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Is "Estimate Accuracy" an Oxymoron?

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Introduction

The subject of estimate accuracy is always guaranteed to be a topic of debate among cost engineering professionals. The phrase itself can be considered an oxymoron, which means that it is a conjunction of contradictory terms. From its definition to its application in the control of projects, ten different people will often have ten different views on the subject. This paper will present the author's viewpoint on the topic.

What is a Cost Estimate?

Cost estimating is the predictive process used to quantify, cost, and price the resources required by the scope of an investment option, activity, or project. The output of the estimating process, the cost estimate, is typically used to establish a project budget, but may also be used for other purposes, such as:

- determining the economic feasibility of a project;
- evaluating between project alternatives; and
- providing a basis for project cost and schedule control.

AACE International defines a cost estimate as, "an evaluation of the elements of a project or effort as defined by an agreed-upon scope [1]." While this definition does describe a cost estimate, I believe it fails to fully portray the uncertainty involved with estimates. I favor describing a cost estimate as, "a prediction of the probable costs of a project, of a given and documented scope, to be completed at a defined location and point of time in the future."

An estimate is a prediction of the expected final cost of a proposed project (for a given scope of work). By its nature, an estimate involves assumptions and uncertainties, and is therefore associated with some level of error. We can correlate this level of error and uncertainty to probabilities of over-running or under-running the predicted cost. So given this probabilistic nature of an estimate, it should really not be regarded as a single point number or cost. Instead, an estimate actually reflects a range of potential cost outcomes, with each value within this range associated with a probability of occurrence.

Now, typically we identify a single cost value (within the range of potential costs) as the estimate value, however we must always understand the uncertainty associated with that single point value, and the true probabilistic nature of an estimate.

When we prepare a conceptual estimate using factored techniques, we usually calculate a single point value as the estimated cost. When preparing detailed estimates, as the sum of many individual estimating algorithms, we also calculate the estimate total as a single point value. However, let's always remember that the identified single estimated cost is in actuality just one point on a probability distribution curve that represents the range of potential cost outcomes.

Most of the end uses of an estimate require a single point value within the range of probable values to be selected. For example, when used to develop a project funding amount or budget, we must select a single value to represent the estimate. When taking into account the uncertainty associated with an estimate, we thus add an amount (contingency) to the initially developed point value to represent the final estimate cost. When doing so, we must take into account such things as the accuracy range of the estimate, confidence levels, risk issues, and other factors in selecting the best single point value to represent the final value of the estimate.

What is Estimate Accuracy?

Accuracy is the degree to which a measurement or calculation varies to its actual value; thus estimate accuracy is an indication of the degree to which the final cost outcome of a project may vary from the single point value used as the estimated cost for the project. Estimate accuracy should generally be regarded as a probabilistic assessment of how far a project's final cost may vary from the single point value that is selected to represent the estimate.

Estimate accuracy is traditionally represented as a +/- percentage range around the point estimate; with a stated confidence level that the actual cost outcome will fall within this range. Since an estimate reflects a range of potential cost outcomes (as discussed above), an estimate can be represented as a probability distribution curve. Figure 1 illustrates the concept of estimate accuracy in relation to the estimate's probability distribution.

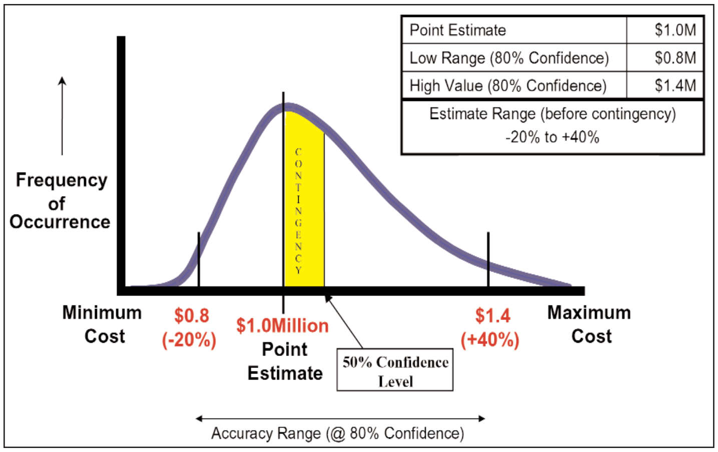

Figure 1—Estimate Accuracy Range around the Point Estimate

In figure 1, the point estimate (the estimated value before contingency) has a value of $1.0 million. In this example, the point estimate has a greater than 50 percent probability of being exceeded by the final cost of the project, and thus a positive amount of contingency would need to be added to the estimate to reflect a 50 percent probability (or a 50 percent confidence level) of underrun or overrun of the expected final cost. The accuracy range at an 80 percent confidence level is bounded by the cost of $0.8 million on the low side and $1.4 million on the high side. In other words, 80 percent of the area under the probability distribution curve lies between these two values. When expressed as a +/- percentage around the point estimate of $1.0 million, the accuracy range would be -20 percent to +40 percent.

When accuracy range is expressed as a percentage, it is always important to note whether it is the percentage range around the point estimate before contingency, or whether it is around the point estimate value including contingency. This important distinction can be appreciated by examining figure 2. In this case, the estimate probability distribution is identical to that in figure 1, and the same amount of contingency has been added to reach a 50 percent probability of underrun or overrun of the expected final cost. At an 80 percent confidence level, estimate accuracy is still bounded by the values of $0.8 million and $1.4 million. However, when expressed as a percentage around the point

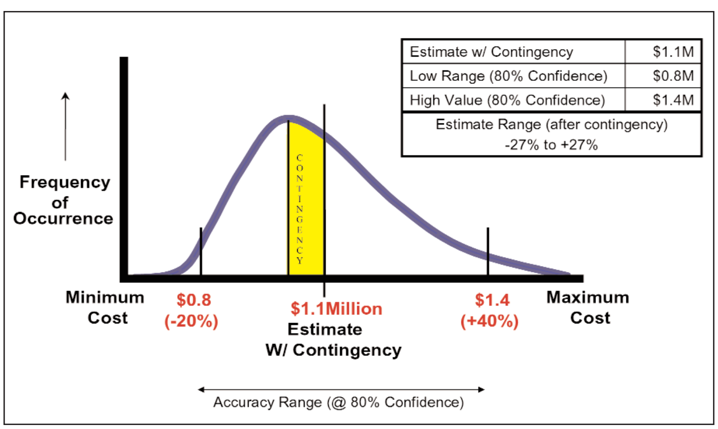

Figure2—Estimate Accuracy Range around Estimate Including Contingency

estimate including contingency ($1.1 million), the accuracy range is now -27 percent to +27 percent.

In figure 2, although the absolute values of the estimate range at an 80 percent confidence level are unchanged from figure 1, the range expressed as a percentage is different. Unfortunately, many estimators fail to note whether a +/- accuracy percentage is applicable to the point estimate before contingency, or the estimate including contingency. As you can see, the difference is extremely important.

As should be expected, estimate accuracy tends to improve (i.e., the range of probable values narrows) as the level of project definition improves. In terms of AACE International's classifications of estimates, increasing levels of project definition are associated with moving from Class 5 estimates, to Class 4

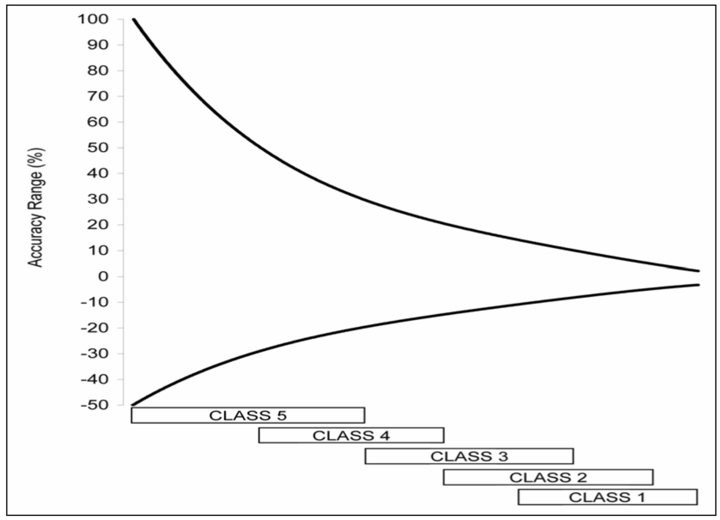

Figure 3—Estimate Accuracy Improves as the Level of Project Definition Improves

estimates, and eventually to Class 1 estimates (associated with the highest level of project definition). Figure 3 illustrates this concept.

This chart is intended only as an illustration of the general relationship between estimate accuracy and the level of engineering complete. As shown in figure 3, and described in AACE International's **Recommended Practices on Estimate Classification**, there is no absolute standard range on any estimate or class of estimate. For the process industries, typical estimate ranges are illustrated as:

- Typical Class 5 Estimate:
  - High range of from +30 percent to +100 percent
  - Low range of from –20 percent to –50 percent
- Typical Class 4 Estimate:
  - High range of from +20 percent to +50 percent
  - Low range of from –15 percent to –30 percent
- Typical Class 3 Estimate:
  - High range of from +10 percent to +30 percent
  - Low range of from –10 percent to –20 percent

This common +/- percent measure associated with an estimate is merely a useful simplification given the reality that each individual estimate will be associated with a different probability distribution explaining its unique level of uncertainty.

Although the percent of engineering complete (or level of project definition) is an important determinant of estimate accuracy, there are many other factors which also affect it. Some of these other factors include the quality of reference cost estimating data (material pricing, labor hours, labor ware rates, etc.), the quality of the assumptions used in preparing the estimate, the state of new technology in the project, the experience and skill level of the estimator, the specific estimating techniques employed, the desired use of the estimate, the level of effort budgeted to prepare the estimate, as well as extraneous market conditions (such as periods of rapid price escalation and labor climate factors).

In addition, other factors that affect estimate accuracy are the project team's capability to control the project, and the capability to adjust the estimate for changes in scope as the project develops. Consideration of all of these factors is the reason that the high and low ranges of typical estimate accuracy are themselves variable. It is simply not possible to define a precise range of estimate accuracy based solely on the percentage of engineering complete or class of estimate. Any specific estimate may not exhibit the patterns shown above. It is possible to have a Class 5 estimate with a very narrow estimate range, particularly for repeat projects with good historical costs upon which to base the estimate. Conversely, it is possible to have a Class 3 or Class 2 estimate with a very wide accuracy range, particularly for first-of-a-kind projects or those employing new technologies.

When discussing estimate accuracy, it is also important to realize that for early conceptual estimates, variations in the design basis will 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 estimate accuracy is poorest. In the early phases of a project, effort should be directed towards establishing a better design basis than concentrating on utilizing more detailed estimating methods.

The +/- percent accuracy range of the estimate should be determined from an assessment of the design deliverables and estimating information used in preparation of the estimate. Cost risk analysis studies will often be used for individual projects to determine their accuracy range based on this type of information. From the resulting output of the risk analysis, the project budget should be derived based on the level of confidence (or risk) acceptable to management in order not to overrun the project budget. Estimate contingency is the amount added to the point estimate in order to provide the desired level of confidence.

Estimate Contingency

To the estimator, contingency is an amount used in the estimate to deal with the uncertainties inherent in the estimating process. The estimator regards contingency as the funds added to the originally derived point estimate to achieve a given probability of not overrunning the estimate (given relative stability of the project scope and the assumptions upon which the estimate is based). Contingency is required because estimating is not an exact science. The word "estimate" implies a judgmental, probabilistic value; and the one sure thing we know about an estimate is that it is not "exact."

Figure 4 illustrates the potential variability of a single component of an estimate. In this example, the variability is shown as a normal probability distribution around the estimated value of $100. Since this is a normal probability distribution, the probability of underrun (shown as the area under the curve to the left of the vertical dotted line) equals 50 percent, the same as the probability of overrun (the area under the curve to the right of the dotted line). The estimate line item has an estimated cost of $100; however the accuracy range of the cost varies from $50 to $150, or an accuracy range of +/- 50 percent.

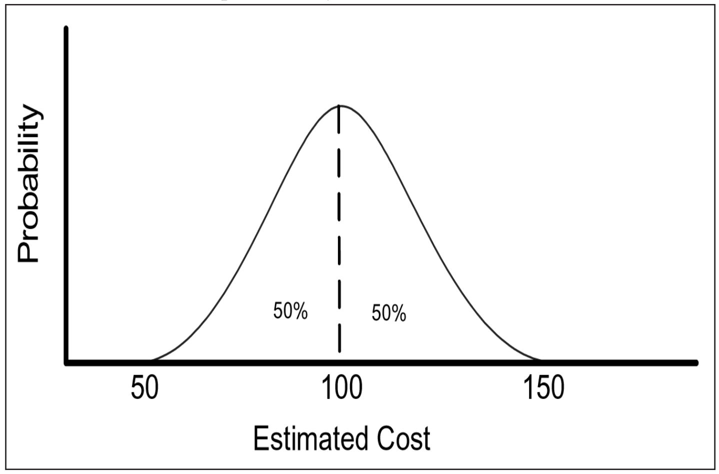

Figure 4—Variation of an estimate line item with normal probability distribution

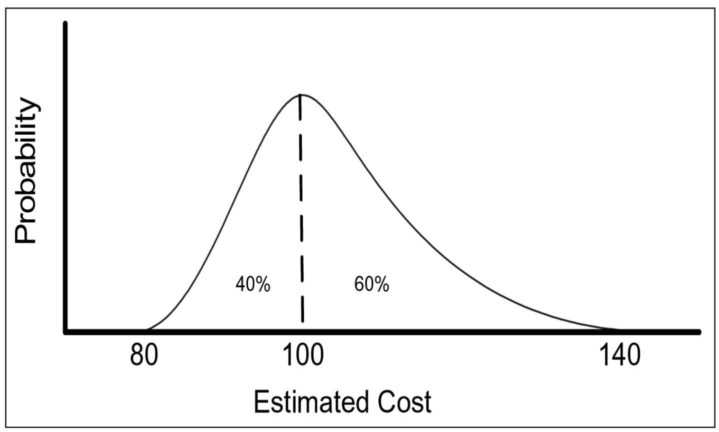

Figure 5—Variation of an estimate line item with a skewed probability distribution

Unfortunately, most items of cost in an estimate do not exhibit a normal probability distribution in respect to its potential variability. Most of the time, variability is more closely associated with a skewed distribution. Figure 5 shows the variability of an estimate line item for which the accuracy range of the cost is skewed to the high side.

In this example, the item has been estimated at $100; how ever the accuracy range of the cost varies from $80 to $140, or -20 percent to +40 percent. With an estimated value of $100, this example shows that there is only a 40 percent probability of underrun, while there is a 60 percent probability of overrun. In order to equalize the probability of underrun and overrun, an amount would need to be added to the original point value of $100. This amount would be considered contingency. Contingency would not change the overall accuracy range of $80 to $140; however it would increase the probability of underrun while decreasing the probability (risk) of overrun.

Most items of cost in an estimate will demonstrate some measure of skewness, usually to the high side where the probability of overrun is higher than the probability of underrun. However, there are usually items where the skewness will be to the low side as well. The variability of the total estimate is then a function of the variability associated with each individual line item. Since the probability distribution of most line items is skewed to the high side, the overall probability distribution for the estimate as a whole is also typically skewed to the high side. Contingency is thus usually a positive amount of funds added to cover the variability surrounding the point value of the estimate, and to reduce the chances of overrunning the point estimate to an acceptable level.

Items typically covered by contingency include:

- Errors and omission in the estimating process
- Quantity variability
  - At the time of estimate preparation, design may not be complete enough to determine final quantities of materials.
  - Some items may defy precise quantification.
  - Some items are generally computed by factored or other conceptual methods as opposed to precise measurement.
- Productivity variability
  - Actual labor productivity may differ from that assumed.
  - There is no such thing as an average tradesman.
  - Weather may differ from that assumed.
  - Labor availability and skill levels may differ from that assumed.
- Wage rate variability
  - Union agreements may expire during the project.
  - Open-shop wage rates may vary depending upon particular individuals.
  - Wages may be uncertain due to labor availability.
- Pricing variability
  - Material pricing may differ from that assumed in the estimate.
  - Materials of construction may be substituted for estimated materials.
  - Changes in quantities may affect applicable discount schedules.
  - Material purchasing policies may vary from the estimate.

Estimate contingency specifically excludes:

- Significant changes in project scope.
- Major, unexpected work stoppages (strikes).
- Disasters (hurricanes, tornados, etc.).
- Excessive, unexpected escalation or currency fluctuation.

The contingency described above is "estimate contingency" meant to cover estimating risk. There are two other types of contingency that may be applied to projects: management reserve typically covers scope growth or owner directed changes; and event driven risk contingency covers project execution risks outside of the assumptions inherent in the estimate – typically extraordinary events that may or may not happen during project execution.

Risk Analysis

Risk analysis is a process that can be used to provide management with an understanding of the probability of overrunning (or underrunning) a specified estimate value. It provides a realistic view of completing a project for the specified estimate value by taking a scientific approach to understanding the uncertainties and probabilities associated with an estimate, and to aid in determining the amount of contingency funding to be added to an estimate. Its purpose is to improve the accuracy of project evaluations (not to improve the accuracy of an estimate). Risk analysis and contingency determination do not change the underlying probability distribution of the estimate.

Risk analysis generally uses a modeling concept to determine a composite probability distribution around the range of possible project cost totals. It provides a way in which to associate a level of risk with a selected project funding value. If the original point value of an estimate is assumed to be approximately the midpoint of the possible actual cost outcomes of project cost, that means that there is a 50 percent probability that the final outcome will exceed the estimated cost (without contingency). In reality, there is usually a greater probability that costs will increase rather than decrease. This means that the distribution of project cost outcomes is skewed, and there is a higher than 50 percent probability that final actual costs will exceed the point estimate (and this is historically the case).

Summary

One definition of an estimate is "the expected value of a complex equation of probabilistic elements subject to random variation within defined ranges." The values assigned to each individual component of an estimate are uncertain, and therefore the estimate as a whole is also subject to variability. Estimates involve uncertainty, therefore variability exists and we need to accept it.

Estimates should be unbiased. Uncertainty should be reflected in the estimate range, and not in padding the costs of each element or component of the estimate. The use of risk analysis provides a means to assess uncertainty and to determine the contingency amount required to select a project budget (a single value required for funding).

At each phase of a project (or for each class of estimate), the estimate should reliably predict the costs to deliver the project, given the scope and assumptions reflected in the estimate. Thus the estimate should provide sufficient accuracy to effectively support the decision at hand.

Is "Estimate Accuracy" an Oxymoron? No

If we follow best estimating practices, if we accept that an estimate is a range of values (associated with a confidence level), if we associate a given point estimate with a probability of overrun/underrun, then we have defined an expected degree of conformity to the actual project result that is obtainable and repeatable.

REFERENCES

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