6.0 CRUNCHING THE NUMBERS

6.1 Introduction

This is the third chapter that expands upon the cost estimating process. The process, presented first in Chapter 3, is repeated below to emphasize the significant steps that must be completed prior to the start of number crunching.

- Plan the estimate
- Research, collect, and analyze data
- Develop estimate structure
- Determine estimating methodologies
- Price or compute the cost estimate
- Document and present the estimate to decision makers for use

This chapter picks up the discussion of the estimating process at the point where a number of steps have already been completed. A review of the steps up to this point, showing clearly how they lay the groundwork for the "crunching of the numbers, " is in order. Section 6.2 will review steps 1 through 4. Section 6.3 will discuss the actual "crunching of the numbers".

6.2 Cost Estimating Process Review

6.2.1 Plan the Estimate

The development of an estimate begins with the definition of the estimating task and the initial planning of the work to be accomplished. The six major steps involved are presented below.

- Determine the use of the estimate
- Determine the level of detail required
- Characterize the project
- Establish ground rules and assumptions
- Select estimating methodologies
- Develop the estimate plan

One of the first things an estimator should determine is the ultimate use, or purpose, of the estimate. Knowing how the estimate will be used helps to shape the overall plan of attack. It is particularly helpful in deciding which elements of cost to include in the estimate and in understanding the level of detail required. The level of detail required for the estimate must be determined fairly early in the estimating process. The level of detail required can impact the type and amount of data to be collected and analyzed significantly. An estimate conducted at a high level of detail generally requires less data than an estimate conducted at a low level of detail.

Knowing the general "character" of the project provides the estimator with a good understanding of what is being estimated. The character of the project refers to those characteristics that distinguish it from other projects. Some of these characteristics include:

- Purpose or mission,
- Physical characteristics,
- Performance characteristics,
- Maintenance concept, and
- Identification of similar projects.

After learning how the estimate is to be used, the level of detail required, and the character of the project being estimated, the estimator is in a better position to establish major ground rules and assumptions (i.e., the conditions upon which an estimate will be based). Ground rules usually are considered directive in nature and the estimator has no choice but to use them. In the absence of firm ground rules, assumptions must be made regarding key conditions which may impact the cost estimate results. The project schedule, if one exists, is an example of a ground rule. If a schedule does not exist, the estimator must assume one.

Selecting the estimating methodologies to be employed is probably the most difficult part of planning the estimate since methodology selection is dependent on data availability. Therefore, the estimating methodologies selected during this planning stage may have to be modified or even changed completely later on if the available data do not support the selected technique. It is still helpful, however, to specify desired estimating methods because doing so provides the estimator with a starting point.

It is important to understand that task definition and planning is an integral part of any estimate. It represents the beginning work effort and sets the stage for achieving a competent estimate efficiently.

6.2.2 Cost Research and Application of Historical Data

During data research and analysis, step 2 of the estimating process, the estimator fine-tunes his estimating plan. Planned methodologies may, however, turn out to be unusable due to lack of data. New methodologies may have to be developed or new models acquired. Cost research may reveal better methodologies or analogies than those identified in the original plan. During this step, also, the estimator normalizes the data so that it is useable for the estimate.

During the process of data research, collection, and analysis, the estimating team should adopt a disciplined approach to data management. The key to data research is to narrow the focus in order to achieve a viable database in the time available to collect and analyze it. Data collection should be organized, systematic, and well documented to permit easy updating. The objective of data analysis is to ensure that the data collected are applicable to the estimating task at hand and to normalize the data for proper application.

6.2.3 Develop Estimate Structure

An essential ingredient for any successful estimate is the work breakdown structure (WBS) since it provides the overall framework for the estimate. The estimator must decide at which level in the WBS to construct the estimate. This will affect the amount of detail in the estimate and have an impact on choice of estimating methodology. For instance, if the system being procured can be defined in great detail, there will be numerous levels in the WBS and estimating methodologies can be chosen at a low level of detail. In this case a detailed estimate appears possible and appropriate. If, on the other hand, the system is in development, it may be possible only to define it at a high-level and the estimator may opt for a top-level parametric estimate.

Reviewing the work element levels should help put the estimate in perspective. According to Stewart and Wyskida in their book *Cost Estimator's Reference Manual*, the typical element levels are shown in Table 6.1.

Table 6.1 Levels of the WBS

LEVEL	BREAKDOWN	COMMON TERMS
I	Total Job	Project, product, process, service
II	Major Subdivisions of Job	System or primary activity
III	Minor Subdivisions of Job	Subsystem or secondary activity
IV	Tasks	Major components or tasks
V	Subtasks	Sub-components, parts, subtasks

Picture an estimating structure with five or more levels. With that many levels, the estimating methodology will be detailed and start at the subtask level, e.g., the smallest parts in a hardware assembly. The estimate will then roll up from that level, with overhead rates and factors adding on higher-level costs. The bigger and more involved the estimate, the more important it is to have a computer program to help crunch the numbers. A computer program that will handle an eight level work element structure will handle virtually any estimate. One that handles four levels will suffice for most estimates. There is a discussion of electronic spreadsheets, a common automated tool for producing estimates, in Section 6.3.1.

6.2.4 Determine Estimating Methodologies

When choosing an estimating methodology, the estimator must keep in mind that cost estimating is a forecast of future costs based on a logical extrapolation of data currently available. Again, data availability is a key consideration in selecting the estimating methodology. In fact, the amount and quality of data available often dictate the estimating approach. Common estimating methodologies are identified and defined in the Table 6.2.

Table 6.2 Common Estimating Methodologies

TYPE	DEFINITION
Parametric	An estimating technique that employs one or more cost estimating relationships for the measurement of costs associated with the development, manufacture, and/or modification of a specified end-item based on its technical, physical, or other characteristics. (Society of Cost Estimating & Analysis/SCEA)
Analogy	An estimate of costs based on historical cost data of a similar (analog) item and using adjustment factors to account for complexity, technical, or physical differences between the items. (SCEA)
Engineering	An estimate developed by requesting and collecting estimates from functional areas within a company or agency for a specific Statement of Work or task. Engineering estimates usually are developed using a combination of cost estimating methods and techniques, but generally are developed by the people who will be accomplishing the work. (SCEA)
Vendor Bid	Uses cost proposals or bids submitted by vendors in response to a request for production proposal.
Expert (Specialist) Estimating	Judgmental estimate performed by an expert in the area to be estimated.
Catalog or Handbook	Handbooks, catalogs, and other reference material are published containing lists of off-the-shelf or standard items with price lists or labor estimates.
Manloading	The number and type of skilled workers needed to complete a specific work effort are projected, resulting in a man-hour estimate.
Industrial Engineering Standards	Used to estimate the time required to perform well-defined tasks in a manufacturing environment based on standard hours.
Estimate at Completion	Based on data contained in Cost/Schedule Control Systems Criteria (C/SCSC) cost reports coupled with trend analysis.

A systematic, disciplined approach in the cost estimating steps discussed above will greatly facilitate the later steps of crunching the numbers and documenting the estimate.

6.3 Putting the Estimate Together and Crunching the Numbes

At this stage of the process, it is time for the estimator to put it all together and crunch the numbers. Many pieces of the estimate have been collected. These pieces need to be assembled into a whole - the final estimate. This section addresses the steps that estimators must go through to load the estimate into the automated tool they have chosen for the estimate. The use of automated tools greatly simplifies updating, documenting, and calculation of the estimate. The steps addressed are: 1) entering data and methodologies into the physical structure of the estimate (the WBS); 2) timephasing the estimate; and 3) dealing with inflation.

6.3.1 Entering Data and Methodologies into the Physical Structure of the Estimate

In general, a computer program is essential to the task of assembling the estimate. Programs allow efficient processing of data, electronic calculations, easier documentation, and simpler updating. There are myriad software tools available to facilitate this process. The most commonly used and widely available program, however, is the electronic spreadsheet. The WBS is the structure of the estimate. Therefore, no matter what program or tool is selected for assembling the estimate, the first step is to enter the WBS into the computer program. Table 6.3

shows how this might be entered into a spreadsheet. Next, estimating methodologies are entered directly into the spreadsheet, or the spreadsheet takes an input from a separate model.

If the estimating team has not yet built a data file, this task must also be accomplished. There should be separate files or locations within files for labor rates, labor hours, material quantities, overhead rates, material prices, data to build cost estimating relationships, data for learning curves, inflation factors, and any other data necessary for the estimate.

Table 6.3 Example of an Estimate in Spreadsheet Form

WORK BREAKDOWN STRUCTURE ELEMENT	11/ 94	12/ 94	1/ 95	2/ 95	3/ 95	7/96 (END EFFORT)
1.0 Weather System (Level 1)	Sum up level 2 estimates, apply General & Admin	→	→	→	→	→
1.1 Weather System Processor (Level 2)	Sum up level 3 inputs	→	→	→	→	→
1.11 Hardware	Similar to 1.12	→	→	→	→	→
1.12 Applications Software (Level 3)	Sum inputs from levels 4 and lower and apply overheads, or enter estimating methodology formulas or data	→	→	→	→	→
1.13 Systems Software	Sum up levels 4 and lower estimates and apply overhead	→	→	→	→	→
1.131 Software Build 1 (Level 4)	Sum up estimates from level five, apply labor rates	→	→	→	→	→
1.1311 CSCI 1 1.1312 CSCI 2 (Level 5)	Use Parametric Model to derive estimates, then enter the model output, e.g. timephased manloading	→	→	→	→	→
1.14 Integration, Assembly, Test & Checkout	Similar to 1.13	→	→	→	→	→
Remaining WBS Elements	Similar to 1.14	→	→	→	→	→

As you can also see from Table 6.3, the estimate is timephased over a number of years. This allows the estimator to apply appropriate inflation indices to each cost element on an annual basis. This provides an easy way to timephase the estimate. Timephasing is an important topic in building an estimate and is discussed in the next section.

6.3.2 Timephasing the Estimate

Estimates reflect tasks that occur over time. Obviously, cost estimates will vary with the time period in which the work occurs, due to changes in labor rates and other factors. For instance, the number of man-hours needed to complete a software development effort may be higher if the development time is shortened, or lower if it is lengthened. Timephasing is essential in order to determine resource requirements, apply inflation factors, and arrange for resource availability.
Determining resource requirements is an important program management task. The program manager needs to know when tasks will be done, so that the people and materials can be put in

place. There are many different scheduling techniques, but these are beyond the scope of this chapter. The reader interested in more information about scheduling should consult any text on project scheduling and/or network scheduling.

The program manager must also ensure that the money will be available to pay for the people and the materials at the time they are needed. The first step to doing this successfully is the scheduling step. The estimator also needs to estimate what inflation will do to resource requirements in the future. Typically, an estimate is first prepared in a base year dollar, often in the prices of the current year. After the costs for an item or system have been estimated in base year dollars, the next step is to express the estimate in current dollars for inclusion in formal budget requests. Translating base year dollars into current dollars requires that the estimate be allocated to specific government fiscal years. The estimator has obtained projected inflation rates during data collection, and now can enter these rates timephased over the period of performance of the task. This will let the program manager know how much a task will cost in the dollars relevant at a future time. This is essential for preparing a realistic budget.

Timephasing Considerations

In timephasing an estimate, there are a number of factors an estimator should understand conceptually. The factors addressed in this chapter are: 1) the FAA concept of full funding, 2) advance procurement, 3) initial operational capability, 4) effect of reduced budgets on the timephasing of the estimate, and 5) program slippage.

FAA Concept of Full Funding

One of the most important considerations in timephasing an estimate for budget planning purposes is the type and source of program funding. Cost estimators need to understand the FAA concept of full funding in order to support budget estimates.

The AMS requires that the JRC commit to fully fund all approved programs. This means that the FAA is committed to the funding profile approved in the APB and will, if priorities remain as they currently are, meet the program's funding profile. In other words, a program that is approved by the JRC is considered full funded. However, these funds will be appropriated annually based on the funding profile described in the APB. When developing a cost estimate, the analyst should assume that fully funded ensures annual fund availability and that quantity discounts will be obtained as if all funding were committed at contract award.

Advance Procurement

Before production can begin, certain resources must be on hand at the production facility. Some of these resources have extremely long lead times and must be ordered far in advance of the actual start of production. Some components (e.g., aeronautical titanium forgings, special bearings and custom integrated circuits) have lead times of nearly two years. The Joint Aeronautical Materials Activity located at Wright-Patterson AFB, Ohio, performs quarterly surveys of the aerospace industry to determine lead times on 126 commonly used manufacturing components. The results of these surveys are published in quarterly *Lead Time Reports*, which are distributed to all AFMC Product Divisions and may be of use to the FAA cost estimator. These items are referred to as long lead time components.

Advance procurement, one of the exceptions to the full funding concept, provides the means for funding long lead time components in advance of the fiscal year in which the related end-item is procured. Long lead time components may be either contractor furnished equipment, or government furnished equipment, if procured by the government from one contractor and provided to another contractor for inclusion in the end-item. Advance procurement is limited to those components whose lead times are significantly longer than other components of the same end-item and their dollar value (i.e., cost) should be relatively low compared to the total end-item. If advance procurement is necessary, a portion of the total costs will have to be funded in advance of the fiscal year(s) in which the end-item is funded.

Initial Operational Capability (IOC)

The required IOC date (i.e., the date the system is required to be operational) is a major consideration in timephasing an estimate. Clearly, the schedule of events will be laid out to support the achievement of the IOC date. The estimate will be timephased to support the schedules and the achievement of the IOC.

Effect of Reduced Budgets on the Timephasing of the Estimate

The normal procedure for the budgeting process is to develop the cost estimate for a program and to let it determine the amount of funding and when the funds are required. That is, the cost estimate drives the budget. Occasionally, though, it is necessary to adjust an estimate because of budgetary constraints. For example, the cost estimate for Program XYZ may indicate that $10 million is required in FY96, but Congress approves only $7 million. A budgetary constraint has been imposed, and the estimate must be adjusted accordingly. Whenever available funds are less than the required funding level and efforts to fix the funding have failed, it becomes a question of "What can be accomplished on this program within available funding?" The estimator will have to rework the entire estimate to fit within budgetary constraints.

Program Slippage

Estimators need to understand the effect of production rate and buy quantity changes on their estimate. Often, an estimator will receive a request to rephase an estimate due to a reduced production rate in any given year, though not a reduced total quantity. For example, instead of buying 100 units for 4 years, the FAA program office may be directed to stretch the program out to buy 100 units for 2 years and then 50 units the following 4 years. Often, Congress has resorted to this approach to reduce the budget in the near term. The economic theory of average unit cost curves indicates that a production rate decrease usually involves an increase in unit costs.

To deal with program slippage in an estimate, the estimator must consider the new buy schedule and the impact on unit costs. In terms of an electronic spreadsheet, this means that your time period columns will increase and your unit cost input will change. Thus, the timephasing of the estimate and the total dollar value must change.

Timephasing Methods

There are several methods for timephasing an estimate. Some common methods are described in this section, along with the situations in which you would be likely to use them.

Contractor Proposal Method

This method of timephasing is common during source selection. The FAA cost estimator can use this method to produce an independent estimate as a test of reasonableness of the bidder's proposal.

To use this method, the government estimator uses the proposal as the basis for preparing the government estimate. The availability of the proposal data simplifies the estimating task when compared to other estimating scenarios where data collection is a larger portion of the estimator's task. The government estimate can then be spread by fiscal year in the same percentages as the contractor estimate. For example, assume the contractor's proposal includes an estimate for prime mission equipment of $15,500,000 that is spread over four years at 25 percent of the total estimate in each of the four years. The government estimator could develop an estimate for the prime equipment using a method different than the contractor, but timephase it in the same percentages to the four years.

Program Schedule and Cost Element Occurrence Method

This method involves timephasing program milestones, such as critical design review and then estimating the percent of total cost required to complete each milestone. It is similar to the Contractor Proposal Method in that it requires detailed schedules to be available. However, this method involves more analysis on the part of the FAA estimator. In this method, the FAA estimator will determine which milestones to use and how to allocate the total estimated cost to those milestones. This will require the input of the program manager or some other functional expert.

In the following example (Table 6.4), presume an estimate has been made for software development costs using a parametric model. The example in Table 6.3 was an example of an electronic spreadsheet approach for this same software development cost estimate. The parametric model output estimated that this would be a 33 man-month effort. Now the estimator needs to timephase this estimate over the 33 months that this development effort is expected to occur, in order to request money to pay bills. The estimator consults with the program manager, and they decide to phase the estimate based on six scheduled major reviews: Software Specification Review (SSR), Preliminary Design Review (PDR), Critical Design Review (CDR), Test Readiness Review (TRR), Functional Configuration Audit (FCA)/Physical Configuration Audit (PCA), and Functional Qualification Review (FQR). The program manager provides an estimate of the percent of budget that should be allocated at the time of each major review; this is a subjective estimate based upon his experience.

Table 6.4 Example of Program Schedule and Cost Element Occurrence Method of Timephasing

Month/Year	Cumulative % Budget Expended	Cumulative Man-months Expended	Scheduled Reviews
3/1994	11.1	3.66	SSR
6/1994	19.9	6.57	PDR
2/1995	50.1	16.53	CDR
8/1995	72.3	23.86	TRR
2/1996	89.2	29.44	FCA/PCA
7/1996	100.0	33	FQR

With the estimate timephased, the estimator can proceed to apply the proper labor rates and escalation.

Analogy Method

Just as a cost estimate for a new system may be developed based on the actual cost of an existing similar system, so too may an estimate be timephased based on the actual funding requirements of another system. The analogous program must be chosen with care to ensure it is similar in regard to scheduling of key milestones, program length, and the timephasing considerations discussed in this chapter. For example, a program requiring 18 months of design effort prior to development test and evaluation may have significantly different funding requirements than one with a three year design effort. Similarly, a program with advance procurement is not a good analogy for timephasing an estimate for a program without this characteristic.

Once a truly analogous program is selected, the estimate for the new program may be timephased in the same proportions as the analogous program. The analogous method is easy to use once the analogous program has been identified and its funding profile determined. However, the process of finding a truly analogous program and determining its funding profile may be quite difficult and time consuming.

Percentage-Time Percentage-Cost (S-Curves) Method

The percentage-time percentage-cost (PTPC) technique is one of the many applications of classical S-curve theory. This is a technique that is used frequently in cost and budget analysis. The PTPC technique of forecasting funding requirements is based on the results of studies by several different researchers. These studies showed that cumulative expenditures on Air Force research and development programs approximate the shape of the first half of a normal frequency distribution curve. Figure 6.1 shows the normal distribution curve and an example of an S-curve. The S-curve in Figure 6.1 shows the percentages of total program funds required at various percentages of total program time. For the example in Figure 6.1, when the program is 60 percent complete, 75 percent of total funds are required.

Development programs are intuitively a growth process characterized by a slow initial development period, followed by a fairly rapid building phase, which, in turn, is followed by a tapering off to completion. There are, of course, entire families of S-curves, which may be created. The exact shape (i.e., slope, inflection point, etc.) of the curve for a particular program will depend upon several factors (e.g., precise schedule of events, design approach, etc.). Historically, cumulative expenditure profiles for development programs have the general S-shape and this fact may serve as an excellent check of the reasonableness of an expenditure profile. If, upon plotting the data, something other than the typical S-shape is observed, then the estimator should question the validity of the profile, and satisfactory reasons should exist for its unusual shape.

The primary advantage of the PTPC technique is that it can be used when detailed schedule information is unavailable. The only milestones required are the beginning and end dates of the program. The disadvantage of the technique is that the exact shape of the curve must be determined from other sources, such as historical data on other programs.

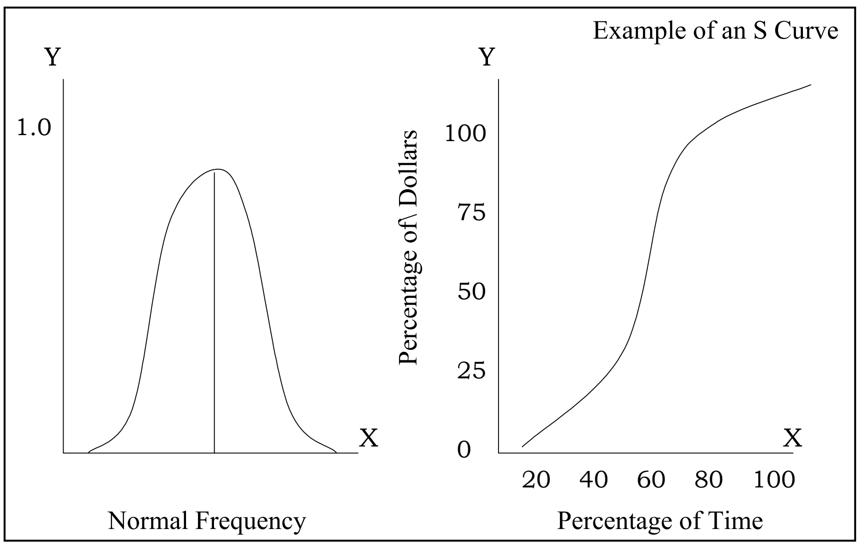

Figure 6.1 Example of an S-Curve

6.3.3 Dealing With Inflation

One of the primary purposes for timephasing estimates is that they may be expressed in current dollars and included in budget requests. Therefore, this section reviews the process of translating base year estimates into “other year” dollars through the application of index numbers.

To demonstrate how inflation indices are used to translate base year dollars into some other current year dollars, let us use the previous example of the software development cost estimate. The estimate of $25 million was developed in 1994 constant dollars, and the goal is to convert it to current year dollars. The $25 million estimate is in 1994 constant dollars, but because the effort will extend over three years, there is a need to spread the estimate over the 33 months and to inflate the dollars to reflect the current year dollars (1996). The current year dollar estimate is $26.424 million. Table 6.5 shows the conversion of the estimate. The FAA cost estimator would use the Office of Management and Budget rates current at the time of the estimate. Refer to Chapter 5 for in-depth discussions on converting dollars into base year and current year dollars.

Table 6.5 Converting Constant to Current Year Dollars

Month/ Year	Cumulative % Budget Expended	Cumulative $ Expended in FY 94 Base Year	Dollars Expended by period	Inflation Factor	1996 Current Dollars	Cumulative Expended in 1996 Current $	Scheduled Reviews
3/1994	11.1	2.775	2.775	1.057	2.933	2.933	SSR
6/1994	19.9	4.975	2.2	1.057	2.325	5.258	PDR
2/1995	50.1	12.525	7.55	1.057	7.98	13.238	CDR
8/1995	72.3	18.08	5.6368	1.057	5.872	19.11	TRR
2/1996	89.2	22.3	4.1382	1.057	4.46	23.57	FCA/PCA
7/1996	100.0	25	2.7	1.057	2.854	26.424	FQR

6.4 Summary

This concludes the chapter on crunching the numbers. The chapter reviewed the steps in the estimating process leading up to number crunching. The subject of timephasing was central in this chapter, as it is a crucial step in building the estimate. The estimate is now ready for documentation and presentation to decision makers for use.