AACE INTERNATIONAL RECOMMENDED PRACTICE

59R-10

DEVELOPMENT OF FACTORED COST ESTIMATES - AS APPLIED IN ENGINEERING, PROCUREMENT, AND CONSTRUCTION FOR THE PROCESS INDUSTRIES

AACE INTERNATIONAL

AACE® International Recommended Practice No. 59R-10

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TCM Framework: 7.3 – Cost Estimating and Budgeting

Rev. June 18, 2011

Note: As AACE International Recommended Practices evolve over time, please refer to www.aacei.org for the latest revisions.

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INTRODUCTION

As identified in the AACE International Recommended Practice No. 18R-97 *Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries*, the estimating methodology tends to progress from stochastic or factored to deterministic methods with increase in the level of project definition.

Factored estimating techniques are proven to be reliable methods in the preparation of conceptual estimates (Class 5 or 4 based on block flow diagrams (BFDs) or process flow diagrams (PFDs)) during the feasibility stage in the process industries, and generally involves simple or complex modeling (or factoring) based on inferred or statistical relationships between costs and other, usually design related, parameters. The process industry being equipment-centric and process equipment being the cost driver serves as the key independent variable in applicable cost estimating relationships.

This recommended practice outlines the common methodologies, techniques and data used to prepare factored capital cost estimates in the process industries using estimating techniques such as: capacity factored estimates (CFE), equipment factored estimates (EFE), and parametric cost estimates. However, it does not cover the development of cost data and cost estimating relationships used in the estimating process.

All data presented in this document is only for illustrative purposes to demonstrate principles. Although the data has been derived from industry sources, it is not intended to be used for commercial purposes. The user of this document should use current data derived from other commercial data subscription services or their own project data.

CAPACITY FACTORED ESTIMATES (CFE)

Capacity factored estimates are used to provide a relatively quick and sufficiently accurate means of determining whether a proposed project should be continued or to decide between alternative designs or plant sizes. This early screening method is often used to estimate the cost of battery-limit process facilities, but can also be applied to individual equipment items. The cost of a new plant is derived from the cost of a similar plant of a known capacity with a similar production route (such as both are batch processes), but not necessarily the same end products. It relies on the nonlinear relationship between capacity and cost as per equation 1:

$$Cost_B/Cost_A = (Cap_B/Cap_A)^r$$

where $Cost_A$ and $Cost_B$ are the costs of the two similar plants, Cap_A and Cap_B are the capacities of the two plants and r is the exponent, or proration factor.

(equation 1)

The value of the exponent typically lies between 0.5 and 0.85, depending on the type of plant and must be analyzed carefully for its applicability to each estimating situation. It is also the slope of the logarithmic curve that reflects the change in the cost plotted against the change in capacity. It can be determined by plotting cost estimates for several different operating capacities where the slope of the best line through the points is r, which can also be calculated from two points as per equation 2:

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$r = \ln(Cap_B/Cap_A)/\ln(Cost_B/Cost_A)$

(equation 2)

The curves are typically drawn from the data points of the known costs of completed plants. With an exponent less than 1, scales of economy are achieved wherein as plant capacity increases by a percentage (say, by 20 percent), the costs to build the larger plant increases by less than 20 percent. With more than two points, r is calculated by a least-squares regression analysis. A plot of the ratios on log-log scale produces a straight line for values of r from 0.2 to 1.1.

This methodology of using capacity factors is also sometimes referred to as the “scale of operations” method or the “six-tenths factor” method because of the reliance on an exponent of 0.6 if no other information is available. With an exponent of 0.6, doubling the capacity of a plant increases costs by approximately 50 percent, and tripling the capacity of a plant increases costs by approximately 100 percent. In reality, as plant capacity increases, the exponent tends to increase as per figure 1. The capacity factor exponent between plants A and B may have a value of 0.6, between plants B and C a value of 0.65, and between C and D, the exponent may have risen to 0.72. As plant capacity increases to the limits of existing technology, the exponent approaches a value of one where it becomes as economical to build two plants of a smaller size, rather than one large plant.

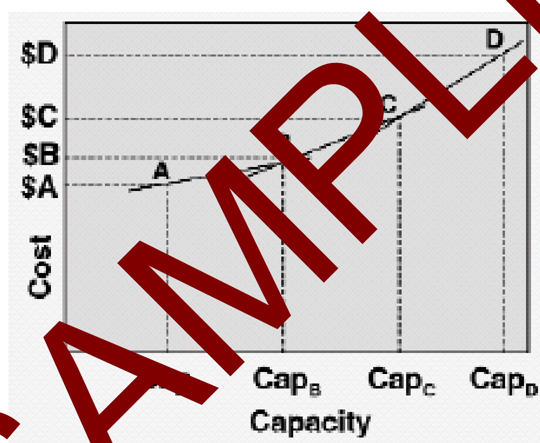

Figure 1 – The Capacity Factored Relationships Shown Here are Logarithmic. Exponents Differ Across Capacity Ranges.

Usually companies should have indigenous capacity factors for several chemical process plants that must be updated with regular studies. However, the above factors should be used with caution regarding their applicability to any particular situation.

If the capacity factor used in the estimating algorithm is relatively close to the actual value, and if the plant being estimated is relatively close in size to the similar plant of known cost, then the potential error from a CFE is certainly well within the level of accuracy that would be expected from a stochastic method. Table 1 shows the typical capacity factors for some process plants. However, differences in scope, location, and time should be accounted for where each of these adjustments also adds additional uncertainty and potential error to the estimate. If the new plant is triple the size of an existing plant and the actual capacity factor is 0.80 instead of the assumed 0.70, one will have underestimated the cost of the new plant by only 10 percent. Similarly, for the same three-fold scale-up in plant size, if the capacity factor should be 0.60 instead of the assumed 0.70, one will have overestimated the plant cost by only 12 percent. The capacity-increase multiplier is Cap_B/Cap_A and in the base, r is 0.7. The error occurs as r varies from 0.7. Further, table 2 shows percent error when 0.7 is the factor used for the estimate instead of the actual factor.

The CFE method should be used prudently. Making sure the new and existing known plants are near-duplicates, include the risk in case of dissimilar process and size. Apply location and escalation adjustments to normalize costs and use the capacity factor algorithm to adjust for plant size. In addition, apply appropriate cost indices to accommodate the inflationary impact of time and adjustments for location. Finally, add any additional costs that are required for the new plant, but were not included in the known plant.

COST INDICES

A cost index relates the costs of specific items at various dates to a specific time in the past and is useful to adjust costs for inflation over time. **Chemical Engineering (CE)** publishes several useful cost indices each month such as the **CE Plant Cost Index** and the **Marshall & Swift Equipment Cost Index**. The **CE Cost Index** provides values for several plant-related costs including various types of equipment, buildings, construction labor and engineering fees. These values relate costs of complete plants over time, using the 1957–1959 timeframe as the base period (value = 100). The **Marshall & Swift** indices provide equipment cost index values arranged in accordance to the process industry in which the unit is used, using 1926 as the base period.

To use either of these indices to adjust for cost escalation, multiply the un-escalated cost by the ratio of the index values for the years in question. For example, to determine the cost of a new chlorine plant in February 2001 using capacity factored estimates where the cost of a similar chlorine plant built in 1994 was $25M, first the cost of the 1994 must be normalized for 2001. The CE index value for 1994 is 368.1. The February 2001 value is 395.1. The escalated cost of the chlorine plant is therefore: $25M x (395.1/368.1) = $25M x 1.073 = $26.8M.

Product	Factor
Acrolynitrile	0.60
Butadiene	0.68
Chlorine	0.45
Ethanol	0.73
Ethylene Oxide	0.78
Hydrochloric Acid	0.68
Hydrogen Peroxide	0.75
Methanol	0.60
Nitric Acid	0.60
Phenol	0.75
Polymerization	0.58
Polypropylene	0.70
Polyvinyl Chloride	0.60
Sulfuric Acid	0.65
Styrene	0.60
Thermal Cracking	0.70
Urea	0.70
Vinyl Acetate	0.65
Vinyl Chloride	0.80

Table 1 – Capacity Factors for Process Plants[8]

Actual Exponent	Capacity-Increase Multiplier (Cap_B/Cap_A)							
	1.5	2	2.5	3	3.5	4	4.5	5
0.20	23%	41%	58%	73%	88%	100%	113%	124%
0.25	20%	36%	51%	64%	75%	87%	97%	106%
0.30	18%	32%	44%	55%	64%	74%	83%	91%
0.35	16%	28%	38%	47%	55%	63%	70%	76%
0.40	13%	23%	32%	39%	46%	52%	57%	63%
0.45	11%	18%	26%	32%	36%	41%	46%	50%
0.50	9%	15%	20%	25%	28%	32%	35%	38%
0.55	6%	11%	15%	18%	21%	23%	25%	28%
0.60	4%	7%	10%	12%	13%	15%	16%	18%
0.65	2%	3%	5%	6%	6%	7%	8%	8%
0.70	0%	0%	0%	0%	0%	0%	0%	0%
0.75	-2%	-4%	-5%	-5%	-6%	-7%	-7%	-8%
0.80	-4%	-7%	-9%	-10%	-12%	[illegible]	-14%	-15%
0.85	-6%	-10%	-13%	-15%	-17%	[illegible]	-20%	-21%
0.90	-8%	-13%	-17%	-20%	-22%	-24%	-26%	-28%
0.95	-10%	-16%	-21%	-24%	-27%	-29%	[illegible]	-33%
1.00	-11%	-19%	-24%	-28%	-31%	-34%	-36%	-38%
1.05	-13%	-22%	-28%	-32%	[illegible]	-39%	-41%	-43%
1.10	-15%	-24%	-31%	-36%	[illegible]	[illegible]	-45%	-47%
1.15	-16%	-27%	-34%	[illegible]	-43%	-46%	-49%	-52%
1.20	-18%	-30%	-37%	-42%	-47%	-50%	-53%	-55%

Table 2 – % Error when factor r = 0.7 is used for estimate instead of actual exponent

Discrepancies are found in previously published factors due to variations in plant definition, scope, size and other factors such as:

- Some of the data in the original sources covered a smaller range than what is now standard.
- Changes in processes and technology.
- Changes in regulations for environmental control and safety that was not required in earlier plants.

Exponents tend to be higher if the process involves equipment designed for high pressure or is constructed of expensive alloys. As r approaches 1, cost becomes a linear function of capacity — that is, doubling the capacity doubles the cost. The value of r may also approach 1 if product lines will be duplicated rather than enlarged. Whereas a small plant may require only one reactor, a much larger plant may need two or more operating in parallel.

Large capacity extrapolations must be done carefully because the maximum size of single-train process plants may be restricted by the equipment's design and fabrication limitations. For example, single-train methanol synthesis plants are now constrained mainly by the size of centrifugal compressors. Costs must also be scaled down carefully from very large to very small plants because, in many cases the equipment cost does not scale down but rather remains about the same regardless of plant capacity.

Despite these shortcomings, the r factor method represents a fast, easy and reliable way of arriving at cost estimates at the predesigned stage. It is helpful for looking at the effect of plant size on profitability when doing discounted cash-flow rate-of-return and payback-period calculations, and it is very useful for making an economic sensitivity analysis involving a large number of variables.