

Project Cost Management

PMG 213

Lecture 3

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Cost Estimating





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3.1.1 Purpose of Estimates:

Estimates are the foundation of all cost engineering activity. They are made for several reasons including:

- Feasibility studies
- Selection from alternative designs
- Selection from alternative investments
- Appropriation of funds
- Presentations of bids and tenders

The type of estimate to be made and its accuracy depends upon many factors including the purpose of the estimates, how much is known about the project, and how much time and effort is spent in preparing the estimate. It must be remembered that an estimated project cost is not an exact number. Rather it is an opinion of probable cost, not an exact calculation.

The accuracy and reliability of an estimate is totally dependent upon how well the project scope is defined and the time and effort expended in preparation of the estimate.

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The one thing that is known with 99.9+% certainty about any estimate is that it is wrong. Actual cost will rarely, if ever, equal the estimated cost. The final cost of a project will be more or less than the estimate.

The difference may be very small, but there will nevertheless be a difference. That fact must always be kept in mind when making project decisions based upon any estimate of costs. It is often said that the only time an estimate is correct is after the project is complete and all of the bills have been paid and totaled.

Question: A manager claims that a project cost estimate is a precise calculation.

Correct this statement and list three reasons why estimates are made

Answer: An estimate is an opinion of probable cost, not an exact calculation . Three reasons they are made: Feasibility studies, Selection from alternate designs, and Appropriation of funds

Lecture 3**3.1.2 Fixed Capital and Working Capital:**

Capital investment is made up of two components: $\text{Total capital} = \text{fixed capital} + \text{working capital}$ That is, the total investment to put a project in operation is comprised of:

1. Fixed capital cost: a one-time cost for all the facilities for the project, including land, design and engineering, equipment, utilities, freight, startup, etc.
2. Working capital: the funds in addition to fixed capital and land investment that a company must contribute to the project (excluding startup expense) to get the project started and to meet subsequent obligations as they come due. Working capital includes inventories, cash, and accounts receivable minus accounts payable. Characteristically these funds can be converted readily into cash. Working capital is normally assumed to be recovered at the end of the project.

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A chemical engineering firm is establishing a new localized production module. The accounting and engineering teams track the following upfront financial metrics for the module:

Purchased land site: \$350,000, Physical plant equipment and installation: \$2,100,000, Engineering and architectural design fees: \$450,000, inventory: \$180,000, Cash on hand for immediate payroll: \$90,000,

Accounts receivable from early distributors: \$110,000, Accounts payable to parts vendors: \$60,000,

Estimated plant startup expenses: \$85,000, Your Task:

Calculate the Fixed Capital Cost, Working Capital , Determine the Total Capital Investment.

- **Fixed Capital Cost:** fixed capital is a one-time cost for all physical facilities, land, design, engineering, and equipment that *startup expenses* are explicitly excluded from the working capital bracket by definition and fall under upfront capital requirements: $\text{Fixed Capital} = \text{Land} + \text{Equipment} + \text{Design Fees} + \text{Startup Costs}$
 $= \$350,000 + \$2,100,000 + \$450,000 + \$85,000 = \$2,985,000$

- **Working Capital:** $\text{Working Capital} = \text{Inventories} + \text{Cash} + \text{Receivables} - \text{Payables} = (\$180,000 + \$90,000 + \$110,000) - \$60,000$
 $= \$380,000 - \$60,000 = \$320,000$

- **Total Capital Investment:** $\text{Total Capital} = \text{Fixed Capital} + \text{Working Capital} = \$2,985,000 + \$320,000 = \$3,305,000$

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As a rough estimate, working capital for a project will be approximately 10 to 20% of the fixed capital or about 25% of annual operating costs in most manufacturing industries. However, working capital requirements can exceed 50% of the fixed capital investment in service industries, industries with high sales costs, and seasonal industries such as construction materials manufacture. As an example, brick is generally manufactured 12 months per year in order to obtain maximum productive use of the kilns used to fire the brick.

However, in colder climates construction with brick may be possible for only six months or less each year. Thus, the brick manufacturers build large inventories during the nonconstruction months, thereby requiring considerably more working capital than might otherwise be needed.

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- Manufacturing vs. Service Capital Allocations:

An industrial investor wants to open two distinct business entities simultaneously : Entity A (Manufacturing Industry Plant): Has a calculated Fixed Capital Cost of \$5,500,000. Entity B (High-Sales Cost Service Industry Firm): Has a calculated Fixed Capital Cost of \$2,200,000. Your Task : Using the standard rough estimation percentages, calculate the maximum baseline Working Capital required for Entity A if it follows standard manufacturing trends, Calculate the minimum baseline Working Capital required for Entity B if it behaves like a service industry with high sales expenses. Answer: -Entity A (Manufacturing Plant Working Capital): manufacturing industry projects require working capital equal to approximately 10% to 20% of the fixed capital. To find the maximum standard manufacturing baseline, we use the upper bound of 20% :

Working Capital (Entity A)=\$5,500,000*0.20*=\$1,100,000

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-Entity B (Service Industry Working Capital): notes that working capital requirements can easily exceed 50% of the fixed capital investment in service industries or industries with high sales costs.

Working Capital (Entity B)=\$2,200,000=0.50=\$1,100,000

- **Calculate Working Capital from Operating Costs:** A factory manager is assembling a budget proposal. The facility has an estimated annual operating cost of \$3,600,000. **Your Task:** what approximate dollar amount should the manager allocate for Working Capital based strictly on these operating costs? Answer:

Calculate Working Capital from Operating Costs: states that working capital is roughly estimated to be about 25% of annual operating costs in most manufacturing operations :

Working Capital = Annual Operating Costs* 25

Working Capital=\$3,600,000*0.25=\$900,000

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Why does a brick manufacturer in a cold climate require a working capital allocation that exceeds 50% of the fixed capital investment?

Answer: Due to seasonality. Kilns must run 12 months/year for efficiency, but construction only happens for about 6 months. The manufacturer must build and hold a massive inventory during non-construction months, requiring huge cash flow to cover expenses before sales begin.

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3.1.3 Current Trends in Capital-Cost Estimating

Projects are becoming larger in scale, they are increasingly more international in scope, and competition is keen worldwide.

More factors than ever before have to be carefully considered in regard to their impact upon an estimate:

- ☐ Technological advances
- ☐ Inflation forecasts
- ☐ Potential price controls
- ☐ Safety and environmental regulations
- ☐ Social concerns
- ☐ Currency fluctuations
- ☐ Import and export considerations
- ☐ Taxation and trade barriers
- ☐ Escalation
- ☐ Inflationary pressures, etc

3.1.4 Types of Estimates

The American National Standards Institute (ANSI, 1991) defines three types of estimates: order-of-magnitude, budget, and definitive.

1. **Order-of-magnitude estimates** have an expected accuracy between +50% and -30%. They are generally based on cost-capacity curves and cost capacity ratios and do not require any preliminary design work.

2. **Budget estimates** are based on flowsheets, layouts, and preliminary equipment descriptions and specifications and have an accuracy range of +30% to -15%. Design generally must be 5 to 20% complete to permit such an estimate to be performed.

3. **Definitive estimates** require defined engineering data, such as site data, specifications, basic drawings, detailed sketches, and equipment quotations. Design is generally 20 to 100% complete, and estimate accuracy should be within +15% to -5%.

The nonuniform spread of accuracy ranges (e.g., +15% to -5% rather than $\pm 10\%$) reflects the fact that the vast majority of estimates tend to fall short of actual costs instead of exceeding them. AACE International has proposed an expansion of the ANSI estimate classifications to five types with expected accuracy levels based upon the amount of project definition available when the estimate is prepared (AACE, 1997). The accuracy of each class of estimate depends on the technological complexity of the project, appropriate reference information, and inclusion of an appropriate contingency determination. In all cases, accuracy ranges could exceed the ranges indicated below in unusual circumstances.

- During the initial project ideation phase, an industrial engineer uses a rough scale-up method to generate a base cost estimate of \$4,500,000 for a new packaging line. No preliminary engineering design work has been completed (0% design completion).
Your Task : Identify the correct ANSI estimate type for this project stage.
Calculate the absolute minimum and absolute maximum potential cost of this project.
Answer:

Because there is 0% design completion, this is an Order-of-Magnitude estimate.
Calculate Low-Side Boundary (-30% Tolerance Minimum Cost)=Base Cost * (1-0.30)=
Minimum Cost=\$4,500,000* 0.70=\$3,150,000
Calculate High-Side Boundary (+50% Tolerance):Maximum Cost=Base Cost* (1+0.50)
Maximum Cost=\$4,500,000*1.50=\$6,750,000
Final Answer: The project cost range spans from \$3,150,000 to \$6,750,000.

- A project manager has completed 15% of the preliminary engineering design for a chemical storage facility. The current base cost estimate is \$8,200,000. The manager must present the financial risk range to the corporate board for partial funding authorization.

Your Task: Identify the correct ANSI estimate type for this project stage.

Answer:

Estimate Type: With 15% design complete (which fits perfectly inside the 5% to 20% range), this is a Budget estimate.

Calculate Low-Side Boundary (-15% Tolerance): Minimum Cost = $\$8,200,000 * (1 - 0.15)$

Minimum Cost = $\$8,200,000 * 0.85 = \$6,970,000$

Calculate High-Side Boundary (+30% Tolerance): Maximum Cost = $\$8,200,000 * (1 + 0.30)$

Maximum Cost = $\$8,200,000 * 1.30 = \$10,660,000$

Final Answer: The board must understand that while the target is \$8.2M, the actual cost could swing between \$6,970,000 and \$10,660,000

- A construction project is 90% through its engineering design lifecycle. A Definitive estimate fixes the baseline project cost at \$14,000,000. A contractor submits a final construction bid of \$16,300,000. Your Task: Determine the maximum allowable high-side cost bound under the ANSI Definitive category, check if the contractor's bid falls inside or outside this expected accuracy standard. Answer:

Calculate Definitive High-Side Boundary (+15% Tolerance):

Maximum Allowed Cost = $\text{Base Cost} \times (1 + 0.15)$

Maximum Allowed Cost = $\$14,000,000 \times 1.15 = \$16,100,000$

Evaluate Contractor's Bid: The contractor's bid is \$16,300,000

The expected ANSI definitive ceiling is \$16,100,000.

Final Answer: The contractor's bid falls outside (exceeds) the standard ANSI definitive tolerance by \$200,000. This indicates the bid is unexpectedly high and needs to be renegotiated or audited.

The revised classifications are:

- 1. Class 5 estimates:** These estimates are generally based on very limited information. They may be prepared within a very limited amount of time and with little effort expended, sometimes less than one hour. Often little more is known than the proposed plant type, location, and capacity. This class of estimate falls into the ANSI order-of-magnitude classification. The required level of project definition is 2% or less and the expected accuracy is -20% to -50% on the low side and +30% to +100% on the high side.
- Calculate the high-side dollar cost of a Class 5 estimate if the base estimate is \$1,000,000.**
- Answer:** The non-uniform range reflects the fact that the vast majority of historical estimates tend to fall short of actual costs instead of exceeding them. For a \$1,000,000 base project, a Class 5 estimate has a high-side accuracy limit of +100%, meaning the cost could reach $\$2,000,000 = \$1,000,000 * 2$

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2. Class 4 estimates: Class 4 estimates also are generally prepared based upon limited information and also have fairly wide accuracy ranges. They are typically used for project screening, feasibility determinations, concept evaluation, and preliminary budget approval. Engineering is only 1% to 5% complete and comprises, at a minimum, plant capacity, block schematics, indicated plant layout, process flow diagrams (PFDs) for the main process systems, and preliminary lists of engineered process and utility equipment. Typical accuracy ranges for this class of estimate are -15% to -30% on the low side, and +20% to +50% on the high side. This class of estimate falls into the ANSI budget estimate classification.

➤ **A team completes 5% engineering for a new chemical storage module. The parametric base estimate is \$3,000,000.**

Task: Calculate the absolute Class 4 high-side cost ceiling using standard AACE tolerances (+50%).

Solution: High-Side Ceiling = $\$3,000,000 * (1 + 0.50) = \$4,500,000$

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3. Class 3 estimates: These are estimates which form the basis for budget authorization, appropriation, and/or funding. These estimates typically form the initial control estimate against which all actual costs and resources will be monitored. The required level of project definition (i.e., completed engineering) is 10% to 40% and includes at a minimum: process flow diagrams, utility flow diagrams, preliminary piping and instrument diagrams, plot plans, developed layout drawings, and essentially complete engineering process and utility equipment lists. Accuracy ranges for this class of estimate are -10% to -20% on the low side, and +10% to +30% on the high side. This class of estimate also falls into the ANSI budget estimate classification.

➤ **A project hits 20% definition for board approval. The baseline estimate is \$6,500,000.**

Task: Calculate the minimum low-side funding boundary using Class 3 tolerances (-20%).

Solution: Low-Side Floor = $\$6,500,000 * (1 - 0.20) = \$5,200,000$

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4. Class 2 estimates: This class of estimate falls into the ANSI definitive estimate category. Class 2 estimates are generally prepared to form detailed control baselines against which all project work is monitored in terms of cost and progress control. For contractors, this class of estimate is often used as the “bid” estimate. Typically engineering is 30% to 70% complete and comprises, at a minimum: process flow diagrams, utility flow diagrams, piping and instrument diagrams (P&IDs), heat and material balances, final plot plans, final layout drawings, complete lists of engineered process and utility equipment, single line electrical diagrams, electrical equipment and motor schedules, vendor quotations, detailed project execution plans, resourcing and work force plans, etc. Accuracy ranges are much improved over the prior classes of estimates. On the low side they are -5% to -15%. On the high side, the ranges are +5% to +20%.

➤ **A contractor with 60% completed engineering sets a Class 2 target baseline of \$12,000,000.**

Task: Find the maximum acceptable bid ceiling using the standard Class 2 high-side tolerance (+20%).

Solution: Maximum Bid Ceiling = $\$12,000,000 * (1 + 0.20) = \$14,400,000$

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5. Class 1 estimates: Also included in the ANSI definitive estimate category, this is the most accurate classification of estimates. Class 1 estimates are generally prepared for discrete parts or sections of the total project rather than for the entire project. The parts of the project estimated at this level of detail are typically used by subcontractors for bids, or by owners for check estimates. The updated estimate is often referred to as the current control estimate and becomes the new baseline for cost/schedule control of the project. This type of estimate is often made to evaluate and/or dispute claims. Typically, engineering is 50% to 100% complete and comprises virtually all engineering and design documentation of the projects, and complete project execution and commissioning plans. Typical accuracy ranges are -3% to -10% on the low side and +3% to +15% on the high side.

➤ **A subcontractor submits a final lump-sum bid of \$920,000 for a specific piping manifold section. The fully engineered Class 1 internal estimate baseline is \$850,000.**

Task: Calculate the Class 1 high-side accuracy threshold (+10%) to check if this bid is acceptable.

Solution: High-Side Threshold = $\$850,000 \times (1 + 0.10) = \$935,000$ (The \$920,000 bid is valid because it falls below the \$935,000 ceiling).

The various types of capital-cost estimates are made for a variety of reasons, the principal ones being

- **Order-of-magnitude estimates:**

- Feasibility studies

- Selection from alternative designs

- Selection from alternative investments

- Budgeting or construction forecasting

- **Budget**

- Budgeting or construction forecasting

- Authorization—partial or full funds

- **Definitive**

- Authorization—full funds

- Check of an authorized project

- Presentation of bids

3.1.5 Functions of Capital-Cost estimates

- **Feasibility Study Portfolio Allocation (Order-of-Magnitude):** A green energy corporation is conducting Feasibility Studies for three separate plant locations. Because these are early feasibility evaluations, they carry Order-of-Magnitude tolerances (-30% to +50%).

The estimated base costs are: Site Alpha: \$2,000,000 Site Beta: \$3,500,000 Site Gamma: \$1,500,000 .

Your Task: Calculate the total combined high-side financial exposure (the maximum potential budget ceiling) that the corporation must prepare for if they decide to fund the development of all three sites simultaneously. **Answer:**

Sum the Base Estimates : Total Base Cost= $\$2,000,000 + \$3,500,000 + \$1,500,000 = \$7,000,000$

Apply the Order-of-Magnitude High-Side Factor (+50%):

Maximum Portfolio Ceiling= $\text{Total Base Cost} \times (1 + 0.50)$

Maximum Portfolio Ceiling= $\$7,000,000 \times 1.50 = \$10,500,000$

Final Answer: The corporation must be financially prepared for a maximum combined exposure of \$10,500,000.

3.1.5 Functions of Capital-Cost estimates

- **Partial Funding Authorization Cap (Budget Estimate):** A manufacturing company's internal regulations state that when a project is at the stage of Partial Funding Authorization, the board will only release an initial down payment equal to the project's absolute low-side boundary cost. Any remaining balance will be released later. A project manager submits an authorization request for a refinery expansion with a base estimate of \$12,600,000.

Your Task: Identify the estimate category used for funding authorization.

Calculate the exact dollar amount of the initial down payment the board will release.

Answer: Identify Category: matches partial funding authorization to a Budget Estimate.

Identify Low-Side Tolerance: defines the low-side tolerance of a Budget estimate as -15%.

Calculate the Down Payment Amount : $\text{Released Funds} = \text{Base Cost} \times (1 - 0.15)$

$\text{Released Funds} = \$12,600,000 \times 0.85 = \$10,710,000$

Final Answer: The board will authorize an initial down payment of \$10,710,000.

3.1.5 Functions of Capital-Cost estimates

- **Evaluating Contractor Bids (Definitive Estimate) :** An infrastructure group is reviewing the Presentation of Bids from external contractors for a pipeline project. The internal project team has advanced the engineering to a Definitive Estimate level (-5% to +15%), establishing a strict internal baseline cost of \$6,000,000. Three contractors submit the following lump-sum bids:

Contractor X: \$5,600,000

Contractor Y: \$6,800,000

Contractor Z: \$6,950,000 Your Task : Determine which contractor bid(s) must be disqualified for falling completely outside the acceptable maximum high-side limit of a standard Definitive estimate. Answer: the Definitive Maximum High-Side Cap (+15%):

Maximum Acceptable Bid=Baseline Cost*(1+0.15)

Maximum Acceptable Bid=\$6,000,000*1.15=\$6,900,000

Evaluate the Bids against the \$6,900,000:

Contractor X (\$5,600,000): Below the cap. (Acceptable)

Contractor Y (\$6,800,000): Below the cap. (Acceptable)

Contractor Z (\$6,950,000): Exceeds the \$6,900,000 ceiling. (Disqualified)

Final Answer: Contractor Z must be disqualified because their bid exceeds the acceptable definitive threshold by \$50,000.

3.1.5 Functions of Capital-Cost estimates

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3.1.6 Cost of Making Estimates

A cost estimate does not come free, and the cost of preparing the estimate rises rapidly with the accuracy required. The expense of an estimate may or may not be calculated to include the cost of detailed engineering required to prepare the estimate. From a practical point of view, the estimate cannot be prepared without adequate engineering work to support the estimate. Thus, whether or not engineering costs are considered to be a part of the cost of making an estimate, the point is moot. For an estimate to be made, engineering must be done to an adequate level to support the estimate. Engineering costs will thus be incurred.

Table 3.1 shows the variability of the expense of performing an estimate. This table shows approximately how the estimate preparation cost varies with the size of the project and the level of design.

As shown, for an order-of-magnitude \$1 million estimate, estimate cost is about 0.15% of the estimated amount; a budget estimate increases this cost to about 0.6%; a definitive estimate raises the cost to about 2.0%

Approximate Cost of Preparing Estimates (Excluding Supporting Engineering Work)

Accuracy range, %	\$1,000,000 project	\$10,000,000 project	\$20,000,000 project
-5/ +15	\$20,000	\$50,000	\$90,000
-15/ +30	6,000	15,000	30,000
-30/ +50	1,500	4,000	8,000

Table 3.1

Table 3.2 Approximate Cost of Preparing Estimates (Including Supporting Engineering Work)

Accuracy range, %	\$1,000,000 project	\$10,000,000 project	\$20,000,000 project
−5/ +15	\$60,000	\$130,000	\$240,000
−15/ +30	35,000	65,000	100,000
−30/ +50	14,000	30,000	45,000

Table 3.2 shows the effect of adding the required engineering work to the estimate cost. For the order-of-magnitude \$1 million estimate, estimate cost increases to about 1.4% of the estimated amount; the budget estimate increases to about 3.5%; and the definitive estimate raises to about 6.0%.

Table 3.2

Clearly, the cost of engineering work must be considered when deciding upon the level of estimate which is required. To perform an estimate at a higher level of accuracy than required is a waste of resources. On the other hand, to attempt to save money by not doing sufficient engineering work leads to estimates which are far less accurate than may be necessary. The estimator must understand the purpose of an estimate and the level of accuracy which is actually needed.

- For a project estimated at \$1,000,000, state the preparation cost percentages (excluding supporting engineering work) for all three ANSI levels .

Answer: Order-of-magnitude is 0.15% (\$1,500); Budget is 0.6% (\$6,000); Definitive is 2.0% (\$20,000)

- Using Table 3.1, find the preparation cost of a budget estimate (-15% +30%) for a \$10,000,000 project. **Answer:** \$15,000

- Using Table 3.2, find the preparation cost of a definitive estimate (-5% +15%) for a \$20,000,000 project. **Answer:** \$240,000

Cost estimates can be prepared from three sources of data:

1. Similar project costs: costs of similar projects, and costs of project components
2. Proprietary cost data files: historical company costs, and in-house projects
3. Published cost information

Extreme care should be used when using published information because the accuracy level of such data is not known. Sometimes the basis for such data is not even indicated (e.g., whether purchased or installed costs are being presented). Installed cost figures also may or may not include auxiliary equipment, and some costs might be for entire plants while others may be for battery-limit installations only



3.1.7
Representation
of Cost Data

Further, unless the published data is dated or includes a cost index value, it is often virtually impossible to correct for inflation since the data was obtained. Do not assume that the publication date reflects the date at which the data was obtained. Publication often takes months or years after an article is first written. Unless the publication is very specific about exactly what is included in the cost figures and about the date of the information, the published data should not be used.

- **Why is it a dangerous assumption to believe that a cost data book's publication date matches the exact date the cost information was collected? *Answer:***
Because publication often takes **months or years** after an article or study is originally written, meaning inflation changes have occurred in the interim.

3.1.7 Representation of Cost Data

The following are typical techniques used to prepare an order-of-magnitude estimate using historical average cost factors. These techniques and the suggested factors must be used with caution and, to the extent possible, be updated based upon actual data for the time and location in question.

- Lang Factors

Total plant capital costs (excluding land) can be approximated from the delivered cost of plant equipment using Lang factors as multipliers. The multipliers, depending on the type of plant, are:

- 3.10 for solid process plants
- 3.63 for solid-fluid process plants
- 4.74 for fluid process plants

These factors were originally proposed over 50 years ago by Lang (1948). Despite the passage of time, they continue to be useful for process industry order-of-magnitude estimates.

**3.1.8
Factored
Estimating**

- Calculate the total plant capital cost (excluding land) for a fluid process plant if the total delivered cost of plant equipment is \$2,500,000

Answer: The **Lang factor multiplier** for a fluid process plant is 4.74

Total Cost = \$2,500,000 * 4.74 = \$11,850,000 .

- **Hand Factors** Rather than using single multipliers, such as the Lang factors, Hand (1958) suggested using a summation of individual factors multiplied by the delivered cost of different types of equipment. The Hand factors were updated by the AACE International Cost Estimating Committee in 1992 (Hand, 1992). The updated factors are:

4.0 for fractionating column shells	2.5 for fractionating column trays
3.5 for pressure vessels	3.5 for heat exchangers
2.5 for fired heaters	4.0 for pumps
3.0 for compressors	3.5 for instruments

3.1.8 Factored Estimating

- An order-of-magnitude estimate requires adding fractionating column shells (delivered cost: \$100,000) and heat exchangers (delivered cost: \$50,000). Apply the updated Hand factors to find the total estimated cost for these items.

Answer: Hand factor for shells = 4.0; Hand factor for heat exchangers = 3.5

Total Cost = $\$100,000 \times 4.0 + \$50,000 \times 3.5 = \$400,000 + \$175,000 = \$575,000$

Wroth (1960) gave a more complete list of factors, as shown in Table 3.3. These factors are also old but are still useful for order-of-magnitude estimates in the process industry.

3.1.8 Factored Estimating

Table 3.3 Process Plant Cost Ratio from Individual Equipment

Equipment	Factor ^a
Blender	2.0
Blowers and fans (including motor)	2.5
Centrifuges (process)	2.0
Compressors	
Centrifugals	
Motor-driven (less motor)	2.0
Steam turbine (including turbine)	2.0
Reciprocating	
Steam and gas	2.3
Motor-driven (less motor)	2.3

3.1.8 Factored Estimating

Ejectors (vacuum units)	2.5
Furnaces (package units)	2.0
Heat exchangers	4.8
Instruments	4.1
Motors, electric	8.5
Pumps	
Centrifugal	
Motor-driven (less motor)	7.0
Steam turbine (including turbine)	6.5
Positive displacement (less motor)	5.0
Reactors—factor as approximate equivalent type of equipment	
Refrigeration (package unit)	2.5
Tanks	
Process	4.1
Storage	3.5
Fabricated and field-erected (50,000 + gal)	2.0
Towers (columns)	4.0

Table 3.3
Process
Cost Ratio
from Individual
equipment

A Multiply the purchase cost by a factor to obtain the installed cost, including the cost of site development, buildings, electrical installations, carpentry, painting, contractor's fee and rentals, foundations, structures, piping, installation, engineering, overhead, and supervision.

**3.1.8
Factored
Estimating**



Thank You