5.0 COST RESEARCH AND APPLICATION OF HISTORICAL DATA

5.1 Introduction

In Chapters 2 and 3, the entire cost estimating process was outlined. Chapter 4 addressed the planning stage of estimating. It discussed the preliminary steps in preparing an estimate: determining the purpose and scope of the estimate; describing the system in technical and programmatic terms; determining estimating constraints like cost, schedule, and time; establishing the estimating framework or work breakdown structure (WBS); and choosing the methodology best suited for each cost element. Once these steps have been accomplished, it is time to start building the estimate.

Most sound cost estimates are logical extrapolations of actual cost experience, usually called historical cost data. Cost data are really the raw materials or the basic building blocks of the estimating process. Therefore, the collection and processing of historical cost data are early and key steps in developing a cost estimate. The first half of this chapter describes cost data considerations and data sources. In the second half of the chapter, the normalization process is explained thoroughly and includes detailed equations and the actual mechanics of index number construction and usage. The chapter concludes with a discussion of normalization for reasons other than economic changes.

5.2 Cost Data Considerations

Analysis of what and how cost data should be used requires an understanding of the different levels of data, the value and limitations of the data, and the applicability of the data.

5.2.1 Levels of Data: Primary versus Secondary Data

Most dictionaries define primary as: 1) original, 2) occurring first in time, and 3) first or best in degree, quality, or importance. Secondary, on the other hand, is defined as: 1) the second rank, 2) derived from what is primary, and 3) a secondary source, minor, lesser. From these simple definitions, it appears that primary sources are preferred to secondary. This tends to be true for cost data because the makeup of primary data is usually easier to track and therefore easier to understand. Secondary data, by definition, are derived from primary data that may have been manipulated many times. To use it with confidence, a cost estimator must be able to track the data back to its original configuration.

To distinguish primary from secondary data, an estimator needs to determine the source of the data. Primary cost data, by definition, are found at an original source. For instance, the original source for manufacturing labor hour data is the end-item manufacturer, while test centers represent the original source for range operations cost data. Logistics centers are the prime source of depot-level maintenance data, and operating organizations collect and report information regarding the cost to operate their particular function. There are two main methods of obtaining primary cost data - reports produced by an original source and on-site data collection.

Secondary cost data are derived from primary or other secondary data sources and altered for new purposes. Documented cost estimates that identify actual costs from a primary source for a particular system would be considered sources of secondary data. The data are secondary for one of two reasons: it has been altered in some fashion or it is used in a new setting. In any event, the source of secondary data should be referenced in the estimate, so that an estimator may trace the data back to assess its usefulness in a new estimate. Many times, adjustments may be made to primary cost data to allow for differences in work content, normalization for inflation, or other types of manipulations with the results reflected in the secondary data. For example, factors identified in a documented estimate may have been derived from primary data, with appropriate adjustments made to fit the factor to the estimate. To assess the usefulness of that factor in a new estimate, an estimator needs access to the primary data.

SECONDARY DATA SOURCES:

- Documented cost estimates (including contractor proposals)
- Cost studies/research that compile cost data from various sources
- Cost improvement curve slopes or other cost measurements (without the primary data for support)
- Subcontractor cost data provided by the prime

Although primary cost data have the advantage of clarity of origin and therefore makeup, there are situations that dictate the use of secondary data. Some examples are listed below. The primary versus secondary data consideration should be evaluated early in the cost estimating process. The by-exception decision to use secondary data can be made if the elements of time, use, and availability make it the smart choice.

SITUATIONS WHERE SECONDARY DATA ARE ADVANTAGEOUS:

- When it is inefficient to duplicate time-consuming efforts.

A study is available that compiles historical cost improvement curve slopes on systems produced in the 1980s. Primary data are available to do the same; however, the methods employed for conducting the original study are known and acceptable.

- When primary data are not easily accessible.

Cost reporting was not provided on a particular Firm Fixed Price (FFP) contract, but a government team was able to obtain actual cost data during an earlier fact-finding visit. These data are fully documented in a cost estimate.

- When sufficient time is not available.

The cost team has access to a set of factors that was calculated previously from various Cost Performance Reports (CPRs), and time is not available to reconstruct a similar set of factors.

- Data are needed for a top-level test of reasonableness only.

Unit costs for a variety of electronic systems are available from secondary sources. This data will be used as a test of reasonableness only against the black box being estimated.

5.2.2 Value and Limitations of Historical Data

> NOTE:
> Historical data generally form the basis of any cost estimating task.

In addition to the primary/secondary decision analysis, historical data must be viewed in perspective. The value of historical data in the construction of individual cost estimating relationships (CERs), complex models, and estimating cannot be overemphasized. Historical cost data not only give the estimator insight into actual costs on similar systems from a variety of contractors to establish generic system costs, but also help establish cost trends of a specific contractor across a variety of systems. Historical data also provide contractor cost trends relative to proposal values versus negotiated values, allowing the estimator to establish adjustment factors when using proposal data for estimating purposes. Additionally, insights into cost accounting structures to allow understanding of how a certain contractor charges for other direct costs (ODCs), overhead etc., can be obtained from examination of historical data.

As can be seen from the foregoing discussion, cost data are essentially the raw materials, the basic building blocks, of the estimating process. However, because of its historical nature, this cost data also inherently contain the associated technologies of the past. As a result, some of the limitations are inherent. Therefore, diligent care always should be exercised when using historical cost data. For example, when using historical cost data for an analogous estimate, the estimator must make appropriate adjustments to account for differences between the new system and the existing system with respect to design characteristics, manufacturing processes (automation versus hands-on labor), types of material used, and other parameters.

Cost estimators should have a thorough understanding of the historical data used in conducting the estimate to ensure a totally credible product. Identifying limitations early in the data research phase will avoid spending valuable time collecting cost data that are not applicable to the estimate. The next section expands the discussion of cost data limitations by focusing on its applicability to a specific effort.

5.2.3 Applicability of Data

To determine the applicability of data to a given estimating task, the estimator must scrutinize it by asking the following questions:

- Do the data require normalization to account for differences in base years, differences in inflation rates, or differences resulting from a calendar year versus fiscal year accounting system (many contractor systems are based on a calendar year)?

- Is the work content of the current cost element consistent with the work content of the historical cost element?

- Do the data reflect actual costs, proposal values, or negotiated prices, and has the type of contract been considered?

- Are there sufficient cost data available at the appropriate level of detail for use in statistical measurements?

- Are cost segregations clear so that functional elements (e.g., engineering, manufacturing) are visible and recurring costs are separable from nonrecurring?

- If the data are presented in dollars versus direct labor hours, what do these costs represent? Are the costs direct or indirect? Are the dollars burdened with overhead, G&A, and/or fee? What adjustments to the cost data are required to account for these factors?

Taking these items into consideration, the estimator may have to adjust the data to make it applicable to the needs at hand, or he may realize at this point that more suitable data are needed. Alternatively, if data are not available, the estimator may have to choose a different estimating methodology.

This concludes the discussion of some of the considerations an estimator faces when collecting data. In short, before starting the data collection process, the estimator must decide on data sources (primary or secondary), assess the usefulness of historical data, and then subject the data chosen for an estimate to a thorough analysis to decide whether it applies to the estimate at hand. To increase the likelihood of finding suitable data, a thorough knowledge of available data sources is important.

5.3 Sources of Data

When conducting research to support a cost estimating effort, an estimator may find that one piece of information leads to another, which leads to another and so on. The amount of data may, in fact, seem endless. The key is to locate the most appropriate data sources within the time constraints of the project so that the data retrieved are applicable to the task at hand. This section will address types of data and data repositories. Although not exhaustive, the sources provided cover the most applicable and frequently used. Appendix 5A is a detailed list of data sources with telephone numbers.

5.3.1 Published Data and Databases

A good estimator must become familiar with data sources and how to conduct research in general. The Federal government has immense quantities of information available. Libraries are, of course, one source of information. Online sources of information are growing continually. New databases and information are made available daily on the World Wide Web by the government and industry. Internet search engines have become very user-friendly and make the retrieval of information easier and more efficient. Much of the information listed in Appendix 5A below about sources can be found by calling the organizations responsible for the data, but often the data will be available online. One useful online source with links to numerous other online sources of cost estimating information is the home page for the Society of Cost Estimating and Analysis.

General Sources of Information

Government

The FAA, Census Bureau, Bureau of Labor Statistics (BLS), Bureau of Economic Analysis, and many other agencies collect, maintain, and report pricing data on thousands of products, services, and commodities. This information is often in the form of indices that can be used to adjust current data to reflect historical information.

The National Technical Information Service (NTIS) is a non-appropriated bureau within the Technology Administration of the U.S. Department of Commerce that serves as the nation's clearinghouse for information produced by and for the U.S. government. This service has extensive resources that could be of benefit to the estimator. The estimator will find cost estimating models, documented cost estimates, documented CERs and the like through NTIS. The NTIS can be reached at 1-800-553-6847.

Various Department of Defense (DoD) services have extensive amounts of cost data. This information is very useful in estimating many FAA programs, as there is often similarity and even overlaps between DoD and FAA systems. For instance, the U.S. DoD acquired the Global Positioning System (GPS) for military purposes, but it is now being used around the globe for civil and military purposes. This global use of GPS necessitated that the FAA evaluate the feasibility of using local area augmentation systems to enable the use of GPS rather than Instrument Landing Systems at some airports. DoD data might be very useful in helping estimate the costs of such systems. In another example, the Defense Communications Agency has established the cost of communication systems, including cost estimating relationships and actual costs of systems like microwave systems, satellite communication systems, cable systems, fiber optic systems, etc.

Each DoD service has a cost center located in the Washington, D.C., area. The cost centers have their own libraries and can provide information about other libraries located at lower level organizations within each service. The phone numbers of each cost center are listed in Table 5.1.

Table 5.1 DoD Information Sources

Air Force Cost Analysis Agency	(703) 604-0387
Naval Center for Cost Analysis	(703) 604-0312
Army Cost and Economic Analysis Center	(703) 681-3217
Defense Systems Management College Library	(703) 805-2293
Defense Technical Information Center	(800) 225-3842

The DoD also has other resources in the Washington, D.C., area that may prove useful to an estimator. The Defense Technical Information Center (DTIC) is an excellent source of information on DoD research of all types. The Pentagon and the Defense Systems Management College (DSMC) also operate excellent libraries. Libraries like these have assigned librarians to help with online searches for information.

Private Sector Cost Estimating Sources

There are many private sector sources of information. For example, there are econometric forecasting services like Data Resources, Inc. (DRI) that publish information on specific industries and sectors of the economy. The Standard Research Institute has information on industry learning curves. Associations are also a rich source of information on specific industries. A detailed list of industry sources is provided in Appendix 5A.

<u>Specialized Sources of Cost Data</u>

Sources of Labor Information

There are two superior sources for wage information: Watson Wyatt Data Services and the BLS. BLS publications cover fewer geographic areas and are disaggregated by broader categories of occupations. Watson Wyatt Data Services publishes seven reports that cover many specific occupations.

The BLS's *Employment and Earnings* publication contains average wage rates for a variety of labor skills. These labor categories are referred to commonly as Standard Industrial Classification (SIC) codes. There are further breakdowns by geographical region. The *National Survey of Professional Administrative*, *Technical and Clerical Pay*, a BLS publication, is a source of pay rate changes.

Sources of Material Information

The BLS publishes annually the *U.S. Industrial Outlook* that contains 5-year projections of prices for the top 500 industries.

Sources of Industry Information

There are numerous trade associations and publications that list useful information as well. The Aerospace Industries Association of America publishes quarterly aerospace economic indicators, including an aerospace composite price deflator. The Electronic Industries Association publishes monthly market trends and an annual data book.

<u>Construction</u>

There are several widely known indices of construction costs. The American Appraisal Company publishes the Boeckh indices, which represent construction costs for three types of buildings: 1) apartments, hotels, and office buildings, 2) commercial and factory buildings, and 3) residences. The *Engineering News Record* publishes monthly a Building Cost Index for 20 U.S. cities, which represents the price of constant quantities of skilled labor, structural steel, lumber and cement.

5.3.2 Documented Cost Estimates

Documented cost estimates may provide useful data for a current estimate. Referring to a previous estimate can save the estimator valuable time by eliminating the need to do research and conduct statistical analysis, provided an acceptable database already exists. For instance, a documented program estimate may provide the results of research of contractor data, development of usable CERs, or actual costs on the system. Properly documented estimates normally detail the WBS and describe each area of the estimate. This information can set the stage for the current estimate. An update is usually easier than starting from scratch. Referring to estimates on systems other than the one being estimated can also provide valuable information for the purposes of analogy estimating, understanding various contractors, and providing gross checks of reasonableness.

Because these cost documents are secondary sources of information, the estimator must understand the primary data fully. For example, if a documented estimate lists factors (ratios) for data cost for a variety of programs, the estimator should understand the development of those factors before selecting one to use in the current estimate. An analysis to determine the validity of using the factor for the current estimate should include the following types of questions.

- What was the base used in the ratio? If data cost was estimated as a percent of design hours, then that is how the estimator would apply that factor in the current estimate.

- Are WBS elements similar to the system being estimated (e.g., is data management included in the Data or the Systems Engineering/Program Management (SE/PM) element? The estimator would want to use the same assumptions in the current estimate.

- What were the precise elements used in computing the factor? For instance, was the factor based on actual costs or on estimated costs?

Previous cost estimates as a data source can provide useful information and save the estimator time by helping the estimator determine what has been accomplished already and, therefore, avoid redundancy. It is not a panacea, however, and should be used recognizing its inherent limitations.

5.3.3 Contractor Proposals

The basic thing to remember when using a contractor proposal as a source of data is that it is a contractor proposal. That is, the document includes the contractor's estimate of cost. Because of this, the estimate within a contractor's proposal should be treated in the same manner as a documented cost estimate discussed in the previous section. Additionally, it is important to remember the business motivations of the contractor. In a source selection environment, for instance, the contractor may buy-in with a low bid to ensure sole source business with later follow-on production options. Analyzing the cost data in light of the acquisition strategy is crucial to the credibility of the estimate.

Keeping the above in mind, a proposal document can provide a plethora of useful information and should be reviewed when available for the following:

- Structure and content of the contractor's WBS
- Contractor actual cost history on the same and/or other programs
- Negotiated bills of material, subcontracted items
- Government Furnished Equipment versus Contractor Furnished Equipment lists
- Contractor unique rate and factor data
- A self-check to ensure inclusion of all pertinent cost elements
- Top level test of reasonableness
- Technological state of the art assumptions
- Management reserve/level of risk

As with any documented cost estimate, detailed analysis of the proposal data is very important to ensure proper application to the estimating task at hand. This becomes especially important when dealing with contractor proposals.

5.3.4 Other Organizations and Agencies

The scope of the estimate may dictate the need to consult other organizations for raw data or to request actual accomplishment of pieces of the estimate. Once government test facilities are identified, for example, those organizations can be contacted for current range cost, test airplane cost, data reduction cost, etc. Of course, the level of detail required would also influence the decision to contact outside agencies. At a minimum, the estimator must know the breadth of these available data sources. The decision to use them, as with all sources, is dependent upon the peculiarities of the estimating task.

5.3.5 Catalogs

Manufacturers publish catalogs, handbooks, and other reference books containing lists of off-the-shelf or standard items with price lists or labor estimates. Typically, these catalogs contain various combinations of the following data - a general description of the item, stock number or part number, technical description, dimensions, location of distributors, index of items, price, and/or number of hours. In some cases, where prices and/or hours are not identified, price lists can often be obtained from a local distributor.

5.3.6 Rate and Factor Agreements

Rate and Factor Agreements (sometimes referred to as Forward Pricing Rate Agreements [FPRA]) contain rates and factors agreed to by the contractor and the appropriate government negotiator. Due to the fluid nature of the contractor's business base, which has a direct impact on these rates and factors, these agreements are not always in existence. That is, the contractor may choose not to enter into such an agreement with the government. When they do exist, they are bilateral in nature and can be canceled by either party. When available, they can provide an excellent source of information for the estimator.

Information contained in rate and factor agreements represents negotiated direct labor, overhead, General and Administrative (G&A), and Facilities Capital Cost of Money (FCCOM or sometimes further abbreviated as FCOM or COM). These agreements could cover myriad factors, depending upon each individual contractor's accounting/cost estimating structure. Typical factors included are: material scrap, material handling, quality control, sustaining tooling, and miscellaneous engineering support factors. Each would be expressed in terms of a percentage of some type of base. For example, quality control may be expressed as a percentage of direct manufacturing hours.

This type of rate and factor information could be used in a detailed estimate by the government estimator to estimate a discrete area such as sustaining tooling, as a factor, or in the construction of detailed wrap rates. It may also be appropriate to use this information for tests of reasonableness on completed estimates.

5.3.7 Historical Cost Data Reports

The DoD has been collecting cost data from contractors since World War II. At that time the reports were called the *Aeronautical Manufacturers Planning Reports* (later changed to *Defense Contractor's Planning Report*). These were superseded by the *Cost Information Reports (CIR)* in 1966 and by *Contractor Cost Data Reporting (CCDR)* in 1973. Both CIR and CCDR are similar in nature and, for estimating purposes, can be used interchangeably. The latest CCDR information and definitions of the data elements are in DoD Directive 5000.2M.

> NOTE:
> In addition to the CCDR, the estimator should be aware of the *Cost Performance Reports* (CPRs) and *Cost/Schedule Status Reports* (C/SSRs) that are also available in cost libraries. These reports are particularly useful to the estimator in determining the ratio of the supporting WBS elements to the main deliverable hardware. They also can be useful in determining the trends existing during an ongoing program as a prediction of future behavior of the program. This subject is discussed in some detail, with examples, in Appendix 5B.

The DD Form 1921 (*Cost Data Summary Report)* is used to collect recurring and nonrecurring costs for selected WBS elements. The contractor is not required to segregate recurring/nonrecurring cost if the anticipated nonrecurring is less than 5 percent of the total contract. The report is split into to date costs (or costs incurred) and at completion costs, which are estimates. The estimates are for planning purposes only and are not binding on the contractor.

The DD Form 1921-1 (*Functional Cost Hour Report*) is designed to collect and identify functional costs, such as engineering, tooling, manufacturing, etc., for specific contracts. It contains to date costs, estimates for the following fiscal years, and quantities specified for the total program. These can be specified separately for recurring, nonrecurring, and total costs.

The DD Form 1921-2 (*Progress Curve Report*) provides a unit or average unit cost during the reporting period. This is the report used to generate cost improvement curves. Only recurring costs are reported for significant hardware elements having tasks that are subject to improvement or learning.

The DD Form 1921-3 (*Plant Wide Data Report*) is not reported by contract, but by total plant. Total plant is defined as a facility with common overhead rates. This report is a standardized overhead report.

5.3.8 Plant Visits

Plant visits and face-to-face discussions with contractor personnel are additional sources of data. The estimator may need to visit the contractor's plants to obtain data for several reasons. They include fact finding proposal estimates, performing what-if exercises, estimate restructure planning, and cost overrun investigations. The estimator may be far less welcome when investigating overruns than when fact-finding proposal estimates. In either case, estimators must be prepared to pursue critical information in a timely manner.

The following is a list of suggestions for estimators to use when visiting a contractor plant. The list is based on lessons learned and successful past cost data collection efforts.

- Be sure all team members are familiar with the product and program prior to the visit. This will save valuable time at the plant. Technical and management personnel in the program office usually can provide such information. Program schedules should be reviewed and understood. Estimators should know generally how the system would function.

- Obtain program office concurrence with respect to the purpose and timing of the visit. The program office should be the first to inform the contractor of the pending visit. The program office should have the contractor identify the company's focal point for the visit.

- Contact the contractor's focal point to convey clearly the nature and scope of the data sought. It is even better to provide the contractor with a detailed written list of questions prior to the visit. The dates of the planned visit should be arranged with the contractor's focal point to assure that key contractor personnel will be available during the visit.

- Send a formal visit letter or message to the contractor. It should include:

  ⇒ The authority and reason for the visit
  ⇒ A list of cost team members and their areas of interest
  ⇒ A proposed agenda with dates
  ⇒ Working space and telephone requirements
  ⇒ Detailed information/data requirements
  ⇒ Name and telephone number of cost team chief or visit focal point

- Organize the cost team prior to the visit. Make sure everyone knows and understands the overall objectives of the visit and their specific responsibilities. If a report is planned, it should be outlined and appropriate parts assigned to each estimator.

Interview checklists should be prepared to assure all interviews are carried out in a complete and consistent manner.

- At the beginning of the visit, give contractor personnel a short briefing - reviewing and expanding on the material contained in the visit letter or message mentioned earlier.

- Limit the contractor's in-briefing on the program and his associated plans and activities. Get the interview process started as soon as possible. Be aware that some contractors may want to provide extensive briefings and plant tours rather than provide the desired detailed cost data. The cost team chief must be prepared to limit such activities in order to ensure there is enough time to accomplish the visit objectives.

- Have the contractor provide a list of personnel expected to have the desired data and their telephone numbers. For cost overrun investigation visits, a list of cost account managers is essential. Many cost account managers will be engineering and manufacturing managers who can provide a more accurate and timely picture of problems than financial reports and financial personnel can.

- Be sure to use the checklist during all interviews. Be persistent in getting data not provided during interviews before leaving the plant.

- Review all data provided as soon as possible so that the appropriate follow-up questions can be asked during the visit. This is one reason it is desirable for plant visits extend over several days.

- Hold short daily cost team meetings to discuss progress and problems.

- Schedule and hold an out-briefing to review the results of the visit with the contractor's program manager. Address any open issues concerning unanswered questions or missing data.

Plant visits are a very important potential source of cost and program information of value to the estimator. Conducting a professional, well-organized plant visit can yield a wealth of information not otherwise available.

5.4 Normalization (Accounting for Economic Changes): Theory

The preceding sections focused on the accumulation of applicable cost data from a variety of data sources for use in the cost estimating process. Since raw data come from a variety of sources, there is generally a lack of uniformity in data and therefore a need for normalization. The Society of Cost Estimating and Analysis (SCEA) provides the following definitions for “normalize”:

- To adjust a measured parameter to a value acceptable to an instrument or technique of measurement.

- To normalize a database is to render it constant or to adjust for known differences.

- For cost or dollars, normalization means that the dollars are expressed in a common base year for comparison.

This section will address the elimination of inflationary or deflationary impacts contained within historical accounting cost data. This process is referred to commonly as normalization for economic changes. Cost data can be normalized for other influences, and these are addressed in Section 5.6.

5.4.1 Using Indices to Express Data on a Common Basis

The fact that the price of goods and services changes over time requires the development of estimating approaches to accommodate that change. The statistical mechanism that has been developed to measure the effect of the changing value of the dollar over time is called an index number. Index numbers are classified into three different types: quantity, value, and price. Quantity indices measure changes in some volume characteristic while value indices measure change in some other criterion of value (e.g., the change in total dollar value of FAA contracts awarded annually). Because the estimator is concerned with obtaining uniform cost or price data, the following text will be limited to the subject of price index numbers.

An index number of prices shows the percentage change of prices from one point in time to another. For example, the Consumer Price Index measures changes in retail prices paid for goods and services. Index numbers are expressed in percentages rather than dollars for two reasons:

- To negate any bias that may result from large dollar value item price changes receiving more weight than equivalent price changes in small dollar value items (e.g., a $50 increase in a $100 item is equivalent to a $1 increase in a $2 item in percentage terms even though there is a $49 difference in relative terms); and

- To allow price change comparisons over time for aggregates of different items.

The percentage change in the price of a single commodity from one time to another is called the price relative. An index number of the prices of a number of commodities is an average of their price relatives. To summarize, a price index number is used to indicate price movements in time.

Most often, index numbers are used to characterize time series phenomena. A time series is business data that are collected sequentially over time (e.g., raw cost data collected on a daily, weekly, monthly, quarterly, or yearly basis). A group of index numbers that provide a measure of
change relative to a fixed point in time is called an index series. The fixed point in time from which all price relatives are calculated is called the base period of the index. Index numbers are used to deflate or inflate prices to facilitate comparative analysis. By negating the impact of inflation that has occurred over time, the estimator is able to make comparisons on a constant

year or "real" dollar basis; therefore, real program cost growth is tracked as opposed to that caused by inflation.

Index numbers are also used by cost/price analysts in the preparation of Economic Price Adjustment (EPA) clauses. These clauses are used to shift the risk of significant unanticipated fluctuations in the economy to the government. Normally, contracts include contingency dollars to cover this cost growth risk, but on major production buys where there are long performance periods, the degree of risk and associated contingency dollars can become excessive. EPA clauses can help mitigate this cost risk. EPA clauses contain an index series tailored to the specific commodity being purchased. The index series projects anticipated inflation over the contract period of performance. The clause also contains a mechanism to adjust contract costs to reflect differences between projected and actual price levels at the time of contract performance

5.4.2 Index Number Construction

A number of major indices are published by the U.S. Department of Labor, BLS to accommodate special purposes. Each has its own unique formula. Nevertheless, the special methods employed are based on standard methods of index number construction. The types of indices, classified according to the method of construction, are:

- Simple Index
- Composite Index
  ⇒ Simple Aggregates Price Index
  ⇒ Weighted Aggregates Price Index
- Laspeyres
- Paasche

Simple Index

A simple index measures the relative change from the base period for a single item. To determine a simple index in any time period, the price in a given time period, Pn, is expressed as a ratio to the price in the base period, Po, multiplied by 100. This is written algebraically in Equation 5.1 (per J. G. Van Matre and G. H. Gilbreath in their book *Statistics for Business and Economics*, Business Publications Inc., 1980).

Equation 5.1

$$SI_{n/o} = P_n/P_o\,(100)$$

Po = Price of an item in the base period
Pn = Price of an item in any other time period
o = Base period
n = Any time period other than the base period

For example, if the average retail price of copper is $2/lb. in 1980, $2.50/lb. in 1981, and $3/lb. in 1982, a simple index of price using 1980 as the base is illustrated in Table 5.2.

Table 5.2 Simple Index for Copper

Year	Price/ Lb.	Percentage Change From 1980	Index (1980=100)
1980	$2.00	0	100.0
1981	$2.50	25	125.0
1982	$3.00	50	150.0

Four basic characteristics of index numbers are illustrated by the above example.

- The index for the base period is 100.
- The price of the item for which the index is formulated must be expressed as a price per measure of quantity (e.g., $/lb., $/sq. ft, $/month). Indices using completely different measures of quantity can be combined.
- The change in the value of the index from the base period to any given period is simply a measure of percentage change from the base period (for simple indices).
- The change in the value of an index for two periods does not indicate percentage change unless one time period is the base period. An index number provides a measure of change from the base period only.

<u>Composite Indices</u>

The items that must be estimated are composed of many different types of material and labor elements. Material and labor prices vary at different rates over time. Thus, a single simple index number is insufficient to reflect the aggregated price changes occurring to the elements that make up any end-item being costed. To overcome this problem, it is necessary to construct composite indices. A composite index measures relative change from the base period for a group of closely related items. The four basic forms of composite indices were outlined previously and are discussed here in greater depth.

Simple Aggregates Price Index (SAPI). The simple aggregate price index is derived by totaling the sum of all the actual prices for a given year and dividing this by the sum of the prices for the base year. Using the information generated in the previous examples and contained in Tables 5.2 and 5.3, the SAPI is obtained by the following steps:

- Step One. Add together the actual prices for all items in the year for which the index is being calculated.
- Step Two. Add together the actual prices for all items in the base year.
- Step Three. Divide the results from Step One by the results of Step Two and multiply by 100.

Table 5.3 Simple Index for Steel

Year	Price/LB.	% Change from 1980	Index (1980=100)
1980	$300	0.0	100.0
1981	$330	10.0	110.0
1982	$350	16.7	116.7

The SAPIs for 1981 and 1982 are 110.1 and 116.9, respectively. The actual calculations are shown below.

$SAPI_{81/80}$ = [($2.50 + $330.00)/($2.00+$300.00)] (100)
= [($332.50/$302.00)] (100)
= 110.1

$SAPI_{82/80}$ = [($3.00 + $350.00)/($2.00+$300.00)] (100)
= [($353.00/$302.00)] (100)
= 116.9

The algebraic formulation for the above procedure is shown in Equation 5.2.

Equation 5.2

$SAPI_{n/o} = (\Sigma P_n / \Sigma P_0)\ (100)$
n = Number of different items contained in the composite

When comparing the results of the SAPI calculations with the individual simple indices for copper and steel, you will note that the SAPI is very close to the simple index for steel. This comparison illustrates the severe bias towards higher-priced items contained within the SAPI formulation. Different units of measurement for various items further amplify this bias. If the SAPI computations are repeated with steel prices converted to dollars per pound to be consistent with the quantity measurement for copper, the results for 1981 and 1982 are 124.0 and 147.7, respectively. The variance in results is substantial, yet both calculations are correct based on the SAPI formulation. The weighted index that follows results from the application of a weighting system to SAPI.

Weighted Aggregates Price Index (WAPI). The relative of WAPI uses a weight, such as quantity, applied against the price of that item. To build this type of index, it is necessary to collect weighting data as well as price data for the different items to be aggregated. Returning to the previous example, assume that 1,000 pounds of copper and 500 tons of steel were consumed in the base year of 1980. To obtain the WAPI, the following steps are necessary:

- Step One. Calculate the weighted price of each item for each year by multiplying the price of each item in each year by the quantity consumed in the base year.
- Step Two. Sum the weighted prices of each item by year.
- Step Three. Divide the results of Step Two by the weighted prices for the base year period.
- Step Four. Multiply the results of Step Three by 100.

This procedure is demonstrated in Table 5.4.

Table 5.4 Weighted Aggregates Price Index for Copper and Steel

ITEM	(1)	(2) PRICE	(3)	(4) QTY	WEIGHTED PRICE (Step 1)		
					(1)x(4)	(2)x(4)	(3)x(4)
	1980	1981	1982				

Copper	2.00	2.50	3.00	10,000	20,000	25,000	30,000
Steel	300.00	330.00	350.00	500	150,000	165,000	175,000
Total (Step 2)					170,000	190,000	205,000
(Step 3)					170,000 / 170,000	190,000 / 170,000	205,000 / 170,000
(Step 4)					1.000 x 100	1.118x100	1.206x100
RWA Index					100	111.8	120.6

Algebraically, the procedure is shown in Equation 5.33.

Equation 5.3

$$WAPI_{n/o} = [(\sum (P_nQ_o) / \sum (P_oQ_o)] * 100$$

Q_o = Base period quantity weights

The index calculated measures the relative change in price that must be paid for the base year bill of goods in another time period. A weighted aggregates price index that uses the original base period weights for the calculation, as above, is called a Laspeyres Index. A second method of computing a relative of weighted aggregates index, called a Paasche Index, uses weights computed for the period at which the index is being calculated. Still a third method employs weights for a neutral period (i.e., a period that is neither the base period nor the period being indexed). The specifics of the calculations for the latter two types of indices are not detailed due to their less frequent usage. Many of the major indices, such as the Consumer Price Index and Producer Price Index (PPI), are computed by modifications of the Laspeyres formula. The popularity of the Laspeyres methodology stems from the simplified data-gathering task, since only base year quantity data are required.

5.4.3 Selecting the Appropriate Index Construction

Equipped with the knowledge of theory and construction for simple index numbers and four types of composite index numbers, the estimator can now turn to practical application considerations. This section will address selection of the appropriate index construction methodology while sections 5.5 and 5.6 talk to its application in real world situations.

The fundamental purpose of an index number is that it fairly represents, so far as one single figure can, the general trend of the many items (e.g., market basket) from which it is computed. With this thought in mind, a review of each type of index number is in order to discover the most suitable for cost estimating applications. The simple index number is a price trend time series for a single item. Since most cost estimating tasks revolve around items composed of multiple material and labor categories, the ability of this index type to represent changes is severely limited and thus will seldom be used. Obviously, composite indices are more representative for most cost estimating tasks.

The first type of composite index is referred to as a simple composite index. The disadvantage of simple composite indices is that they implicitly assign equal weights to all items. The SAPI method is a composite of absolute prices; therefore, with each item receiving equal weight, the higher-priced item will influence the total price more than the lower-priced items. There is a built-in bias towards higher-priced items. To eliminate these biases, an explicit weighting system must be employed. This is the case in the last type of composite index, the WAPI.

Even with WAPI, one question remains.

- What weights should be used?

To address this question, the amount of an item consumed or purchased is the most commonly used weighting. Whether this weighting is determined from base year, given year, or neutral year consumption data is a decision made by the index preparer based primarily upon data availability. Remember, the WAPI methodology can use any weighting period, but a lack of consumption data results in the vast majority of published indices being computed with base year weightings. It should be emphasized at this point that with few exceptions, estimators do not prepare true indices in the same sense that say, the BLS does. Rather, the estimator takes previously prepared indices for material and labor and recomposites them to develop a peculiar index that is most representative of the particular item being costed. The weighting values applied in the formulation of this peculiar index are derived from the percentage consumption of particular material or labor categories in the making of the end-item being costed.

5.4.4 Shifting the Base Year (Rebasing)

The base period of many major indices is changed occasionally in order to reflect current trends and economic activity. For example, the BLS usually changes the base year period every ten years. A change of base period may also be desirable for measuring changes from a fixed time period, other than the base period, and for comparing indices that do not have the same base period. The base year of an index is shifted by dividing the index number of any given period by the index number of the desired new base year and multiplying the result by 100. An index series with base year 1976 is shifted to a new base year of 1980 in Table 5.5. A shift of the base year in no way affects the information relayed by the index, it simply facilitates its usage in a particular set of circumstances.

Table 5.5 Base Year Shift from 1976 to 1980

(1) Year	(2) Old Index (1976=100)	(3) New Index (1980=100) (2) / 113.0 × 100
1974	92.1	81.5
1975	95.7	84.7
1976	100.0	88.5
1977	101.4	89.7
1978	107.3	95.0
1979	112.8	99.8
1980	113.0	100.0
1981	116.2	102.8
1982	119.1	105.4

5.4.5 Common Index Series Used in Cost Estimating

When conducting a particular analysis, the estimator will, in most cases, rely upon previously constructed price index numbers rather than undertake construction of a new index. These published indices can be tailored to reflect anticipated price changes for a specific item through the use of weightings derived from the composition of the item being costed. This weighting process can help to alleviate the inherent error resulting from the use of generic composite indices whose composition is different from the specific item being estimated. There are numerous price indices published by private and governmental sources. Refer to Appendix 5A for a detailed list of cost data sources.

Government Indices

The BLS and the Bureau of Economic Analysis are two rich sources of free price index information. The OMB provides guidelines to government agencies on inflation assumptions to use for budget inputs.

OMB Guidelines to Federal Agencies

The OMB requires that budget estimates use the economic assumptions provided by OMB. OMB publishes its assumptions twice a year, at the time the budget is initially published in January or February and at the Mid-Session Review in July. The general inflation assumption is the rate of increase in the Gross Domestic Product deflator.

Gross Domestic Product Chained Price Index

The Gross Domestic Product (GDP) chained price index covers the prices of all goods and services included in GDP, so it is the most comprehensive indicator of price level. In addition, it is less sensitive to economic shocks than national product indices because it includes only domestically produced goods. The Department of Commerce publishes it in the *Survey of Current Business*. This is the best single measure of changes in the general price level. The chained index is the result of the Bureau of Economic Analysis's revision of GDP weighting.

$$\text{Gross Domestic Product Deflator} = \frac{\text{Nominal GDP}}{\text{Real GDP}}$$

The weighting methodology was revised to improve the accuracy of measurement of national output. The old methodology (GDP deflator) used fixed weights that biased measurements. Chain-weighting calculates a geometric mean of figures from adjacent periods to derive an index number. The result is a direct measure of inflation, in contrast to the GDP deflator that is an implicit measure.

The Consumer Price Index

The Consumer Price Index is published by the BLS in the *Monthly Labor Review*, and it uses a fixed mix of goods and services used in day-to-day living at retail prices. This is the best measure of the price level for changes in the purchasing power of consumers.

Economic Sector Price Levels

Price levels of sectors of the economy represented by the various components of the GDP are measured by the respective deflator for the component. For example, there are deflators for fixed investment, nonresidential structures, and government purchases of goods and services. These deflators are also published in the *Survey of Current Business*.

Producer Price Indices

The BLS publishes the Producer Price Indices. These are indices for prices of specific products and commodities. There are indices at various levels of aggregation ranging from individual products up to a general aggregation for total United States production. For instance, there are indices for coal, coke, gas fuels, electric power, crude petroleum, refined petroleum products, and a composite of them. Also contained in these price indices are electric and electronic devices, and indices for SIC code industries. The estimator can choose the most appropriate index from a multitude of indices for numerous products at various levels of aggregation.

Labor Costs

The most appropriate index to escalate labor cost is the Employment Cost Index (ECI), published by the BLS. There are several permutations of the index. ECI is calculated for many broad classifications of occupations, such as white-collar workers. In addition, many disaggregations are broken out by wages, benefits, and total compensation that include wages and benefits.

The BLS' *Employment and Earnings* publication contains average wage rates for a variety of labor skills. These labor categories are commonly referred to as SIC codes. There are further breakdowns by geographical region. The *National Survey of Professional Administrative, Technical and Clerical Pay*, a BLS publication, is a source of pay rate changes.

There are various data series available, thus it must be left to the individual estimator to conduct further research to find specific time series that are most applicable to a particular estimating task.

5.5 Normalization (Accounting for Economic Changes): Application

Section 5.4 described the theory and mathematical construction of index numbers. This section will focus on the practical application of this theory to eliminate the effects of inflation on historical data.

5.5.1 Base Year

The first step is to establish an appropriate base period for data normalization. Normally the data are expressed in the base year of the program being estimated. A base year is a fiscal year whose midpoint is selected as a reference point for computing an index; a program base year is usually the year of initial program funding. Normalizing to the program base year facilitates the analysis of data on a comparative basis during the cost estimating process.

This section will expand upon the analysis presented in the previous section by discussing constant and current dollars and how they relate to the cost estimating process. The relationship between raw and weighted indices will then be explained. Finally, the construction of raw and weighted indices will be demonstrated, followed by helpful examples.

5.5.2 Constant Dollars versus Current Dollars

An estimate is said to be in constant (real) dollars if costs are adjusted so that they reflect the level of prices expressed in the dollars of a fixed base year (by convention at the midpoint of the base year). The base year chosen for a program estimate is usually the year the program officially starts, such as the year of the investment decision. The terms real or constant dollar are used interchangeably to refer to the purchasing power of the dollar for the specified base year. When cost estimates are stated in real dollars, the implicit condition is that the purchasing power of the dollar has remained and will remain unchanged over the time period of the program being costed. Normalizing data to exclude changes due to inflation allows an estimator to track price changes explained by other causes.

Current dollars reflect the purchasing power in existence when expenditures actually are made. Prior costs expressed in current year dollars are the actual amounts paid out in those years. Future costs stated in current year dollars are projected actual amounts to be paid, including changes in the purchasing power of the dollar. Terms such as current, then-year, and nominal dollars sometimes are used interchangeably.

Cost estimates normally are prepared in constant dollars to eliminate the distortion that would otherwise be caused by price-level changes. This requires the transformation of historical or actual cost data into constant dollars. For budgeting purposes, however, the estimate must be expressed in current year dollars to reflect the program's projected annual costs by budget appropriation. These annual appropriations actually are expended over a number of years. This requires that the appropriation request takes into account the effect of the anticipated inflation that corresponds to the outlay pattern for each appropriation. The dilemma facing the estimator is how to bridge the gap between the estimate in constant year dollars and a budget request in current year dollars.

5.5.3 Selecting the Proper Indices

While preceding sections dealt mainly with index number types and construction, this section examines two more practical considerations; which index should be used, and, after selecting the proper index, how to extend it into future years beyond that forecasted by the index.

When To Use Various Indices

Generally, the estimator will not need to construct an index, but rather select one and apply it to the problem at hand. Choosing the most appropriate index, therefore, is the challenge. There is no method of index selection that will guarantee the proper choice is made in every case. However, there are a few general guidelines that will enhance the estimator's ability to select the correct index.

Because all inflation indices measure the average rate of inflation for a particular group or classification of goods, the objective in choosing an index is to select the with goods most similar to the costs to be estimated. The key is to use common sense and objective, mature judgment. For example, the Consumer Price Index (CPI) would be a poor indicator of inflation for a new radar system. CPI is a measure of purchasing power of consumers, and a radar system could never be deemed a consumer good.

Periodically, the estimator is required to evaluate contractor cost estimates or proposals that often forecast inflation many years into the future in the form of labor rates and material prices. The BLS publishes inflation indices for many categories of labor and material goods by SIC. Further, Data Resources, Incorporated (DRI) forecasts these indices approximately 20 years into the future. Together, the BLS indices and the DRI forecasts can enhance the analysis of labor rates and material prices. Again, the key is to select the indices that most closely match the products being estimated. Significant differences between the proposed prices and those projected using the appropriate BLS index and the DRI forecast should be documented and placed on the agenda for negotiation and/or fact finding.

Another frequent use of the BLS indices is for EPA clauses. Simply stated, an EPA clause affords both the contractor and the government some degree of protection from abnormal inflation. If the rate of inflation actually experienced (as measured by the agreed upon BLS index) is greater than that anticipated, the contractor receives more money than the stated contract price. Conversely, if inflation is less than anticipated, the contractor receives less than the contract price. The estimator may be asked to provide estimates of contract funding requirements or to assist in the selection of an appropriate inflation index for inclusion in the EPA clause.

The choice of index is generally up to the estimator. The main point to remember is that the objective of any price index is to express the impact of price changes over time for a particular classification of goods. The impact will be captured to the same degree that the classification of goods of the index matches the cost element being estimated.

Extending Indices

After selecting the proper index, it is frequently discovered that the forecasted period is less than the time period for which costs are to be estimated. For example, the Office of the Secretary of Defense (OSD) forecasts inflation rates for five years, but most programs' life cycles extend beyond a five-year period. It is, therefore, sometimes necessary to extend the index beyond the forecast period.

All inflation indices are calculated based on a percentage change in inflation for a given time period, usually annual. Therefore, the examples shown below are based on annual inflation rates, although the procedures presented are equally valid regardless of the time period. Further, it is assumed that at least some of the index values have already been calculated and are readily available to the estimator. Extending an index requires only one additional element: the percentage change in inflation for each time period beyond the last index value. The procedure to follow is a simple multiplication of the last index value times one, plus the inflation rate for the next time period. An example is shown below using the data in Table 5.6.

Table 5.6 Example Inflation Data for the Sequential Method

Year	Inflation Rate (%)	Index Value
1	7.2	0.875
2	7.0	0.936
3	6.8	1.000
4	7.3	X
5	6.6	Y

To extend the index value in Table 5.6 to years 4 and 5, the calculation is:

X = (1 + 0.073) times 1.000 = 1.073 (index value for year 4)
Y = (1 + 0.066) times 1.073 = 1.1438 (index value for year 5).

It quickly becomes apparent that a formula for extending index values can be easily generated as shown in Equation 5.4.

Equation 5.4

$IV_i = (IR_i)(IV_{i-1})$
i = *Time period*
IV_i = *Index value for period i*
IR_i = *Inflation rate for period i*
Iv_{i-1} = *Index value for period i-1*

Equation 5.4 requires the calculation of each year's index value sequentially and is aptly called the sequential method. That is, the index value for year 4 must be known before computing the value for year 5. The arithmetic can be somewhat reduced if the value for year 5 is all that is desired. The same result, except for rounding error, can be obtained for year 5 by multiplying the index value for year 3 (1.000) times the product of one, plus the inflation rates for years 4 and 5 (1.073 x 1.066). This is called the products method, shown in Equation 5.5. The index value for year 5 (IV5) = 1.100 x (1.073 x 1.066) = 1.1438.

Equation 5.5

$$Iv_j = IV_i \prod_{k=i+1}^{j} (1 + IR_k)$$

IV_j = The desired index value for period j (j can be any period outside the time period of the index)

IV_i = Index value for period i (can be any period for which an index value is already calculated)

$\prod$ = The product of

IR_k = Inflation rate for period k

K = Specifies the number of inflation rates required for the calculation

A further example using the products method and the data in Table 5.6 is shown below.
To expand the index value in Table 5.6 to year 10, the calculation is:

$$IV_{10} = 1.000 \text{ x } (1.073 \text{ x } 1.066 \text{ x } 1.066 \text{ x } 1.066 \text{ x } 1.066 \text{ x } 1.066 \text{ x } 1.066) = 1.574.$$

Again, slight differences between the sequential and products methods may result because of rounding error. Any number of time periods may be omitted when using the products method.

The procedures developed in this section apply to any index. Extending indices is a simple concept, but the manual arithmetic can be tedious, especially for weighted indices. Computer programs are available to assist in this process. Understanding the mechanics is important, however, to allow the estimator to calculate manually and to understand more thoroughly the basis of inflation indices provided for estimating purposes.

5.5.4 Application of Indices

Sections 5.4 through 5.5.3 discussed the different types of indices, how to construct an index, how to select an index to use, and how to extend an index. As with any tool, the background information on its features is important, but the tool will be useless if the user does not know how to use it properly. This is most certainly the situation with indices.

Perhaps the most common application of indices is to convert prices from one year to reflect the price level of another year. The goal of conversion is straightforward and very important. When comparing price levels in effort to examine increases, the costs of each year must be standardized such that mere inflationary pressures do not bias the calculation of percentage increases. To accomplish this goal, the price levels for all years usually are converted to the same, chosen base year. For example, if the current year is 1996, the stream of data is given in 1990-96 unadjusted price levels, and the base year is 1987, then a conversion of current to constant price levels with a base year of 1987 would be accomplished to standardize the price levels.

Before converting price levels, an estimator must at a minimum understand three concepts: base year, constant or real price levels, and current year or nominal price levels. Table 5.7 defines these terms. Beyond term recognition, application becomes a matter of thinking through the logic of the conversion.

Many indices are discussed in this chapter. In general, estimators will not construct their own price indices, but will do research to pick the index most representative of the inflation affecting the item they are estimating. Thus, it is incumbent upon the estimator to pick the most representative index and to understand its construction and application.

Case studies 5-1 through 5-4 show the application of a GDP index using the data in Tables 5.8 and 5.9.

Table 5.7 Terms and Definitions

Term	Synonym	Definition	Application
Base Year	--	The reference year to which the prices of other years are compared.	The base year should be one of economic normalcy or stability and eliminate faulty comparisons due to technological advance or changes in consumer attitude.
Constant Dollars	Real Dollars	Value of goods or prices at a specified base year price. An estimate is in constant dollars when prior year costs are adjusted to reflect the level of prices of the base year and future costs are estimated without inflation. (Rodney Stewart, p.565)	When doing comparisons, such as in a cost benefit analysis of more than one alternative solution, use constant dollars. For instance, assume an estimator is studying clock industry trends and needs to compare clock prices over time. Assume it is 1995 and a clock costs $10. In 1985 the same clock cost $6. Inflation for this industry from 1985 to 1995 has been 50 percent, so the price index is 1.5. Considering just those price level changes, the clock should cost $9 in 1995 ($6 ×1.5), but it costs $10 in 1995.

Table 5.7 Terms and Definitions, Cont.

Term	Synonym	Definition	Application
Constant Dollars (Continued)			Looking at the situation from a 1985 perspective, the clock that costs $10 in 1995 would have cost $6.7 (10/1.5) if the only change were caused by inflation. But the clock cost $6 in 1985. Clearly, something other than inflation accounts for the change in clock prices. The estimator must do more research; perhaps there has been a decline in productivity that explains the real increase in clock prices. Comparisons like this necessitate the use of constant dollars.
Current Dollars	Nominal, Then-Year Dollars	Value of goods stated in prices current at the year the work is performed. Prior costs stated in current dollars are the actual amounts paid out in these years. Future costs stated in current dollars are the projected actual amounts (including inflation) that will be paid. (Rodney Stewart, page 574.)	When estimating to support a request for funding over the next few years, it will be necessary to present the estimate in current dollars. This is so that decision makers can plan to have the dollars needed in the future to pay for goods needed in the future. If a desk costs $500 today, but inflation will raise its cost to $550 next year and a manager wants to purchase that desk next year, the budget request should be for $550 then-year dollars.
Nominal Dollars	Current, Then-Year Dollars	Same as current dollars.	Same as current dollars.
Real Dollars	Constant Dollars	Same as constant dollars.	Same as constant dollars.
Then-Year	Current, Nominal	Same as current dollars	Term used commonly in DoD.

Table 5.8 GDP Index (Base Years 1990 and 1992)

GDP Index	Index With Base Year = 1990	Rebase Of Column (2) To Show A New Base Year Of 1992
1990	1.00	.735
1992	1.360	1.000

Table 5.9 Constant and Current GDP for Selected Base Years

GDP	Base Year = 1990	Base Year = 1992
1990 Constant GDP	32 Million	43.5 Million
1992 Constant GDP	33 Million	44.9 Million
Current GDP	32 Million	44.9 Million

CASE STUDY-1.

Convert 1992 current GDP (base year=1992) to 1992 constant GDP (base year=1990).
$40.8 Million/1.360 = $30 Million

The $33 million 1992 constant GDP (in base year 1990) is what the 1992 GDP was worth in 1990 prices. Comparing this to the 1990 constant GDP (in base year 1990), the estimator can see that there has been growth in the GDP that is not accounted for by inflation.

CASE STUDY-2.

Convert 1990 current GDP (base year=1990) to 1990 constant GDP (base year=1992).
$32 Million/.735 = $43.5 Million

The $43.5 million 1990 constant GDP (base year 1992) is what the 1990 GDP is worth in 1992 prices, with inflation included since 1990. Comparing the $43.5 constant 1990 GDP to the $44.9 million constant 1992 GDP (base year 1992), the estimator can again see that there has been growth that is not due to inflation.

CASE STUDY-3.

Convert 1992 current GDP (base year=1992) to 1992 constant GDP (base year=1992).
$44.9 Million/1.000 = $44.9 Million

From this case study, the reader can see that current and constant GDP of the same base year are the same. This is because GDP is a measure of past domestic product and does not make any projections of effort into the future. If the measure projected effort into the future, a constant and current estimate would not be the same. The OSD, in developing current year (then-year) indices for its estimators to use, incorporates typical expenditure rates directly into the index. This is done for ease of use of the indices. As a result, however, this case study would not yield the same results if the indices used were OSD indices. This clearly points out the need for estimators to understand the construction and applicability of any rate they choose to use to normalize their data.

CASE STUDY-4.

Convert 1990 current GDP (base year=1990) to 1990 constant GDP (base year=1990).
$44.9 Million/1.000 = $44.9 Million

This case study shows the same as the preceding one.

5.6 Normalization for Other than Economic Changes

The majority of this chapter has focused on economic normalization, because it is generally the only adjustment made to cost data outside of any restructuring that may be necessary. Obviously, adjustments for other influences are possible and this section will expound on some of these.

5.6.1 Technology Normalization

Technology normalization is the process of adjusting cost data for productivity improvements resulting from technological advancements that occur with the passage of time. In effect, technology normalization is the recognition of the maturation of technology over time and a subjective attempt to measure its impact on historical program costs. For example, an item built in the early 1960s, which extensively employed solid state/integrated circuitry technology, may have been, at that time, a state-of-the-art activity and would have correspondingly high costs associated with it. The same activity could be accomplished in the 1980s with an off-the-shelf piece of equipment and the costs would be minimal. Significant estimating error would occur if no adjustments were made in the historical costs other than for inflation.

Inherent in technology normalization is the ability to forecast technology. Technology forecasting can be defined, according to Joseph P. Martino in his book *Technological Forecasting for Decision Making* (American Elsevier Publishing Company, New York, New York, 1972), as “a quantified prediction of the timing and character of the degree of change of technical parameters and attributes associated with the design, production, and use of devices, materials, and processes, according to a specified system of reasoning.” Adjustment for technology advancement is a very subjective process because it requires the identification of the relative state of technology at different points in time. The estimator is, in effect, trying to model the engineering learning process that occurs with the passage of time. Estimators are not the only ones interested in measuring technology. The technology forecasting community has investigated the nature of technological advancement and has regularly reported the results in *Technological Forecasting and Social Change*. This journal has been the showcase of the technology forecasting community since the early 1970s.

The technology forecasting community has proposed several methodologies for quantifying the level of technology of a given type of system. One approach is to use time as a proxy for technological advancement. Another approach counts the number of new designs since the first operational system was deployed. Still another approach uses a subjective measure in which the estimator along with system engineers select a level of technical advance or system complexity.

There are cost estimating models that devote significant effort to technology normalization. Two well-known models are the Unmanned Spacecraft Cost Model developed by Space Division and the PRICE-Hardware model as discussed in *Price Parametric Cost Models*, Technical Bulletin No. 4, dated October 1981. Other approaches to quantifying technological advancement are possible and the estimator should investigate them. The first step, of course, is for the estimator to learn as much as possible about the system technology to be estimated.

5.6.2 Other Normalization

Normalization techniques can be applied to other factors that influence cost. The Unmanned Spacecraft Cost Model, for example, includes factors for complexity of design normalization. To quantify complexity it was necessary to identify key operational criteria that could relate the degree of complexity to an impact on cost. Then each operational criterion had to be described, so that a realistic assessment could be made. As with technology normalization, this process is very subjective because there is no concrete method of measurement available.

Research and analysis continues in an effort to better define both the outside forces that can impact cost and ways of modeling for these influences so that the use of historical cost data can be enhanced in the cost estimating discipline. Currently, the area of data normalization is a particularly fruitful area, and the latest cost estimating literature should be reviewed regularly to stay abreast of the advances being made.

There is also a very generic area of data normalization previously discussed in general terms. This is the area that addresses the question: Is there an 'apples-to-apples comparison?" In other words, are the data used in today's estimating task like data used in yesterday's estimating task/historical database? Generally, this falls in two broad categories:

- Normalization for work content differences
- Normalization for cost accounting structure differences

When dealing with the issue of work content differences, the estimator should be sensitive to the types of cost captured in the historical data, so that appropriate additions or deletions can be made to ensure that the desired work content is reflected in the estimate. When developing a cost element database, the estimator would want to normalize for these work content differences by establishing a standard definition of what costs should be included. The standard WBS approach helps tremendously in this regard, but there are still inconsistencies in data captured. For example, the work element of "data management" may be found within data costs in some historical programs and in SE/PM in others. An estimator would want to be consistent in applying historical data management factors to a current estimate.

Closely related to work content is the second category of cost accounting structure. A contractor's cost accounting structure has a direct bearing upon the work content of specific WBS elements. Included within this category of normalization are the more purely accounting related differences observed in such things as direct versus indirect charging and the calculation and application of G&A and/or various overheads. For example, normalizing historical data may require deleting specific direct charges (e.g., travel, computer costs, certain program management tasks) so that the data are compatible with an accounting structure that charges these types of cost as indirect within various overhead pools.

The key in this generic area of normalization is a thorough analysis to determine incompatibilities. Once a determination is made, adjustments may be possible if costs are detailed at a low enough level. If not, recognition of differences can at least enhance the estimator's ability either to compensate subjectively for them in a research project, or to identify them when explaining the content of a final estimate.

5.7 Summary

This chapter has dealt with the subject of data in some detail. Data collection can be a tedious, time-consuming business, but it is a crucial building block of the estimate. Finding the best data source and documenting it well will make any estimate more credible and useful for future estimates. Normalizing the data for inflation and other influences is also an important step before the actual data "crunching" can begin.

5A. INDUSTRY ASSOCIATIONS, DIRECTORIES, AND PUBLICATIONS

Table of Contents

I. Aerospace Industry

1.) Air Transport Association of America
301 Pennsylvania Avenue NW
Suite 1100
Washington, DC 20004
202-626-4000
http://www.air-transport.org

2.) American Institute of Aeronautics and Astronautics
1801 Alexander Bell Drive
Suite 500
Reston, VA 20191-4344
703-264-7500
http://www.aiaa.org

3.) Airline Employment Assistance Corps.
P.O. Box 462151
Aurora, CO 80046-2151
303-683-2322
http://www.avjobs.com

4.) International Civil Aviation Organization
International Aviation Square
999 University Street
Montreal Quebec, Canada H3C 5H7
514-954-8219
http://www.cam.org/~icao/

5.) National Aeronautic Association of USA
1815 North Fort Meyer Drive
Suite 500
Arlington, VA 22209
703-527-0226
http://www.naa.ycg.org

6.) Professional Aviation Maintenance Association
1707 H Street NW
Suite 700
Washington, DC 20006-3915
202-730-0260
http://www.pama.org

II. Architecture, Construction, and Engineering

1.) Association for the Advancement of Cost Engineering
209 Prairie Avenue
Suite 100
Morgantown, WV 26505
800-858-2678
http://www.aacei.org

2.) American Consulting Engineers Council
1015 15th Street NW
Suite 802
Washington, DC 20005
202-347-7474
http://www.acec.org

3.) American Institute of Architects
1735 New York Avenue NW
Washington, DC 20006
202-626-7300
http://www.aiaonline.com

4.) American Society for Engineering Education
1818 N Street NW
Suite 600
Washington, DC 20036
202-331-3500
http://www.asee.org

5.) American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, VA 20191
703-295-6000
http://www.asce.org

6.) Amer. Society of Heating & Refrigerating & Air Conditioning Engineers
1791 Tullie Circle NE
Atlanta, GA 0329
404-636-8400
http://www.ashrae.org

7.) American Society of Landscape Architects
636 Eye Street NW
Washington, DC 20001
202-898-2444
http://www.asla.org

8.) American Society of Mechanical Engineers
345 East 47th Street
New York, NY 10017
212-705-7722
http://www.asme.org

9.) American Society of Naval Engineers
1452 Duke Street
Alexandria, VA 22314
703-836-6727
http://www.jhuapl/ASNE

10.) Illuminating Engineering Society of North America
120 Wall Street
17th Floor
New York, NY 10005
212-248-5000
http://www.iesna.org

11.) Institute of Industrial Engineers
25 Technology Park
Norcross, GA 30092
770-449-0461
http://www.iienet.org

12.) National Action Council for Minorities in Engineering
350 5th Avenue
Suite 2212
New York, NY 10118
212-279-2626

13.) Junior Engineering Technical Society
1420 King Street
Suite 405
Alexandria, VA 22314
703-548-JETS
http://www.asee.org/jets

14.) The American Ceramic Society
735 Ceramic Place
Westerville, OH 43081
614-890-4700
http://www.acers.org

15.) National Society of Black Engineers
1454 Duke Street
Alexandria, VA 22314
703-549-2207
http://www.nsbe.org

16.) National Society of Professional Engineers
1420 King Street
Alexandria, VA 22314-2715
703-684-2830
http://www.nspe.org

17.) Society of Fire Protection Engineers
1 Liberty Square
Boston, MA 02109-4825
617-482-0686
http://www.wpi.edu/Academics/Depts/Fire/SFPE/sfpe.html

18.) Society of Manufacturing Engineers
P.O. Box 930
One SME Drive
Dearborn, MI 48121
313-271-1500
http://www.sme.org

19.) American Association of Engineering Societies
1111 19th Street NW, Suite 608
Washington, DC 20036
202-296-2237
http://www.asee.org/external/aaes

III. Chemical/Rubber and Plastics Industry

1.) American Chemical Society
1155 16th Street NW
Washington, DC 20036
202-872-4600
http://www.acs.org

2.) American Institute of Chemical Engineers
345 East 47th Street
New York, NY 10017
212-705-7338
http://www.aiche.org

3.) Chemical Manufacturers Association
1300 Wilson Blvd.
Arlington, VA 22209
703-741-5000
http://www.cmahq.com

4.) Chemical Management Resources Association
60 Bay Street
Suite 702
Staten Island, NY 10301
718-876-8800
http://www.cmra.org

5.) Society of Plastics Engineers
14 Fairfield Drive
P.O. Box 403
Brookefield, CT 06804-0403
203-775-0471
http://www.4spe.org

6.) Society of Plastics Industry
1801 K Street NW
Suite 600K
Washington, DC 20006
202-974-5200
http://www.socplas.org

IV. Computer Hardware, Software, and Services

1.) Association for Computing Machinery
1515 Broadway
17th Floor
New York, NY 10036
212-869-7440
http://www.acm.org

2.) Information Technology Association of America
1616 North Fort Myer Drive
Suite 1300
Arlington, VA 22209
703-522-5055
http://www.itaa.org

V. Electronic/Industrial Electrical Equipment

1.) American Electronics Association
5201 Great America Parkway
Suite 520
Santa Clara, CA 95054
800-284-4232
http://www.aeanet.org

2.) Electrochemical Society
10 South Main Street
Pennington, NJ 08534-2896
609-737-1902
http://www.electrochem.org

3.) Electronic Industries Association
2500 Wilson Blvd.
Arlington, VA 22201
703-907-7500
http://www.eia.org

4.) Electronic Technicians Association
602 North Jackson Street
Greencastle, IN 46135
765-653-8262
http://aavox.com/etasda/index.html

5.) Institute of Electrical and Electronics Engineers
345 East 47th Street
New York, NY 10017
212-705-7900
http://www.icee.org

6.) Institute for Interconnecting and Packaging Electronics Circuits
2215 Sanders Road
Northbrook, IL 60062
847-509-9700
http://www.itc.org

7.) International Brotherhood of Electrical Workers
1125 15th Street NW
Washington, DC 20005
202-833-7000
http://ourworld.compuserve.com/homepages/flanagan/ibewgrph.html

8.) International Microelectronics and Packaging Society
850 Centennial Park Drive, Suite 105
Reston, VA 20191
800-535-4746
http://www.ishm.ee.vt.edu

9.) International Society of Certified Electronics Technicians
2708 West Berry Street
Forth Worth, TX 76109
817-921-9101
http://www.iscet.org

10.) National Electrical Manufacturers Association
1300 North 17th Street
Suite 1847
Rosslyn, VA 22209
703-841-3200
http://ftp.nema.org

11.) National Electronics Service Dealers Association
2708 West Berry Street
Forth Worth, TX 76109
817-921-9061
http://www.nesda.com

12.) Robotics International of the Society of Manufacturing Engineers
P.O. Box 930
One SME Drive
Dearborn, MI 48121
313-271-1500
http://www.sme.org

13.) Semiconductor Equipment and Materials International
805 15th Street, NW
Suite 810
Washington, D.C. 20005
202-289-0440
http://www.semi.org

14.) The Center for Innovative Technology
2214 Rock Hill Road
Suite 600
Herndon, VA 20170
703-689-3000
http://www.cit.org

VI. Fabricated/Primary Metals and Products

1.) American Foundrymen's Society
505 State Street
Des Plaines, IL 60016
847-824-0181
http://www.afsinc.org

2.) ASM International
9639 Kinsman Road
Materials Park, OH 44073-0002
216-338-5151
http://www.asm-intl.org

3.) American Welding Society
550 LeJeune Road NW
Miami, FL 33126
305-443-9353
http://www.aws.org

VII. Manufacturing and Wholesaling: Misc. Consumer

1.) Association for Manufacturing Technology
7901 Westpark Drive
McLean, VA 22102
703-893-2900
http://www.mfgtech.org

2.) National Association of Manufacturers
1331 Pennsylvania Avenue NW
Suite 600
Washington, DC 20004
202-637-3000
http://www.nam.org

VIII. <u>Manufacturing and Wholesaling: Misc. Industrial</u>

1.) Association for Manufacturing Technology
7901 Westpark Drive
McLean, VA 22102
703-893-2900

2.) National Tooling and Machining Association
9300 Livingston Road
Fort Washington, MD 20744
301-248-1250
http://www.ntma.org

3.) National Center for Manufacturing Sciences
3025 Boardwalk Ave.
Ann Arbor, MI 48108-3266
313-995-4928
http://www.ncms.org

IX. <u>Transportation</u>

1.) American Bureau of Shipping
2 World Trade Center
106th Floor
New York, NY 10048
212-839-5000
http://www.eagle.org

2.) American Trucking Association
2200 Mill Road
Alexandria, VA 22314-4677
703-838-1700
http://www.truckline.com

3.) Institute of Transportation Engineers
525 School Street SW
Suite 410
Washington, DC 20024
202-554-8050
http://www.ite.org

4.) National Motor Freight Traffic Association
2200 Mill Road
Alexandria, VA 22314
703-838-1810
http://www.erols.com/nmfta

5.) Shipping Digest
51 Madison Avenue
New York, NY 10010
212-689-4411

6.) Transport Topics
2200 Mill Road
Alexandria, VA 22314
703-838-1772

X. Utilities: Electricity/Gas and Sanitation

1.) American Public Gas Association
11094D Lee Highway
Fairfax, VA 22030
703-352-3890
http://www.apga.org

5B. CONTRACTORS MANAGEMENT INFORMATION SYSTEMS AND REPORTS

Contractors produce many reports from their integrated management system that are useful in estimating. The degree that one can rely on the data is in direct proportion to the quality and standardization of the integrated management system. This is not to say that all contractors are indeed the same or that contractors use the same system at all plant sites. They do not. However, there should be integrity in the system. DoD encouraged the development of an industry standard of integrated cost, schedule, and technical performance management. The 32 Criteria presented in the Earned Value Management System (EVMS) Guidelines are equivalent to the previous 35 DoD Cost/Schedule Control Systems Criteria (C/SCSC). Appendix VI of DoD 5000.2-R, Mandatory Procedures for Major Defense Acquisition Programs (MDAPS) and Major Automated Information System (MAIS) Acquisition Programs; 10 June 2001, addresses the EVMS Guidelines, Mandatory Procedures, & Reporting.

Earned Value Management

Earned value management is a tool that provides government and contractor program managers visibility into technical, cost, and schedule progress on their contracts. The implementation of an EVMS is a recognized function of program management. It ensures the cost, schedule, and technical aspects of the contract are truly integrated. An EVMS:

1. Relates time-phased budgets to specific contract tasks and/or statements of work.
2. Indicates work progress.
3. Properly relates cost, schedule, and technical accomplishments.
4. Ensures all data are valid, timely, and auditable.
5. Supplies managers with information at a practical level of summarization.
6. Is derived from the same internal EVMS used by the contractor to manage the contract.

No single EVMS can meet every management need for performance measurement. Due to variations in organizations, products, and working relationships, it is not feasible to prescribe a universal system for cost and schedule control, relative to the scope of the contract. The Criteria approach establishes the framework within which an adequate integrated cost/schedule/technical management system must fall.

The DoD has formally recognized 32 Criteria as defining acceptable EVMS parameters. The Criteria are defined in the industry-standard Earned Value Management Systems Guidelines, dated August 1996. Contractors with systems formally recognized by the DoD as meeting the 35 C/SCSC prior to December 1996 will be considered compliant with the new 32 EVMS Criteria.

The 32 Criteria represent requirements, which a contractor's EVMS must meet. The Criteria approach continues to provide contractors flexibility to develop and implement effective management systems tailored to meet their respective needs, while ensuring the incorporation of fundamental earned value management concepts.

The EVMS Criteria do not call for data, but government program managers will want to ask for certain cost and schedule information from the contractor. There are standard government reports that the program manager can put on contract. These are the CPR and the C/SSR introduced in section 5.3.7. The DoD has data item descriptions for each of these reports that spell out the format in detail. Contracts should reference these data item descriptions to ensure adequate knowledge regarding preparation of these cost reports.

The EVMS has been used to varying degrees of success since its inception in the Air Force in 1967 as the Cost/Schedule Performance and Control Specification (C/SPCS). The C/SPCS evolved into the C/SCSC and became the way of doing business for the entire DoD. The Department of Energy (DOE), National Aeronautics and Space Administration (NASA), the Internal Revenue Service (IRS), and the Department of Transportation (DOT) through the FAA also applied C/SCSC to their larger contractual efforts. The Federal Acquisition Streamlining Act (FASA) did not eliminate the C/SCSC because it is essentially a requirement for following good commercial practices. EVMS Criteria replaced C/SCSC in 1996 as part of re-engineering implementation practices.

Cost Data Reports

Generally speaking, the CPR is the primary report of cost and schedule progress on contracts containing EVMS Criteria compliance requirements. In the case of contracts that have lower dollar values and are less risky procurements, a C/SSR is normally sufficient. The C/SSR criteria are simpler for contractors to implement and the report itself is simpler to produce.

The main thrust of performance measurement reports such as the CPR and the C/SSR is to display time phased budgets, actual costs, and quantitative measures of contractor performance. This is accomplished through the primary concept of "Earned Value." Earned value, simply stated, is what work is completed for the money and time spent. The three basic elements of earned value are:

- Budget: called BCWS (Budgeted Cost of Work Scheduled)
- Actual Costs: called ACWP (Actual Cost of Work Performed)
- Earned Value: called BCWP (Budgeted Cost of Work Performed)

These elements will be defined further in subsequent paragraphs. But first, to illustrate the concept of earned value and its usefulness in cost estimating, the following very simple example is provided:

BCWS = $1.00 (Budgeted Amount)
BCWP = $1.00 (Earned Value)
ACWP = $1.50 (Actual Amount Spent).

Assuming the program being estimated is significantly underway, the data above reveal that the program is overrunning cost-wise. However, it is on schedule. It has cost the contractor (and the program) $1.50 to do $1.00 worth of planned work. When estimating, it would be a mistake to consider 100 percent efficiency as the track record when 67 percent efficiency is being reported. This can be a valuable estimating tool, and at the very least, an effective cross check.

Budgeted Cost of Work Scheduled (BCWS) is the amount of money put aside to complete a specific piece of work over a stated period of time. It is specific in the sense that the work is described in some detail so that there can be no confusion regarding the job that was planned. The schedule is to indicate when the work is to be accomplished. The work scope is usually small and the time period relatively short. This tends to make the estimating of BCWS more accurate. When it is difficult or impossible to plan the work effort in distant time periods, the contractor will put the work in Undistributed Budget until such time as definition is possible.

Budgeted Cost of Work Performed (BCWP) or earned value is the prime statusing tool in the cost reports. It represents what portion of the work is completed with the value in dollars based on the BCWS. At completion of any piece of work BCWS = BCWP. During any interim period, the difference between BCWS and BCWP reflects the schedule position expressed in dollars. This is called the Schedule Variance (SV).

Actual Cost of Work Performed (ACWP) is the actual booked or accrued costs of the piece of work. This is also expressed in dollars. The difference between BCWP and ACWP is the cost position expressed in dollars. This is called the Cost Variance (CV).

Schedule Variance (SV) is the difference between BCWS and BCWP. The fact that the schedule variance is expressed in dollars can be difficult to interpret, as schedule is usually time oriented (i.e., days behind schedule). Considering that any work not only takes time but costs money, measuring the schedule variance in dollars becomes understandable. Another way to look at this schedule variance in dollars is a behind schedule position (BCWP < BCWS), i.e., it is going to take at least the variance amount to get back on schedule. Possible additional costs associated with SV, such as premium time, overtime, and the delay or wasted time for the people scheduled to do the follow-on work but waiting until the late effort is finished, are not shown in SV. On the other hand, a positive schedule variance (BCWP > BCWS) is not money left over or under run, since it is merely an indicator of schedule condition, indicating work has been completed ahead of schedule. In short, a positive SV cannot be considered money in the bank.

Cost Variance (CV) is the difference between what was spent and the amount of budgeted work completed. It is expressed as BCWP - ACWP. A negative cost variance (ACWP > BCWP) is a true dollar variance and means more money was spent for work done than originally budgeted. It is money spent, not work done. Negative cost variances are usually difficult to recover from because future work would have to be completed using fewer resources than originally budgeted. A positive cost variance (ACWP < BCWP) is usually a good sign, and barring catastrophic events, can result in an under run. It can also occur when excess budget has been allocated to the early periods of contract performance. This is called front loading and gives program management a sense of well being that does not, in fact, exist. Careful examination of the validity of the budgets early in the program will control front loading to a great extent.

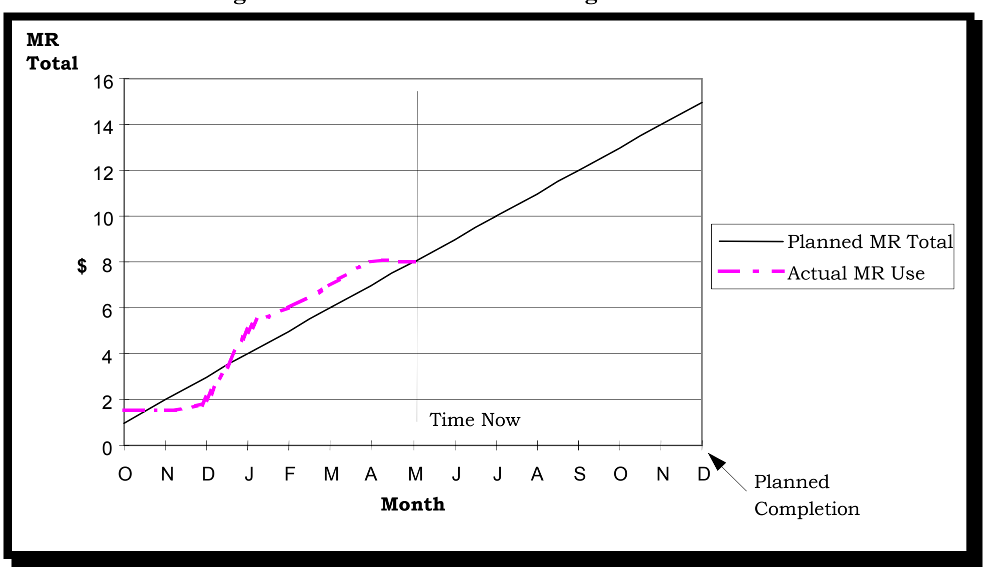
Budget at Completion (BAC) is the total of BCWS over the life of the program. It is in effect the "spend plan" for the contract and should be established as quickly as possible after contract award. The latest DoD guidelines require the government program manager to review the spend plan for the contract no later than 6 months after contract award.

Estimate at Completion (EAC) is an estimate made by the contractor of the total expected cost of the program. Simplistically, the EAC is ACWP plus the work that still needs to be completed. This can be expressed as BAC - BCWP. Therefore, EAC = ACWP + BAC - BCWP. When BAC - EAC is a negative number, an overrun exists. The difference between BAC and EAC is called the Variance at Completion (VAC) and is the contractor's prediction of the eventual cost overrun or under run. When cost variances are relatively low and BAC = Latest Revised Estimate (LRE), the estimator can consider this to be an indication of a program under control.

Management Reserve (MR) is another significant item reported in the CPR and C/SSR. MR is the amount the contractor extracts from the negotiated contract value to cover the effort that might not have been predictable when the original budget for the contract was being developed. Depending on the contractor's management philosophy, the MR may be extracted to create goal oriented or challenge budgets. MR is not to cover an overrun situation. It is monitored and controlled to ensure that it is used for work that is in scope to the contract but out of scope to the contractor's original plan. MR should not be confused with the government program manager's MR. The government program manager may retain some reserve budget for changes to the basic statement of work (SOW), such as engineering changes.

The use (or non-use) of MR is highly indicative of the contractor's thoroughness in laying out the basic budgets. If the CPR or C/SSR show early heavy use of MR, the chances of there being sufficient MR to sustain the program to completion are doubtful. An estimate made on a contract reporting this type of action must take the lack of sufficient MR into account by adding a factor to the estimate to recreate additional MR.

Figure 5B.1 Linear Use of Management Reserve



Plots of MR are useful tools to evaluate program planning as can be seen in Figure 5B.1 This plot predicts a linear use of MR during the life of the contract, and it is posted as time passes to reflect the actual usage of MR. If the usage of MR generally follows the predicted line, it can be considered an indicator of a carefully planned program.

These reports can be used for estimating in many ways. Both the CPR and the C/SSR have an EAC column included as an integral part of the report. The contractor is required to forecast, on a periodic basis, the estimate to complete the contract work. As discussed above, this forecast can take the form of the money spent for the work completed plus the estimated cost of the amount of work to go. The contractor's estimate should come from a grassroots review of incomplete work, multiplied by the efficiency factor of the completed work. This factor is called the Cost Performance Index (CPI) and is derived by dividing the BCWP (earned value) by the ACWP (actual costs). The Estimate to Complete (ETC) can be calculated in other ways using available budget, earned value, and actual data as the basis for forecasting the future.

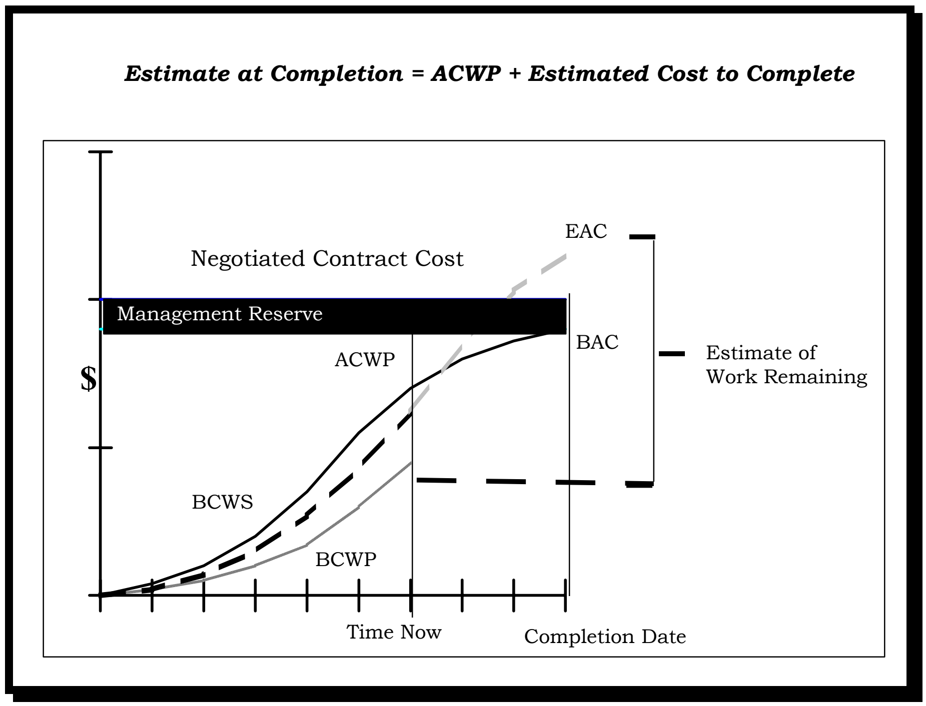
Simple projections of plotted BCWS, BCWP, and ACWP data extended with straight lines are indicative of the possible path of the use of the contract dollar. There are models available which will temper the straight-line projections to take advantage of experience gained on analogous programs or on an earlier phase of the same program. The DoD has developed computer software that allows the estimator to quickly compute estimates at completion using these models. The software is called Performance Analyzer and is available from the Air Force Cost Analysis Agency. Bear in mind that CPR and C/SSR data are available for ongoing programs as well as historical programs.

Analyzing Cost Data Reports

CPRs and C/SSRs are most useful when there is a requirement for determining an EAC for on-going contracts. The cost reports contain the contractor's EAC. The estimator is frequently called on to check the reasonableness of this contractor prepared estimate and, in many cases, to develop an EAC using the same reported database. The estimator should be familiar with analyzing cost data reports.

There are many different ways to analyze cost data reports, but they all use the three basic elements (BCWS, BCWP, and ACWP) in various combinations and perturbations. Probably the simplest method is to plot the monthly cumulative values of these elements on a simple Cartesian coordinate graph over a period of at least three months. The extension of these points, by means of a straight line, provides an extrapolation of the direction and an approximation of the magnitude of the amounts. However, straight-line predictions can be dangerous. This method is acceptable when it is used for a short period of analysis (about three months). Another approach is to lay out the BCWS for the life of the program (this is available from Format 3 of the CPR called the Baseline Format) and plot BCWP and ACWP as forecasts (straight line technique) keeping the difference between the curves (variances) the same. This assumes that the variance remains constant, which would be a rare occurrence. This method of forecasting can be useful as a check on the reasonableness of a detailed cost estimate. Figure 5B.2 is a graphical display of an estimate at completion calculation using a forecast technique.

Figure 5B.2 Estimated Cost at Completion



When cost data reports are to be used to estimate an analogous program, it is reasonable to expect similar programs at similar contractor's plants to have a relationship. This relationship may not be in the costs of hardware or software but may be in the peripheral WBS areas of data, program management, systems engineering, and the like. If the estimator can establish costs for the major deliverables such as hardware or software, a factor may be applied for each of the peripheral areas of the WBS, based on historical data available from CPRs and C/SSRs.

The estimator must first examine the WBS breakdown on the CPR for applicability. Usually, the data listed in the WBS includes elements that the estimator may not be using in the present estimate. These might be spares, training, or support equipment. The analysis of the CPR should include removal of the values for these extraneous elements and re-evaluation of the variances and trends prior to using the data for estimating purposes.

Performance trends are useful in preparing an estimate and these can be calculated in many ways. One of the more popular techniques is to plot the schedule and cost variances for each reporting period as a deviation to a zero axis. Figure 5B.3 shows the plotting of this trend and also includes the status of management reserve. The plot can be in dollars or in percentages and gives a synopsis of the contract position at a glance. Performance to date is important to the preparation of an estimate for an ongoing program. This depiction of current cost and schedule performance, as well as the use of management reserve, is a significant indicator of cost problems. However, this presentation can be misleading in some instances because it is designed to highlight current trends and usually addresses only the recent effort or a portion of the contract. Often, major programming actions involving significant variance adjustments made earlier in the contract are not readily apparent in this presentation. An example of this masking of variance adjustment is when an Engineering Change Order (ECO) is issued. The contractor may choose to put a significant amount into MR, thus displaying a healthy upward swing to the MR line.

Figure 5B.3 Performance Trends

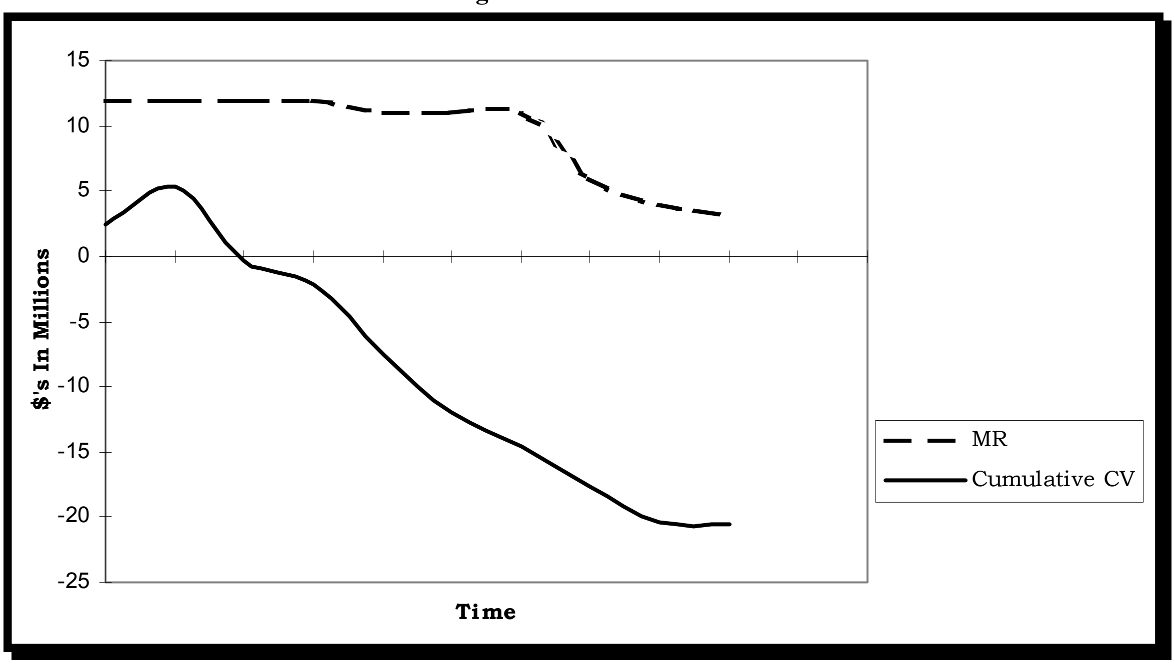


Figure 5B.4 is the Cumulative Performance chart. This chart plots BCWS, BCWP, and ACWP on a cumulative basis from the beginning of the contract and illustrates the total contract and current status. The example shown indicates a contract that is behind schedule and is overrunning cost, with both the cost and schedule trends getting progressively worse. A disadvantage associated with this chart is that after a contract has progressed significantly, current problems do not show up very well unless they are of major proportions.

CPR and C/SSR data can provide the estimator with good information to estimate the cost of a similar system, an estimate to complete on an ongoing program, or as a test of reasonableness of an estimate generated by other means. The challenge to the estimator is to obtain the best and most applicable data from historical or ongoing programs to insure that the estimate being performed is as accurate as possible and that several checks as to the reasonableness of the estimate have been conducted.

Figure 5B.4 Cumulative Performance