ACCEPTANCE CRITERIA FOR A COST ESTIMATING RELATIONSHIP

Stuparu Dragoş
Universitatea din Craiova Facultatea de Economie şi Administrarea Afacerilor Drobeta Turnu Severin, Str. Topolniţii, nr. 11, Bl.2, Sc.2, Ap.5 e-mail: d_stuparu@yahoo.com tel. 0745-835764
Vasile Tomiţă
Universitatea din Craiova Facultatea de Economie şi Administrarea Afacerilor Drobeta Turnu Severin, Str. R. Calomfirescu, nr. 9, Bl.C5, Sc.1, Ap.11 e-mail: vasiletomita@yahoo.com tel. 0747-323076
Dăniasă Cora-Ionela
Universitatea din Craiova Facultatea de Economie şi Administrarea Afacerilor Drobeta Turnu Severin, Str. Adrian, nr. 42 tel. 0741-043125

T*he Cost Estimating Relationship (CER) is a mathematical expression which describes, for predicative purposes, the cost of an item or activity as a function of one or more independent variables. The methodology can provide accurate and supportable contractor estimates, lower cost proposal processes, and more cost-effective estimating systems. The contractor community uses parametric cost models, especially during product concept definition. These estimates are used for decision making regarding bid strategies. As part as the process of build of a parametric model the acceptance criteria are important.*

Key words: parametric cost estimating, parametric cost model, acceptance criteria

JEL classification: C: Mathematical and Quantitative Methods; C5: Econometric Modeling; C51: Model Construction and Estimation

1. INTRODUCTION

The origins of parametric cost estimating date back to World War II. The war caused a demand for military aircraft in numbers and models that far exceeded anything the aircraft industry had manufactured before. While there had been some rudimentary work from time to time to develop parametric techniques for predicting cost, there was no widespread use of any cost estimating technique beyond a laborious buildup of labor-hours and materials.

The Military saw a need for a stable, highly skilled cadre of analysts to help with the evaluation of such alternatives. Around 1950, the military established the Rand Corporation in Santa Monica, California, as a civil "think-tank" for independent analysis. Over the years, Rand's work represents some of the earliest and most systematic studies of cost estimating in the airplane industry.

In the mid 1950's, Rand developed the most basic tool of the cost estimating discipline, the Cost Estimating Relationship (CER), and merged the CER with the learning curve to form the foundation of parametric aerospace estimating. This estimating approach is still used today.

A Parametric Cost Estimate derived from statistical correlation of historic system costs with performance and/or physical attributes of the system.

Defined, a Parametric Cost Model is mathematical representation of parametric cost estimating relationships that provides a logical and predictable correlation between the physical or functional characteristics of a system, and the resultant cost of the system. A parametric cost model is an estimating system comprising cost estimating relationships (CERs) and other parametric estimating functions, e.g., cost quantity relationships, inflation factors, staff skills, schedules, etc.

Parametric cost models yield product or service costs at designated levels and may provide departmentalized breakdown of generic cost elements. A parametric cost model provides a logical and repeatable relationship between input variables and resultant costs.

2. ACCEPTANCE CRITERIA FOR A COST ESTIMATING RELATIONSHIP

How good is a CER equation and how good is the CER likely to be for estimating the cost of new projects? What is the confidence level of answers at questions from the number estimated, i.e., how likely is the estimated cost to fall within a specified range of cost outcomes?

First, certain necessary conditions for a statistical analysis of a CER need to be stated:

1. There are more data points than coefficients to be estimated.
2. Error terms do not form a systematic pattern.
3. The independent variables are not highly correlated.
4. The form of the equation to be estimated is linear or has been translated into a linear form using logarithms.
5. The model makes sense from an economics and technical point of view.

The "t" statistic is also used for other applications. For example, in order to determine if two groups of data are from the same population or from two different populations.

When then degrees of freedom in a data set approach 30, the statistics of the "t" distribution approach the normal distribution. If it is not known whether a normal distribution is justified, the "law of large numbers" can be invoked that states that for a large enough sample (large enough cost database), the error term involved in estimating cost will approach a normal distribution. That is, the normal distribution can be used instead of the "t" distribution to test the null hypothesis. The "t" is of similar shape to the normal distribution, except that there is a larger probability of lower cost or higher cost (extreme outcomes) associated with the "t" distribution rather than the normal distribution.

Also, an analysis of the plot residual values can be useful. If a pattern exists, then correlation may be explained by other factors. If the plot of residuals is a scatter plot with no patterns, then the CER equation may be good if other factors are favorable.

Another important statistical measure is the bandwidth or confidence interval associated with the application of the CER cost estimates. The bandwidth of the cost estimate depends upon the confidence interval required or desired, the parameter value, and the degrees of freedom of the data.

3. ANALYZING A CER

3.1. CER Analysis

Cost estimating relationships (CERs) relate cost to some other program element in a definite way. Examples of CERs are per diem rates, "shop supplies", sales tax estimates, etc. CERs supposedly relate one cost to another or with a well defined parameter. When rolled into an interlocking algorithm, analysts have to probe both the estimate and the underlying data used to develop a CER. What distinguishes a CER from a conventional estimating approach is that CERs define a general relationship based on a set of data rather than a specific relationship based on a direct precedent. A CER may be less precise than a convential estimating method but the cost savings resulting from the CER approach may be worth the potential loss of precision.

Within detailed cost estimates, CER's may be used for estimating small or derivative cost elements. CER's are also commonly used for budgetary estimates, "rough order of magnitude" estimates, and simple cost-benefit calculations when the preliminary or uncertain nature of the project discourages a costly estimating effort. However, well built cost models in the hands of a professional can be better cost predictors than detail methods because certain judgement and other biases are more controlled.

3.2. General Features

A CER can be a functional relationship between one variable and another and may-represent a statistical relationship between some well defined program element and some specific cost. Since most company overhead rates are percentages of direct labor expense, these are CERs. Computer and travel costs often show statistical relationships to engineering costs; design is frequently closely correlated to drafting costs and these, in turn, to the number of drawings, parts, size, weight, etc. Many costs can be related to other costs or non-cost variables in some fashion but not all such relationships can be turned into a CER.

A CER must have two characteristics. First, it should link in some rational way the underlying variable - the independent variable, and the cost being developed. Second, the CER should have a strong statistical fit and confidence interval, with the basis element.

3.3. Evaluating an Estimate

CERs are used in lieu of a direct substantive link between a cost element and some basis of estimate (BOE). Since CERs are developed from collections of cases and represent average values, CERs have uncertainty built into them. (A direct BOE to cost estimate extrapolation is preferred if the cost element is significant, if a good BOE can be found, and if some well defined extrapolation can be postulated between the BOE and the cost element.) The first step in an analysis of a CER influenced estimate is to identify how much of the total estimate is CER driven.

The second step in analyzing a proposal using CERs is to evaluate the CERs themselves. Since CERs supposedly relate an element of cost to some variable or factor, the analyst must determine whether the relationship is truly functional and statistical. If the CER is a factor implied by a functional relationship, the analyst needs an explanation of the function and support for the assertion of a relationship. Both deterministic and statistical support are required. In other words, does the relationship make logical sense and is the pattern of influence regular enough to be helpful? Base data must be available for examination, preferably original, "unsmoothed" data. Again, the purpose of a CER is to save time and effort. If the amount of the proposal affected by CERs is not great, the evaluation effort applied to the CER should be an appropriate amount.

In a "worse case" situation, the analyst may have to back track to the original data set used to develop a CER. In that case the analyst should attempt to see if all the relevant cases have been included and no "cherry picking" has occurred. In other words, what "risk" is involved by using the CER?

Assuming the original data set is available and complete, the developer of the CER must explain the theory of the relationship and the data processing performed. If "outliers" were excluded, the estimator needs to explain why. If the explanation of the exclusion is unsatisfactory, the analyst may want to develop a set of CER's with the outliers included. Ordinarily, outliers affect the deviation of the estimate rather than the value of the CER, but it is useful to check. If several data points have been excluded and if these influence the CER mean and standard deviation significantly, the CER may not be operationally useful even if theoretically valid. To illustrate, suppose a relationship is identified between variable K and cost variable C. Suppose the CER is $5 \times K = C$. If the value 5 is developed from an arithmetic average of a dozen values but three "outliers" have been excluded, then inclusion of the outliers may spread out the sample standard deviation to the point that confidence in the relationship may become suspect. The CER estimator should be able to supply the original data set and his/her analysis. The cost analyst may need to replicate the estimate to verify the calculation. If this is done, the CER statistics should be examined for:

1. The sample size. Confidence in the estimate will increase as the sample size increases.
2. The standard error of the mean (or the point estimate) should be shown along with the standard deviation of the calculated mean.
3. The standard deviation of the sample set. What is the range of the majority of the data points? Confidence in the estimate increases as more and more data points fall within a specified range.

4. If the CER is developed from a correlation calculation, the cost analyst can examine the coefficient of correlation. Correlation infers a link between the two factors but the relationship may be accidental. Standard statistical tests exist for checking the likelihood that a given correlation coefficient is accidental and should be used if the sample set is small, or if "R" is less than 0.8 ($R^2 = 0.64$) (R - coefficient of correlation and R^2 the coefficient of determination).
The last step in evaluation of a CER is calculating the effect which reasonable variations on the CER value can have on the estimate. If reasonable variations on the CER impact the estimate greatly, the analyst has to be skeptical of the explanatory power of the CER. The effect of this is to widen the actual range of an estimate.
CER analysis requires addressing the questions:
1. What is the proportion of the estimate directly affected by CERs?
2. How much precision is appropriate to the estimate in total and to the part affected by the CERs?
3. Is there a rational relationship between the individual CER affected variables and the underlying variables?
4. Is the pattern of relationship functional or purely statistical?
5. If functional, what is the functional relationship? And why?
6. If statistical, is the history of the relationship extensive enough to give a confidence that it operates in the given case?
7. Is the pattern of relationship statistically significant? And at what level of confidence?
8. What is the impact on the estimate of using reasonable variations of the CERs?
If the CERs represent a cost-effective response to an estimating problem and if they are rationally developed and solidly based, the CERs are valid and accurate tools for an estimate.
Assuming no "show stopper" problems are uncovered, the analyst can accept the concept of the CERs and apply such margins of variance as seem reasonable.

REFERENCES
1. Stuparu, D., Vasile, T. – „*Matematici aplicate în economie*", Editura Şcoala Mehedinţiului, Drobeta Turnu Severin, 2002,
2. Vasile, T. – "*Metode statistice în managementul afacerilor*", Editura Sitech, Craiova, 2008,
3. Vasilescu, N., Costescu, M., Ionaşcu, C., Babucea, G., Vasile, T., Stuparu, D. – „*Statistică*", Editura Universitaria, Craiova, 2003,
4. Wonnacott, T., H., Wonnacott, R., J. – „*Statistique*", Editure Economica, Paris, 1991.