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Early Conceptual Estimating Methodologies

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Abstract–A common issue often faced by estimators is how to prepare an estimate when there is little information or scope definition on which to base the estimate. This paper provides an overview of conceptual estimating methodologies commonly used for the preparation of Class 5 estimates. Particular application to preparing capital facility estimates for the process industries is used although the techniques can be used to support estimating in other industries as well.

There are many order-of-magnitude or conceptual estimating methods, and each can be useful in a specific situation. Often, a single estimate may rely on using a combination of estimating techniques for different portions of the project. The conceptual estimating methods that will be discussed in this paper include:

- Analogy Estimating
- Capacity Factored Estimating
- End-Product Units Estimating
- Physical-Dimensions Estimating
- Parametric Estimating
- Expert Judgement

This paper expands upon an earlier AACE International paper *So You Think You're an Estimator?* [1], incorporating information from AACE International (AACE) recommended practices such as AACE RP 59R-10: *Development of Factored Cost Estimates – As Applied in Engineering, Procurement, and Construction for the Process Industries* [2]; as well as from other sources, such as *Sharpen Your Cost Estimating Skills* [3], an article reprinted in the AACE Cost Engineering Journal.

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Introduction

To maximize capital cost effectiveness, organizations must make effective early decisions for their investments in their capital facilities – whether it is to create a new asset, modify an existing asset, or retire an existing asset. Most organizations will utilize a stage-gate project process, in coordination with an estimate classification system, to provide project funding in a phased approach that allows for incremental funding of the project until final project authorization and full commitment of project funding. [2] [4] The gates at the end of each stage of the project development process require cost estimates of increasing accuracy to support the decisions to proceed to the next stage of project development, or ultimately to sanction the project and authorize full project funding.

This paper will provide an overview of some of the available conceptual estimating technologies typically used to develop estimates during the FEL 0 (identify opportunity) stage and to support gate decisions at the end of the FEL 1 project development stages.[1] These techniques are common estimating methodologies for the preparation of AACE Class 5 estimates. The estimating techniques, and the information (and expected maturity level) required to support them, should be understood by all estimators and estimating stakeholders. [4] Although focusing on estimating for the construction of process facilities, the conceptual estimating methodologies described in this paper can be used in preparing cost estimates for many other industries.

Overview of Conceptual Estimating

Conceptual estimates are generally prepared in the early phases of project development when the level of scope information is minimal and still maturing. They are often prepared to support sound business decisions between various potential project alternatives, which may involve various technologies, capacities, project locations, contracting strategies, project timing, and other considerations. Conceptual estimates typically are not used to determine a final funding amount for project sanction (or approval), but instead are used to support decision making to maximize capital effectiveness (i.e. to maximize the economic return that can be attained from investment in the potential project). Well-prepared conceptual estimates can also support decisions to abandon potential projects that do not provide adequate returns on investment as early as possible.

Conceptual estimating techniques generally involve forms of analogy estimating or rely on stochastic methods, where the independent variables used in the estimating algorithm involve modeling or factoring based on statistical (or inferred) relationships between the dependent variable (cost) and the independent design-related parameters and other project characteristics.

"A key difference between conceptual estimating and detailed estimating is that conceptual estimating requires a significant effort in data-gathering and methods development before

[1] Front-End Loading (FEL) and the FEL stages are described in *Supporting Estimates with Effective Scope of Work Definition* [4].

estimate preparation ever begins." [5] The required time to prepare conceptual estimates is relatively short, certainly in respect to more deterministic estimating methods; however, conceptual estimating involves substantial effort and time for data collection and analysis to support the development of conceptual estimating factors, data, techniques and tools.

An estimate is a *prediction* of the expected final cost of a proposed project (for a given scope of work). As such, an estimate is always associated with uncertainty, and therefore is also associated with a probability of over-running or under-running the predicted cost. Generally, the uncertainties are greater for conceptual estimates than for detailed (or deterministic) estimates due to the lower maturity of project definition for conceptual estimates; and thus, the potential range of expected estimate accuracy is usually much broader. Conceptual estimating techniques can be very reliable and accurate in certain situations such as for estimates prepared for repeat projects for which accurate scope definition, project characteristics, and costs for analogous projects are well known.

For early conceptual estimates, experience has shown that variations in design assumptions often have the greatest impact on costs. Estimating tools and methods, while important, are not usually the main problem during the early stages of a project when estimating accuracy is poorest. In the early stages of a project, effort should normally be directed toward establishing a firmer design basis rather than concentrating on using more detailed estimating methods. Attempting to quantify specific quantities of project components to support a more deterministic estimating methodology when the overall level of design is still immature is usually not value-adding, and often results in an estimate of much less quality (or accuracy) than an estimate prepared using reliable conceptual estimating factors and methods. Deterministic estimating requires a high degree of precision in the completeness of scope definition, quantity determination, and pricing that is simply not supported by the maturity level of design in early project phases, and may result in less accuracy than using well developed conceptual estimating techniques and supporting data. Conceptual estimating methods can be sufficiently reliable to support the business decisions required during early project development stages.

Conceptual Estimating Methodologies

Analogy Estimating

An analogy is a similarity between like features of two things upon which a comparison can be made. Conceptual estimating methodologies are often dependent on analogous (or comparative) relationships to derive the costs for a new proposed project by making comparisons with similar, completed projects for which there is reasonably accurate cost and technical data. The methodology is based on the premise that there is a reasonable correlation between the proposed and known project (or projects), but also requires the estimator to make subjective evaluations to account for the differences between the proposed and known project(s).

Analogy estimating is thus characterized by the use of historical data for similar projects as the basis for the cost estimate of a proposed project. Often, it may be a single historical project (or data point) that is used for the basis of comparison, but it may involve evaluating cost comparisons with multiple similar facilities. As an example, for large projects comprised of multiple process units, the estimate for one process unit may be based on historical cost information from one completed facility; while the estimate for another process unit may be based on historical information from a second completed facility (a type of *systems approach* to preparing the estimate for a complete facility).

The following are the typical steps (algorithm) in preparing an analogy estimate:

- Find and review known analogous projects
- Remove costs for known scope items in the analogous project(s) that are not required in the proposed project
- Normalize the costs of the known project(s) for location and time of the proposed project
- Apply cost adjustments for the differences in scope between the known project(s) and the proposed project
- Add costs for scope in the proposed project that did not exist in the known project(s)

Due to the reliance on the historical costs from past known project(s), the process to compare the characteristics of the new proposed project and the known project(s) and the extrapolation process used to derive the costs for the proposed project are critical to achieve sufficient accuracy for the analogy estimate. Often, technical experts (e.g. engineering support) are used to assist in the assessment of quantitative technical differences between the known project(s) and the proposed project. It is then the estimator's responsibility to identify the cost impact of the quantified differences. This may involve both objective and subjective judgments. Some differences in scope, such as size or capacity, can be calculated using relatively deterministic methods such as capacity factors (described later in this paper). Other differences, such as metallurgy or other physical characteristics, can also be calculated using historically reliable adjustment factors. On the other hand, some quantified variances between the known project(s) and the proposed project such as complexity or certain performance factors may require significant subjectivity to identify the cost impacts of these differences.

Consider the following simple example to estimate the cost (in 2020 US Dollars) of a 1.45MM Ton/Year Ethylene plant to be constructed in eastern Pennsylvania. In this example, the estimator has reliable actual cost information for three similar projects (as shown in Table 1).[2]

[2] Note that all cost and related information for this and other examples in this paper are for the purposes of illustration only and are not to be relied upon.

Project	Capacity	Year	Location	Cost
Project 1	1.1MM Ton/Year	2017	Ohio	$1,836,952,000
Project 2	1.5MM Ton/Year	2018	Texas Guf Coast	$2,043,477,000
Project 3	1.8MM Ton/Year	2016	Louisiana	$2,209,566,000

Table 1–Known Costs for Ethylene Projects

For this example, the estimator decides to utilize a single data point (Project 2) as the analogous project upon which to base the estimate. In reviewing the available scope and other information for Project 2, the estimator realizes that the indicated cost included approximately $24M for the construction of port facilities that will not be required for the proposed project in Pennsylvania. Overall technology and facility design appear similar; and the capacities of (1.50 MM tons/year to 1.45MM tons/year) are considered close enough to not require other cost adjustments before normalizing for location and time.

The estimator considers that construction for Project 2 was by an open-shop (non-union) contractor; however, the proposed plant in Pennsylvania will require union construction (resulting in higher labor costs). Based on information that the estimator can review, she determines that she must add 12% to the costs of the project constructed in the Texas Gulf Coast to account for the change in location to construct a similar facility in eastern Pennsylvania. She also researches information to determine that normalizing for time (to 2020 US Dollars) will require 2 years escalation at 4.3% per year (8.9% compounded).

Finally, the estimator determines that the new plant in Pennsylvania will require additional product storage that was not needed for the base case Texas Gulf Coast facility, and she estimates that cost as $10M in 2020 US Dollars. The analogy estimate for this example is shown in Table 2.

Known Cost for 1.5MM Ton/Year Plant in Texas Gulf Coast	$2,043,477,000
Deduct for Port Facilities Not Required	-$24,000,000
Adjusted Cost Subtotal	**$2,019,477,000**
Texas Gulf Coast to Pennsylvania (+12%)	$242,337,000
Adjusted Cost Subtotal	**$2,261,814,000**
Escalate to 2020 (+8.9%)	$201,301,000
Adjusted Cost Subtotal	**$2,463,115,000**
Add for Additional Storage Required	$10,000,000
Estimate Total - 1.45MM Ton/Year Plant in Pennsylvania	**$2,473,115,000**

Table 2–Analogy Estimate for Ethylene Project Example

In this example, although the estimator had three projects upon which to prepare the analogous estimate, she chose to select the single project (data point) that provided the closest match to the proposed project to use as a base case (the Texas Gulf Coast project was very close in capacity, and also the closest available project in terms of date of construction). Alternatively, she could have normalized all three projects for scope, location and time; and then used the average (or perhaps median) cost as the starting point for the calculations.

The example illustrates the estimate preparation steps (previously identified) that are common to analogous estimates. As with all estimating methods, analogy estimating is both easier to apply and typically results in improved accuracy when a systematic approach to estimate development is employed. The proposed project should be as clearly defined as possible, particularly in reference to key project characteristics (capacity, technology, metallurgy, complexity, etc.). This is important in locating the best comparable or known project (or projects) to use as a starting point for estimating the costs; and in identifying any scope differences to be accounted for.

When identifying the project characteristics used to determine comparable base cases, the estimator should focus on those scope characteristics that will drive significant cost impacts. As an example, for a process facility the required metallurgies will generally be much more important than the size of the administration building.

For a proposed project where it may be difficult to find comparable projects (such as those involving new technology), it may be able to be broken down into sub-systems, of which only a portion will involve significantly new technology. Therefore, most sub-systems can be estimated to comparable known sub-systems with a relatively high degree of accuracy compared to the few sub-systems that involve significant changes in technology (or other characteristics), and are therefore subject to greater estimating uncertainty because they involve a higher degree of subjectivity in evaluating the cost impacts of the variances to the known base cases.[3]

As previously indicated, a technical expert or specialist may be able to assist in finding comparable sub-systems or components, when necessary; and in identifying and assessing the impact of the differences between the proposed and comparable systems. Due to the limited design information available during the early phases of project development (that typically use utilize analogous estimating techniques), the technical expert may still need to rely on subjective assessments (such as the new component is 40% more complex, or has 25% more moving parts than the known component). The key is to have the technical expert provide as much objectivity as possible in evaluating differences and limit subjective assessments as much as possible.

Th estimator remains responsible for collecting, analyzing, and normalizing the costs from the base case sub-systems or components, and determining the cost adjustments required to account for the technology or other difference in characteristics. After making the objective and subjective adjustments, the costs for the various sub-systems or components can be summarized into the total aggregate cost estimate.

[3] The FAA Life Cycle Cost Estimating Handbook provides additional detail on using analogy estimating for estimating sub-systems. [14]

Some of the adjustments to consider between the proposed project and the known base case project(s) include:

- Scope
  - Physical scope differences between the projects
  - Technology/Complexity
  - Infrastructure
  - Logistics
- Location
  - Labor Productivity/Labor Methods
  - Labor Wages/Labor Crew Mix
  - Material Pricing/Sourcing
  - Material Specifications/Building Codes
  - Weather
  - Currency
- Time
  - Labor Rates
  - Material Pricing
- Market Conditions

It is also important to recognize the uncertainty and potential errors that may be associated with analogy estimating: 1) the historical cost data for the known project(s) may be in error; 2) the identification of project characteristics; and therefore, the evaluation of similarities and differences between the projects may be in error; and 3) the factors or other cost adjustments used to account for the differences may be in error. Consideration of these potential risk issues and the general uncertainty associated with this estimating methodology must always be considered during a risk analysis to determine the specific expected estimate accuracy associated with a specific analogy estimate.

Many of the principles of analogy estimating and the basic steps of the methodology also apply to other conceptual estimating techniques.

Capacity Factored Estimating

A capacity factored estimate is a form of an analogy estimate wherein capacity is one of the primary characteristic differences between the proposed project and a known base case project.

With this methodology, the cost of a new proposed project is derived from the cost of a known project of a known, but different, capacity.

This estimating methodology is often used to prepare Class 5 estimates during FEL 1 to provide a relatively quick and sufficiently accurate estimating technique to support a gate decision to determine whether to proceed with development of a proposed project or to decide between alternative designs or plant sizes. For process facilities, capacity factored estimating is primarily used to estimate the cost of battery-limit process units; but is often applied to both complete process facility plants and to individual equipment items. The concept can also be applied to cost estimating for many other industries.

The basic capacity factor cost estimating relationship[4] (CER) relies on a typically non-linear correlation between cost and capacity as shown in the following equation:

$$\$B/\$A = (Cap_B/Cap_A)^e$$

where *\$A* and *\$B* are the costs of two similar projects, Cap_A and Cap_B are the capacities of the two projects, and "*e*" is the exponent that drives the non-linear relationship, as shown in Figure 1.

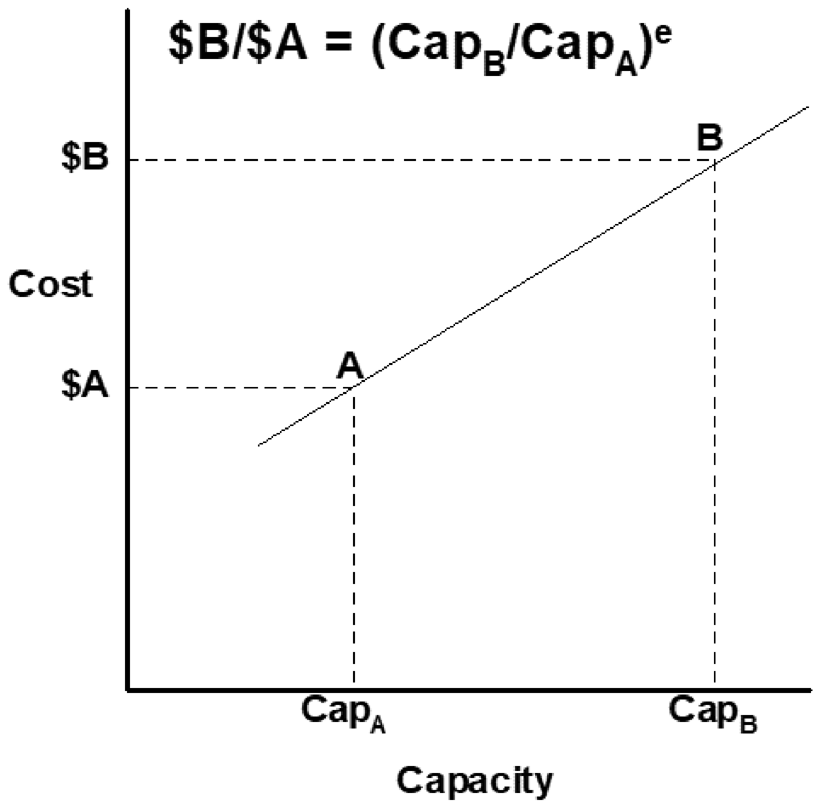


Figure 1–Cost/Capacity Factor Relationship

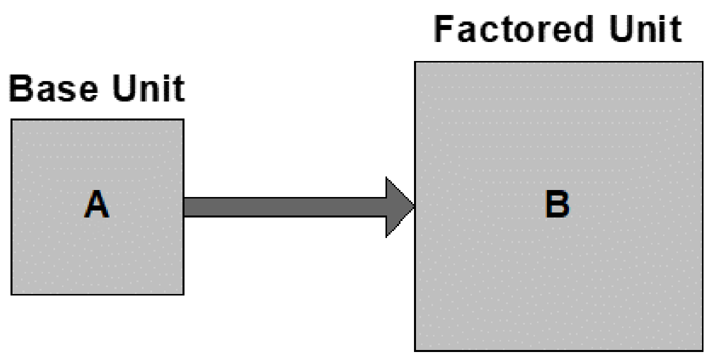
The exponent "*e*" (or the capacity factor) represents the slope of the log-curve that has been drawn to reflect the change in the cost of a project as the capacity increases or decreases[5,6]. These curves are typically based upon the normalized actual costs (representing a common location and time) of completed projects. When the exponent has a value less than 1, it reflects

[4] A cost estimating relationship is the equation (or more involved algorithm) that identifies the relationship between cost (the dependent variable) and the drivers of cost (one or more independent variables).
[5] Note that when displayed on a logarithmic graph, the curve displays as a straight line with slope "*e*".
[6] When more than two data points are shown on the curve, the exponent "*e*" is typically determined from a least-squares regression analysis and identifies the slope of the resulting regression equation.

an *economy of scale* relationship for the change in the capacity of a project. For example, if we were to estimate the cost of a refinery that is 20% larger than one just completed, we would expect the cost to build the larger facility to increase by less than 20% (all other conditions remaining the same). A capacity factored estimate is sometimes referred to as an *economy of scale* or a *scale of operations* estimate.

For the process industries, the exponent "*e*" typically has a value between 0.5 and 0.85, depending on the particular process plant, process unit, or equipment type, but should be evaluated carefully for its applicability to a specific estimating situation. Another name of the capacity factored estimating technique is the *six-tenths rule* due to a common reliance on an exponent value of 0.6 (for process industry applications) when no better information is available. This is due to the first published articles that documented this estimating technique [5] [6]. With an exponent of 0.6, doubling the capacity of a facility (or project) increases the cost by approximately 50%; while tripling the capacity of a facility increases the cost by a little less than 100%.

When applying the capacity factor estimating equation, solving for *$B* (the cost of the proposed plant) yields the equation shown in Figure 2.



$$\$B = (\$A)(Cap_B/Cap_A)^e$$

Figure 2–Capacity Factored Estimating Equation (Solving for Cost of the Factored Plant)

Where *$B* is the estimated cost of the new plant, *$A* is the actual cost of a similar plant, Cap_B is the capacity of the new plant, Cap_A is the capacity of the similar plant, and "*e*" is the capacity factor exponent. This equation simply states that the cost of the proposed plant will equal the cost of a known similar plant multiplied by the ratio of the capacities taken to an exponential power. In most cases, the exponent has a value less than one which results in an economy of scale.

As a conceptual estimating methodology, the emphasis of using capacity factoring is not on detailed accuracy, but on obtaining a reasonable cost with limited project development (and maturity of design) that is of sufficient accuracy to support management decision-making. Often used in the FEL 1 stage of project development, capacity factoring can be used to prepare a screening estimate that is often used to determine whether a proposed project meets economic thresholds to continue with further project development.

In the following example, an owner company is evaluating the construction for a 2,000 ton/day Methanol plant to be located in Midland, TX, and desires a Class 5 Estimate to include in the economic evaluation. The company had constructed a Methanol plant of a similar design but at a capacity of 2,500 tons/day four years ago in the Philadelphia, PA area for a cost of $758M. The company has performed studies that indicate the capacity factor exponent for Methanol plants is 0.76.

The simple approach is to just apply the capacity factor equation:

$$\$B = \$758M \text{ X } (2000/2500)^{.76} = \$639.8M$$

However, this would be too simple and incorrect, as it did not incorporate the steps previously identified in the analogy estimating algorithm to adjust the estimate for scope, location, and time.

In evaluating the available project information for the proposed and known projects, the estimator discovers that included in the scope and costs for the known Methanol plant already constructed in Philadelphia was a product transportation pipeline that will not be required for the Midland plant; instead, the Midland plant will require the construction of rail facilities for product transportation. The estimator also researches and discovers that overall project costs are assumed to be 9.5% less for plant construction in Midland than in Philadelphia; and also verifies that an annual escalation rate of 4.5% should be used to adjust for the 4-year difference between projects. Considering this information, the estimator prepares the capacity factored estimate shown in Table 3:

Known Cost for 2500 Ton/Day Methanol Plant in Philadelphia, PA	$758,000,000
Deduct for Pipeline Not Required	-$21,000,000
Adjusted Cost Subtotal	**$737,000,000**
Philadelphia, PA to Midland, TX (-9.5%)	-$70,015,000
Adjusted Cost Subtotal	**$666,985,000**
Escalate to 2020 (+19.3%)	$128,795,000
Adjusted Cost Subtotal	**$795,780,000**
Capacity Factor = $749.671M X (2000/2500)$^{.76}$	**$671,648,000**
Add for Rail Facilities	$12,500,000
Estimate Total - 2000 Ton/Day Plant in Midland, TX	**$684,148,000**

Table 3–Example Capacity Factor Estimate for 2000 Ton/Day Methanol Plant

The estimator followed basic estimating steps common to all types of analogy estimates. The estimator first deducted costs for differences in the known Philadelphia plant that are not in scope for the Midland plant, and then normalized for both location and time. The estimator then used the capacity factor equation (with the exponent of 0.76) to adjust for capacity, before including an estimated cost for additional scope (rail facilities) required in the proposed Midland plant that was in scope for the known Philadelphia plant.

Note that in the example illustrated in Table 3, the proposed plant was smaller in capacity than the known plant. The capacity factor equation can be used to scale either upwards or downwards in size or capacity.

For the example, it was indicated that the owner had performed studies to determine the exponent for methanol plants. If the owner had the costs for two completed Methanol plants, the determination of the exponent can be calculated by rearranging the capacity factor equation to solve for "*e*", the exponent:

$$e = ln(\$B/\$A) \ / \ ln\ (Cap_B/Cap_A)$$

where "*e*" is the exponent that drives the non-linear relationship, *$A* and *$B* are the costs of two similar projects, and Cap_A and Cap_B are the capacities of the two projects. Note when solving for the exponent, it is important to normalize the costs for the two projects for scope, location, and time as best as possible, so that capacity remains as the primary drive of cost variance.

If the costs for more than two completed Methanol plants are available, then all projects are normalized to a common scope (except for capacity), location, and time; and then a least-squares regression (using cost and capacity as the variables) is performed to determine the exponent (as the slope of the regression equation).

For process plants where the process equipment can grow volumetrically in size to achieve plant capacity increases, the exponents are typically relatively small (in the 0.5 to 0.7 range). Where multiple trains[7] are required to achieve the increase in plant capacity (usually due to a limitation in how large certain types of equipment can be manufactured, or sometimes for the desire for redundancy), then the capacity exponents may be between 0.75 and 0.95, and sometimes even higher. Although the costs for the duplicated process trains will not exhibit an economy of scale, the supporting utilities and infrastructure may yield economies of scale that result in the overall plant still reflecting an associated capacity factor less than 1. There are also situations when using multiple trains to achieve the increase in capacity that the overall plant capacity exponent will be larger than 1.0, often due to additional interconnecting piperacks and other associated infrastructure.

Also note that where there are significant changes in the technologies or designs between plants, the determination of accurate capacity factor exponents is very difficult if not impossible due to

[7] A process plant train is a series of process equipment and process steps to convert a feedstock to an interim or final product.

the high potential variation in scope between the plants (even when producing the same end product). General scope (except for capacity), location, and time must be normalized across the historical projects before attempting to solve for the capacity exponent.

Although capacity factoring is very common in the process industries, the technique can be appropriately applied to other industries as well, where an economy of scale exists between cost and capacity. For example, the building construction industry uses this concept when the estimator decides to use a lower cost per square meter of floor area as a unit cost when the total number of square meters of floor area increases from one building to another. The software development industry may use this concept when using the expected lines of code to be written as an indicator of capacity for the software program to be developed.

For process plants, the capacity factors may not remain constant throughout the entire range of capacities or plant sizes. This is illustrated in Figure 3.

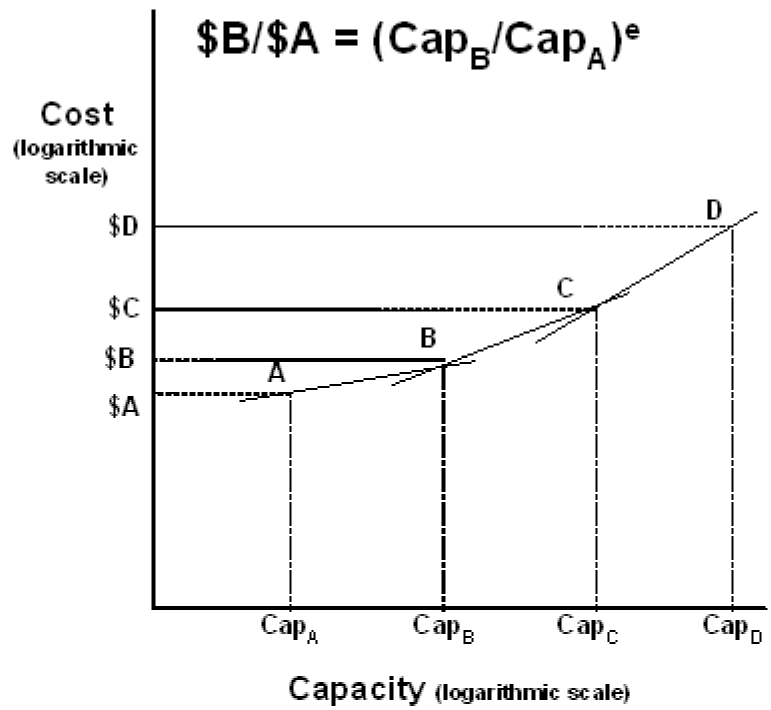


Figure 3–Capacity Factor Exponents May Not Remain Static Over Large Increases in Capacity

In Figure 3, the capacity factor exponents between plants A and B may have a value of 0.6; between plants B and C, the exponent may have a value of 0.65; and between plants C and D, the exponent may have risen to 0.72. As plant capacity increases to the limits of existing technology it becomes more likely that at least some of the equipment will need to be duplicated to achieve the required capacity increase simply because larger equipment is not available. As the limits of technology are reached across more types of equipment or process units, the capacity factor exponent approaches the value of 1.0. At this point, it becomes as economical to construct two plants of a smaller size, rather than one large plant. Increases in overall redundancy and reduced risk exposure for building two smaller plants will also factor into the decision.

Capacity factor estimates can be reliable even if the exact value of the capacity factor exponent is unknown [7]. If the assumed capacity factor exponent used in the estimating equation is relatively close to the actual value, and if the plant being estimated is relatively close in size to the similar plant with a known cost, then the potential error from capacity factoring is certainly within the level of expected estimate accuracy associated with a conceptual estimating method. Generally, it is the probable errors in adjusting for scope (other than capacity), location, and time between the proposed and known projects that will drive more uncertainty and potential error than selecting an incorrect capacity factor exponent (as long as it is reasonably close). Table 4 illustrates the percent error that will occur if 0.6 is for the capacity factor exponent, when another value (the actual values) should have been used instead.

Percentage Error If Capacity Factor of 0.6 Used For Estimate

	Capacity Increase Multiplier (Cap_B / Cap_A)							
Actual Capacity Exponent	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**
0.20	19%	32%	44%	54%	66%	74%	83%	91%
0.25	15%	28%	37%	46%	55%	63%	69%	75%
0.30	13%	24%	31%	39%	45%	51%	57%	62%
0.35	11%	20%	25%	31%	37%	42%	46%	49%
0.40	9%	15%	20%	25%	29%	32%	35%	38%
0.45	7%	11%	15%	18%	21%	23%	25%	28%
0.50	5%	8%	10%	12%	13%	15%	17%	17%
0.55	2%	4%	4%	6%	7%	8%	8%	9%
0.60	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
0.65	-2%	-3%	-4%	-5%	-6%	-7%	-7%	-8%
0.70	-4%	-6%	-9%	-11%	-12%	-13%	-14%	-15%
0.75	-6%	-10%	-13%	-15%	-17%	-19%	-20%	-21%
0.80	-7%	-13%	-17%	-20%	-22%	-24%	-26%	-27%
0.85	-9%	-16%	-21%	-24%	-27%	-29%	-31%	-33%
0.90	-11%	-19%	-24%	-28%	-31%	-34%	-36%	-38%
0.95	-13%	-21%	-28%	-32%	-36%	-38%	-41%	-43%
1.00	-15%	-24%	-31%	-36%	-39%	-43%	-45%	-47%
1.05	-16%	-27%	-34%	-39%	-43%	-46%	-49%	-52%
1.10	-18%	-29%	-37%	-42%	-47%	-50%	-53%	-55%
1.15	-20%	-32%	-40%	-46%	-50%	-53%	-56%	-59%
1.20	-22%	-34%	-42%	-48%	-53%	-56%	-59%	-62%

Table 4–Percentage Error (Overestimate or Underestimate) if Assumed Exponent of 0.6 is Used Instead of Actual Exponent

Table 4 shows that if the proposed plan is double in size to cost of the known plant, and the estimator used 0.6 as the capacity factor instead of 0.85, then the estimator will have underestimated the cost of the proposed plant by only 16%. If the true value of the capacity factor estimate should have been 0.5 instead of 0.6, then the estimator overestimated the cost of the proposed plant by 8%. These variances are well within expectations for Class 5 conceptual estimates.

The takeaway from this is that with limited time, do not focus hours on attempting to decide between using 0.65 versus using 0.70 for the capacity factor exponent. Instead, use available time to ensure that the best evaluations are incorporated for adjusting for scope (other than capacity), location, and time between the proposed and known projects. If the estimator is reasonably close on selecting the proper capacity factor exponent, it is the other adjustments that are like to drive more uncertainty and error than the capacity factor exponent.

End-Product Units Estimating

The end-product units estimating methodology is another form of analogy estimating. This method relies on having historical information from similar projects to be able to relate the end-product (capacity units) of a project to its costs. Examples of the relationship between costs and end-product units are:

- the capital construction cost of an oil refinery and the plants capacity in barrels per day;
- the capital construction cost of solar electric generating facility and the facility's rated nameplate capacity in megawatts;
- the capital construction cost of a hospital and the number of patient beds;
- the development cost of a software application and the number of function points (screens, calculations, reports, etc.) to be included in the application; and
- the construction cost of a parking lot and the number of parking spaces required.

As an example, consider the construction of a 200 room mid-scale hotel, and assume that a similar hotel has recently been completed at a nearby location. The hotel just completed included 165 guest rooms, including a lobby, meeting rooms, restaurant, parking lot, and the facilities to support 24-hour per day guest services. The total construction cost for the 165 guest room hotel was $34,620,000 (resulting in a per room construction cost of $228,000).

The cost of the proposed 200 room hotel of comparable design, features and amenities is then $45,600,000 (200 rooms X $228,000 per room). This simple calculation has ignored many of the factors that have been already discussed in this paper that may impact costs. As an example, it has ignored any economies of scale (exponential capacity factors) that may result from constructing the larger hotel; and it has assumed that the cost of all of the common facilities (lobby, restaurant, parking lot, laundry facilities, etc.) will vary directly with the increase in the number of rooms. If supporting scope and cost information exists to evaluate the cost impacts of these or other differences, then additional adjustments to the factored costs should be made to account for these variances.

This simple example also assumed that the nearby location of the recently completed hotel allowed the estimate of the new proposed hotel to ignore the impacts of location and time. For most estimates, however, these will be critical factors to be accounted for and involve many of the individual adjustments identified in the previous discussion of analogy estimating (infrastructure, logistics, building specifications/codes, labor productivity, labor rates, etc.).

When using the scope and cost information from a single known project to determine the end-product unit cost (such as cost per hotel room) for a new proposed project, the estimator needs to adjust for the cost impacts of all significant differences between the two projects. There will obviously be times when data has been collected and analyzed from a large number of projects to present relevant cost information (such as the cost per hotel room) in either published sources or perhaps an internal historical database to an owner or contractor organization. When data is collected and analyzed to develop relevant supporting cost estimating information, it must be normalized to a common location and time frame and, if necessary, stratified for scope characteristics.[8] See the simple example displayed as Table 5.

Cost per Hotel Room			
Cost Range	**Low-Scale**	**Moderate-Scale**	**High-Scale**
Low	$66,000	$118,000	$416,000
Median	$99,000	$223,000	$803,000
Average	$96,000	$257,000	$898,000
High	$122,000	$396,000	$1,345,000

Notes:

Costs are in 2018 US Dollars
Costs Normalized to Dallas, Tx Region
Low-Scale Costs exclude restaurant and fitness room
Moderate and High-Scale Costs include restaurant and fitness room
Costs exclude pools, golf courses and special amenities

Table 5–Normalized Cost Information for Hotel Construction

Table 5 shows cost range information (based on cost per hotel bed) for three classes of hotel and provides limited notes on data normalization associated with the cost information. Let's assume another example of preparing information using Table 5 for construction of a 250 bed moderate-scale hotel in Minneapolis, MN, which will also include a pool.

When presented with cost information similar to that in Table 5, one of the first questions to decide is which cost value within the range to use for the purposes of the estimate. For the cost range associated with moderate-scale hotels, there is an approximate 15% difference between the average value (numerical mean) and the median value (ordinal midpoint) of the cost range. This indicates that the distribution of the underlying costs data is skewed to the high side with the possibility that a few high costs for hotels within the data set are influencing the mean or average value; thus, using the average value for the estimate would be a conservative choice. When cost data is skewed (high or low), the median value often provides a better indication of central tendency of the underlying distribution; and in this case the estimator decides to use the median value. The estimate is shown in Table 6.

[8] The process and procedures of normalizing data and information for cost estimating databases or reference information is beyond the scope of this paper.

Estimated Cost for 250 Bed Moderate-Scale Hotel in Dallas, TX (250 X $223,000) assuming median value from cost table	$55,750,000
Base Estimate	**$55,750,000**
Location Adjustment - Dallas, TX to Minneapolis, MN (+ 3.2%)	$1,784,000
Adjusted Cost Subtotal for Location	**$57,534,000**
Escalate to 2020 (+5.7%)	$3,279,000
Adjusted Cost Subtotal	**$60,813,000**
Add for Pool	$200,000
Estimate Total - 250 Bed Moderate-Scale Hotel w/ Pool in Minneapolis, MN	**$61,013,000**

Table 6–End-Product Units Estimate for 250 Bed Hotel in Minneapolis. MN

The estimator first calculated the base cost of a 250 bed hotel in Dallas, TX using the median value for moderate scale hotels from Table 5. He then accounted for a location adjustment for constructing the hotel in Minneapolis by 3.2% (from reference cost indices he had access to); and normalized for escalation by adding 5.7% (2.8% compounded for 2 years) to convert to a 2020 time frame. Lastly he added costs to construct the hotel pool (in 2020 Dollars and the Minneapolis location) since the cost data in Table 5 did not include for pool construction costs.

Again, this is a simple example but illustrates the importance of closely examining all cost data and the available supporting information for the basis of that cost information when preparing estimates. In a real world situation, the cost data and notes may have included other information related to identifying the floor areas (square meters or square feet), number of floors, or other scoping information and/or adjustment factors that could be applied to further refine the estimate.

Physical-Dimensions Estimating

Similar in concept to end-product units estimating, this form of analogy estimating methodology uses the physical dimensions (length, area, volume, etc.) of the item being estimated as the primary driver of costs. For example, the cost to construct a building may be based on the square meters of the total floor area or the cubic meters of building volume, while the costs for a highway or a pipeline may be based on lineal kilometers (or some other lineal measure).

Like other analogy estimating methodologies, this technique relies on cost data and information from other similar projects or other historical information. Consider the cost to estimate the construction of a 4,000 m^2 warehouse in Dayton, OH. For this example, a 3,500 m^2 warehouse was recently completed at a nearby location for a cost of $1,260,000, or $360/$m^2$. The wall height for the completed warehouse was 4.25 m; thus, enclosing a volume of 14,875 m^3 (or a cost of $84.71/$m^3$).

To determine the cost to construct the 4000 m2 warehouse, the estimator first estimates the cost on a square meter basis as $1,440,000 (4000 m^2 X $360/$m^2$); however, since the new warehouse will have a wall height of 5.5 m, she decides that estimating on a volume basis may be more appropriate. The volume of the new warehouse is 22,000 m3, and she calculates the revised estimate (based on volume) as $1,864,000 (22,000 m^3 X $84.71/$m^3$). The estimate based on volume is approximately 29% higher than the estimate based on area, which matches the approximate 29% increase in wall height between the proposed and known projects.

As previously discussed, the common adjustments for location, time, and scope between the known and proposed projects needs to be accounted for. In this example, the location (Dayton, OH) is the same, and the recent project was completed in the same year (2020) as the cost basis for the new estimate; so location and time will not need to be accounted for in this simple example. The new proposed project will utilize a different construction method than the just completed project (tilt-up concrete panels versus steel frame with insulated metal panels) and allocates more space to office area than the just completed project (20% versus 10%). The resulting cost data and estimate are shown in Table 7.

Cost for Recent Warehouse in Dayton, Ohio			
Unit of Measure	**Qty**	**Cost**	**Cost per Unit**
Square Meters	3,500 SM	$1,260,000	$360 / SM
Cubic Meters	14,875 CM	$1,260,000	$84.71 / CM

Notes:

Single-Story Warehouse Completed in 2020 in Dayton, Ohio
Wall Height is 4.25 M
Steel Frame Construction with Insulated Metal Panel Exterior Closure
Office Area is 11.5% of Total Area

Estimated Cost for 4,000 SM Single-Story Warehouse with Wall Height of 5.5 M in Dayton, OH (4,000 SM X 5.5M X $84.71) assuming volume in CM as cost basis	$1,864,000
Base Estimate	**$1,864,000**
Location Adjustment - Not Required	$0
Adjusted Cost Subtotal for Location	**$1,864,000**
Escalation Adjustment - Not Required	$0
Adjusted Cost Subtotal for Location and Escalation	**$1,864,000**
Adjust for Tilt-Up Concrete Panel Construction (-6%)	-$112,000
Adjusted Cost Subtotal for Location, Escalation, and Exterior Closure	**$1,752,000**
Adjust for 20% Office Space (400 SM * [$540/SM - $360/SM])	$72,000
Estimate Total - 4,000 SM Warehouse (5.5 M Wall Height) Using Tilt-Up Concrete Panel Construction	**$1,824,000**

Table 7–Physical Dimensions Estimate for 4,000 SM Warehouse in Dayton, OH

The estimator first calculates the base cost of the 4,000 SM warehouse based on the volumetric unit cost from the recently completed warehouse (4,000 SM X 5.5 M Wall Height X $84.71/SM). In this example, location and escalation to the 2020 time basis do not need to be accounted for; however the estimator does need to account for the scope differences between the project used for the cost basis and the proposed project (method of construction and percentage of office space). From other historical data, she can determine that for warehouses of similar size, tilt-up concrete panel construction has been approximately 6% less in cost than warehouses with steel frames and insulated metal panels, and accounts for that difference.

She is also able to determine from cost records that the office area of the previous warehouse cost approximately $540/SM. For the previous warehouse, the office area was approximately 400 SM (3,500 SM X 11.5%), and the office area for the new warehouse will be 800 SM (4,000 SM X 20%). Since the cost of the previous warehouse included costs for 400 SM of office space, she needs to account for 400 SM of additional office space in the proposed project; or, 400 SM at the cost difference between the office area and the warehouse area (400 SM X [$540/SM - $360/SM]). Her cost estimate totals $1,824,000 for the 4,000 SM warehouse, as shown in Table 7.

Parametric Estimating

Parametric estimating typically involves the use of one or more cost estimating relationships (CERs), and often multiple dependent variables to calculate (or determine) the cost of the item being estimated; and is another useful methodology for preparing early conceptual estimates. [8] [9] A parametric estimating model is a mathematical representation of one or more CERs that provides a logical and predictable correlation between the functional and physical characteristics (independent variables) of an item and its cost (the dependent variable). Parametric models can be used to determine the cost of a single item (e.g. a control valve or an individual equipment item) or a complete plant or facility.

A capacity factored estimate utilizes a simple parametric modeling equation that employs capacity as a single independent variable; however most parametric models will involve several independent cost drivers (or independent variables) and sometimes multiple cost estimating relationships. Parametric estimating models can be very sophisticated and elaborate when use to estimate complete facilities.

Development of an effective parametric estimating model can be a complicated undertaking, and typically involves an intermediate understanding of statistics. The first step in developing a parametric model is to establish its scope, which involves defining its end use, physical characteristics, critical components, and the cost drivers (or independent variables) of the model. Definition of the end use of the parametric model should identify what item or facility is being estimated; and takes into consideration the types of processes to be covered, the types of costs to be derived, and the targeted expected accuracy range for the model. The types of costs to be estimate should defined whether the model is estimating only the material cost of an item or the installed cost; and when estimating a complete facility (or part of a facility) whether the model is estimating total direct costs, total field costs, or total installed costs.

Preferably, the model should be based on the collection and analysis of actual costs from completed projects; although if not enough data points for actual projects are available, reasonable estimated costs may need to be substituted. Data collection includes key engineering and design information, and other project characteristics that may influence costs; and should reflect the organization's project practices and technology. A key principle is to identify and collect significant project design parameters and characteristics that can be defined with reasonable accuracy early in project scope development and are correlated with statistical significance to costs. Focusing on key parameters that are identified early in project development allows the tool to support conceptual estimating. The model should also provide the capability for the estimator to adjust for specific factors that may affect the proposed item or project being estimated. Typically, the model incorporates required escalation normalization factors to generate current year costs and may be able to escalate costs to future time periods.

The collection of cost, design parameters, and other project characteristics requires significant effort. It is best to collect the data at as granular a level as possible, as that allows the data to be summarized later to an aggregated level if it results in a better cost model. [10] Obviously, the date (typically year) of the cost information needs to be collected to normalize all costs to a consistent time frame; however, the data should also be normalized for location, site conditions, project specifications, and cost scope. All data needs to be normalized to a consistent basis before the next step for model development of data analysis.

Data analysis involves performing regression of cost versus various collected design parameters to identify which of those parameters are actually key drivers of costs. During data analysis, it is common to discover that some design parameters initially identified and collected do not substantially affect costs; and discover that there may be a need to collect additional parameters to understand whether they significantly influence costs. Data analysis is a very iterative process to identify those few key parameters that most influence costs; and to determine the best-fit equations or mathematical relationships that most accurately describes the correlation (or behavior) between costs and the critical parameters. Data analysis is a complex statistical process achieved by a variety of techniques that are too complex to fully describe in this paper. [8] [11]

Most spreadsheet applications will provide tools that are relatively easy to use. Advanced statistical applications can quicken the overall process but can be more difficult to use than spreadsheets. Typically, regressions are performed between cost and an individual parameter to understand whether it can be established as a cost driver; and subsequently, multiple variable regressions may be run between cost and multiple parameters to understand the behavior between costs and several key cost drivers (or parameters). During the iterative process of testing relationships between cost and a design parameter, equations are discovered that may appear to provide good results (describing the correlation between costs and the variables), but the equations must always be tested to ensure that the they properly explain the data.

During data analysis, erratic or outlier data points may be discovered that should be removed from the input data so as not to bias the relationships; but these should be carefully evaluated using statistical techniques to ensure that the results are not arbitrarily distorted.

The resulting equations will typically be expressed in one of the following forms.

A linear relationship such as:

$$Cost = a + bV_1 + cV_2 + \ldots$$

or as a non-linear relationship, such as:

$$Cost = a + bV_1^x + cV_2^y + \ldots$$

Where V_1 and V_2 are input design variables; *a*, *b*, and *c* are constants derived from the regression analysis; and *x* and *y* are exponents (also derived from the regression analysis). Often, a multi-variable regression equation will identify a linear relationship to cost for some variables, while identifying a non-linear relationship for other variables.

The cost estimating relationship equations must be carefully examined to ensure that they provide reasonable and expected relationships between costs and the key design parameters. During the iterative data analysis process of running multiple regressions to determine best-fit equations for the parametric model, the R-squared (R^2) value of each equation is evaluated. This value, known as the coefficient of determination or coefficient of multiple determination, is calculated during the regression and will always appear as part of overall regression results. The R-squared value is a statistical measure that represents the proportion of the variance for the dependent variable (cost in this case) that is explained by the independent variables (design parameters) for a particular regression. It is a *goodness-of-fit* measure.

Best-fit equations from the data analysis will typically have the highest R-squared values, indicating that the variance between the observed values (the costs associated with the input data) and the model results (costs based on the regression equation) are relatively small; however R-squared by itself is not sufficient to fully evaluate whether the equation is adequate. The R-squared value does not indicate whether the equation is biased (always underestimating or overestimating cost) and does not indicate whether the resulting equation is statistically significant.

A cursory examination of the model results can often identify whether the model equations are providing expected results, for example that costs are increasing as capacity increases. If the relationships appear reasonable then additional statistical tests can be run to determine that the model is statistically significant and is providing results within an acceptable margin of error. The f-test is commonly used to determine statistical significance. Consult a statistics manual for more information. A quick check should always be performed by running the regression analysis directly against the input data to evaluate the percent error associated with each set of data inputs, and to look for bias. This often allows the estimator (or model developer) to determine obvious problems and to refine the regression equations. If individual regression equations are to be included as part of a more complex model, then it is also important to test the model as a whole against new data (not used in the development of the model) to verify that the parametric estimating model is performing as expected.

The AACE paper *An Introduction to Parametric Estimating* [9] walks through the development of a multi-variable parametric regression equation for estimating the cost of induced-draft cooling towers. The resulting equation was:

$$\text{Predicted Cost} = \$86{,}600 + \$84{,}500(\text{Cooling Range in Deg F})^{.65} - \$68{,}600(\text{Approach in Deg F}) + \$76{,}700(\text{Flow Rate in 1000GPM})^{.7}$$

The equation was based on the costs and design parameters for six completed projects normalized to a Northeast US location and year-2000 time basis. The equation indicates that the cooling range and flowrates associated with the cooling tower affect costs in a non-linear manner, while the approach (the temperature difference between the cold water leaving the cooling tower and the wet-bulb temperature of the ambient air) affects cost in a linear manner. The approach is also inversely correlated with cost, which is a reasonable assumption since increasing the approach increases the efficiency of the heat transfer taking place. The equation resulted in a R-squared value of 0.96 indicating that the equation was a *good-fit* to explain the variability in the data, showed statistical significance, and was un-biased.

The results using this parametric equation to estimate the cost of a cooling tower with a cooling range of 40 Deg Fahrenheit, and approach of 15 Deg Fahrenheit, and a flowrate of 50,000 Gallons per Minute is shown in Table 8.

Estimated Cost for Induced Draft Cooling Tower			
Cooling Range Def F	Approach Deg F	Flowrate 1000 GPM	Predicted Cost
40	15	50	$1,173,000

Table 8–Sample Parametric Equation Estimate

In this particular example, the predicted cost of $1,173,000 varied from the actual cost of a cooling tower with the same design parameters by only 3.8% (actual cost was $1,129,550), which is well within the expected accuracy for a conceptual cost estimate. In actual application of the equation for a specific cooling tower, additional adjustments may need to be made for location, timeframe, or other characteristics different than the normalized basis that the equation was determined from.

In this simple example, the parametric equation can be used directly to estimate the cost of a cooling tower; or a simple spreadsheet application can be developed that would accept input for the three design parameters and calculate the estimated cost. An advantage of a simple spreadsheet application is that it can validate the inputs to ensure that they are within the limits associated with the estimating equation. For example, in this particular case the parametric model was developed based on actual cooling ranges from 25 Deg F to 40 Deg F, approach ranges from 8 Deg F to 20 Deg F, and flowrates from 30,000 GPM to 50,000 GPM; therefore, the model developer may want to restrict data inputs to be between these values.

Lastly, one of the most important steps in developing a parametric (or any other cost estimating) model is to ensure that it is thoroughly documented. Record the actual data (costs, design parameters, and other characteristics) used to develop the model, the resulting regression equations, test results, and information on how the data was adjusted or normalized before the data analysis stage. Any assumptions and/or allowances incorporated into the model should be documented, as well as any exclusions. The range of applicable input values and any limitations of the model's equations should be documented. If the model has been developed into a spreadsheet or other software application, a user guide should be written to demonstrate the steps involved in preparing an estimate using the model.

It should be noted that parametric cost estimating models can be much more complex and elaborate than the simple equation shown above. In addition to using several CERs, a sophisticated parametric estimating model may include an extensive database of technical and cost history; and may require extensive documentation to communicate the basis, assumptions, logic and estimating steps incorporated into the model. Parametric estimating models have been developed to prepare estimates for everything from commercial construction projects to the space shuttle to software development.

Expert Judgment

The conceptual estimating methods described above have been very reliant on the collection, analysis, and normalization of historical data cost information; whether using the cost of one or more past analogous projects as the starting point to adjust from, or using the data to support derivation of capacity factors or parametric model equations. Conceptual estimating methods are characterized by requiring significant effort in data gathering, analysis, and development of cost estimating relationships, factors, and equations in order to be ready to apply that knowledge to the preparation of a conceptual estimate to a proposed new project. Often, preparation of the conceptual estimate itself takes very little time.

There will be times, however, when there may be no analogous projects, historical information, estimating factors or equations which will be applicable to a proposed new project. Perhaps the project involves innovative technology for which there is no available cost history; or historical cost and technical information on similar projects simply has not been collected in the past and analyzed to develop conceptual estimating factors, equations and tools. In these cases, the estimator may need to rely on *expert judgment* for to develop the estimate.

As the name of this estimating technique implies, expert judgment relies on the experience, knowledge and assessment of one or more experts to develop the conceptual estimate. Without objective cost history and validated cost estimating relationships or factors, expert judgment will depend on the subjective opinions of one or more subject matter experts that may have some relevant knowledge or experience upon which to determine the project costs. The expert(s) may be acquainted with project costs for similar projects from prior employment; or otherwise have some useful knowledge upon which to base a prediction of costs.

The more objective experience and applicable knowledge that the expert (or experts) can apply to the specific proposed project, the better the predicted result will be. A problem, however, is that the personal familiarity of a single expert may represent limited familiarity with the proposed project, or otherwise exhibit bias. To avoid this situation, an expert knowledge estimate will often use a group of experts to develop the estimate. A common technique to reaching group consensus is the *Delphi Method*, first conceived by the Rand Corporation in the 1950's.

This technique allows a group of subject matter experts to reach group consensus using a disciplined, systematic approach using the following steps:

- The team of experts is assembled but directed not to discuss their work (or any preconceived ideas) with each other.
- A facilitator provides each subject matter expert with the available project information (scope, location, and any other project planning information developed to-date), and requests that each expert provide a cost estimate based on their applicable experience and knowledge.
- The facilitator then distributes all estimates (usually anonymously) to the team, allowing each expert to view all of the estimated values.
- Each expert is then allowed to revise their estimate and submit an updated cost; and the process continues until the range of estimated values is relatively small, and a consensus cost can be determined.

There are many variations in employing the techniques described above. Some facilitators will allow each expert to discuss their individual assumptions, potential risks, and other information that they considered in developing their cost estimate between every round of revised estimates, while others may wait a round or two before getting into such discussions.

Generally, as each review round process, the experts start developing a general consensus or agreement on the various assumptions, and the individual estimates get closer and closer. Eventually, the range of estimates is relatively close, and a particular value is selected as the project estimate (often the median or average value of the last round of submitted estimates).

The goal of a process such as the Delphi Method is to reduce bias from the subjectivity of the individual expert opinions and reach consensus in a non-confrontational manner. There will be times, however when it is still difficult to reach group consensus. For example, there may be a situation where three out of four experts may agree on a value of $100 million for a project, and one expert will not agree on a value less than $130 million. There are various ways in which this situation may be addressed. One way would be to accept the value of $100 million as the estimate, but address and consider the higher $130 million value as part of the risk evaluation associated with the estimate; another way might be to average the four values and settle on an estimate of $108 million. Another option is to have each expert attempt to break down their overall estimates into a consistent set of sub-categories and attempt to ascertain which sub-category is providing the most variance; and then continue trying to reach consensus on that particular issue. It's very important that all experts assess and evaluate all the various elements and project characteristics for the projects, and carefully consider all their assumptions that may influence or affect their determination of projects costs.

Rounding/Precision

It is very important in conceptual estimating to not imply a higher level of precision than is justified by the estimating techniques used in preparation of the cost estimates. Our estimating tools (formal estimating applications, spreadsheets, or manual calculations) can often produce cost results that are displayed down to the penny. This is never appropriate for a conceptual estimate.

Round appropriately at all levels of calculations for an estimate. Whether you decide to follow formal standards regarding *significant figures* or use a common-sense approach, round appropriately to provide the stakeholders and reviewers of the estimate with an appropriate intended level of precision to be associated with the estimate.

Some organizations will develop guidelines for the rounding of the total cost values associated with specific class of estimate. For example, for Class 5 estimates, it may specific that an estimated value of greater than $10B be rounded to the nearest $100M; an estimated value greater than $1B should be rounded to the nearest $10M, an estimated value greater than $100M should be rounded to the nearest $1M, and so forth.

Uncertainty

The level of scope definition for a project during the early FEL stages is relatively low, resulting in uncertainty. During these early estimates, the estimator may often be involved directly with the sponsoring business unit or with a small technical project team, and extensive and communication must exist between the estimator and the business unit or project team to adequately identify the total scope of the project.

It is especially important that all associated project scope and requirements have been identified. For example, if the scope of the project is to prepare the cost for an 80,000 barrel per day refinery, it should be clearly identified if the estimate is to include only the process units of the refinery; or whether the scope includes supporting utility plants or other facilities such as the administration facilities, dock facilities, non-process buildings, etc.

For any of the estimating techniques involving a reliance on cost estimating relationships (algorithms, equations, or factors), adjusting for the unique characteristics of the project being estimated is important. For example, when using a capacity factored technique, an estimator may fail to properly adjust for project scope differences between the analogous project and the proposed project. If the base project (or analogous project) contained costs for utility generation not required in the new project, then those costs must be deducted from the analogous project before normalizing the historical costs for any difference in time or location. Similarly, if the new project contains scope for new facilities (e.g. port facilities for product shipping) that the analogous project did not include, then the capacity factor equation will not account for those costs and they must be estimated separately for inclusion in the total cost estimate for the proposed project.

It is important that the estimator understand the normalized basis for the historical information to be relied upon during the preparation of a conceptual estimate. If a historical end-product unit cost per hotel room of $215,000 was normalized to only include the hotel building itself, and not the associated costs for a parking lot, pool, or other facilities, then the estimator needs to account for those associated costs accordingly if the new project contains those items.

The important concept to recognize is that uncertainty arising during conceptual estimating may be realized from many issues such as: 1) understanding the scope of the proposed project in relation to the scope for analogous or other historical projects; 2) effectively adjusting and accounting for the costs differences in scope; and 3) effectively adjusting and accounting for cost difference in time and location.

It is not the intent of this paper to describe the potential quantification of cost for the uncertainty associated with conceptual estimating methods; other than indicating that AACE has developed recommended practices regarding application of risk analysis for contingency determination. RP 42R-08: *Risk Analysis and Contingency Determination Using Parametric Estimating* is often applicable for conceptual estimating. [13]

Conclusion

Conceptual estimating techniques can be effectively used to prepare AACE Class 5 estimates that are sufficiently accurate to support project decisions at the earliest stages of project development. Well-prepared conceptual estimates require the proper evaluation of the limited project scope information available and selection of the appropriate conceptual estimating technique. They also require effective adjustment and normalization to the supporting cost data and estimating factors for the unique project to be estimated. When this is accomplished, the conceptual cost estimate enables project stakeholders to make sound early financial and business decisions allowing organizations to maximize the returns on their capital project investments.

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