required in a refinery are difficult to estimate without detailed drawings.
- The cost is normally included in the "offsite" facilities.
- "Offsites" are facilities, which are not included in the costs of major refinery facilities.
- Examples are:
  1. Electric power distribution
  2. Fuel oil and fuel gas facilities
  3. Water supply, treatment, and disposal
  4. Plant air systems
  5. Fire protection systems
  6. Flare, drain and waste containment systems
  7. Plant communication systems
  8. Roads and walks
  9. Railroads
  10. Fence
  11. Buildings
  12. Vehicles
  13. Product and additives blending facilities
  14. Product loading facilities
- The offsite requirements vary widely between different refineries.
- The values shown below can be considered as typical for grassroots refineries when estimated as outlined in this text.

Table 15-2

Crude oil feed (BPSD)	Offsite costs, % of total major facilities costs*
Less than 30,000	50
30,000–100,000	30
More than 100,000	20

* Major facilities as defined herein include process units, storage facilities, cooling water systems, and steam systems.

- Offsite costs for the addition of individual process units in an existing refinery can be about 20 to 25% of the process unit costs.

Special Costs

- Include land, spare parts, inspection, project management, chemicals, miscellaneous supplies, and office and laboratory furniture.
- For preliminary estimates these costs can be estimated as 4% of the cost of the process units, storage, steam systems, cooling water systems, and offsites.
- Engineering costs and contractor fees are included in the various individual cost items.

Contingencies

- Most professional cost estimators recommend that a contingency of at least 15% be applied to the final total cost determined by cost-curve estimates of the type presented herein.
- The term contingencies covers many loopholes in cost estimates of process plants. The major loopholes include cost data inaccuracies when applied to specific cases and lack of complete definition of facilities required.

Escalation

- All cost data presented in this book (capital cost, utilities, catalyst and other) are based on U.S. Gulf Coast construction averages for the year 1999.
- To use the data for current estimates some form of escalation or inflation factor must be applied.
- The most commonly used cost index numbers by estimators and engineers in the U.S. refining industry are,
    1. the Chemical Engineering Plant Cost Index
    2. the Nelson-Farrar Refinery (Inflation) Index
- The use of these indices is subject to errors inherent in any generalized estimating procedure, but some such factor must obviously be incorporated in projecting costs from a previous time basis to a current period. It should be noted that the contingencies discussed in the previous section are not intended to cover escalation.

- For simplicity you can use the following equation for a quick estimation of inflation rate

$$Cost_{2015} = Cost_{1999}\,(1+f)^{n} \qquad (2)$$

where n = number of years 2015- 1999 = 16 and f is the average price inflation which is approximately = 3% (or 2.8% to be more accurate).

- Escalation or inflation of refinery investment costs is influenced by items that tend to increase costs as well as by items that tend to decrease costs.
- Items which increase costs include obvious major factors, such as:
    1. Increased cost of steel, concrete, and other basic materials on a per ton basis.
    2. Increased cost of construction labor and engineering on a per hour basis.

3. Increased costs for excessive safety standards and pollution control regulations.
4. Increase in the number of reports and amount of superfluous data necessary to obtain local, state, and federal construction permits.

- Items which tend to decrease costs are basically all related to technological improvements. These include:
    1. Process improvements in research, design, and operation
    2. More efficient use of engineering and construction manpower
- Examples of such process improvements include
    1. improvement of fractionator tray capacities
    2. improved catalysts which allow smaller reactors
    3. improved instrumentation allowing for consistently higher plant feed rates.

Plant Location

- The main factors contributing to these variations are:
    1. Climate and its effect on design requirements and construction conditions.
    2. Local rules, regulations, codes, taxes, etc.
    3. Availability and productivity of construction labor.
- Relative hydrocarbon process plant costs on a 1999 basis at various locations are given below:

Table 15-3

Location	Relative cost
U.S. Gulf Coast	1.0
Los Angeles	1.4
Portland, Seattle	1.2
Chicago	1.3
St. Louis	1.4
Detroit	1.3
New York	1.7
Philadelphia	1.5
Alaska, North Slope	3.0
Alaska, Anchorage	2.0