Risk-Based Cost Estimation

White Paper

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Introduction

Cost estimation for an engineering project traditionally involves development of an "engineer's estimate" of the project cost to which contingency is added to develop the "total project cost." Contingency is used to reflect the fact that regardless of the diligence and competence of the estimator, there is uncertainty in the final cost of the project. Material costs change over time, markups and markdowns vary from job to job, field conditions arise that were unforeseen during design, and other factors add to the uncertain nature of cost estimating.

Contingency is added to account for these unforeseen conditions that are sure to occur. Traditionally, the contingency is a percentage of the engineer's estimate. At a study level, a 25% to 30% contingency is typically added. At successive project phases smaller contingency numbers are typically used to reflect the fact that there are fewer unknowns in the estimate.

Risk Based Cost Estimating

- ? Develop most likely cost.
- ? Develop contingency based on risk.

In recent years, the weakness of applying a percentage to the engineer's estimate has been the subject of considerable discussion and research. The traditional approach does not provide decision-makers with a clear indication of the likelihood that the project will be completed for the budgeted amount. This approach does not allow managers to budget more money to accept less risk. And this approach tends to either overstate the costs, in a fairly typical project where there is little uncertainty, or understate the costs, in a project where there is significant uncertainty. Statistical techniques have been developed to address the shortcomings of the traditional approach and provide a clearer indication of the expected costs.

This white paper outlines a technique to model each line item that makes up the engineer's estimate as a probability distribution. The probability distributions can then be combined to create a statistical view of the total project cost.

This approach shows the most likely construction cost and the probability that the cost will exceed any given contingency amount. This information allows decision makers to set budgets based on the amount of risk they are willing to accept.

Methodology

The cost estimation methodology described in this paper is one that has been used successfully by Timberline on a number of projects over the past four years. The methodology includes five steps: set bounding conditions, develop a cost estimate model, develop cost data, perform statistical analysis, analyze and communicate the results. These steps are discussed in detail below.

Set Bounding Conditions

It is important that the engineer and the audience understand the limitations of the cost model. Because the cost estimate model includes ranges in costs and quantities, the limitations of the model must be explained and agreed upon.

For example, at an early stage in a communications project, a design decision could be that the antenna supporting structures will be steel lattice-type towers between 50 and 150 feet tall. The design could call for three or four towers depending on the route chosen. These details must be communicated as bounding conditions of the model. If five towers are ultimately needed, if monopoles are to be used rather than towers, or if the project will use buried fiber optic cable rather than microwave towers, the boundary conditions have been violated and the resulting cost estimate can not be trusted.

Cost Estimation Methodology

? Set Bounding Conditions
? Develop Model
? Develop Cost Data
? Perform Statistical Analysis
? Analyze and Communicate Results

When management and the design team understands the bounding conditions, they are more likely to recognize when a design decision has been made that requires a fresh look at project cost.

Once bounding conditions are understood, the cost model can be developed. However, setting the bounding conditions and developing the cost model are iterative activities. As the model is refined so must the bounding conditions. As bounding conditions change, the model must be refined.

Develop Cost Estimate Model

The cost estimate model is simply a list of the major items of construction in the project, their quantities and their unit costs. Quantities and costs are expressed as a range described by two points and a description of the probability distribution for the item.

The two points are generally two of the following:

? Lowest likely (10% confidence).

- ? Most likely (50% confidence).
- ? Highest likely (90% confidence).

The technical description of these points is that there is some probability that the actual cost will be less than the stated cost. The lowest likely cost, for example, has only a 10% chance of being greater than the actual.

The probability distribution selected for most commercial items is the triangular distribution. A triangular distribution has a 50% probability at the mean cost and reaches 0% and 100% at finite costs. With a triangular distribution, the 10% and 90% points have equal probability of occurrence with the most likely value being the average of the 10% and 90% points. This forms a triangular-shaped distribution, with values near the minimum and maximum being less apt to occur than those near the most likely value. Triangular distributions provide a good approximation of a normal distribution but have finite maximum and minimum values.

Occasionally, a line item in a cost estimate has a finite lowest likely cost for an item and a well understood average cost, but the maximum value of the cost could be orders of magnitude higher than the mean. (This is typical of labor activities on a time and materials type contract and home remodeling projects.) In this case log normal distribution is more appropriate than a triangular one. Many other distributions might also be used to model costs with special characteristics

Once the quantities and costs have been expressed as probability distribution functions, extended costs are generated and summed to create the engineer's estimate.

The development of this type of sophisticated cost model would have been beyond the computing capability of all but the most sophisticated specialists fifteen years ago. However, there are now spreadsheet programs that not only make this work possible, but actually allow rapid development and analysis of the model.

Develop Cost Data

Once the decision makers agree to the boundary conditions and the model has been created, the model must be populated with cost data. This process progresses much like a typical estimating process with selection of unit costs from manufacturer's pricing information or from published estimating guides. However, each cost must be assessed to determine the probability that the actual price will be less.

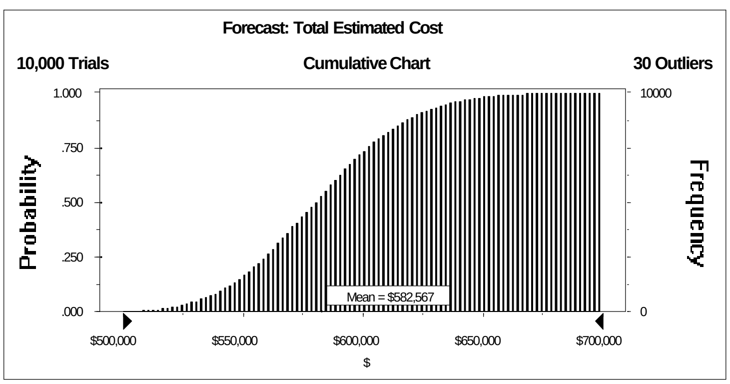
Where prices are well understood, the published price might be considered "most likely" (50% confidence) with a very small increase to the 90% confidence level. Where prices are subject to fluctuation or a number of competing products vary widely in cost, a greater spread between the 50% and 90% values is warranted.

Items of labor that are performed as distinct units repeated many times over the course of a job can be estimated as a unit cost and a quantity with the unit cost being an estimate of the range from unit to unit. Items of labor that span the entire job (such as project management) must be estimated as a single activity.

Perform Statistical Analysis

Once the cost model has been populated, statistical analysis of the model will yield the probability distribution of the cost for the entire project.

The Mean Estimated Cost is calculated summing the estimated cost of each line item 10,000 times with each trial using a randomly generated cost based on the probability distributions for each cost element. Each trial then generates an estimated project cost. These costs are recorded and a probability density function is created from which a mean value is extracted. The mean, then, is the average cost of the project if it was to be performed 10,000 independent times. That cost is called the Mean Estimated Cost.



Analyze and Communicate Results

In addition to the Mean Estimated Cost, the probability density function generated by the statistical analysis also allows the engineer to determine the cost at any confidence level. In a typical project a confidence level between the 85% and the 95% level will be chosen as the Total Project Cost. Contingency, then, is the difference between the Mean Estimated Cost and the Total Project Cost.

The choice of confidence levels represents management's risk posture. If the 90% level is chosen, management is accepting a 10% risk that the project will overrun the budget.

Conclusion

This paper outlines an approach to cost estimation based on statistical risk analysis. This approach overcomes serious limitations of traditional approaches and results in a better understanding of the cost risk involved in a project.

This technique has been used successfully by Timberline and other organizations for the past several years. The availability of powerful PC-based software for performing this analysis has made these techniques available to everyone.

For more information on this or related SCADA engineering topics, please feel free to contact Timberline Engineering, Inc. as noted below:

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