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Economic Analysis Handbook

Input - Estimating Cost

CHAPTER III

A. PREFACE: THE APPROACH - INPUT VS OUTPUT

Once we have chosen discrete hypothetical alternatives which may satisfy our objectives, we must reduce each of these alternatives to its most general components. Each alternative will have some "input" (the cost of achieving benefit, worth of yield) and "output" (benefit, worth or yield). This chapter suggests an approach for determining the input (costs) necessary to accomplish future courses of action.

B. TWO COSTING METHODS

There are many methods for conducting a cost estimate; including Industrial Engineering, Parametric, Analogy, & Factor Costing. The two most frequently used methods are described below:

1. Industrial Engineering Method

This approach consists of a consolidation of estimates from various separate work segments into a total project estimate. As an example, the estimated cost of production of a new model "widget," consisting of work contributions from 10 separate work divisions in a plant, could well be a consolidation of 10 separate and detailed estimates, each of which may be composed of several estimates itself.

Estimating by engineering methods is based on extensive knowledge of the system characteristics. It is necessary for the analyst to have a detailed knowledge of the system, the production processes, and the production organization. In using the engineering method, the system or item of hardware is broken down into its lower level components and estimates of each component are made. Parametric methods are usually used in estimating the costs of these components, and the results are combined with estimates of the costs of integrating the components to arrive at a total system cost. An advantage to this method is that it separates the parts of the system on which little data is available and which require special treatment.

However, the detail required for an engineering analysis is not always available to a government cost analyst, thus making this approach difficult to apply. The time expended for each operation such as setup, milling, and filing, must be multiplied by a labor rate and each of these costs must then be added to reach the total cost. The approach is sometimes difficult to apply, even by the vendor. For an example, one large aerospace firm judges that the use of this approach to estimate the cost of an airframe requires more than 4000 separate estimates. Additionally, each individual making his separate estimate often has insufficient information available to make a reliable estimate, and little means to evaluate inherent errors. Therefore, a cost estimate combined from as few as 10 separate estimates also combines the errors in each of those estimates and, in aggregate forms, there is no means of evaluating the errors involved or the level of uncertainty in the estimate.

However, where detailed cost data exists, the Industrial Engineering Method is the best method for estimating costs.

2. Parametric Cost Estimating

In parametric cost estimating, the total cost of an alternative is based upon ascribed physical and performance characteristics and their relationships to highly aggregated component costs. In other words, a functional relationship must be set up between the total cost of the alternative and the various characteristics or parameters of the alternative. In the formal sense, the term "parameter" is defined as a cost-related explanatory attribute which may assume various values during a particular calculation. For our purposes, it is best to consider a parameter of an alternative as a definable characteristic of that alternative; one of the parts that can be added to give an expression of the value of the whole system, device, or item. Parametric cost estimating is applicable to many situations encountered within the DoD; for this reason, it will be covered in some detail.

The result of a parametric estimate depends directly upon the ability of the analyst to establish relationships between the attributes or elements that make up the alternative. That is, our first job must be to properly choose and then describe the cost influencing factors of the alternative. The descriptions of these factors are called Cost Estimating Relationships (CER).

C. DATA SOURCES

Sources for linking the parameters of an alternative to costs include: expert opinion, catalog prices by item, industrial engineering standards, cost estimating relationships for analogous programs, and specific cost estimating relationships.

The data from all these sources are both historical and statistical. That is, we will normally be dealing with relationships that have been established by using statistics from the cost histories of prior programs. Because of this, when using cost/parameter relationships we must keep in mind two things: (1) the uncertainty inherent in the extrapolation of statistics, and (2) whether the indicated relationship is logically sound and reasonable.

The first problem is unavoidable. However, the influence of the second can be diminished through careful checks of the derived relationships. This can be accomplished through inspection, simple test data plots, or by more complicated techniques which involve looking at the parameter over a range of possible values. The more complicated techniques should be left to the qualified Cost Analyst. However, obviously unreasonable relationships can be intuitively analyzed and corrected, When benefit (for example, greater speed) is inversely associated with cost, the relationship should be investigated before attempting to derive the predicted cost of the alternative.

D. DEVELOPING CERs

Central to any parametric analysis of cost, is the development of valid Cost Estimating Relationships. CERs are developed from the historical cost of like systems and the parameters (e.g., weight, maximum speed, load capacity) of these systems. The statistical technique normally applied to developing CERs from historical cost and parametric data is called regression analysis. Regression analysis is primarily concerned with the determination of the equation of a line or curve which will predict how one variable (e.g., cost) will vary with respect to some parameter (e.g., load capacity).

The techniques of regression analysis are relatively sophisticated and should be used only by an individual familiar with statistical methods. For our purposes, it is sufficient to know that after a regression analysis is conducted, the statistical analyst will provide the manager with first, and most important, the estimating equation, and next, two measures of the usefulness of this equation:

1. The standard error of the estimate. This will show the variance associated with the prediction made from the estimating equation; it expressed how useful the estimating equation is as a tool;

2. The coefficient of correlation. This will express the closeness with which one variable (e.g., load capacity) influences the other variable (cost). Put another way, it measures to what extent the variation of cost is due to the variation in load capacity or whether an amount of the variation in cost is due to certain factors that are not explained by the changes in load capacity.

E. INGREDIENTS FOR PARAMETRIC ANALYSIS

We can derive a parametric cost estimate of our alternative if we have:

1. The existence of historical cost/parameter information on like systems.

2. The ability to predict with some degree of likelihood the expected parameters of our future alternative; (e.g., weight, maximum speed, or payload).

3. A competent statistical analyst who can tell us if the historical costs of the like systems do vary in some defined way with the chosen parameters. If they do, he will give us the estimating equation.

F. PITFALLS

Some factors to consider and pitfalls to be avoided when deriving or reviewing CERs are:

1. Be aware of the source of the estimate, and the purpose for which it is intended. Regardless of the integrity of the individual analyst, it should be expected that some personal or organizational bias may creep in. Contractors naturally want to sell their products or services, and their interests may be served by a high estimate. In this regard you would have an advantage if you have a broad range of historical cost data from several sources while the same data may not be available to private contractors. Application of statistical analysis or simple analogy can give you an excellent means of checking estimates provided from other sources.

2. A simple check of the equations used in cost estimating relationships, along with common sense, will often indicate whether or not the relationship is a reasonable one. The pitfall to be avoided is that an equation may adequately describe one system but not be predictive of another.

3. Consistency of data is essential. When combining data for a regression sample, for instance, it is usually necessary to adjust dollar figures into constant year dollars. Because labor and materials may have not increased at the same rate it may be necessary to consider each separately. If actual expenditure for equipment still in the design state will take place in the future, it may also be necessary to consider inflation factors. In the area of physical characteristics, one must further insure that such common terms as weight, speed, and distance are measured in like units. Often conversion is necessary to be certain that all elements of the sample are indeed compatible.

4. Care must also be taken to insure that historical cost data, which may be accumulated from several sources, truly reflects the actual costs incurred. Accounting differences among studies and contractors could easily result in wide variations in the costs actually included.

5. Finally, do not become so enamored with an estimating model that you ignore the assumptions made in its development, and the reliability of the sample input data. A computer will furnish an impressive and detailed readout, even if the input data is unreliable. Carefully scrutinize sample data, data sources, and assumptions made in developing estimating relationships.

G. JUDGMENT

In cases where there are no qualified cost analysts available, or where there is little or no historical information on the specific alternative, or when the cost estimate is required so quickly that an extensive data search is precluded, we must base our cost estimate entirely on expert judgment. Even in cases where we have cost analysts, historical information, and time available and can adopt a formal method of costing, judgment must be used to reach conclusions not directly supported by data. Expert judgment may be used to construct CERs, or to check their behavior when they extend significantly beyond the data base, or when the data base is too small to be statistically significant.

A specialized method of judgment, called the analogy method, may be used to estimate costs by making direct comparisons with historical information on like or similar existing alternatives or their components. It is, in fact, the most widely used method of analysis to date, although it is surely not the most accurate. The major caution of the analogy method is that it is basically a judgment process and, as a consequence, requires a considerable amount of expertise if it is to be done successfully. There are two types of analogues that may be used. One is based upon similar products and the other upon similar concepts. Similar products can be compared such as using cost data on commercial aircraft. Secondly, when a new concept or system must be costed, experience gained on a different product may be used. An example of this is estimating missile production costs based on aircraft production experience.

The necessity of using experienced judgment to fill gaps in data has long been recognized. In some cases the majority, or even the entirety, of our cost estimate must be based upon judgment. The complexity of the problem, the predisposition of the manager, the point of view of the analysis, the importance of the project (in terms of both mission and finances), and the availability of qualified statistical analysts, all determine the extent of analysis, necessary. The keynote in using judgment must be reasonableness tempered with a large dose of impartiality. Moreover, judgment must always be identified as what it is, a guess, albeit an educated guess.

H. INPUT - COST AND TIME

Present Value. Most expenditures will be time phased. Since there is time value to money, it is necessary to determine when the expenditure for the alternative will be made. Economic analysis expands cost analysis activities by examining the effects of the time-value of money on the investment decision. Once cost estimates have been generated, they must be time-phased to allow for alternative expenditure patterns. The time value of money is considered by computing present value costs. Present value costs are computed by applying a discount rate to the time-phased expenditure amounts. The present value costs are the sum total of the discounted costs. The present value of $100 payable in two years can be defined as the amount of money necessary to invest today at compound interest in order to have $100 in two years. Thus, present value depends on the rate of interest, the frequency of compounding, and the time horizon selected.

The present value of the alternative is the money cost which would be required to finance the alternative when a specified percentage could be earned, this then represents the "opportunity cost" of capital. Assuming equal benefits, the alternative whose present value cost is least is the more desirable, because it implies a more efficient allocation of resources. The lowest present value cost means that resources are allocated more efficiently in the sense that fewer current resources must be diverted to satisfy the requirement.

The discounting technique requires an analyst to use an interest rate to discount future alternative costs to present values. The present value of x dollars which will be received at the end of n years from now may be computed by use of the following formula:

$$PV = x \frac{1}{(1+i)^n}$$

where i is the applicable interest or discount rate.

It is realized that present value is being considered here in much the same way that it is considered in the private sector of the economy. That is, money not expended on current projects can be invested and will yield investment costs. Some would argue that the Government is not a profit-making concern and present value analysis is inapplicable because money not immediately spent on one project would be spent on another and in no case could it be saved as interest as in the private economy. However, the Federal Government as investor should have as its objective the maximum well-being of the Nation as a whole as reflected in the national income; therefore no public investment should be undertaken when it earns a return which is less than the return on the alternative use of the funds which it absorbs.

Discount Rate Policy. In order to compute net present value, it is necessary to discount future benefits and costs. This discounting reflects the time value of money. Benefits and costs are worth more if they are experienced sooner. All future benefits and costs, including nonmonetized benefits and costs, should be discounted. The higher the discount rate, the lower is the present value of future cash flows. For typical investments, with costs concentrated in early periods and benefits following in later periods, raising the discount rate tends to reduce the net present value. The Office of Management and Budget (OMB) has established an appropriate rate of 7% for most government expenditures.

Other Discount Rates. Analyses should show the sensitivity of the discounted net present value and other outcomes to variations in the discount rate. The importance of these alternative calculations will depend on the specific economic characteristics of the program under analysis. For example, in analyzing a regulatory proposal whose main cost is to reduce business investment, net present value should also be calculated using a higher discount rate than 7 percent.Table 1 lists illustrative discount factors for a discount rate of 7%.

Table 1
Illustrative Discount Factors for a Discount Rate of 7 Percent

Year since Initiation, Renewal or Expansion	Year-end Discount Factors	Mid-year Discount Factors	Beginning-of-year Discount Factors
1	0.9346	0.9667	1.0000
2	0.8734	0.9035	0.9346
3	0.8163	0.8444	0.8734
4	0.7629	0.7891	0.8163
5	0.7130	0.7375	0.7629
6	0.6663	0.6893	0.7130
7	0.6227	0.6442	0.6663
8	0.5820	0.6020	0.6227
9	0.5439	0.5626	0.5820
10	0.5083	0.5258	0.5439
11	0.4751	0.4914	0.5083
12	0.4440	0.4593	0.4751
13	0.4150	0.4292	0.4440
14	0.3878	0.4012	0.4150
15	0.3624	0.3749	0.3878
16	0.3387	0.3504	0.3624
17	0.3166	0.3275	0.3387
18	0.2959	0.3060	0.3166
19	0.2765	0.2860	0.2959
20	0.2584	0.2673	0.2765
21	0.2415	0.2498	0.2584
22	0.2257	0.2335	0.2415
23	0.2109	0.2182	0.2257
23	0.2109	0.2182	0.2257

24	0.1971	0.2039	0.2109
25	0.1842	0.1906	0.1971
26	0.1722	0.1781	0.1842
27	0.1609	0.1665	0.1722
28	0.1504	0.1556	0.1609
29	0.1406	0.1454	0.1504
30	0.1314	0.1359	0.1406

This technique helps the decision maker evaluate whether dimly perceived benefits are worth their present and future costs. The technique can be helpful in making comparisons of the costs of long-range programs that have different time horizons but have equal benefits. In focusing on cost profiles over time, discounting assures that wrong or uneconomical alternatives are not inadvertently accepted.

In discounting, cost estimates are taken as "givers" and future cash flows are then made comparable in terms of their present value. Of course, to do this it is assumed that capital has a cost and that the timing of future cash flows is an important factor to consider. In short, discounting is not a cost estimating technique in the sense that it makes the figures more valid or accurate for the analysis. It is an adjustment to show the cost of capital, computed after the cost analysts use all their techniques to put their estimates together.

Both discounted and undiscounted costs are useful for analysis. Raw (undiscounted) costs are needed by the budgeteers for funding purposes and for determining the obligational authority required to finance proposed investments. Present value costs are necessary for making tradeoff analyses in project and force level selection. Discounting is important for planning.

Treatment of Inflation. Future inflation is highly uncertain. Analysts should avoid having to make an assumption about the general rate of inflation whenever possible.

Real or Nominal Values. Economic analyses are often most readily accomplished using real or constant-dollar values, i.e., by measuring benefits and costs in units of stable purchasing power. (Such estimates may reflect expected future changes in relative prices, however, where there is a reasonable basis for estimating such changes.) However, where future benefits and costs are given in nominal terms, i.e., in terms of the future purchasing power of the dollar, the analysis should use these values rather than convert them to constant dollars as, for example, in the case of lease-purchase analysis.

Nominal and real values must not be combined in the same analysis. Logical consistency requires that analysis be conducted either in constant dollars or in terms of nominal values. This may require converting some nominal values to real values, or vice versa.

Recommended Inflation Assumption. When a general inflation assumption is needed, the rate of increase in the Gross Domestic Product deflator from the Administration's economic assumptions for the period of the analysis is recommended. For projects or programs that extend beyond the six-year budget horizon, the inflation assumption can be extended by using the inflation rate for the sixth year of the budget forecast. The Administration's economic forecast is updated twice annually, at the time the budget is published in January or February and at the time of the Mid-Session Review of the Budget in July. Alternative inflation estimates, based on credible private sector forecasts, may be used for sensitivity analysis.

Treatment of Uncertainty. Estimates of costs (and benefits) are typically uncertain because of imprecision in both underlying data and modeling assumptions. Because such uncertainty is basic to many analyses, its effects should be analyzed and reported. Useful information in such a report would include the key sources of uncertainty; expected value estimates of outcomes; the sensitivity of results to important sources of uncertainty; and, where possible, the probability distributions of costs (and benefits and net benefits).

Characterizing Uncertainty. Analyses should attempt to characterize the sources and nature of uncertainty. Ideally, probability distributions of potential benefits, costs, and net benefits should be presented. It should be recognized that many phenomena that are treated as deterministic or certain are, in fact, uncertain. In analyzing uncertain data, objective estimates of probabilities should be used whenever possible. Market data, such as private insurance payments or interest rate differentials, may be useful in identifying and estimating relevant risks. Stochastic simulation methods can be useful for analyzing such phenomena and developing insights into the relevant probability distributions. In any case, the basis for the probability distribution assumptions should be reported. Any limitations of the analysis because of uncertainty or biases surrounding data or assumptions should be discussed.

Expected Values. The expected values of the distributions of benefits, costs, and net benefits can be obtained by weighting each outcome by its probability of occurrence, and then summing across all potential outcomes. If estimated benefits, costs, and net benefits are characterized by point estimates rather than as probability distributions, the expected value (an unbiased estimate) is the appropriate estimate for use.

Estimates that differ from expected values (such as worst-case estimates) may be provided in addition to expected values, but the rationale for such estimates must be clearly presented. For any such estimate, the analysis should identify the nature and magnitude of any bias. For example, studies of past activities have documented tendencies for cost growth beyond initial expectations; analyses should consider whether past experience suggests that initial estimates of benefits or costs are optimistic.

Sensitivity Analysis. Major assumptions should be varied and net present value and other outcomes recomputed to determine how sensitive outcomes are to change in the assumptions. The assumptions that deserve the most attention will depend on the dominant benefit and cos t elements and the areas of greatest uncertainty of the program being analyzed. For example, in analyzing a retirement program, one would consider changes in the number of beneficiaries, future wage growth, inflation, and the discount rate. In general, sensitivity analysis should be considered for estimates of: (i) benefits and costs; (ii) the discount rate; (iii) the general inflation rate; and (iv) distributional assumptions. Models used in the analysis should be well documented and, where possible, available to facilitate independent review.

Other Adjustments for Uncertainty. The absolute variability of a risky outcome can be much less significant than its correlation with other significant determinants of social welfare, such as real national income. In general, variations in the discount rate are not the appropriate method of adjusting net present value for the special risks of particular projects. In some cases, it may be possible to estimate certainty-equivalents which involve adjusting uncertain expected values to account for risk. .

Requirements uncertainty is most noticed in the development of new systems. That is, when a new system is conceived, its preliminary design seldom turns out to be very similar to the final design. Early estimates of cost for those systems have historically relied heavily upon the preliminary design information. It follows from this that if preliminary characteristics are in error, cost estimates relying on this information will also be in error.

The alternatives analyzed at unit level will not usually involve design considerations and their characteristics do remain constant. However, a cost estimate is still likely to contain error because cost estimating relationships (CERs) cannot be assumed to hold exactly. This means that in estimating a certain cost component as a function of some variable or variables, it is foolhardy to believe that the variables predict the particular cost with certainty.

There are other reasons why cost estimates may be incorrect. For example, errors may be introduced when one is forced to extrapolate beyond the range of the sample or data base from which the estimating relationship is derived. Errors are sometimes introduced by adopting different ground rules. Examples include the use of different discount rates, the use of different price rates, and the use of different price levels expected to prevail in future years.

Sunk Costs and Incremental Costs. If costs have been incurred as a result of past decisions they are known as "sunk costs." Sunk costs should not be included in our cost calculations. Once a decision has been made which causes costs to be incurred, those costs are beyond the control of the current decision. Sunk costs no longer represent any alternative for the decision maker and, if included, would only confuse the decision making problem. The analyst should present only the future cost or "incre-mental cost" of each alternative. These are those increments of cost that will be incurred as the result of choosing one or another of the alternatives available. They may be looked upon as "consequential costs" since they are the consequences of the decision makers current choice.

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