CHAPTER 18

USE OF COST ESTIMATING RELATIONSHIPS

1. INTRODUCTION

Cost Estimating Relationships (CERs) are an important tool in an estimator's kit, and in many cases, they are the only tool. Thus, it is important to understand their limitations and characteristics. This chapter discusses considerations of which the estimator must be aware so the CERs can be properly used.

2. LIMITATIONS

The widespread use of CERs in the form of simple cost factors, equations, curves, nomograms, and rules of thumb attest to their value and to the variety of situations in which they can be helpful. Thus, it is essential that their limitations be understood to preclude their improper use.

A. Historical Data

A statistical CER can be derived from information on past occurrences, but the past is not always a reliable guide to the future. An estimate based on past performance is very likely to be wrong. Admittedly, there may be other factors at work, but the problem remains the same as that encountered in any attempt to predict the course of future events; that is, how much confidence can be put in the prediction?

B. Bounds of the Sample

Uncertainty is inherent in any application of statistics. This pertains primarily to articles estimated as being well within the bounds of the sample on which the relationship is based. Although extrapolation beyond the sample is universally deplored by statisticians, it is universally practiced by cost analysts in dealing with advanced hardware because, in most instances, it is precisely those systems outside the range of the sample that are of interest. The question is whether or not the equation is relevant if it must be extrapolated. Good statistical practice would question the validity of such an approach.

C. Different Characteristics

The article being estimated may have characteristics somewhat different from those of the sample CER.

3. CHARACTERISTICS OF THE ESTIMATING RELATIONSHIP

The degree of emphasis placed on statistical treatment of data can cause two fundamental points to be overlooked: first, that an estimating relationship must be reasonable, and second, that it must have predictive value.

Reasonableness

Although it is not possible to resolve all uncertainties with the information available, an estimator can feel reasonably confident that the estimating relationship does not contain a systematic bias, that it should be applicable to normal programs, and that it provides reasonable estimates throughout the breadth of the sample.

Reasonableness can be tested in various ways—by inspection, by simple plots, and by complicated techniques that involve an examination of each variable over a range of possible values.

1. Inspection will often suffice to indicate that an estimating relationship is not structurally sound.

   For example, assume that historical information on hazardous waste disposal costs had been input into a computer with statistical software.

   The statistical package generated the following equation:

   $$C = 200 + 275D - 0.19M$$

   where

   C = cost to dispose of drummed hazardous waste
   D = number of drums
   M = number of miles between waste location and hazardous waste disposal facility.

   The equation is checked and the statistical parameters are within acceptable tolerances. The equation also fits the data very well.

   An examination of the equation for reasonableness shows that it predicted that transportation costs reduced the overall disposal cost. This is contrary to experience.

What is not known about the data is that some of it came from a project where the procurement and contract administration departments were able to negotiate a reduced transportation fee from the disposal company. Therefore, the historical data, out of context, does not provide an accurate forecast of future events. A reexamination of the sample data and equation is in order.

2. Cost estimating relationships may also have a limited range of validity. When an estimating relationship is developed to make a particular estimate, it may have little predictive value outside its narrow range. Use of the estimate outside of the estimate's range may lead to erroneous estimates.

A common method of examining the implications of an estimating relationship for values outside the range of the sample is to plot a scaling curve. The theory on which a scaling curve is based is as follows: As an item increases in one variable, the incremental cost of each addition will decrease or increase in a predictable way. Scaling curves may be plotted on either arithmetic or logarithmic graph paper as Figure 18-1 illustrates.

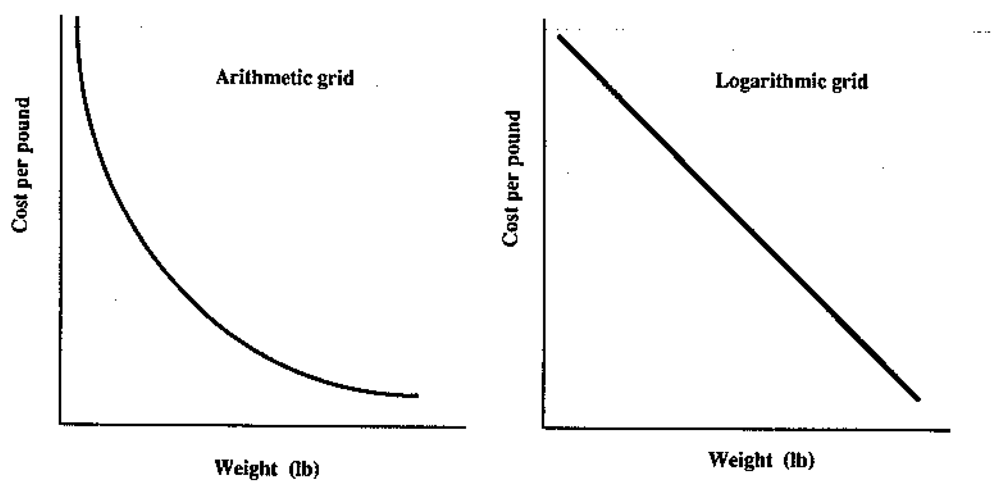

Figure 18-1. Scaling Curve Cost

The slope of the curve in Figure 18-1 is fairly steep. If the curve were extended to the right, it might be expected to flatten. Eventually, the curve might become completely flat at the point at which no more economies of scale can be realized, but it is unlikely that the slope would ever become positive.

Now examine Figure 18-2, in which total cost is plotted against a project variable based on values obtained from an estimating relationship.

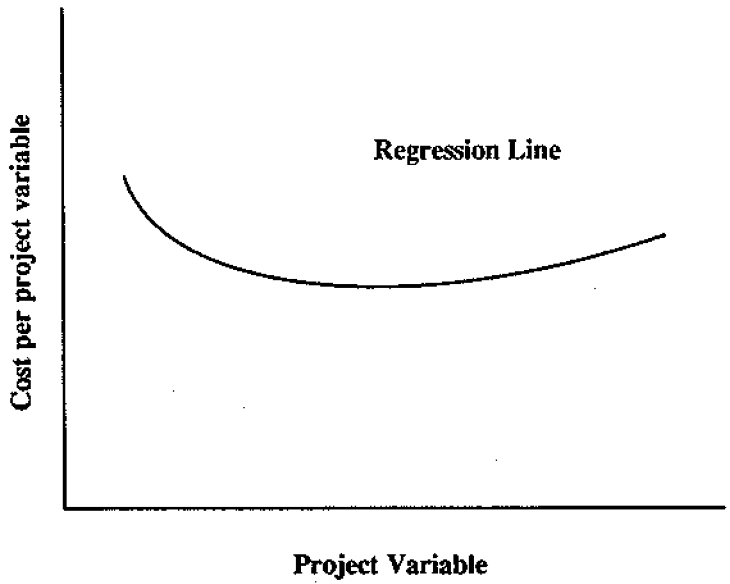

Figure 18-2. Cost Versus Project Variable

Two differences are immediately seen. First, the left-hand portion of the curve is unusually steep. Second, the slope becomes positive in another part of the curve. In some instances, fabrication problems increase with the size of the object being fabricated and a positive slope may result. No such problems are encountered in the manufacture of some items, however, and continued economies of scale are to be expected. Therefore, use of Figure 18-2 for cost estimating the latter case may inflate the estimate.

This figure also illustrates another point: A more useful estimating relationship could have been obtained by drawing a trend line rather than by fitting a curve. With a small sample, it is often possible to write an equation that fits the data perfectly, but the equation is useless outside the range of the sample. Statistical manipulation of a sample this size rarely produces satisfactory results.

3. A final example of the kind of error that overdue reliance on statistical measures of fit may bring about is based on the previous drummed waste example.

   Initially, the equation for estimating disposal costs was based on a variety of drummed wastes. It was then determined that grouping the wastes by type should give a better correlation of disposal costs. Assume that when liquid waste, flammable waste, heavy metal waste, and radioactive waste were considered separately, the average deviation between estimates and actual values was markedly reduced. However, the estimating equation for radioactive waste was as follows:

   $\text{Cost} = 2500\ (\text{drum weight})^{1.08}\ (\text{transportation})^{4}$

   This equation predicts that increased weight will increase the overall cost. New technology focuses on the type of radioactive waste. It cannot be assumed that all future radioactive waste will conform to this trend, especially if new technologies for radioactive waste disposal become available.

4. The cost derived from the use of a CER must be reasonable in a comparison with the past cost of similar hardware. A typical test for reasonableness is to study a scattergram, such as Figure 18-3, of costs of analogous equipment at some standard production quantity.

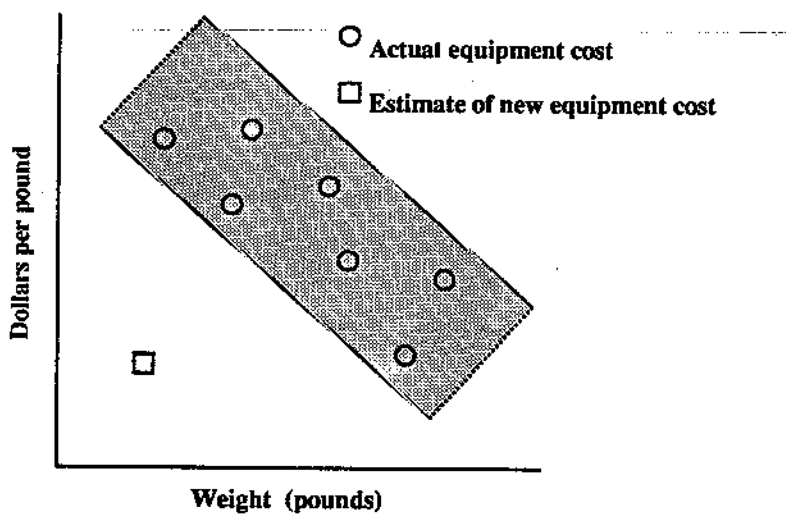

Figure 18-3. Cost Comparison of Analogous Equipment

The estimate of the article may be outside the trend lines of the scattergram and still be correct, but an initial presumption exists that a discrepancy has been discovered and that this discrepancy must be investigated. An analyst who emerges from deliberations with an estimate implying that new, higher performance equipment can be procured for less than the cost of existing hardware knows that the task is not finished. If, after research, the analyst is convinced that the estimate is correct, he/she should then be prepared to explain the new development that is responsible for the decrease in cost. Costs should not be raised arbitrarily by a percentage to make the figure appear more acceptable or because it is felt that the estimate is too low. Such adjustments are the province of management and are generally occasioned by reasons somewhat removed from those discussed here.

4. HARDWARE CONSIDERATIONS

The estimator must decide whether the cost estimating relationship is relevant or how it can be modified to be useful. An estimating relationship can be used properly only by a person familiar with the type of equipment or hardware whose cost is to be estimated. To say that an analyst who estimates the cost of a pump should be familiar with the characteristics of pumps is a truism; however, an estimator is sometimes far removed from the actual hardware. Further, estimators may be expected to provide costs for a construction project one week and for a new waste site remediation facility the next. The tendency in such a situation may be to use the equation that appears most appropriate without taking the required measures to determine whether the equation is applicable.

Further measures could be taken in the form of another independent estimate that uses a different estimating relationship. An estimator does not have this option for most kinds of hardware because estimating relationships are not plentiful. However, in some cases, a number of equations have been developed over the years; it is good practice to use one to confirm an estimate made with another.

5. JUDGMENT IN COST ESTIMATING

The need for judgment is often mentioned in connection with the use of estimating relationships. Although this need may be self-evident, one of the problems in the past has been too much reliance on judgment and too little on estimating relationships. The problem of introducing personal bias with judgment has been studied in other contexts, but the conclusions are relevant to this discussion.

In brief, a person's occupation or position seems to influence his or her forecasts. Thus, a consistent tendency toward low estimates appears among those persons whose interests are served by low estimates; for example, proponents of a remediation technology or an energy alternative whether in industry or in Government. Similarly, there are people in industry and in Government whose interests are served by caution. As a consequence, their estimates are likely to run higher than would be the case if they were free from all external pressures.

The primary use of judgment should be to decide first, whether an estimating relationship can be used for an advanced system, and second, if so, what adjustments will be necessary to take into account the effect of a technology that is not present in the sample. Judgment is also required to decide whether the results obtained from an estimating relationship are reasonable.

Judgments must be based on well-defined evidence. The only injunction to be observed is that any change in an estimate be fully documented to ensure that the estimate can be thoroughly understood and to provide any information that may be needed to reexamine the equations or relationships in light of the new data.