COST ESTIMATION

Fixed Capital Investment: Cost of equipment and facilities

\[ FCI = \text{(Direct Costs)} + \text{(Indirect Costs)} \]

Direct Costs:
1. Purchased equipment: Columns, Heat Exchangers, pumps, tanks, etc.
2. Equipment Installation
3. Piping (includes insulation)
4. Instruments and Control
5. Electrical Equipment.
6. Buildings: Process, Administration, Maintenance shops, etc.
7. Site Preparation
8. Service Facilities: steam, water, air, fuel, etc. Waste treatment, fire control, offices, etc.
9. Land
COST ESTIMATION

**Indirect Costs:**

2. Construction Expenses
3. Contractor's fee
5. Start up expenses
COST ESTIMATION

Types Of Cost Estimates

1. **Order of Magnitude estimate**. Extrapolate similar plant cost
   Accuracy: over 30%

2. **Study Estimate**. Knowledge of major pieces of equipment
   Accuracy: ± 30%

3. **Preliminary Estimate**. Enough for budget authorization.
   Accuracy: ± 20%

4. **Definitive Estimate**. Based on basic Engineering and quotes
   from suppliers and contractors.
   Accuracy: ± 10%

5. **Detailed Estimate**. Based on Detailed Engineering.
   Accuracy: ± 5%
COST ESTIMATION

Cost Indexes

Present Cost = (original cost at time t) * \[
\left( \frac{\text{index value now}}{\text{index value at time } t} \right)
\]

- Marshall and Swift.
  1. All industry-equipment index. Arithmetic average of 47 equipment types.
  2. Process-industry equipment index. Weighted average of 8 of these:
     - cement: 2%
     - chemicals: 48%
     - clay products: 2%
     - glass: 3%
     - paint: 5%
     - paper: 10%
     - petroleum: 22%
     - rubber: 8%

M&S was 100 in 1926. Published in “Chemical Engineering”. 

———

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COST INDEXES

- **Engineering News-Record Construction Cost index.**
  Steel, lumber, labor, concrete.
  Published in “Engineering News-record”.
  ENR value reported based on 100 in 1913, 1949 or 1967.

- **Nelson-Farrar Refinery Construction Cost index.**
  Skilled and common labor, iron and steel, building materials, miscellaneous equipment.
  Published in “Oil and Gas Journal”.
  N-R value of 100 in 1946.

- **Chemical Engineering Plant Cost Index.** Chemical Plants.
  Equipment, machinery supports 61% | Engineering and supervision supports 10%
  Installation labor 22% | Buildings, material, labor 7%

Published in “Chemical Engineering”.
PCI value of 100 in 1957-59.

ChE 4253 - Design I
Figure 2.3 The variations in several commonly used cost indexes over the seventeen-year period 1978 to 1995.

From Turton et al., 1998
COST INDICES (as inflation indicators)

Figure 7.3 The Variations in Several Commonly Used Cost Indexes Over 15 Years (1992–2006)

From Turton et al., 2009
Methods For Estimating Capital Investment

1. **Detailed-Item Estimate.**

All items in the direct and indirect cost are evaluated with as much detail as possible. All specs are known. (± 5% accuracy, contractor’s estimate)
Methods For Estimating Capital Investment

2. **Unit-Cost Estimate.**

Prices from quotations or index-corrected records.

\[ C = \left[ \sum (E + E_L) + \sum (f_x M_x + f_y M_L) + \sum f_e H_e + \sum f_d d_n \right] f_F \]

See p. 250 in Peters et al., 2003).

(10-20% accuracy, definitive or preliminary estimate)

- **E**: delivered equip. cost
- **E_L**: labor for equipment cost for field labor
- **f_x**: material unit cost
- **f_e**: unit cost for engineering
- **f_d**: drawing cost
- **f_F**: field expense factor
3. **Percentage of Delivered-Equipment Cost.**

All items in the direct and indirect cost are evaluated as a percentage of the delivered-equipment cost. (definitive estimate in certain cases, ±10%)

\[
C = \left[\sum E + \sum (f_1E + f_2E + f_3E + \ldots)\right] f_1
\]

See Table 7-8, p. 194 in TBW&S

4. **Estimation based on "Lang" factors.**

Named after Lang (1947). The Fixed Capital Investment is found by multiplying equipment cost by a factor (see Table 7-7, p. 192 in TBW&S) (±30% accuracy, order of magnitude estimate)
Table 6-9 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 $100 million.

<table>
<thead>
<tr>
<th>Percent of delivered-equipment cost for</th>
<th>Solid processing plant</th>
<th>Solid-fluid processing plant</th>
<th>Fluid processing plant</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Direct costs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purchased equipment delivered (including fabricated equipment, process machinery, pumps, and compressors)</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Purchased-equipment installation</td>
<td>45</td>
<td>39</td>
<td>47</td>
</tr>
<tr>
<td>Instrumentation and controls (installed)</td>
<td>18</td>
<td>26</td>
<td>36</td>
</tr>
<tr>
<td>Piping (installed)</td>
<td>16</td>
<td>31</td>
<td>68</td>
</tr>
<tr>
<td>Electrical systems (installed)</td>
<td>10</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Buildings (including services)</td>
<td>25</td>
<td>29</td>
<td>18</td>
</tr>
<tr>
<td>Yard improvements</td>
<td>15</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Service facilities (installed)</td>
<td>40</td>
<td>55</td>
<td>70</td>
</tr>
<tr>
<td><strong>Total direct plant cost</strong></td>
<td>269</td>
<td>302</td>
<td>360</td>
</tr>
<tr>
<td><strong>Indirect costs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engineering and supervision</td>
<td>33</td>
<td>32</td>
<td>33</td>
</tr>
<tr>
<td>Construction expenses</td>
<td>39</td>
<td>34</td>
<td>41</td>
</tr>
<tr>
<td>Legal expenses</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Contractor’s fee</td>
<td>17</td>
<td>19</td>
<td>22</td>
</tr>
<tr>
<td>Contingency</td>
<td>35</td>
<td>37</td>
<td>44</td>
</tr>
<tr>
<td><strong>Total indirect plant cost</strong></td>
<td>128</td>
<td>126</td>
<td>144</td>
</tr>
</tbody>
</table>

| Fixed-capital investment                |                        |                             |                        |
| Working capital (15% of total capital investment) | 397                    | 428                         | 504                    |
| **Total capital investment**            | 467                    | 503                         | 593                    |

*Because of the extra expense involved in supplying service facilities, storage facilities, loading terminals, transportation facilities, and other necessary utilities at a completely undeveloped site, the fixed-capital investment for a new plant located at an undeveloped site may be as much as 100 percent greater than that for an equivalent plant constructed as an addition to the existing plant.
# Fixed Capital Investment Cost (Peters et al, 2003)

<table>
<thead>
<tr>
<th>Direct Costs</th>
<th>Fluid Processing Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Onsite</strong></td>
<td></td>
</tr>
<tr>
<td>Purchased Equipment</td>
<td>E = 15-40% I_F</td>
</tr>
<tr>
<td>Installation</td>
<td>6-14% I_F</td>
</tr>
<tr>
<td>Instrumentation</td>
<td>2-12% I_F</td>
</tr>
<tr>
<td>Piping</td>
<td>4-17% I_F</td>
</tr>
<tr>
<td>Electrical</td>
<td>2-10% I_F</td>
</tr>
<tr>
<td><strong>Offsite</strong></td>
<td></td>
</tr>
<tr>
<td>Buildings</td>
<td>2-18% I_F</td>
</tr>
<tr>
<td>Yard Improvement</td>
<td>2-5% I_F</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Service Facilities</td>
<td>8-30% I_F</td>
</tr>
<tr>
<td>Land</td>
<td>1-2% I_F</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Fixed Capital Investment Cost

<table>
<thead>
<tr>
<th>Indirect Costs</th>
<th>Fluid Processing Plant</th>
<th>5-30% D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering</td>
<td>4-20% $I_F$</td>
<td>33 % E</td>
</tr>
<tr>
<td>Construction</td>
<td>4-17 % $I_F$</td>
<td>41% E</td>
</tr>
<tr>
<td>Contractor’s Fee</td>
<td>2-6 % $I_F$</td>
<td>22 % E</td>
</tr>
<tr>
<td>Contingency</td>
<td>5-15% $I_F$</td>
<td>44 % E</td>
</tr>
<tr>
<td></td>
<td>Included in</td>
<td>Contractor’s fee</td>
</tr>
<tr>
<td></td>
<td>10-20 % $I_F$</td>
<td>5-15% $I_F$</td>
</tr>
<tr>
<td>Working Capital</td>
<td>10-20% $I_F$</td>
<td>15 % TCI</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10-20% TCI</td>
</tr>
</tbody>
</table>
METHODS OF PROFITABILITY EVALUATION

Return of Investment (ROI)

The formula is:

\[
ROI = \frac{CF}{TCI}
\]
METHODS OF PROFITABILITY EVALUATION

Net Present Worth

The formula is:

\[
NPW = \sum_{k=1}^{n-1} \frac{CF_k}{(1+i)^k} + \frac{CF_n + V_S + WC}{(1+i)^n} - TCI
\]

IRR it is the interest rate that makes \( NPW = 0 \)
METHODS OF PROFITABILITY EVALUATION

Pay Out Time, POT
Minimum time needed to recover the investment.

\[ POT = \frac{FCI - V_s}{\text{Average Cash Flow}} \]

Other names: Payback time, Cash Recovery Period.

Time value of money can be taken into account with the inclusion of a minimum acceptable rate of return on TCI:

\[ POT = \frac{(FCI - V_s) + TCI \times i \times n}{(\text{Average Cash Flow})_{\text{Annuity}}} \]

In this case the annual cash flow is viewed as an annuity