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FAA Life Cycle Cost Estimating Handbook

Parametric, Analogy, Engineering Estimation
Risk Analysis
Modeling and Simulation

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FAA LIFE CYCLE COST ESTIMATING HANDBOOK

Foreword

The *FAA Life Cycle Cost Estimating Handbook* provides a complete reference for the cost estimator. It also provides guidance to program and financial analysts who use or must understand cost estimates. This document conforms to both the spirit and the letter of the FAA Acquisition Management System (AMS).

The first three chapters cover the management system discipline and provide a general perspective on cost estimating and its role in the FAA AMS. These chapters establish a foundation of general estimating terminology, methodology, techniques, and approaches upon which details of the cost estimating discipline can be discussed in greater depth in later chapters.

Chapters 4-7 discuss the cost estimating process and provide a detailed amplification of the material contained in Chapters 1-3. Chapters 4-7 offer the cost estimator a rigorous discussion on the cost estimating process, which includes estimate planning, data research, and methodology development, as well as proven approaches for the presentation and documentation of estimate results.

Chapters 8-14 address specific aspects and applications of cost estimating and encompass the three methods of estimating (parametric, analogy, and engineering), cost risk and uncertainty, source selection, cost models, and operations and support cost estimates.

FAA personnel have reviewed this handbook and rigorous attention was applied to make the *FAA Life Cycle Cost Estimating Handbook* as complete as possible. A special thanks goes to David Schwartz for developing an FAA-related cost reference book patterned after a similar document created by the Department of Defense. Thanks also go to personnel in ASU, ASD, APO, and SETA-II for their review and comment. It is requested that any comments or additions be sent to Alice Harball, ASD-410, (202-358-5489).

FAA LIFE CYCLE COST ESTIMATING HANDBOOK

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1.0 COST ESTIMATING ENVIRONMENT

1.1 Introduction

With the advent of the Acquisition Management System (AMS) within the FAA came a new emphasis on investment analysis and cost estimating. The FAA was directed, in response to Section 348 of the 1996 Department of Transportation (DOT) Appropriations Act, to:

> *"develop an acquisition management system that addresses the unique needs of the agency and, at a minimum, provides for more timely and cost-effective acquisition of equipment and materials."*

The FAA AMS emphasizes certain guiding principles that impact heavily on the cost estimator. For example, emphasis is placed on full life cycle partnership between the acquisition and operational workforces; in-depth, comprehensive analysis of alternative solutions to mission needs; stable performance, cost, schedule, and benefit program baselines; and unified agency planning, programming, and budgeting within a long-range strategic framework.

These principles mean that cost estimates generally will be in life cycle terms. It also means that estimates will occur at major points in the life cycle of a program such as during mission analysis, investment analysis, or when there is a breach to the established program baseline. The cost estimate is a major consideration at the investment decision, when decision makers must choose among competing alternatives for limited resources. It is also the basis for the Acquisition Program Baseline (APB), the National Airspace System (NAS) Architecture, and the budget request. In fact, the cost estimate and the budget it supports are the traditional "yardsticks" by which program affordability, progress, and success are measured.

The life cycle processes addressed in the AMS revolve around and focus on the cost (estimate) of an item and the availability of adequate funding levels at the proper time. In other words, a reasonable and supportable budget is essential to the efficient and timely execution of acquisition programs. Such budgets are founded on competent estimates developed by the cost estimating community. Once management has approved the budget and its underlying estimate, they will measure the performance of programs in relation to this cost position. Therefore, it is mandatory that estimates accurately reflect program financial requirements. A less than competent estimate can impact a program's viability seriously.

The Society of Cost Estimating and Analysis (SCEA) provides the following definition of cost estimating: "The art of approximating the probable cost or value of something based on information available at the time." In practice, cost estimators usually focus on longer-term projections, such as developing program cost estimates prior to an investment decision. This handbook focuses on providing the cost estimator with the essential tools needed to support the FAA cost estimating requirements as outlined in the AMS.

1.2 Acquisition Policy

The federal government and airport service users pay for FAA's multi-billion dollar major system acquisitions. With such a taxpayer investment at stake, it is not surprising that numerous policy statements and rules exist regarding the acquisition of these systems. Acquisition policy is designed to instill discipline and sound management into the acquisition process. As stewards of public moneys, it is incumbent upon each individual cost estimator involved in the acquisition of these systems to assure that taxpayer dollars are spent prudently.

1.2.1 Executive Acquisition Policy

Public Law 104-50 directed the FAA to develop an AMS to address the unique needs of the agency. The law exempts the FAA from many acquisition regulations, including the Federal Acquisition Regulations, although the FAA has the discretion to adopt the portions of acquisition law into its system, as the FAA deems appropriate.

1.2.2 FAA Policy

The FAA AMS is a fully coordinated set of policies, processes, guidelines, and computer-based tools that guides the acquisition workforce through the entire acquisition life cycle. The FAA Acquisition System Toolset (FAST), an online information system available via the Internet (http://fast.faa.gov), provides access to the AMS. It is important for the cost estimator to be familiar with the AMS.

1.3 FAA Life Cycle Acquisition Management Process

The preceding discussion highlighted the policy that spawned the FAA life cycle acquisition management process. The process itself is a logical flow of activity that represents an orderly progression from the identification of a requirement through the disposal of the system that satisfied the requirement. This section provides a definition for an FAA program, identifies the acquisition decision makers, and outlines the life cycle acquisition process. The role of the FAA cost estimator is highlighted throughout the discussion.

1.3.1 The Program

The term acquisition program is defined in the FAA AMS as:

> *"a sponsored, fully funded effort initiated at the investment decision of the life cycle acquisition management process by the Joint Resources Council (JRC). An acquisition program is created in response to an approved Mission Need Statement. The goal of an acquisition program is to field a new capability that satisfies requirements, cost, schedule, and benefits stated in an Acquisition Program Baseline. Typically an acquisition program is a separate budgeted line item and may have multiple procurements and several projects, all managed within the single program."*

The FAA has three major categories of acquisition programs: systems and software, services, and facilities. Within the three categories, there are different types of acquisition programs with tailored processes (e.g., simple purchases of commercial equipment, non-developmental item hardware with developmental software, full developmental programs, leased services, major new facilities, and modification of existing facilities). An understanding of the type of program is crucial in developing a cost estimate. Simply stated, the choice of estimating methodology and the availability of data will be influenced greatly by the type of acquisition program. For example, a simple purchase of commercial equipment is much easier to estimate than a full developmental program. Estimating the cost of commercial equipment may involve research to obtain price quotes from vendors and some analysis, perhaps to adjust for quantity discounts and/or inflation. On the other hand, estimating the cost of a full developmental program may require the formulation of many ground rules and assumptions, an extensive data collection effort, the development of mathematical models, and detailed risk analysis.

The FAA AMS stresses commercial and non-developmental solutions to mission needs and provides a framework for evolutionary development so the upgrade of complex systems can be done efficiently and cost effectively. There is an emphasis on pre-planned product improvements (P3I). Hence, the estimator can expect to see activity in this area of estimating.

1.3.2 Acquisition Decision Makers

A key element in the FAA acquisition reform process was to place decision making and accountability at the appropriate level. The approach adopted is one of centralized policy decision making and decentralized program execution. This approach was designed to provide for both program stability and efficient execution. The following discussion identifies the key decision makers and the role of the cost estimator within the context of the FAA acquisition life cycle.

The Joint Resource Council (JRC) makes corporate level investment and resource allocation decisions, based on investment analysis prepared by an Investment Analysis Team (IAT). The JRC focuses on such corporate level issues as mission need decisions to determine what capability the FAA will pursue; investment decisions; APB change decisions; approval of the FAA Research, Engineering & Development (RE&D) and Facilities & Equipment (F&E) budget submissions; participation in the development of the FAA operations budget submissions; and approval of the NAS Architecture baseline. The corporate level nature of the decisions the JRC makes requires corporate level membership. As such, the JRC has as its members: Associate Administrators of the FAA lines of business, the Acquisition Executive, the Chief Financial Officer, Legal Counsel, and some Assistant Administrators.

The JRC is assisted in the investment analysis phase by many organizations. The major players are the Investment Analysis Staff (IAS), the Systems Engineering/Operational Analysis Team (SEOAT), and the IAT. Each of these teams is discussed in more detail below.

In recognition of the importance of the investment decision to the future of the NAS, the FAA created an Investment Analysis Staff to coordinate the activities in the investment analysis process and be the center of the agency's cost estimating capability. The IAS provides standards and guidance for the investment analysis, including how cost estimates are to be prepared. The IAS also is responsible for the FAA's investment corporate history (repository for cost data) and for developing tools and techniques for cost estimating. The Director of the IAS determines readiness for an investment decision and approves the Investment Analysis Report (IAR), which is presented to the corporate decision making body, the JRC.

An IAT is an ad hoc team assembled for each specific investment analysis. It draws experts from the IAS, sponsoring FAA organizations, the Integrated Product Development System, and other organizations. This team conducts the detailed analysis of alternatives during the investment analysis phase.

The SEOAT is a team of senior level managers representing the FAA's lines of business, systems engineering, and other appropriate acquisition functional disciplines responsible for supporting the JRC in establishing and maintaining year-round prioritization of all ongoing acquisition programs, performing affordability assessments for new proposed programs, preparing annual budget submissions, and preparing recommendations for reprogramming of funds. The SEOAT plays a crucial role during the investment analysis phase as the organization responsible for the affordability assessment.

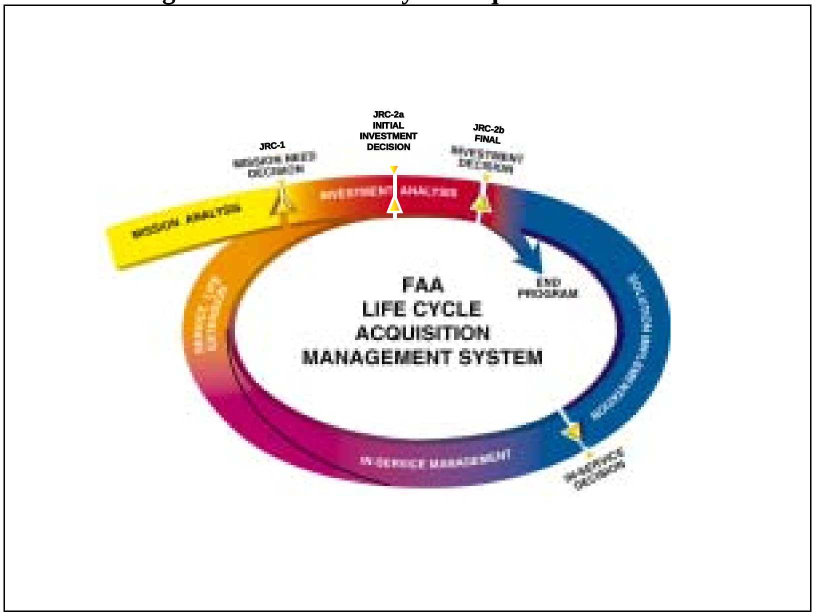
The cost estimator plays a key role during the entire acquisition process, but clearly the estimator's role is highlighted during the investment analysis phase. The Integrated Product Teams (IPTs) and the Product Team (PT) will need estimators to represent them on the IAT, specifically to help them build the life cycle cost estimates for their candidate solutions. The dedicated IAS consists of professional cost estimators, so the estimator will be involved in the full range of this organization's activities, including support to the IAT during investment analysis, and building databases, estimating tools and techniques, and standard agency-wide estimating guidelines.

1.3.3 Life Cycle Acquisition Phases

A brief description of each acquisition phase follows. The focus here will be on major cost estimating activities and products to which cost estimates are input during each phase. For an in-depth discussion of the acquisition life cycle, the reader should consult the FAA AMS document, available through the FAST. The FAST also includes detailed process descriptions of each of the life cycle phases.

The life cycle acquisition process is organized into a series of phases and decision points. This process is depicted in Figure 1.1. The process is shown as circular to convey the idea that a mission need is defined and then translated into the most advantageous solution, which goes through a continuous loop of evolution and improvement until it is retired.

Figure 1.1 FAA Life Cycle Acquisition Process



The life cycle acquisition process starts when the FAA determines that there is a potential need to expend funds to meet a mission capability shortfall or to take advantage of a technological opportunity. This determination is made at the conclusion of the mission analysis phase. Once the mission need is approved, the process of investment analysis starts. Cost estimating activities are conducted and products prepared to support two decision points of the investment analysis phase. The JRC 2a decision point, known as the initial Investment Decision, requires an initial IAR, initial APB, initial Requirements Document (RD), initial Acquisition Strategy Paper, and Action Plan/Exit Criteria for the final Investment Decision. In support of the initial Investment Decision, the FAA collects cost, schedule, benefits, human factors, and safety data, and conducts an alternatives analysis. This analysis is documented in the IAR and includes life cycle cost estimates of each candidate solution. The analysis is also used to develop the APB. At this decision point, the JRC selects a candidate solution for implementation; however, there is no variance tracking performed against the initial APB. During the JRC 2b decision point, known as final Investment Decision, the cost estimators address the Action Plan/Exit Criteria, refine APB parameter estimates, and collect operational data in order to finalize the documents prepared in support of the initial Investment Decision. Remember that an alternative has been selected, so the data at this point is focused on that selected alternative. At the final Investment Decision, the APB is approved and the program has an official baseline. From that point on, variance tracking is conducted. The process then moves out of the planning and into the execution phases of the life cycle. Corporate level decision making is still required when there are breaches to the APB established at the Investment Decision, or significant program changes.

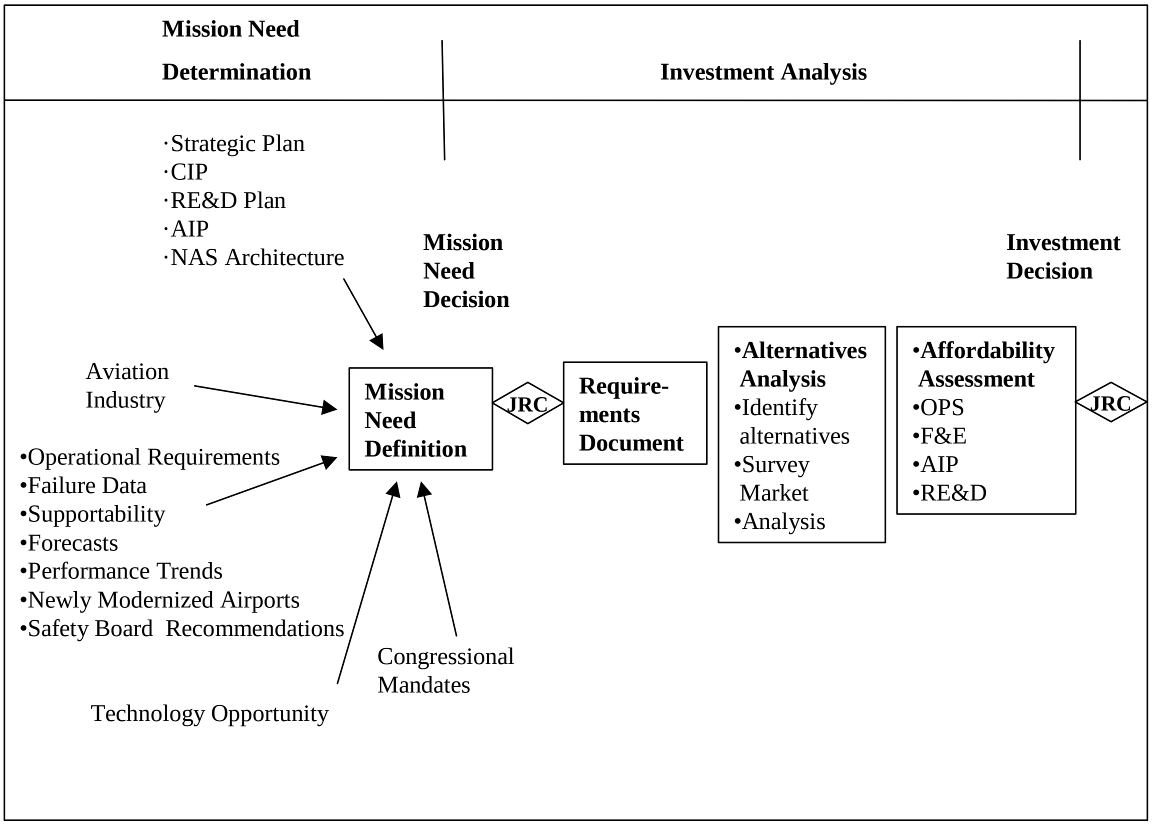
The execution phases consist of solution implementation, in-service management, and service life extension. During solution implementation, the approved alternative is fielded. This phase may be a lengthy, complicated phase with activities ranging from full development and production of new systems to integration of off-the-shelf equipment into the NAS Architecture. During the in-service management phase, the solution is operating in the field. This phase lasts as long as the product is in use. During this phase, IPTs have great flexibility for sustaining and enhancing the fielded capability without the need for corporate level approval. Pre-planned product improvements may be implemented as stipulated at the Investment Decision. Sustainment resources may be used to upgrade fielded products. The objective is evolutionary product development and rapid insertion of new technology. The service life extension phase starts when the FAA projects that the current capability will be unable to satisfy demand for services or when another solution offers potential for improving safety, lowering costs, or improving effectiveness. This should trigger action to support the investment analysis process leading to a new investment decision. With this, the loop is closed; and the acquisition life cycle has come full circle.

Mission Analysis Phase

Performing mission analysis requires an overall understanding of NAS Architecture, Congressional mandates, and FAA strategic plans. Mission analysis is done by each of FAA’s lines of business: Air Traffic Services, Commercial Space Transport, Regulations and Certification, System Safety, Airports, Administration, and Research and Acquisition. As shown in Figure 1.1, mission analysis is depicted off of the main life cycle path to underline that it is a continuous. The front-end acquisition process is an independent process from which needs emerge and is outside the environment of individual program execution. Mission analysis is the comprehensive process undertaken to identify and prioritize the most critical FAA service deficiencies. Each need is documented in a Mission Need Statement (MNS). The MNS clearly describes the capability shortfall and the impact of not satisfying the shortfall. It also assesses the criticality and timeframe of the need. All of this information assists the FAA in prioritizing the need in conjunction with other agency needs and in determining which needs to approve for the next step in the process, investment analysis. This process is depicted in Figure 1.2.

Cost Estimator's Role in Mission Analysis

Figure 1.2 The Front-end Acquisition Process



During the mission analysis phase, cost estimators will be called upon to assist in determining a range of rough order of magnitude life cycle cost estimates to serve as "placeholders" representing the mission need in the NAS Architecture. Also, the estimator can expect to be involved in assisting with the quantification of the benefits for satisfying the mission need. Examples of how to quantify such benefits include number of lives saved and reduced equipment downtime. Furthermore, the FAA AMS states that the cost of not addressing the need should be estimated.

<u>Investment Analysis Phase</u>

As shown in Figure 1.2, the receipt of an approved MNS starts the activities identifying the most advantageous solution. This is known as the investment analysis phase. Investment analysis generates the information used by the JRC to determine the best overall solution for satisfying a mission need, called the Investment Decision. Principal investment analysis activities are to:

- Determine initial requirements
- Finalize requirements
- Identify alternatives and survey market
- Determine viability of nonmaterial solutions
- Analyze alternatives

- Assess affordability,
- Develop APBs
- Prepare the IAR
- Select an optimal solution
- Initiate a program

An agency decision on whether to fund and implement the selected solution completes the investment analysis phase.

Cost Estimator's Role in Investment Analysis

The cost estimator contributes significantly in this phase. The IAS, serving as the FAA's cost estimating center, leads the effort to identify and analyze candidate solutions that satisfy the mission need. As a member of the IAT, cost estimators from the IPT, assisted by estimators from the IAS, will develop life cycle cost estimates of the candidate solutions. Also, they will be involved heavily with the cost benefit analysis of all candidate solutions. The estimator's input will be a significant piece of the IAR, which goes to the JRC for selection of the solution. Each organization represented on an IAT has a role in developing an APB. The APB includes the cost, schedule, performance, and benefit baselines that each candidate solution is intended to achieve. During this phase, an affordability assessment is developed by the SEOAT, which compares the life cycle cost estimates to the NAS Architecture estimates developed during mission analysis. Only affordable solutions that fall within the boundaries of the NAS Architecture range of estimates go forward to the JRC.

Cost Estimating Products from Investment Analysis

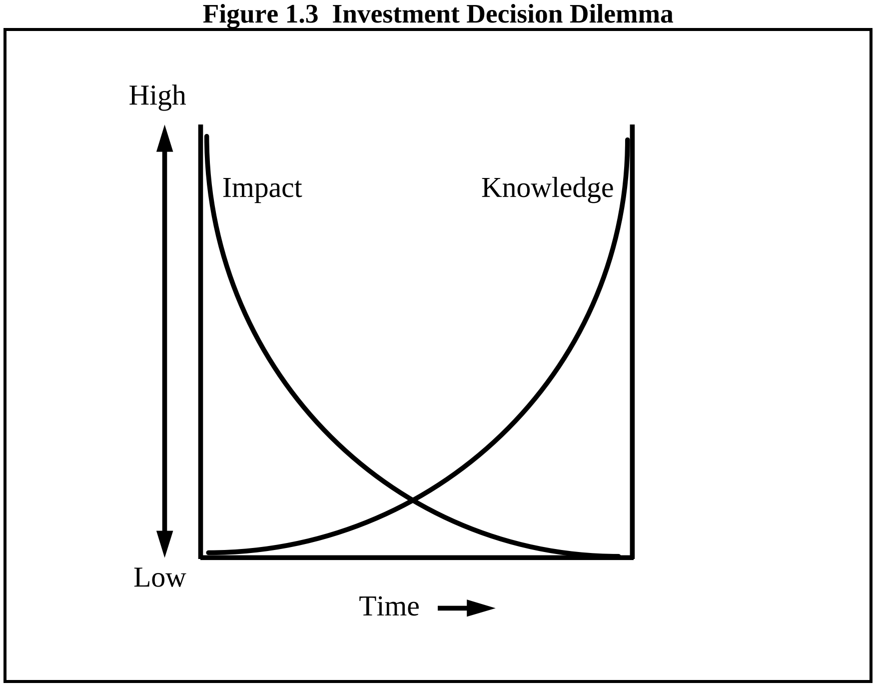
The investment analysis products that are used in future phases and that have heavy cost estimating input are the IAR; the APB (for performance, cost, schedule, and benefits) for the selected solution; the Basis of Estimate (BOE) and an adjusted NAS Architecture and budget planning documents. The IAR allows decision makers to choose the optimum solution to a mission need. A critical tool to help with this choice is the cost-benefit analysis prepared with heavy input from the cost estimator. Once a solution has been implemented, the life cycle cost estimate for the chosen solution becomes the APB against which program performance is measured for the rest of the life cycle. The BOE, which documents the data upon which the estimates were made, is a key product that is provided even though it is not mandatory. It is important in support of any follow-up analysis, such as rebaselining. The NAS Architecture and budget documents are adjusted to reflect the APB estimates for the chosen solution. The FAA's AMS intends to fully fund programs, since full funding of programs is a prerequisite to stable program management. Credible estimates are crucial ingredients to these documents and to the entire life cycle acquisition process.

FAA acquisition policy mandates rigorous analysis of requirements, market capability, and affordability during investment analysis to determine whether mission need can be satisfied with commercial or non-developmental products as a first priority. Greater use of commercial products minimizes cost and risk to the government, and delivers new capabilities to the user more quickly. FAA acquisition policy also attempts to maintain a healthy tension between the pull of requirements and the push of technology that enables the organization to satisfy requirements. Whether the product or service to be acquired is non-developmental or requires research and development expenditures by the government, the estimator will play an important role during investment analysis.

Cost Estimator's Dilemma During Investment Analysis

Evaluating viable solutions during mission analysis and investment analysis, particularly when the solutions require large developmental expenditures or where a good historical database does not exist, presents difficulties for the cost estimator. Decision makers seek precise cost estimates for solutions that have not been well defined, making precision impossible. This typical situation, depicted in Figure 1.3, presents a significant dilemma. During mission analysis and investment analysis, the impact of decisions has great influence over a solution's final content, configuration, and cost. However, during this time frame, there is a limited amount of specific program knowledge available to assist in rendering these important decisions. For instance, the cost estimate may (from necessity) be based upon technical generalizations and historic cost data that may not capture the technology and potential cost of the proposed system adequately. Yet, cost and performance trade studies developed using these early estimates will influence the selection of the "optimum" solution and dictate the system design and configuration that ultimately will be developed and produced. Once the program is established, the system's technical definition will become more refined, and actual program cost data will become available.

Figure 1.3 Investment Decision Dilemma



This "information known versus information required" mismatch is inherent to the early stages of the system acquisition process or where an organization is in the early stages of building a good historical cost estimating database. Thus, the mismatch presents to the cost estimator a significant challenge, which is to formulate accurate estimates early in the life cycle and with limited data in order to assist management in rendering correct decisions before a major commitment of money is made. The estimator must respond to these challenges through proper selection of estimating methodology. The estimating methodology used later in the life cycle typically will rely on predicting trends from actual program cost data, while estimates early in the life cycle are forced to rely on parametric or mathematical modeling or analogous systems.

To alleviate this dilemma, the FAA must develop sophisticated tools and good historical databases. This can be accomplished best by creating a centralized organization responsible for agency-wide standards for developing cost estimates, applying margins for risk mitigation and other cost growth factors, defining the elements of cost estimates, etc. This will ensure that cost estimates are consistent in their content and calculations, and absent of random errors that emerge if different organizations develop their own unique cost models. Establishing a centralized cost estimating capability will allow for a central repository of historical cost information – leading, in turn, to refinement of cost estimates over time because of the availability of more and better data.

The FAA has recognized this need for a centralized focus on cost estimating through the creation of an IAS, which will work with the FAA line of business that have justified a mission need to expend funds. Also, the IAS is proceeding with plans to further develop the corporate history.

Solution Implementation Phase

After the most advantageous solution from investment analysis is selected and a program is approved, the solution implementation phase begins. It ends after the new capability is developed, procured, tested, and is ready to go into service. Implementation is the responsibility of the IPT.

Cost Estimator's Role During Solution Implementation

During the implementation phase, the cost estimator will be involved in a number of activities. The IPT must manage the APB and report to the acquisition executive any anticipated breaches before they occur. Potential breaches can occur because of Congressional mandates, changes in requirements, unanticipated development problems that impact schedule, or cost growth on contracts. The cost estimator potentially will be involved in explaining cost impacts or reasons for cost growth in all of these scenarios. There will be acquisition reviews during which the cost estimator may be involved in reporting the cost status of the program.

In-Service Management Phase

The in-service management phase begins when the new system, software, or facility goes into service in the NAS, and continues for as many years as the product is in use by the operators. During this period, IPTs are responsible for many things. They include developing and incorporating planned improvements; inserting new technology upgrades; developing engineering changes to fix problems; and planning, programming, and budgeting resources for the operators to sustain the fielded products. The IPTs also are responsible for monitoring and assessing performance, cost of ownership, and support trends; planning and preparing for service life decisions to correct capability shortfalls; and seeking technology opportunities to enhance the fielded capability.

Cost Estimator's Role and Products during In-Service Management

In addition to monitoring cost of ownership and supporting budget estimates, the cost analyst can expect to be involved in a new investment analysis process anytime there is a significant program change during this phase. This would occur if there were a breach of a program's established APB. An investment analysis would be performed if the current capability must be increased to such an extent that sustainment funding is not sufficient or when another solution offers potential for lowering costs significantly or improving effectiveness. When a new investment analysis is necessary, the IPT must prepare for a new FAA investment decision. The decision may be to dispose of the current system and replace it with a new one, extend its service life, or continue as is. The IPT will have to work with the IAS to identify all reasonable alternative solutions for attaining the needed capability. The IPT will have to revalidate the existing mission need, but a new MNS is not required. An IAR is required. This will, of course, involve life cycle cost estimates of all alternatives and a cost benefit analysis to identify the best solution. At the service life extension or disposal decision point, the program has come full circle in the program life cycle acquisition process and a decision to extend the service life or replace the system will require a new investment analysis.

The FAA acquisition process is an organized and effective means to initiate and conduct acquisition programs. From the cost estimator's viewpoint, it is important to recognize the role that life cycle cost estimates play in the entire process. It should be clear that the cost estimate is an integral part of program formulation, decision milestones, program execution, and a program's status is measured in relation to the program's initial estimate as reflected in the APB. Therefore, the initial estimate must attempt to forecast accurately the actual costs that will be incurred during the conduct of the program. If the estimating community strives for something less than this goal, it will not provide management of the information required for competent decision making and may provide Congress, review authorities, and the public an inadequate yardstick to measure program progress and performance.

2.0 OVERVIEW OF COST ESTIMATING

2.1 Introduction

This chapter, along with Chapter 3, "Process and Methodology," provides a basic overview of the cost estimating discipline. These chapters set the stage for more specific chapters by addressing the following questions:

- What is cost estimating?
- Why is it needed?
- When is it needed?
- How is the type of estimate defined?
- How is the estimate accomplished?

2.2 Cost Estimating Defined

Defining key cost estimating terms helps answer the question "What is cost estimating?" As presented in Chapter 1, the SCEA defined cost estimating as the art of approximating the probable cost or value of something based on information available at the time.

When an operational requirement is identified that calls for an acquisition of systems, software, facilities or services, FAA decision makers require estimates of all sorts - operational capability, technical characteristics, logistics requirements, schedules, and, of course, cost. A realistic cost estimate is an essential element in the decision making process because it can help decision makers determine the optimal course of action necessary to meet operational requirements. The cost estimate distills information into the common denominator of dollars. Whether cost estimating is viewed as an "art" or a "process," its purpose is to predict future costs based on today's knowledge. The rest of this handbook describes, in detail, the development of cost estimates to support FAA decision makers. This chapter addresses basic cost categories, types of cost estimates, and uses of cost estimates.

2.3 Cost Categories

To further define cost estimating, the reader is introduced to common terminology. The jargon of any profession enhances communication, so it is important for estimators to have common definitions and an understanding of cost estimating terms. This section defines well-known cost categories. Grouping costs into common categories satisfies different needs for cost data. For instance, depending on the decision at hand, management may want to see cost estimates categorized by phase of the life cycle (e.g., solution implementation phase versus the in-service management phase), frequency of occurrence (nonrecurring versus recurring), by cost allocation scheme (direct versus indirect), or by appropriation.

2.3.1 Life Cycle Cost (LCC)

To make intelligent acquisition decisions for the selection of a system to fulfill a specific need, it is necessary to look beyond the immediate cost of acquiring that system, software, facilities, or service. Suppose you are in the solution implementation phase of a given procurement and are considering various alternatives. To assist decision makers with an investment decision, should the estimate consider only the costs of the solution implementation phase? If this is done without considering in-service management phase costs, what may appear to be an expensive alternative among competing systems may be the least expensive when the cost of operating and supporting each is considered. For this reason, it is important to consider all relevant costs or each acquisition's LCC when making acquisition decisions. An acquisition's LCC has been captured when the estimate includes the total costs to acquire, install, operate, maintain, and dispose of it.

LCC elements reflect the program life cycle. Typically, there is an overlap of life cycle phases, but the costs can be identified with a certain phase based upon the effort they reflect. The acquisition portion of the life cycle is complete when a system is placed into operation. Therefore, total program acquisition costs refer to those costs incurred in the solution implementation phase. Because of shortfalls in available FAA O&M funds, acquisition costs may include the purchase of an initial set of spare and repair parts (one to three years supply), even thought these costs really should be considered a part of the in-service management phase. When the user takes ownership of the system or services, the ownership or in-service management phase begins. Costs incurred in this period consist of operating and maintenance costs.

For example, the manpower cost for an air traffic control terminal is an operating and maintenance cost. This cost occurs day after day and year after year, as the air traffic controller uses the terminal. The effort expended to design and build that terminal is a program acquisition cost, incurred once to buy the system. The following paragraphs discuss these standard cost definitions in more detail.

<u>Solution Implementation Costs</u>

The activities conducted during solution implementation vary widely depending on the nature and scope of an acquisition program. For example, the activities associated with buying and deploying a commercial product may be much less than those associated with a product requiring development, if the product is not safety-critical in its FAA application. Conversely, if the product is needed in an FAA safety-critical application, there are significant costs associate with proving the safety and effectiveness of the COTS product that may well more than offset the cost advantages accruing from the economies of scale in the commercial market. The FAST contains generic process flowcharts for representative types of acquisition programs. (The FAST can be accessed via the Internet at http://fast.faa.gov.) Also included are instructions, templates, best practices, examples, and lessons learned. The types of cost elements in an estimate will depend on the type of acquisition program.

Acquisition Costs

> NOTE:
> Estimates generally are disaggregated into Acquisition and Operating and Maintenance pieces because the estimating methodologies for each phase tend to differ substantially.

The costs incurred during solution implementation fall into the broad category of acquisition costs. Depending on the type of acquisition (developmental, non-developmental, etc.), this category may or may not include research and development costs and production/installation costs.

Research and Development Costs. Requirements definition costs will be incurred for any kind of acquisition, developmental or non-developmental. If the FAA is purchasing a developmental item, it will incur costs of the following nature.

- Requirements definition
  - ⇒ Costs of defining mission need, preparing requirements documents, etc.
- Concept analysis
  - ⇒ Costs of identifying alternative system concepts and design approaches
- Design and demonstration
  - ⇒ Costs to design, produce, and test alternative engineering models
- Full scale development
  - ⇒ Engineering design, fabrication, manufacture, and test of development articles and related support
  - ⇒ Government test and contractor support
  - ⇒ Software development

Production and Installation Costs. Production cost includes the costs associated with the purchase of off-the-shelf or non-developmental items or the production of developmental items in the quantities required to support FAA objectives. Normally, the production category would include costs associated with the following:

- Government and contractor program management
- Land
- Real property improvements
- Prime mission products (equipment, software, services, etc.)
- Peculiar support equipment
- Common support equipment
- Equipment installation and test
- Software installation and test
- Initial stocks of consumables and spares
- Maintenance training of initial cadre of maintenance personnel
- Training of initial cadre of system operators
- Data

<u>In-Service Management Costs</u>

Operating & Maintenance (O&M) Costs

The in-service management phase of the life cycle includes ownership costs of the operating and maintenance type. These costs start with system delivery and continue throughout its operational life. The following list identifies the majority of O&M cost elements. A more detailed explanation of this cost category can be found in Chapter 13.

Operating Costs. This cost area includes those costs incurred to operate a system, such as:

- Personnel
- Consumables
- Energy and utilities
- Facilities
- Telecommunications
- Computer service costs
- Training
- Travel

Support Costs. This cost area includes those costs required to maintain a system, such as:

- Personnel
- Consumables
- Energy and utilities
- Facilities
- Telecommunications
- Computer service costs
- Spares and support equipment
- Packaging, handling, and transportation
- Training
- Travel

<u>Disposal Costs</u>

These are the final costs incurred to terminate a program at the end of a system's life cycle. They include dismantling costs of all kinds, transportation and packaging costs to ship old assets from the dismantled site to the disposal site, site restoration costs, environmental cleanup costs, hazardous waste disposal costs, and storage costs for assets removed from an operational site prior to disposal.

2.3.2 Nonrecurring and Recurring Cost

> NOTE:
> A separation of nonrecurring and recurring costs is useful if costs of continued production are expected to be required at a later date (e.g., building a learning curve for future production estimates).

Nonrecurring costs are the capital expenses incurred prior to the production of the first unit of output. For example, nonrecurring costs could include initial engineering, system test, tooling, and pre-production activities. These capital costs exclude prepaid materials, supplies, and parts used to produce a unit of output. Nonrecurring costs can be defined broadly (program nonrecurring), or narrowly (nonrecurring costs on a specific contract). Whether narrowly or broadly defined, the one-time nature of nonrecurring costs is what distinguishes them from recurring costs.

Recurring costs are the ongoing costs required to generate the first unit of output or acquire the first item and to operate and maintain the proposed system. These costs may occur either annually or periodically over the system's life. The major types of recurring costs are commercial acquisition costs, production costs, technology refreshment costs (i.e., periodic replacement of COTS components to ensure supportability), personnel costs, consumables, energy, and utility costs. These are repetitive in nature and occur when there are like costs on a repetitive basis. They are similar to variable costs because they vary based on quantity acquired. Recurring costs can be defined broadly (program recurring) or narrowly (recurring costs on a specific contract).

2.3.3 Direct and Indirect Costs

> NOTE:
> Estimating methods tend to differ for direct versus indirect costs, just as they do for other categories of cost.

The above cost categories can be defined further as either direct or indirect costs. A direct cost is any item of cost that can be identified specifically with one end objective such as a product, service, program, function, or project. These costs may be charged directly to a given contract charge number. For example, if a company produces filing cabinets for sale, the sheet metal used to form the cabinets would clearly be a direct cost associated with the cabinets, and with no other product.

Conversely, an indirect cost is a cost that cannot be specifically and consistently identified to direct work orders. Indirect costs are also known as overhead or burden. They are accrued and accounted for in cost pools, and allocated to end products or services over a direct cost base, such as dollars or hours. A typical example of an overhead cost is facility power. Lights and heat must be available to keep a building operating, regardless of what particular projects are in work. Therefore, this cost is allocated in a consistent, objective manner to all projects in work for a given period of time. For an estimator, this means that indirect costs will be calculated by applying an overhead rate to a direct cost base. For example, factory overhead (such as utilities) may be applied to the direct manufacturing hours or dollars expended on all jobs in the factory.

Each company will have different cost accounting methods, but it is very common to see costs segregated into direct and indirect categories. The cost estimator must be aware of these categories, since both play a sizable role in a typical estimate. This type of cost breakout is especially important during source selection. Competing contractors will have different rates and allocation bases and government analysts need to understand how the rates are applied in order to do a correct cost analysis of these contractor proposals.

2.3.4 Fixed and Variable Costs

A common way of classifying costs is to break them into fixed and variable costs. In particular, this classification of costs is used in doing break-even analysis, such as in making an investment decision.

> NOTE:
> In some analyses, an estimator may want to determine the effect of rate of production on costs, such as when the government proposes stretching programs out in order to live within current funding constraints. In this scenario, it would be necessary to be able to break costs into fixed and variable categories.

In his book, *Cost Estimator's Reference Manual*, Rodney Stewart defines fixed cost as that group of costs involved in a repetitive process that remain relatively constant regardless of the quantity of output. For example, general plant maintenance costs tend to be fixed from month to month, regardless of how many units are produced in a given month. Machine maintenance costs will also be fixed up to a point, but clearly will be affected more by quantity of output being processed on the machine. This might be considered a semi-fixed cost. The timeframe of consideration for a given analysis will affect the classification of costs as fixed or variable (in the long run all costs are variable).

Variable costs are those that vary in direct relationship to the rate of output. Following through on the plant example used above, a clear variable cost would be the amount of labor hours expended in a machining process. Those labor hours are expended only if output goes through the machining process.

> NOTE:
> There is overlap among all the cost categories. An experienced cost estimator will recognize the nuances among the categories. For example, nonrecurring costs are those costs generated to incur the first item of output. Thus, they include many costs in the fixed category like plant construction and tooling. However, they also include variable costs of labor and material to produce the first unit of output. Classifying costs as recurring versus nonrecurring facilitates the use and development of learning curves, a method discussed in Chapter 9. Classifying costs into fixed and variable categories is essential to doing a break-even analysis to determine if an investment is advisable.

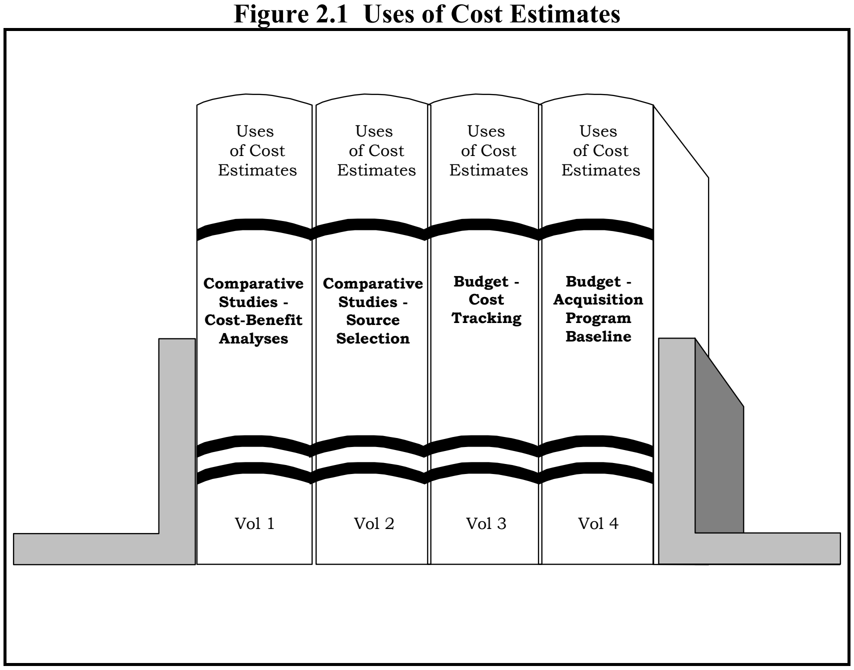
2.3.5 Costs Categorized by Appropriation

Cost estimates are prepared at various stages of the acquisition process, but ultimately will be used to justify funding for an acquisition. In other words, the cost estimate eventually will have to be compared to a budget to see if an acquisition is affordable. Thus, there is a need to categorize cost estimates by budget category. For a government agency, this means cost estimates will have to be presented by appropriation since that is how Congress allocates money to agencies. The FAA has four appropriations, already mentioned in Chapter 1: the Research, Engineering, and Development (RE&D) appropriation, the Facilities and Equipment (F&E) appropriation, the Airport Improvement Program (AIP), and the Operations (OPS) appropriation.

2.4 Uses and Types of Estimates

The previous paragraphs provided a brief definition of cost estimating and described various categories of costs the cost estimator is likely to encounter. This narrative answered the question "What is cost estimating?" Now to the question "Why and when is cost estimating needed?" The answer is straightforward. In spite of all the names and labels ascribed to various estimates, they fall into two major "use" categories: comparative studies for planning purposes and budget estimates that allow plans to be translated into action. These uses dictate when estimates will be prepared. Comparative studies are done when there is a new mission need, a revalidation of an existing mission need, or such a change in program that it makes sense to evaluate alternative solutions to the mission need. Figure 2.1 presents a high level view of how cost estimates are used. Each of these uses will be discussed below.

Figure 2.1 Uses of Cost Estimates



The use of an estimate at a particular point in time depends on where a program is in its life cycle. If a program is in the investment analysis phase, estimates will be prepared to support that decision making process. Once decision makers choose a course of action, they must translate estimates into an APB to manage the program and into a budget in order to obtain funding. Many estimates eventually turn into budget estimates.

The requirements of the mission need drive costs. Comparative studies during the investment analysis phase are particularly useful in that they can help avoid "requirements creep" by focusing attention on the cost impact of those requirements. But programs are not stagnant; and requirements creep, changes in mission need, and enhanced technologies are facts of life. The FAA AMS has published a number of guiding principles, which include evolutionary product improvement and faster insertion of new technology. To support these principles, cost estimating is an ongoing process throughout the life of a program. It is an overriding input during the investment analysis phase, but requirements for cost estimates will continue during other phases as the need arises - if there is a program change due to a new technological development, a service life extension decision, or a baseline breach. The following paragraphs discuss each “use” category in more detail.

2.4.1 Use Category 1: Comparative Studies (Alternatives Analysis)

Comparative studies or alternatives analyses are an integral part of any investment analysis since they provide decision makers with the information they need to make good choices. Decision makers face various options in trying to solve problems. Comparative studies are designed to provide decision makers with the information they need to choose among these options. Typically, these studies involve technical, performance, and cost comparisons. In comparative studies, the cost estimate is a valuable tool and is often the critical selection criterion.

Comparative studies are particularly valuable in the early stages of planning when the primary objective is to establish an efficient and economical course of action, i.e., in the investment analysis phase. However, comparative studies are not restricted to the early planning activities and, in fact, are used throughout all phases of a system’s life cycle. Even after a system has been in operation, comparative cost studies (called “trade studies” by systems engineers) are often the determining factor in deciding whether to modify a system to increase its performance and life (service life extension) or to acquire a new system. Comparative studies also are used in selecting various in-service management phase choices, such as whether to use in-house or contractor support. Comparative studies are used in source selection when the decision rendered is translated into a contractual obligation. In source selection the government must have an independent government estimate to assist in the best choice of contractor.

2.4.2 Use Category 2: Program Execution

Cost estimates used for the comparative analysis will become refined at some point in the acquisition life cycle to allow management of the actual execution of the approved program. In other words, once a decision has been made to select one of the alternatives used in a comparative study, money will be made available to give the program life. The next major “use” category for estimates can be defined as program execution. Once the decision has been made to pursue a certain course of action, the IPT will establish an acquisition program baseline that includes the life cycle cost estimate of the program. Management will measure progress of a program by comparing actual performance against the cost, schedule, and technical baseline in the acquisition program baseline. As the program moves through different life cycle phases, the acquisition program baseline is updated to reflect the current program. If there is a baseline “breach,” a “mini” investment analysis is triggered. The affordability assessment process allows funding to be made available to translate plans into action. Since this program execution process is ongoing, the IPT is wise to structure the acquisition program baseline estimate to allow for easy “what-if” drills. This will make affordability assessments easier to calculate when requirements may be reduced or stretched out to accommodate reduced budgets.

Many cost estimates start as decision making tools at major program decision points and end up as the foundation for acquisition program baselines and budget estimates. The primary differences between an estimate prepared for comparative studies and one prepared for budget purposes are in the detailed time phasing of costs. The budget estimate is more detailed, and time phasing is more involved and precise. Also, budget estimates must display costs by appropriation, which is how Congress allocates money to accomplish its objectives.

2.4.3 Types of Analyses and Estimation

The following types of cost estimates can be used for comparative studies and as the basis for program execution estimates. In fact, the IPT estimator or budget analyst should be able to reconcile the most current cost estimate in the APB with the budget estimate.

Cost Benefit Analysis

The Cost Benefit Analysis (CBA) is an integral part of the Investment Analysis Report developed in the investment analysis phase. The CBA analyzes the relationship between LCC and the operational benefits and cost savings of concepts or alternatives that are technically feasible and can meet the mission need. The purposes of the CBA are to:

- Facilitate decision making among decision makers and staffs, at all levels, by early identification and discussion of all reasonable concepts and alternatives to meet mission need;
- Determine whether a program is justified economically;
- Aid decision making by indicating clearly the relative advantages and disadvantages of the concepts/alternatives being considered; and
- Document acquisition decisions by providing the analytical underpinning or rationale for decisions on a program.

The CBA must contain an LCC estimate for each alternative and the reference system identified as candidates to satisfy the mission need. The CBA also contains an analysis of the benefits of each alternative. Finally, the CBA will present certain financial measures or ranking criteria to assist the decision maker in choosing among the alternatives. A separate chapter on how to prepare a CBA is included in this handbook.

Acquisition Program Baseline

The APB is the contract between the providing and user organizations concerning what the acquisition program will provide, how much it will cost, and when it will deliver products and services. It defines the performance, supportability, and benefit requirements of the program and sets the cost and schedule boundaries within which the program is authorized to proceed. The APB is established at the Investment Decision and represents the solution chosen by the JRC.

The APB contains a performance baseline that defines mission-critical performance parameters, a schedule, a benefits baseline, and a cost baseline. The cost baseline includes a time-phased life cycle cost estimate and a funding baseline. The funding baseline is included in the NAS Architecture. Both the funding and life cycle cost baselines are presented as a single "ceiling" value. They include all costs (RE&D, F&E, and OPS) that will be spent on the system over its entire life. The life cycle costs are broken out by year, WBS element, and life cycle phase.

Independent Government Cost Estimate

Once the investment decision is rendered, the government actively begins to translate the requirements into contractual obligations. Requests for proposal are issued to industry and source selection occurs. The government should then prepare an Independent Government Cost Estimate (IGCE) of the most probable cost of contracting with industry for a given product, service, or mission (sometimes called the "should cost" estimate).

2.5 Summary

This chapter defined cost estimating, discussed the importance of a cost estimate in the FAA decision making process, and identified cost categories as they relate to acquisition program phases. Also, the two basic uses of cost estimates (comparative studies and program execution studies) were addressed, and different types of cost estimates were discussed. The chapter answered the first four questions posed in the introduction. The final question, "How is the estimate accomplished?" will be answered in Chapter 3, "Process and Methodology."

3.0 PROCESS AND METHODOLOGY

3.1 Introduction

The preceding chapter defined cost estimating and discussed its categories, uses, and types. The next step is to understand the estimating process and to answer the question "How is the estimate accomplished?" The discussion in this chapter is drawn from a number of estimating references and represents a "common sense" approach to estimating distilled from processes used in a variety of organizations. The FAA, through the establishment of a central cost estimating function in the Investment Analysis Staff, has made significant progress toward improving estimating by fostering standardization of methods and processes. This will result in more consistent estimates and accuracy as the corporate history management system and estimate formulation techniques are refined. Therefore, the FAA cost estimator will want to refer to the guidelines for estimating developed by the Investment Analysis Staff, in addition to what is found in this chapter.

3.2 Cost Estimating Process

The cost estimating process can be viewed as a systematic approach consisting of the following steps or tasks:

- Plan the estimate (Chapter 4)
- Research, collect, and analyze data (Chapter 5)
- Develop estimate structure (Chapter 4, Section 4.5.1)
- Determine estimating methodologies (Chapter 3, Section 3.3)
- Compute the cost estimate (Chapter 6)
- Document and present the estimate to decision makers for use (Chapter 7)

As shown above, each task either is discussed in this chapter in its entirety, or introduced in this chapter and discussed more fully in later chapters of this handbook.

3.2.1 Planning the Estimate

The first step in developing an estimate is defining the estimating task and planning the work to be accomplished. The definition and planning stage includes determining the ultimate use of the estimate; understanding the level of detail required; outlining the total characterization of the system being estimated; establishing ground rules and assumptions; selecting the estimating methodologies; and finally, summarizing all of these in an estimating plan. Chapter 4 will provide a detailed examination of each of these areas. For now it is important to understand that task definition and planning is an integral part of any estimate. It represents the initial work effort and provides the framework for achieving a competent estimate efficiently.

3.2.2 Data Research, Collection, and Analysis

A function of task definition and planning is the initial identification of estimating methodologies. Once methodologies have been identified, preliminary research can commence to determine the availability of data required to support the final selection of the methodology. This research may dictate a different approach due to lack of adequate data. For instance, if an analogy method (Section 3.3.2) is initially selected, but technical and cost data are not available on a similar system, a parametric method (Section 3.3.1) may have to be employed instead. Beyond preliminary research, this estimating phase will involve one of two paths, or both, depending on the selected methodology.

On the first path, data research, collection, and analysis may be required to develop a cost estimating relationship (CER) to estimate a particular area. This path involves a considerable amount of time. In addition to the research, collection, and analysis of the data to be used, the cost estimator must construct the estimating relationship and ensure it is statistically sound and logically represents the area to be estimated. If the hypothesis proposed at the start proves false, the cost estimator has invested a significant amount of time without deriving a workable methodology. The potential for this type of eventuality should be factored into the estimating schedule.

The second and most commonly used path is the direct application of historical cost data to the estimate, either through use of similar programs or data on the same programs. This approach involves research to determine the most applicable data to use. For instance, when estimating a modification to a radar system, it may be appropriate to limit the data collection to radar modifications rather than including new radar systems. These decisions require estimator judgment based on knowledge obtained during the definition and planning phase. The key point is to narrow the research scope to achieve a viable database in the time available.

The analysis portion of this phase should ensure that the cost data collected are applicable to the estimate. It often is necessary to delete elements of data and adjust or normalize others to derive a database that will support the selected methodology. When analyzing contractor data, the cost estimator must understand the peculiarities of each contractor's accounting system, work breakdown structure (WBS), and labor rate content. When applying historical factors to estimate various cost elements (e.g., systems engineering and program management as a percent of recurring hardware), the estimator must consider differences between the work content represented by historical data and that of the current system. The analysis function cannot be overemphasized. For this reason, analysis of contractor data is discussed throughout the handbook, and Chapter 5 is dedicated to this important subject.

In addition to technical and cost data, the estimator requires programmatic information to phase the estimate properly, understand interrelationships with other systems, and ensure inclusion of all cost elements. Normally as the estimating task is being defined and planned, this programmatic information will be collected. The following is a list of FAA source documents from which programmatic information is available. Specific estimate requirements along with the stage and nature of the program will influence the exact data to be extracted from these documents.

- Mission Need Statement
- Requirements Document
- Investment Analysis Report
- Acquisition Program Baseline (performance, cost, schedule, benefits, risk)
- NAS Architecture and budget planning documents
- Acquisition Strategy Paper
- Integrated Program Plan

Because the availability and applicability of data are key to the selection of cost estimating methodologies, it is important to understand the area of data collection in detail. Chapter 5 discusses this topic.

3.2.3 Development of the Estimate Structure

When forming the estimate structure for purposes of data collection, as well as the actual estimating task, the first step is to break down the estimate into broad groups of cost. For a LCC estimate, acquisition and O&M would form the basic sections of the estimate. The next step would be a further breakdown of these broad categories into more discrete areas of cost. Chapter 2 included a discussion of subcategories within these broad categories. However, when forming the estimating structure for a specific acquisition, the logical tool to use is the work or cost element structure. The work element structure refers to a hierarchical structure of work elements that defines the full family tree of a work activity. (Rodney D. Stewart, *Cost Estimator's Reference Manual*, page 4.)

A standardized form of work element structure that is commonly used by government agencies is the WBS. The WBS is used to manage acquisition programs by defining the elements of work typically found in acquisition programs. The FAA Standard Work Breakdown Structure is intended for use across the FAA for developing life cycle cost estimates of solutions and is available on FAST. It represents the complete set of activities that may be accomplished to provide a solution that satisfies a FAA mission need. The WBS also will support management of solutions during the solution implementation and in-service management phases, and will aid in the comparison of life cycle cost estimates to actual costs that are collected through the FAA Accounting System.

3.2.4 Determining the Estimating Methodology

There are various cost estimating methodologies that a cost estimator can use throughout a program's life cycle. The choice of the proper methodology for a given estimating scenario is clearly an important determinant for producing a good estimate. It should be noted that more than one methodology could be used during the course of preparing a cost estimate. Section of this chapter introduces a variety of cost estimating methodologies and focuses on the key factors to consider in choosing an estimating methodology. The three main estimating methodologies (parametric, analogy, and engineering), with step-by-step instructions on how to use each one, are explored in detail.

3.2.5 Computing the Cost Estimate

The coming together of data analysis, the cost structure, and the selected methodologies signal the start of number crunching, or the pulling together of the estimate. Generally, an electronic spreadsheet will be employed for the majority of the estimator's computing needs. Chapter 6 discusses in detail the process of entering data and methodologies into the physical structure of the estimate (the work element structure); time phasing the estimate; and dealing with inflation.

3.2.6 Documenting and Presenting the Estimate

The job is not finished when the numbers are down on paper or contained in an electronic spreadsheet. Throughout the performance of the estimate, the cost estimator should be considering the final product and how and where it will be reviewed and presented. The different types of estimates discussed in Chapter 2 require various levels of review and standards of presentation. Establishing a "baseline presentation package" during the early stages of the estimate is extremely beneficial because it provides a format that can be expanded to facilitate internal progress reviews. Since pertinent programmatic, cost, schedule, and technical information are captured, they will serve as the basis for the final briefing package. The FAA Investment Analysis Process guidelines include presentation and documentation formats that are required in the Investment Analysis Report. The estimator should refer to these guidelines for the most up-to-date information on formatting.

Establishing the baseline presentation package is another way of ensuring that all cost elements are being covered in the estimate, thereby eliminating last minute briefing preparations. Initial review of the baseline package with management will minimize the potential for surprises as the briefing enters the review cycle. Here again, the Investment Analysis Staff guidelines and the staff itself are an invaluable resource for the estimator.

Documentation is often viewed as the final task and, with that perspective, becomes a most difficult task. If documentation is left untouched until the end of the estimate, it becomes extremely difficult to recapture the rationale and judgments that formed the estimate. Four key considerations will be offered here regarding documentation.

- First, documentation should not be postponed until the estimate is complete. Documenting the estimate as it is performed lends efficiency to its preparation and quality to its content. The documentation process, if done diligently, will virtually eliminate calculation errors inherent to number crunching.

- Second, an abundance of detail is preferred to a shortage of information about an estimate. Documentation should start with the premise that the reader knows nothing about the program or estimate. Consequently, documentation should be written in a step-by-step fashion.

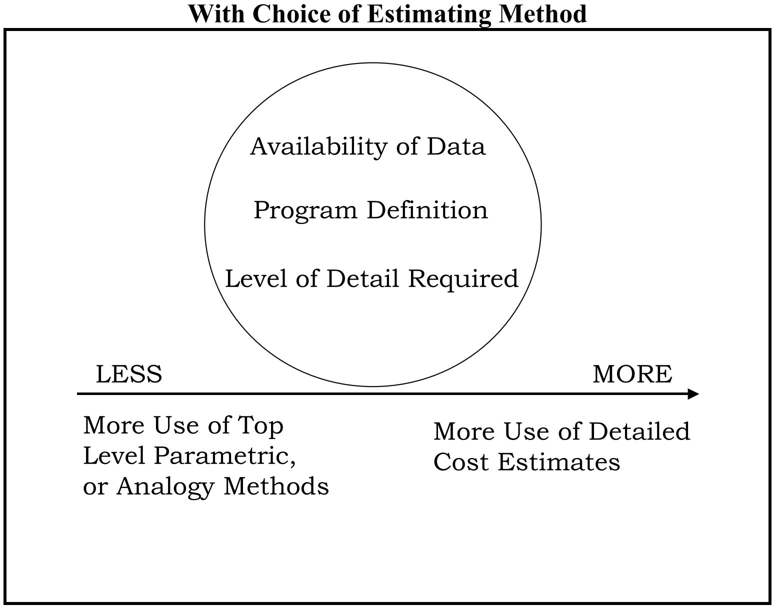
- Third, replication is the keystone of good documentation. Everything that is necessary to replicate the estimate by another cost estimator who had not participated in its formation should be included. Keep in mind that the person normally using the documentation is another cost estimator who needs to update the estimate contained in the documentation or desires to use it to support some other estimating endeavor. Consequently, it should represent a technical document and serve as a useful tool to the cost estimator referencing its content.

- Fourth, and finally, the written documentation package is frequently the only exposure that reviewers and users have to a cost estimate. Consequently, for many reviewers, it may become the sole basis for judging the quality of the estimate. Others view a poorly documented estimate as a poorly conducted estimate; hence, little credibility will be placed in the results of that estimate. In addition, the cost estimator is likely to be regarded as incompetent and may lose one of the most valuable attributes required of all cost estimators, credibility.

3.3 Estimating Methodologies

When choosing a methodology, the cost estimator must always remember that cost estimating is a forecast of future costs based on a logical extrapolation of available historical data. Therefore, availability of data will be a major factor in the estimator's choice of estimating methodology. In addition to availability of data, the type of cost estimating method an estimator chooses will depend on such factors as adequacy of program definition, level of detail required, and time constraints. These factors are all interrelated, as shown in Figure 3.1.

Figure 3.1 Interrelationship of Program Factors With Choice of Estimating Method



Availability of data clearly affects the choice of estimating methodology. The FAA AMS emphasizes the use of commercial off-the-shelf (COTS) and non-developmental Items (NDI), so the FAA estimator can anticipate frequent instances where there are actual or catalog prices for the item being estimated or at least closely analogous items to use as a basis for the estimates. This type of estimating is low risk and relatively simple to do. When little data exists, the cost estimator's choices are more limited and involve more cost estimating risk. For instance, if the estimator must estimate the cost of a completely new concept that exists only in the minds of scientists and has never been made before, data on such a system will be severely limited. There will be no actual production data and an analogy or actual costs from a similar system cannot be used. In this case, an expert opinion may be the only choice of estimating methodology. These are the two extreme examples in the spectrum of potential estimating scenarios.

Now consider the question of program definition and level of detail required - two factors closely related to availability of data. During the early stages of program planning in a developmental program, program definition is typically very broad and decision makers are considering several widely diverging solutions to meet their requirements. In this scenario, the use of a parametric model is a sound approach because parametric models can function with very little information. Once a design is baselined and the program is defined more adequately, an analogy approach might be feasible. A parametric model still can be useful when the design is baselined, but if a good analogous system is available, it becomes feasible to use this as the primary estimating methodology. When a prototype or initial production units exist, a detailed engineering methodology becomes a viable approach. With the FAA AMS emphasis on use of COTS and NDI items, the estimating challenge will be less rigorous than it would be if the FAA philosophy were to develop new systems. However, there will still be plenty of estimating challenges, such as estimating COTS and NDI integration costs and the costs of ensuring safety-critical performance.

Time constraints also affect the choice of estimating methodology. When the time available to do the estimate is limited, the time available to collect and process data is also limited. Under severe time constraints, the cost estimator may choose a top-level parametric model for the sake of expediency, if a good one is available.

The three major estimating methods are discussed in more detail in the next sections.

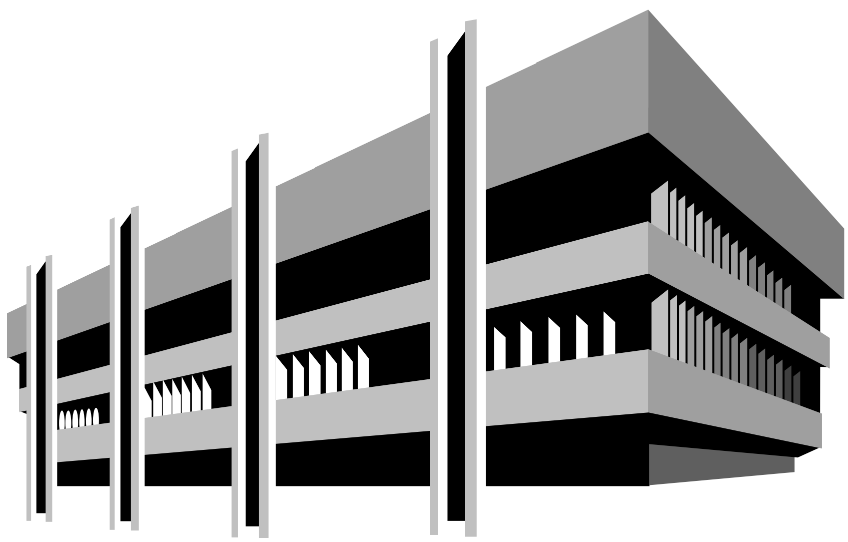
3.3.1 Parametric Estimating

The parametric method estimates costs based upon various characteristics or attributes of the system being estimated. It depends upon the existence of a causal relationship between system costs and these parameters. Such relationships, known as CERs, typically are estimated from historical data using statistical techniques. If such a relationship can be established, the CER will capture the relationship in mathematical terms relating cost as the dependent variable to one or more independent variables. Examples would be estimating costs as a function of such parameters as equipment weight, vehicle payload or maximum speed, number of units to be produced, or number of lines of software code to be written.

Parametric methods can be used to estimate costs at all levels of detail. As shown in Figure 3.2, they can be used to capture total costs of a system at a high level of detail such as when floor space is used to estimate building cost. On the other hand, they can also be used at a lower level of detail, for example to estimate the cost of electronic items. According to the *Joint*

Government/Industry Initiative Parametric Cost Estimating Handbook, certain manufacturers of electronic items have found that the cost of an electronic item varies directly with the number of electronic parts in the item. In other words, the sum of the number of resistors, capacitors, inductors, and transistors in a circuit design may be useful as a predictor of the circuit design's cost. This type of CER may be useful to an FAA estimator. There are also parametric cost models available to estimate the costs of individual custom microcircuit chips and/or electronic modules. Some of these models are flexible enough to allow input on custom chips, as well as COTS items. These models allow estimating at a very low level or a higher level of the WBS, depending on the availability of data.

Figure 3.2 Example of A Top Level Parametric Estimate



Building Cost = f{Floor Space}

This method is applicable to all elements of life cycle costs; but in the early stages of a program life cycle, this may be the only viable method because of limited program definition and data availability.

A widely used specific CER is the cost improvement curve, sometime called the learning curve. The theory states that as the total number of units produced doubles, the cost per unit declines by some constant percentage. In this CER, cumulative quantity is the independent variable; cost (measured by hours or dollars) is the dependent variable. Since quantity is the independent variable, this method works best when there is repetitive quantity production of like items. Table 3.1 shows an example of a 90 percent cost improvement curve. As the quantity doubles, the hours per unit to produce decreases by a constant 10 percent. If a company experiences a 90 percent learning curve, an estimator can use this information to predict what the cost per unit to produce is each time the quantity doubles. For instance, in Table 3.1, assume that an estimator has established that a 90 percent cost improvement curve has been observed in a manufacturing operation by reviewing the actual cost to produce certain quantities. With this knowledge, what would an estimator predict to be the cost required to produce a quantity of 16? Learning curve theory tells us that the cost to produce a unit should decrease by the amount of observed learning each time production quantity doubles. Production quantity has doubled from 8 to 16 units. Therefore, with a 90 percent learning curve, the cost to produce unit 16 should be 90 percent of the cost to produce unit 8. This equates to $131 ($146 for unit 8 × .90) to produce unit 16.

Chapter 9 discusses cost improvement curve applications and CERs in greater detail.

Table 3.1 90 Percent Cost Improvement Curve

Cumulative Units	Cost	Cost Reduction
1	200	--
2	180	10 percent
4	162	10 percent
8	146	10 percent
16	?	10 percent

The major advantage to using parametric techniques is that they capture major portions of an estimate in a limited amount of time and with limited program definition. Additionally, when using some of the more complex parametric models, the cost estimator is able to encompass the majority of the total program costs with this one method. Because CERs are based on actual program cost history, they reflect the impact of system growth, schedule changes, and engineering changes.

ADVANTAGE OF PARAMETRIC METHOD: This method can capture major portions of an estimate in a limited amount of time and with limited program definition.

There are, however, limitations to this methodology that an estimator should recognize. When the parametric employed captures cost at a very high level, it will not provide a low-level of visibility into discrete areas.

DISADVANTAGE OF PARAMETRIC METHOD: May not provide low-level visibility, and subtle changes in sub-elements cannot be reflected in the estimate easily.

As a result, subtle changes in areas such as design or manufacturing techniques cannot be reflected in the estimate. Another limitation is that individual pieces of the estimate may not be separable.

3.3.2 Analogy

The analogous or comparative method takes into consideration that no new program, no matter how advanced, represents a totally new system. Most new programs originated or evolved from already existing programs or simply represent a new combination of existing components. This method of estimating uses this idea as a foundation for estimating new components, subsystems, or total systems. Simply stated, it uses actual costs of a similar existing or past program, and adjusts for complexity, technical, or physical differences to derive the new system estimate.

ADVANTAGE OF ANALOGY METHOD: If a good analogy can be found, it allows for a lower level of detail, thus enhancing credibility.

DISADVANTAGE OF ANALOGY METHOD:
Can be difficult to find a good analogy and the required engineering judgment.

Normally an estimator would choose this method when there is insufficient actual cost data to use as a basis for a detailed approach but an analogous item exists on which to base an estimate, e.g., a custom item is being built in a microcircuit. If the chip is very similar to one that has been made before, and the custom chip's difference can be quantified in terms of amount of new design or additional number of transistors, it may be possible to estimate from this information. Comparisons may be made in terms of functional capabilities, module size, material composition, number of sides used for component mounting, or design complexity. A detailed engineering assessment is required to ensure the best analogy has been selected and proper adjustments are made. The ability to break the estimate down into a low-level of detail further enhances the credibility of the estimate, since separate analogies can be chosen for each component.

There are two limitations in using an analogous approach. First, is the requirement for a detailed program and technical definition of both the analogous system as well as the system being estimated. Engineering judgment becomes the mainstay of this approach and, at the same time, a limitation.

Without access to sound engineering support, this methodology is difficult to employ. Secondly, once the technical assessment has identified the analogous system, actual cost data on that system must be acquired. Without this, the transition from the analogous system to the current system cannot be made.

3.3.3 Engineering Estimating

ADVANTAGE OF DETAILED ENGINEERING ESTIMATING: Level of detail makes it easier to substantiate a cost estimate.

The engineering method (also referred to as detailed, grassroots, or bottoms-up estimating) is an estimate that starts at a very low level of detail and builds up to a total cost. This type of estimate is used when detailed data are available on a system. Therefore, it is typical to find this type of estimate during Solution Implementation. At this stage of the life cycle, system technology and configuration are now expressed in actual cost data, and considerable detailed information is available about components and piece parts. The anatomy of such an estimate is shown in Table 3.2.

Table 3.2 Anatomy of a Detailed Estimate

Skill	Man-hours	Labor Rates	Labor $	Overhead Rates	Overhead $	Labor Plus Overhead $	Gen. & Admin.	FEE	Price
Engineering									
Manufacturing									
Quality Assurance									
Tooling									
Test									
Material									
Total									

This figure shows how the detailed estimate proceeds from a basic skill breakdown. Man-hour estimates of each basic skill are made in some manner (through labor standards, a learning curve, or an analogy). The application of labor rates to these estimates of hours yields a labor dollar estimate. Material quantities and rates are estimated similarly and combined to develop a direct material dollar estimate. After that, overheads, general and administrative costs, and fee are applied to generate the total estimate. The detailed engineering estimate, as you can see from this discussion, can incorporate other methods such as analogy or parametric methods. What distinguishes the detailed engineering method of estimating from these other estimates is the level of detail.

The detailed engineering estimate requires large amounts of information concerning labor and material requirements, but also provides very detailed estimates on every aspect of the project. Electronic spreadsheets are invaluable in generating a detailed estimate because they allow easy adding and subtracting of the various elements and levels of the estimate. They also allow large amounts of data to be summarized into useful reports for management. When buying COTS items the vendor would usually have detailed cost estimates, but these are not presented to the government. The government may just see a price.

DISADVANTAGE OF DETAILED ENGINEERING ESTIMATING:
The time-consuming nature of the task and the need for detailed actual cost data.

3.3.4 Other Methods Often Used with COTS and NDI Procurements

The various other methods used are described below. The first two are excellent choices for COTS and NDI procurements.

- The vendor bid method is a good method where vendor price data exist, such as with COTS and NDI items. If the item is developmental, the usefulness of this method as an estimating tool is limited because cost estimates usually are required prior to receipt of bids. However, previously developed contractor estimates may be used at times, provided they are assessed as reasonable.

- A method used for estimating off-the-shelf items is catalog or handbook estimating. Handbooks, catalogs, and other reference books are published that contain lists of off-the-shelf or standard items with price lists or labor estimates. The estimator can use these catalog prices directly as unit values for standard components within a larger system.

- Expert estimating or specialist estimating is a judgmental estimate performed by an expert in the area to be estimated. Obtaining an estimate of lines of code from a software engineer or the number and duration of tests from the program test manager are examples of the use of this type of estimating approach. Surveying a number of experts independently to reach a consensus of opinion, the Delphi Technique also may be used. This methodology is limited by the availability of expert judgment and the credibility of that judgment. This approach is best used as a cross check against an existing estimate or in combination with other methodologies.

- The manloading method of estimating is an estimate made by a contractor functional manager or the estimator. The manager or estimator projects the number and type of skilled individuals needed to complete a specific work effort. The projection is then transferred into a man-hour estimate. This approach requires a high experience level. It is often used in combination with other methods. For example, the cost of contractor flight test support may be estimated by determining the number of individuals required at the test site.

- Industrial Engineering Standards (IES) - sometimes known as engineered standards - are used frequently as an estimating tool. Normally IES are used to estimate the time required to perform well-defined tasks in the manufacturing environment. A standard hours estimate is developed by summing the standard hours for each operation required to build the product. A standard hours estimate represents the optimum time required to produce the product and usually is unachievable in the real world. A realization factor is applied to the IES estimate to account for the reality of learning, lot sizes, and process inefficiencies.

- Estimates-at-Completion (EACs) can be obtained from the performance measurement data submitted on a Cost Performance Report or a Cost/Schedule Status Report. The trends indicated in the reports, by both cost variance and schedule variance, are indicative of past and present performance. These trends can be extrapolated carefully to predict the trend of the future. This extrapolation, added to the actual expenditures to date, supplies the estimator with an EAC. This is a useful method for estimating on-going programs that require such reports from contractors.

3.3.5 Combination Methods

Most estimates require the use of a variety of methods. A different approach may be used for each area of the estimate so that the total system methodology represents a combination of methodologies. The examples on this page help illustrate this concept.

The estimator chooses and combines estimating methodologies based on the peculiarities of the estimating task. As no two estimates are alike, there are many combinations of methodologies possible. The choice should be made after careful consideration of those factors listed in the opening paragraph of this section - adequacy of program definition, level of detail required, availability of data, and time constraints.

EXAMPLE: ENGINEERING APPROACH
For a system in production, the engineering approach is selected. To project future costs for each of the functional areas, cost improvement curves are employed. Catalog prices are used for off-the-shelf items.

EXAMPLE: PARAMETRIC AND ANALOGOUS APPROACH
An electronic module consists of off-the-shelf and custom components. For the off-the-shelf components, catalog prices exist. For the custom components, a parametric estimate based on number of pins, transistors, and gates exists. The components must be integrated to construct the module, which must then be mounted into a radar. The estimator uses expert engineering judgment to estimate the initial number of hours to integrate the custom and off-the-shelf chips and then applies a standard electronics industry learning curve to estimate the costs for all the electronic modules in the acquisition. Finally, radar insertion costs are estimated using insertion costs experienced on a similar program.

3.4 Summary

This chapter answered the question, "How is the estimate accomplished?" A successful estimate is the result of following a systematic estimating process. This includes planning, data research/collection/analysis, and selecting applicable methodologies, structuring the estimate, number crunching, and presentation/documentation of the estimate.

The main estimating methodologies fall into three general categories - detailed engineering estimate, analogy, and parametric. Most estimates will make use of a combination of methods. The estimator's task is to choose the best methodology for the task, given estimating constraints.

4.0 PLANNING THE COST ESTIMATE

4.1 Introduction

The cost estimator, like any other professional, will perform more efficiently if he or she has knowledge of the challenge facing him and a plan for meeting the challenge. Chapter 4 provides a general discussion about prerequisites that assist the estimator in defining the estimating task and contribute to the overall conduct of a competent estimate.

4.2 Knowing the Purpose of the Estimate

The purpose of the estimate is determined by its ultimate use, which in turn will influence the level of detail required and the scope it encompasses. Ultimate use, level of detail, and scope are the subjects of the following discussion.

4.2.1 Ultimate Use of the Estimate

The ultimate use of an estimate is based on the specific requirement that it is intended to fulfill. Specific applications support trade studies, program change and funding level decisions, agency resource decisions, program reviews independent of advocacy, procurement strategy alternatives, and acquisition decision points.

Over time, estimates have been given formal titles and descriptions that indicate their ultimate use and purpose. These were detailed in Chapter 2, and include the Cost Benefit Analysis (CBA), Acquisition Program Baseline (APB), and Independent Government Cost Estimate (IGCE). Often a single estimate serves both of the general purposes described earlier.

Beyond the formality of these types of estimates are “what-if” exercises. These provide a quick-look estimate for exactly the same purposes that more formal estimates serve, but are accomplished in a much shorter period of time. The concern always associated with a “what-if” exercise is that as it “goes up the line” decision makers have a tendency to forget that the estimate was conducted under severe time constraints. Consequently, key decision makers may adopt the “what-if” as an official position, assuming that it possesses a level of competence equal to an estimate developed under normal circumstances. Being aware of this potential, the estimator should ensure that “what if” exercises are caveated properly and that management is knowledgeable of their limitations. Beyond this point, the estimator loses influence in the decision making process, but should have documented the estimate and any abnormal circumstances surrounding its accomplishment. This will provide a record that will assist in explaining (at a later date) why actual costs may have deviated from those estimated.

Finally, the estimator should include in the estimate’s presentation and documentation, a clear statement identifying its intended purpose. While this will not guarantee proper use, it will minimize misuse (e.g., using a quick “what-if” cost estimate as firm budget input). Also, estimates intended for different uses may have different review criteria and the time associated with these reviews should be considered when planning the estimate’s timetable.

4.2.2 Level of Detail Required

Given adequate time and resources to conduct the estimate, the level of detail is influenced by the estimate's ultimate use and data availability. From the perspective of ultimate use, an ICE (which typically is afforded the time and resources to conduct a thorough investigation) is expected to devolve to a lower level of detail than a "what-if" exercise. However, from the perspective of data availability, an ICE or "what-if" exercise on a production system for which a plethora of actual cost data exist should supply more detail than one conducted on a system that is still in the early stages of development.

Planning the estimate, which is discussed more fully in Section 4.6, should include tailoring the estimate detail to coincide with its ultimate use and data availability. Of course, each program must be assessed on its own when it comes to level of detailed data available. For a program entering development, it is quite typical to see a level of detail at the first indenture of the checklist (e.g., Prime Mission Equipment (PME), peculiar support, etc.). As the program enters the production phase and actual cost data become available from the development phase and production articles, a lower indenture of estimating is possible. For instance, if the estimate for PME used an engineering methodology, the estimate would contain a functional build-up for each hardware element. Similarly, support equipment requirements would be defined now by item and maintenance level. This level of detail would support analogy estimating or direct pricing rather than the application of a gross historic factor. The estimator must know the level of definition and data availability in the program requiring an estimate before choosing the appropriate estimating methodology.

A key point to keep in mind is that more detail does not always equal more accuracy. Certainly, as actual costs for the system being estimated accrue, more detail can be incorporated into the estimate. In this case, it is not the detail alone that increases accuracy but rather the combination of detail and actual cost data. This combination allows the estimator to gain an in-depth understanding of past cost behavior and to apply to the estimate only those elements of actual cost that will recur through program completion.

Prematurely pursuing extensive detail can be detrimental to the achievement of a quality estimate. In the absence of a detailed technical description of the system and a similar level of analogous cost data, it becomes highly difficult to identify and estimate all elements of cost. In this situation, it is appropriate to estimate at a relatively high system level that will allow the capturing, albeit not the specific identification, of lower level cost elements. This is the essence of parametric estimating tools that operate at a gross level of detail and are useful when the system lacks detailed technical definition and cost data.

Time provided to accomplish the estimate could become an overriding constraint on the level of detail achievable, regardless of the estimate's ultimate use and data availability. When defining the elements to be estimated and developing the estimating plan, the estimator must consider the effect of time constraints on the level of detail to incorporate into the estimate.

4.2.3 Scope of the Estimate

The scope provides boundaries for the development of an estimate. It describes the breadth of the analysis and provides a time frame for accomplishment.

Several factors drive the scope of the estimate:

- The elements that the recipient of the estimate wants included
- Criticality of the estimate
- Resources available
- Point at which the program is in acquisition

It is important that all stakeholders agree to the scope of an estimate, in order to avoid major changes once the analysis has begun. In addition, the cost estimator must have a full understanding of the scope prior to the analysis and should keep the scope in mind during the conduct of the analysis. The scope provides a focus for the estimator as the analysis progresses.

4.3 Understanding the Program

It is impossible to estimate credibly a system that does not have an adequate technical and programmatic description. An automobile sales person would not be expected to provide the customer with the price of a new auto until the customer defined the model and options desired. The same requirement applies to any system being estimated. It must be defined before the estimator can conduct a viable cost estimate. Obtaining the Mission Need Statement and the Requirements Document are good starting points for understanding what is to be estimated. This section will provide general guidelines and insights into the type of technical and programmatic information that is required to fully understand and estimate a typical FAA program.

4.3.1 System Purpose

Understanding the system's purpose provides the estimator with the ability to make an initial assessment of the relative magnitude of the system's cost. While knowledge of much greater technical and program depth is necessary to construct a credible estimate, an understanding of the system's purpose does provide the estimator with a mental sizing of its complexity and cost. For instance, if the system's purpose has a space application rather than ground or airborne, the experienced estimator will have visions of high reliability through design redundancy and extensive testing. This translates into greater program complexity and ultimately into higher costs.

4.3.2 Physical and Performance Characteristics

With the system's purpose defined, the next step in characterizing the system is to understand its physical and performance characteristics. Clearly an automobile's purpose is to provide ground transportation. To characterize a specific ground vehicle further, information regarding how many individuals it transports comfortably and its overall size (physical), as well as its acceleration from zero to 60 and average fuel consumption (performance), is required.

The same type of knowledge is required to develop a cost estimate for complex air traffic control systems since these characteristics directly influence cost. The list of descriptors varies depending on the system involved. Examples of a limited array of system physical and performance descriptors for various types of systems are presented in Table 4.1. The specific list of descriptors for the system being estimated will be dictated by the system itself (radar systems would not be described by maximum speed and altitude) and the methodology used to perform the estimate. Permeating all systems today is information technology cost. Descriptors that characterize information technology aspects of a system include memory size, processing speed, lines of code, language employed, expansion factors, proficiency of programmers, and others.

Table 4.1 Typical System Descriptors

Electronic	ADP
Frequency	Software
Operating Power	Processor Speed and Capacity
Cooling Power	Number of Positions
Packaging	Number of Sites
Data Rate	Communications Interfaces
Bit Error Rate	Availability/Reliability
Weight and Volume	Peripherals
Location	Maintenance Concept

Parametric models prescribe exact non-cost parameters as input that serves as the independent variable in the model's cost estimating relationships. Therefore, at a minimum, system characteristics must be described accurately. On the other hand, if using the analogous form of estimating, the estimator needs a comprehensive list of descriptors to assist in selecting the strongest analogy from predecessor or similar systems.

The importance of system descriptors tends to decline as the program matures and actual costs of the system being estimated become available. Consider an estimate being generated for five hundred production units with actual cost data available on one thousand units procured in subsequent year buys. Inherent in the actual cost data is the influence of the system's characteristics. Consequently, an engineering estimate of the next five hundred units could be developed with primary reference to the recurring aspects of the actual cost data and minimal knowledge of the system's physical or performance characteristics.

Clearly the most important input required for determining an estimating methodology early in a system's life cycle is a detailed description of its physical and performance characteristics. The challenge facing the estimator is obtaining this input. Unless the estimator also is technically competent to describe the system, the input of technical program personnel is crucial. However, during the early stages of a program, these individuals can only provide estimates of the system's physical and performance characteristics. Since these estimates form the foundation of the entire cost estimate, it is important to document clearly the fact that they are estimates upon which the system cost estimate depends. The importance of having done this will become evident when an estimate update is required to support a change in the system's physical and performance characteristics.

4.3.3 Technology Implications

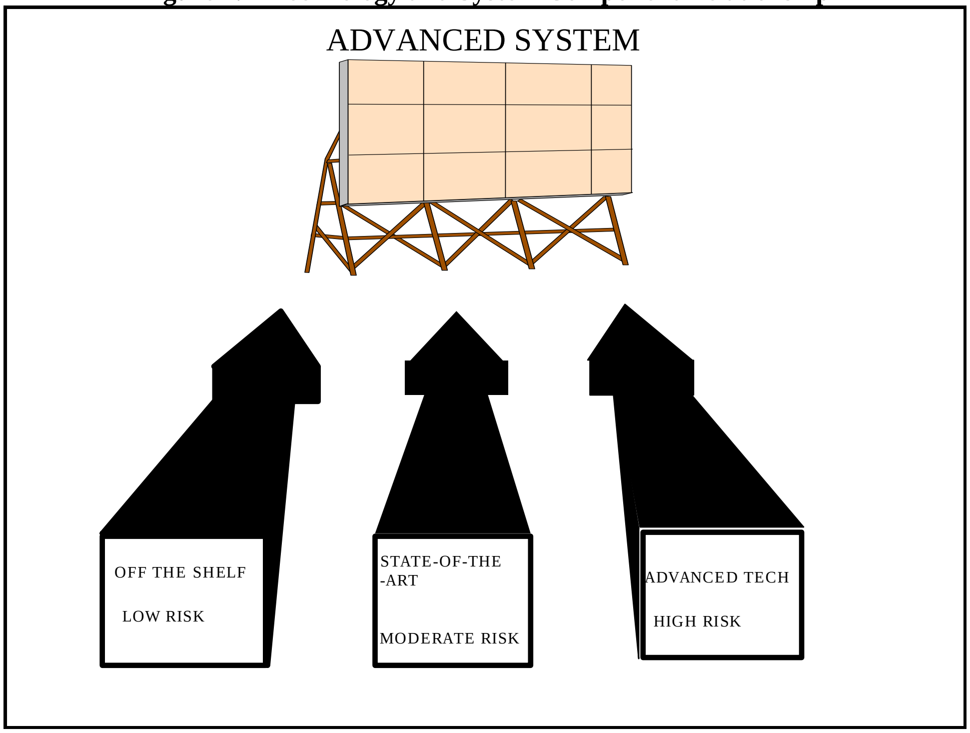
Information about the physical and performance characteristics of a system does not provide a complete knowledge base upon which to construct a quality estimate. It is also important to address the technology that must exist to make the system a reality. In other words, where does the new system reside in relation to the state-of-the-art?

At one end of the technology spectrum is the off-the-shelf item that uses existing technology. The term off-the-shelf is used for those items that do not require development and are available readily. For the estimator, off-the-shelf items represent one of the lesser-cost analysis challenges. In any system, not all subsystems, subassemblies, components, electronic modules, and parts are new. Many items that compose the system have been developed and purchased before and are available in the supply system or commercially through various suppliers and vendors. Estimates of the cost of these items normally use catalog prices or vendor quotes which the prime system contractor will have obtained and reflected in the bill-of-material. Estimates of this type can vary in complexity, however. If the majority of the estimate involves obtaining prices for off-the-shelf items, the estimator still must ascertain whether the items will be integrated into an existing system or used to build a new system, in which case there may be design and development required to make sure the interfaces work.

At the other end of the technology spectrum are the items that make up a system that is truly new and therefore, will undergo design, development, and test. The estimator must understand the key relationship of the item to the state of technology: whether the technology required for the new item lies behind or ahead of the leading edge of technology. If technology has advanced beyond the state required for the new item, then the estimating scenario is a new application of existing or mature technology. For the estimator, the focus will be on costing the manpower requirements (particularly engineering, material, and test facility time) to design, develop, and test the new item fully. The technical community will be required to make estimates of the end item's physical and performance descriptors, which will allow the estimator to cost the new item directly or through the use of a parametric or analogy methodology. Since we are talking about a new application of a mature technology, risk would tend to be moderate. However, if severe schedule constraints exist, risk could increase dramatically. The estimator must be sensitive to cost and schedule risk whenever the system being estimated involves new design, development, and test.

So far, discussions have centered on those items composing a new system that either are off-the-shelf or use existing technology. In addition, there are new items that cannot be developed fully until specific technological advances are realized. These represent a significant challenge to program management, the technical community, and the estimator. They also add a high degree of risk to program schedule and cost. Typically the estimator will apply the same approach to these new items as to those for which mature technology exists. Specifically, the estimator will assume that the technology required to design, develop, and test the new item will arrive on schedule and be available to support the effort. While this assumption allows the estimate to proceed, the risk and attendant cost and schedule impact associated with it cannot be ignored. The estimate should include a risk assessment with excursions to depict the impact that will occur if the technology is not available as required. These technology and system component relationships are summarized in Figure 4.1.

Figure 4.1 Technology and System Component Relationship



The estimator should not take technology implications on a program lightly, since minor errors in the analysis of technological challenges can alter the estimate drastically. Overly optimistic technology forecasts should not trap the estimator. Advocates of the system will tend to understate the real technological challenge facing the successful development of the new system. Because of this optimism, the estimator may fail to state clearly the technology availability assumptions that underlie the estimate or perform less than rigorous risk analysis to depict the cost implications of a delayed technology arrival. The estimator should be the skeptic in this situation and provide management with a complete portrayal of assumptions and risks along with excursions that will demonstrate the cost and schedule impact of a technological delay.

4.3.4 System Configuration

Various configurations normally are available to achieve the physical and performance characteristics prescribed for a system. This is most evident in source selections when each bidder submits a different system configuration that will achieve the physical and performance characteristics specified in the Screening Information Request (SIR). Even though proposed configurations may meet the specified system characteristics, each is evaluated in detail to determine its strengths and weaknesses in terms of technical, operational, and support criteria. Configuration variances not only merit higher and lower scores in view of these evaluation criteria, but permeate the estimator's assessment of the cost to design, develop, produce, operate, and maintain these various configurations.

Because the system designer has many options, different configurations evolve to meet specified physical and performance characteristics. One designer may select to use more of the current inventory analog voice recorder that requires over 20 square feet of floor space at a site. Another system designer may use a new state-of-the-art digital voice recorder that requires only six square feet of floor space. Either approach could satisfy a requirement to provide more legal voice recording capacity at a site.

While the designer can achieve prescribed performance through various configuration options, these trade-offs each have an associated cost and therefore influence the system's estimate. Using an available recorder may be necessary to deliver an operational system within a certain time frame. However, the cost to create more recorder storage rack space at a site may be very expensive. Also, the life cycle cost of the analog configuration could be more expensive when parts become obsolete compared to the alternative that uses the new digital voice recorder.

While this example focused on a recorder in a source selection environment, the implication holds true for any system in any estimating environment. Understanding a system's configuration is a necessary prerequisite for identification of its cost drivers and for accomplishing a viable cost estimate. This is especially true when the estimate will use an analogy to an existing system for which actual cost data are available. The estimator needs to analyze the technical parameters of the existing system and its costs before an analogous estimate can be constructed. This is necessary to help identify configuration differences between the existing and proposed system, which in turn will provide the technical base upon which to develop cost complexity factors. These factors, when applied to the actual cost of the existing system's components, will provide an estimate of analogous components within the new system.

4.3.5 Interrelationships with other Systems

Very few systems operate independently. When systems are employed in an operational scenario, they become linked to one another either physically via mechanical, electrical, and other connections or non-physically via electronic signals. Prior to take-off, an airplane is linked physically to the air traffic control tower through visual identification. After takeoff it remains linked non-physically via radio and radar information received through electronic transmissions. While a satellite is not connected to other systems physically, it may (through data links) conduct two-way communication with ground stations, ships, and airplanes. These interfaces are important aspects of system design. If proper attention is not given to these interfaces during the early stages of design, the integration of the new and existing system may not be possible without costly redesign.

The level of difficulty associated with estimating the cost to integrate systems is a function of the degree to which the systems are disturbed by the integration. Communication linkages do not create disturbances as great as those created by the physical integration of two systems. Often these latter undertakings involve structural changes, increased power and cooling requirements, protection devices to avoid operating disruption of other system components, software updates, and modification of support equipment.

The interrelationship that a new system has with others significantly influences its design and may necessitate alterations to existing systems before this interrelationship can be realized. Consequently, when a total program estimate is required, the estimator must look beyond the immediate system to gain a technical description of integration requirements.

4.3.6 Support Concepts

The support concept for the system affects acquisition, as well as operating and support costs. As the upgrade of the NAS proceeds, the trend is toward more complex systems with a high degree of interdependency. This complexity dictates that increased emphasis be placed on early planning for integrated logistics support and its standardization across the NAS to preclude the cost and schedule impact of correcting deficiencies after equipment deployment and to minimize subsystem life cycle costs. To achieve this goal, the FAA requires an integrated process by which the support elements of a system/subsystem are planned early, acquired, verified, and deployed in a uniform and systematic manner. This process is known as National Airspace Integrated Logistics Support (NAILS).

The estimator must be aware that support of a system involves a number of elements. Supply support includes spare parts, repair parts, and special supplies to operate a NAS subsystem. A large cost element is maintenance, which includes labor and support facilities. In addition, support and test equipment, training, training equipment, technical data, packaging, handling, storage, and transportation must be addressed in the estimate.

Maintenance can be organic (in-house) or provided by a contractor, and the choice obviously will affect costs. If the choice is a contractor maintenance approach, the estimator needs to pay attention to the type and amount of contractor repair. There are various possibilities: a contractor repair service for certain exchange and repair items, a full contractor maintenance logistics support capability, or simply contractor depot logistics support. Even if an organic support concept is selected, the estimator must recognize that interim contractor support typically is required during the system's early operational period. This is because support equipment and data generally are not developed until the system's production configuration is fairly definite.

Consequently, early production systems delivered to the operational inventory must be supported by contractor equipment and data. This, combined with the fact that an organic capability cannot exist until an initial cadre of personnel is trained, sometimes requires contractor support for a period of several years.

Another consideration for the estimator is the number of maintenance levels that will be required to support the system. Two levels of maintenance (field and depot) are discussed below.

- Field. The organization that is operating the system performs this maintenance. It is best thought of as the servicing level of maintenance. It includes activities such as inspection, service, lubrication, adjustment, trouble-shooting, designated modifications, and the replacement of parts, minor assemblies, and subassemblies.

- Depot. This is the highest level of maintenance and is the responsibility of the FAA Depot. There are various FAA Depot branches that support the field at deployment of subsystems and assure subsystem readiness for operation. The Depot branches are: Storage and Transportation Branch, Engineering and Production Branch, Quality Control Branch, Supply Management Branch, and Cataloging Branch. There is also a systems engineering and integration contractor who shares responsibility with the depot. Depot maintenance occurs at organic or contractor facilities and is the overhaul level. It involves the support of field activities by providing resources (personnel, skill, facilities, and equipment) of a much more extensive nature than the field level possesses. It also includes the repair, modification, alteration, modernization, overhaul, rebuild, and reclamation of parts, assemblies, subassemblies, components, and end items, as well as the manufacture of parts, assemblies, components, and end items.

Each level of maintenance possesses a specific capability. For instance, given the above description, the organizational capability may be limited to that of removing a failed line replaceable unit (LRU) and replacing it with a serviceable unit drawn from field supply. In turn, the failed LRU would go to the Depot for repair. The estimator must be aware of how both levels of repair play in the estimate.

The support concepts and options discussed above are the ones that the estimator will encounter most frequently. However, as systems become more advanced and complex, so does their support. Because of this, innovative support approaches continue to evolve, each with its own cost implications that affect the system's life cycle estimates. The estimating of operating and support costs is the subject of Chapter 13.

4.3.7 Development, Test, and Production Quantities and Schedules

The estimator typically will have access to the system's development and production schedules and the quantities to be manufactured during these program phases. The estimator should analyze this information in detail and challenge any aspect that appears unreasonable.

The development schedule and quantities of test articles usually represent the areas that are most problematic to the estimator. The estimator should be suspicious of schedules that produce funding profiles that build and decline several times during the development program. One would expect a development program to build up gradually as design and development efforts commence; to continue this trend to support the test article manufacturing process; to decline to some constant level throughout testing; and to taper off as the development program completes.

Certainly, not every development program follows this smooth funding profile. The cost estimator should examine major peaks and valleys to understand their cause. It is highly inefficient and unlikely for a contractor to hire to a level, and then lay off workers only to rehire them to regain the original level of employment. Often schedule inconsistencies of this nature initially surface when the estimator highlights them through the funding profile. Therefore, the estimator should not feel reluctant to challenge these variances and to obtain either a rational explanation for their cause or a schedule revision that will produce an acceptable funding profile.

Quantities of required test articles are often understated because it is assumed that a single article can support multiple test events. While the article can withstand recurring test events, difficulty arises when a test event requires more time than initially envisioned and therefore, the article undergoing the test is not available in time to support the next event. When time tolerances between test events are close, the solution is to delay the follow-on test or to manufacture additional sets of development hardware. The estimator, in conjunction with individuals from the engineering and test community, should perform an in-depth analysis of the test schedule and hardware quantities to identify time and quantity constraints that would jeopardize achievement of the development schedule. If there is no relief from these constraints, the risk analysis section of the estimate should reflect their potential impact.

Another schedule concern arises when development and production programs run concurrently. Depending on its severity, this overlap can add considerable cost to early production buy-years and increase retrofit requirements because production articles are being manufactured while development testing is ongoing. Consequently, configuration revisions resulting from the test program retard the production learning process and require articles delivered to the operational inventory to undergo configuration update modification. The number and complexity of configuration changes determine the cost impact that concurrency has on total program cost.

Production schedules tend to be straightforward and normally have not been problematic to the estimator. However, the estimator should focus on basic and rate tooling. The estimate should be timephased to ensure funding is provided at the appropriate time to support build-up to the planned maximum production rate. Also the timephasing of the production estimate must recognize the need for advanced-buy funding to procure long lead requirements that protect the production schedule.

Beyond the foregoing discussion, the estimator should always be cautious of schedule over-optimism. This success orientation can lead to schedule slips and cost growth that will invalidate the highest quality estimating effort. The risk section, as discussed earlier, is the appropriate place to portray the cost consequences that accrue if schedule milestones slip.

Schedules are an extensive and integral part of any estimate. However, for the estimator to provide a deeper analysis, a complete schedule assessment should be conducted. While performing a detailed schedule assessment is ideal, time and resources often are not available to conduct one.

4.3.8 Program Implementation Plan

A program implementation plan is developed and maintained as an agreement between the program manager, NAS Transition and Implementation Service, and the regions. The plan addresses the requirements to support the deployment and operation of a product in the field.

Consider the procurement of one hundred operational articles. If the implementation plan establishes that these articles will be dispersed to ten main locations, the cost to acquire their support and maintenance will be significantly higher than if they were dispersed only to five locations. As dispersion increases so does the number of locations that must be capable of supporting the system.

If the situation is thought of in terms of fixed (or more accurately semi-variable) and variable requirements, it is easy to visualize. For instance, some support resources remain constant when the number of systems supported varies (within certain bounds). Consequently, the number of systems supported could increase from ten to twenty with no increase to the level of fixed resources. A case in point would be ann air traffic control computer at an Air Route Traffic Control Center (ARTCC). There has been a steady growth in air traffic, and the computers' capacity to handle the traffic growth is fixed. Therefore, there may be requirements for more capable computers, improved software, etc. The implementation plan for the upgrade of the air traffic control computers must project traffic growth by location. In this case, the air traffic control computer is fixed in terms of total air traffic supported but variable below that threshold.

Other requirements are strictly variable and change proportionately with the number of systems supported, regardless of dispersion. For example, each system may require its own operator's manual. The number of manuals procured now becomes a function of the number of operational systems deployed and is insensitive to the amount of air traffic.

The estimator must be aware of the effect that the implementation plan has on the total program estimate. The implementation plan has the most influence in production and O&M. This influence is strongest in the areas of support equipment, spares, data, trainers and training, as well as indirect support costs. Each of these areas should be estimated with knowledge of their fixed and variable elements and how the plan will affect the requirements for these resources.

4.3.9 Procurement Strategy

Procurement strategy involves structuring contracts and formulating a procurement approach that allows the government to reduce program risk and receive the most value per dollar spent. The two most prevalent acquisition strategies are "competition versus sole source" and "multi-year" procurements. The reason many programs pursue these strategies is because their payoff, in terms of cost savings, can be significant. For this same reason, the estimator must be prepared to understand these strategies fully and conduct a credible estimate of their impact on program costs.

Competition Versus Sole Source

Competition comes in many forms and can be introduced into a program anytime during its development and production phases. The type of competition strategy introduced and its timing will determine its ultimate effect on program costs.

Most programs start in a competitive mode by inviting bidders to participate in source selection for the development phase. While this up-front competition is beneficial, the program immediately finds itself in a sole source mode after the selection of a development contractor. Often a program will continue in this mode attempting to negotiate the best price possible with the single source throughout the acquisition program. However, there will be a distinct disadvantage when attempting to negotiate a favorable price when only one source is qualified to provide the required system.

To overcome this negotiating handicap, several procurement strategy alternatives have evolved which permit two or more sources to become qualified to deliver the required system. These alternatives allow price competition for a longer duration and are discussed below.

- Funding two or more contractors to design and develop a system in response to the stated requirement. At some point in the program, there will be a competitive evaluation with down-selection to a single contractor for the remaining program. The objective at this point will be to negotiate either a basic contract and/or priced options for a large portion of the remaining program while the advantage of a competitive environment exists. Beyond the negotiated basic contract and/or priced options, the program returns to a sole source mode.

- A variant of the previous alternative involves the continuation of two or more contractors throughout the entire acquisition phase, thus preserving the competitive environment. Generally, each contractor is guaranteed some fixed share of each year's total buy with the remainder awarded to the lowest bidder. This allows the contractors to maintain a production capability while the customer maintains the program in a partially competitive mode.

Often, a program that is in sole source mode desires to establish a competitive mode. Achieving a competitive mode from this position typically is accomplished either through a second sourcing or a leader-follower approach. Qualifying a contractor through the second sourcing approach requires that the primary contractor provide for the transfer of technical data and a limited production run to the second source. This allows the second source to competitively produce a system that meets specifications. Leader-follower is similar. The customer pays the sole source contractor to qualify the second source through technical and manufacturing assistance.

There are advantages and disadvantages to the various acquisition strategies that enable a program to establish a competitive environment. The key question is whether or not the initial investment required to establish and maintain competing contractors is less than the savings that result from negotiating cost in a competitive environment. Determining the answer is the responsibility of the estimator. To assist the estimator in this regard, there are various studies on competition impacts as well as models to assess these impacts quantitatively. Much of this work relies on evidence that competition entices contractors into efficiencies that might not have been achieved otherwise.

Before the estimator applies any methodology or model to determine the cost impacts of dual source procurement, it is necessary to conduct an extensive analysis of the program. The first step that the estimator should undertake is to identify those program elements that will be subject to competition. If the sole source contractor were competing major portions of structure, then it would be inappropriate to apply the model at the system level. Likewise, if the system uses significant quantities of common government furnished equipment, these would be excluded from additional competitive consideration. In other words, the system must be disaggregated and each element analyzed to determine if a competitive environment for it already exists. If so, that system element would be removed from the analysis since the benefits from its ongoing competition should be inherent to the basic estimate.

Beyond this initial step, the next examination would be to determine the presence of capable and willing rival competitors. This analysis leads to assumptions regarding the market's competitive environment. The likelihood of realizing cost reductions due to dual sourcing increases if:

- Firms exist that possess the capability to manufacture the item to be competed

- These firms are willing to introduce cost efficiencies and reduce profits to make themselves competitive

At this point, selected methodologies and models can be applied intelligently to the basic sole source estimate to determine the gross cost savings that potentially could accrue to the program as a result of competition. However, even if the model indicates substantial savings in the manufacture of system elements included in the competitive procurement, this does not translate necessarily to a net savings to the program.

The following costs associated with competition must be considered as offsets to the initial calculation of savings:

- Maintenance of two or more contractors through the development phase
- Procurement of technical data package
- Technical assistance to the second source
- Qualification program
- Excess contractor capacity
- Economy of scale sub optimization
- Higher fixed cost burden per unit
- Split learning and purchases

The estimator's analysis must include these non-recurring and recurring costs and deduct them from gross savings to derive net program savings or loss resulting from the procurement strategy of competition.

Multi-year Procurement

The essence of multi-year procurement is to authorize the contractor to purchase materials and parts to support several system buy years, thus achieving savings through economic order quantity procurements. Without approval for multi-year procurement, the contractor only has authority to purchase in support of a single buy year. Therefore, purchases for several buy years cannot be aggregated into an economic order quantity and attendant savings cannot be realized.

When multi-year procurements are authorized, the estimator is confronted with two challenges. The first is the determination of the cost reduction (quantity discount) that results from buying materials and parts in greater volume. A quantity discount allows the consumer to realize a lower per unit cost when greater quantities are purchased. Often the estimator can obtain direct quotes from vendors and suppliers that describe the discount that is applicable to quantity purchases of various sizes. In the absence of this information, the estimator may have to rely on a historical multi-year savings factor.

The second challenge facing the estimator involves a rephasing of the funding profile. Rephasing is needed because the government must indemnify the contractor against loss if an out year buy of systems for which material and parts were purchased under multi-year provisions is canceled. The rephasing of funds usually is based on the contractor's termination liability to vendors and suppliers that may amount to something less than the full value of the items involved. Termination liability means obligating sufficient contract funds to cover the contractor's expenditures plus non-cancelable commitments. In the case of a multi-year contract terminated before completion of the current fiscal year deliveries, termination liability would include an amount for both current year termination charges and out year cancellation charges. Policy regarding the application of multi-year procurement and indemnification requirements tends to undergo revision from time to time. Because of this, the estimator is well advised to seek the latest guidance from local procurement and budget offices.

Lease versus Buy

Lease versus Buy is another option available to reduce program risk and cost. Leases are classified into a variety of types. The three major classifications are operating, sale and lease back, and financial or capital leases.

Operating leases are characterized by the lease period being less than the economic life of the item. Therefore, the lease payments do not amortize the item fully or recover its full cost over the life of the lease period. Operating leases normally allow the lessee to cancel the lease within a short period of time without any penalties or surcharges. The only requirement is that the lessee return the item leased to the lessor. In addition, the lessee generally does not acquire an ownership interest in the item.

A sale and lease back arrangement occurs where a particular organization owning land, buildings, or equipment sells to a bank or financial institution (buyer) and immediately leases back the item. The seller or lessee receives the purchase price for the item sold to the buyer. The lessee continues to occupy or use the equipment but now remits a lease payment to the lessor (buyer). The lease payments amortize the sales price and provide the lessor an adequate rate-of return over the life of the lease.

According to *Financial Accounting Standards Board Statement (FASB) No. 13*, paragraph 7, a lease that satisfies any one of the following criteria is a capital lease. Otherwise, the lease is an operating lease.

Common Characteristics of Capital Leases:
- Usually will not provide for maintenance service
- Non-cancelable
- Fully amortized

- Ownership of the leased asset is transferred to the lessee at the end of the lease period.
- The lease gives the lessee the option of purchasing the leased asset at less than fair value at some point during or at the end of the lease period.
- The period of the lease is 75 percent or more of the service life of the leased asset.
- The present value of the minimum lease payments is 90 percent% or more of the fair value of the leased asset.

The decision maker often considers qualitative factors in evaluating a lease versus buy analysis. Factors that the government may want to consider are as follows:

- Leasing increases the tax base of the community (Leasing under section 801 of Public Law 98-115 for family housing).
- Leasing can provide a catalyst for community growth (Leasing under section 801 of Public Law 98-115 for family housing).
- Leasing provides flexibility.
- Leasing provides a lower initial government outlay.
- Leasing can shift the risk of obsolescence to the lessor.

A lease versus buy analysis provides a decision maker with data to choose the most financially sound option. Ignoring qualitative concerns, the lease option with the smallest present value should be chosen. To perform this type of economic analysis, consult FAA APO 82-1, *Economic Analysis of Investment and Regulatory Decisions - A Guide.*

There are other acquisition strategies available to reduce program risk and cost including warranties and contract incentives. Procurement strategy panels are charged with tailoring a procurement strategy to meet the needs of specific programs. To conduct a competent cost analysis, the estimator must take the time to understand the intricacies of the procurement strategy and incorporate their cost implication in the estimate.

4.3.10 Identification of Predecessor or Similar Systems

As technical and programmatic information is gathered, the estimator gains an intimate understanding of the system to be estimated. The primary purpose for having gained this understanding is to equip the estimator with the knowledge required to identify other systems that possess similar characteristics. The identification of analogous systems, for which there exists detailed technical and cost data, is an important step in formulating a credible estimate.

The data collected will be used either to calibrate a parametric estimating tool or to estimate the system directly using analogy methodology. In the first instance, it is important to ensure that the parametric model performs as an accurate predictor of costs for the development, production, operation, and support of the system. To assist the model in overcoming error that is inherent to its construction, it is important to test it against a system that is most analogous to the one being estimated. The procedure simply involves the use of the analogous system's known technical and performance parameters as input to the model to determine if its output accurately portrays the analogous system's actual cost.

Given that computed cost deviates from actual cost, a correction factor or multiplier can be calculated to bring them into alignment. The estimator uses this factor to calibrate the in-progress estimate. Application of the factor compensates for inherent model error and enhances the estimate's accuracy. Some parametric models have this calibration process built into their routines. Regardless of how the correction factor is derived, this calibration process is a mandatory step in the generation of competent estimates through parametric methodology. Further, it must be performed every time a different system is estimated since the model's inherent error is not consistent throughout its estimating range.

In the next instance, the data collected will be used to estimate the system directly using analogy methodology. Chapter 10 discusses this methodology in detail; therefore, it will not be repeated here.

4.4 Establishing Ground Rules and Assumptions

Whenever an estimate is undertaken, it is necessary to create a series of statements that define the conditions upon which the estimate will be based. When conditions are directed upon the estimator, they become the ground rules by which the estimate will be conducted. In the absence of a firm ground rule, the estimator has the privilege of establishing assumptions that fill this void and allow the estimate to proceed.

When exercising this privilege, the estimator must ensure that assumptions are not arbitrary but rather are founded on expert judgments rendered by experienced program and technical personnel. To do otherwise could create a need to revise the entire estimate. This extensive impact is possible since many assumptions profoundly influence cost and the rejection of even a single assumption by management could invalidate many aspects of the estimate. To minimize this potential, the estimator must seek competent opinions regarding the formulation of specific assumptions and formally advise management of them as early and as far up the line as possible. Beyond this, the estimator should present and document all ground rules and assumptions.

Because of the potentially significant cost implications of key assumptions and ground rules, it is a good practice to do a sensitivity analysis of them in the risk analysis section of the estimate. It is necessary for management to understand the decision making implications if these key assumptions and ground rules do not hold in practice.

The list of ground rules and assumptions is unique for each program. Therefore, this section addresses only the ground rules and assumptions that generally are established. From this core, a complete set can be tailored to satisfy the requirements of a specific program estimate. The core elements discussed are the program schedule, cost limitations, timephasing, base year, inflation indices, government versus contractor furnished equipment, and contractor relationships.

4.4.1 Program Schedule

The ideal situation is to have the time, resources, and authority to perform an in-depth schedule assessment before the estimate begins. This is desirable because of the optimism that often is inherent to program schedules. The manufacturing and technical community should be involved in the schedule assessment. Once a complete schedule assessment exists, there is opportunity to introduce risk-reducing revisions as appropriate. This will provide the estimating team with a schedule that has a high probability of achievement and, therefore, a low probability of invalidating the estimate.

In the absence of a detailed schedule assessment, the estimator must accept the schedule provided. While it is always important to depict the schedule and its source as a ground rule, this is important particularly if there is no opportunity to assess the risk of the schedule. Management needs to be well aware that the estimate's confidence level is only as high as the probability of achieving the directed schedule. Without a thorough schedule "scrub", the probability of achieving the schedule is more questionable.

As an intermediate approach, the estimator can seek assistance by performing a high-level quick-look schedule assessment. This will identify obvious inconsistencies that, along with a risk analysis, can be highlighted to management during estimate presentation.

Whatever the situation may be, the estimator must present and document the program schedule and its source. Also, any other pertinent schedule information that may have a bearing on the estimate's outcome and confidence level should be included.

4.4.2 Cost Limitations

The estimator will seldom find a management directed cost limitation for a program of given scope. However, there will be occasions when management desires to establish a program and technical baseline that will allow a system to be delivered within a certain cost limitation. Tailoring the program, through a process of weighing program alternatives in relation to their cost, is highly desirable and results in a program technical and cost baseline that becomes a management objective.

When management directs a certain baseline for an estimate, it is important to note as a ground rule all conditions that led to the baseline. Even though these conditions may appear to depart radically from traditional program approaches, the estimator is responsible for basing the estimate on the directed baseline. However, this responsibility does not restrict the estimator from performing a risk assessment on various baseline conditions and presenting it for management's consideration.

Other areas of cost limitation that the estimator may encounter are constraints from the current budget, planning wedge, or out-year funding level. This is often imposed to avoid reprogrammings, budget revisions, or exceeding fiscal ceiling limitations in a particular year.

There is nothing wrong with these types of cost constraints. They are not challenging for the estimator as long as there is flexibility to shift program content to stay within the limitations. If this flexibility is not available and the estimate exceeds the limitation imposed for a particular year, the estimator must reflect this funding shortfall to management. Regardless of its nature, whenever a program scope or cost limitation exists, the estimate's ground rules and assumptions should contain the details.

4.4.3 Timephasing

Much of the foregoing discussion of schedules relates to the subject of timephasing. Timephasing is the spreading of the total estimate over the program schedule. Scheduled activity in a given year drives the requirement for money in that year. Clues to schedule anomalies and risk become more evident when the estimate is timephased. The estimator should question unusual peaks and valleys or exceptionally high funding levels required in a particular year.

In addition to schedule conditions, cost limitations discussed in the preceding section also influence the timephasing of the estimate. If there is a cost limitation in a given year, the estimator will have to take action to spread the work scheduled to stay beneath the cost limitation. In both cases these conditions and their effect on timephasing need to be addressed in the estimate.

4.4.4 Inflation Indices and Base Years

Dollar value provides a yardstick for the estimate. This yardstick must remain unchanged for all quantities measured if resulting measurements are to be meaningful and comparable with each other. The value of the dollar rarely is constant from one year to the next. Changes in the prices of goods and services continuously affect the purchasing power of the dollar. Chapter 5 addresses in detail how to “normalize” estimates to account for changes in the prices of goods and services.

Any normalizing to account for inflation involves the use of a price index of some sort, which is a measure of relative value. The estimate should document in the ground rules and assumptions the base year in which the estimate is made and the price index used to adjust to current year dollars. A current dollar estimate is an estimate expressed in the prices of the current year. The estimate will be expressed in the constant dollars of the base year of the estimate. Typically, the base year is the year in which the program started or in which the first estimate was done. Constant dollars are expressed without inflation in the prices of that base year. By comparing constant to current year dollars, management can see how much the cost growth in a program is due simply to price level changes and how much to other factors. Price level changes are often beyond the control of management, while other types of cost growth may be within the control of management.

4.4.5 Government versus Contractor Furnished Equipment

Arrangements between the government and contractor regarding responsibilities for providing required equipment and material must be delineated clearly as an estimating condition. The government frequently agrees to provide major elements of equipment and material to support contractor efforts. These items can range from common items of supply, to complex electronic components, to delivery of newly developed propulsion units. If the government becomes delinquent in providing these items, it is responsible for the costs incurred by the contractor as a result of this delivery failure. Depending on the exact source of the equipment and material, as well as the causes responsible for its late delivery, the government may be able to seek damages from its source of supply.

This arrangement has different implications than when the contractor is responsible for acquiring all the equipment and material necessary to fulfill the contract. In this case, the terms and conditions of the contract determine how the consequences of late deliveries affect the contractor. In contrast, the program cost impacts resulting from late delivery of equipment and material will most likely be greater when the government, rather than the contractor, is responsible for these items. The estimator cannot predetermine the occurrence of late deliveries and attendant cost implications. Therefore, it is important to present, as an estimate condition, the assumption that no adverse impacts will accrue to the program as a result of the government providing major elements of hardware.

4.4.6 Contractor Relationships

An accepted approach is to conduct the estimate initially without regard to specific contractual relationships. This baseline estimate can then be adjusted for the business and acquisition strategies selected for the program.

Each contract type must be analyzed for its cost influence on the baseline estimate. For instance, some contracts have fixed values or ceilings that represent the limit of government liability. If the baseline estimate for program portions covered by these types of contracts exceeds the fixed or ceiling value, the estimate frequently is reduced to this value. This is logical since the government is only responsible to the contractor for the fixed or ceiling value. Beyond these amounts, the contractor assumes responsibility for cost incurred. The only mitigation to this would be if the estimate exceeded the fixed or ceiling value by a significant amount. In this case, the amount of risk or engineering change order dollars included in the estimate may be increased to accommodate the potential for a higher than normal flow of contract changes. This is a technique a contractor may use to cover costs incurred in excess of negotiated fixed values and ceilings.

Government and contractor sharing arrangements and award fee reservation of funds are also considerations that will influence the baseline estimate and its timephasing. Since the total array of contract influence is too massive to detail in this handbook, the estimator must become acquainted with the specific contract type or types applicable to the estimate being conducted. Because the estimate depends on the specific relationships involved, these should be detailed in the ground rules and assumptions section. It is also appropriate throughout the estimate presentation and documentation to clearly depict and provide rationale for these adjustments.

4.5 Selecting the Methodology

Armed with the knowledge of system and estimate aspects discussed to this point, the estimator is prepared to enter into the initial stage of estimate planning. Once the estimating approach is selected, a viable plan (Section 4.6) can be developed. Attempting to establish an estimating plan without having conducted this preplanning phase diligently may lead to estimate dead-ends and re-dos. These inefficiencies are time-consuming and represent estimator-imposed constraints that are entirely unnecessary and could hinder accomplishment of a quality estimate. Time spent in the next four areas of the estimating process represents an investment that provides returns that contribute heavily to the realization of a competent estimate. These involve defining the elements of cost, choosing estimating methods, determining risk analyst’s strategy, and identifying crosscheck methods.

4.5.1 Defining the Elements of Cost

An estimate must have a structure for collecting and displaying life cycle costs. For organizations like the FAA that have a large volume of acquisition programs, there is a distinct advantage to having a standard approach for describing those acquisitions. All parties involved in the effort can refer to a common language for describing the entire system. A standard work breakdown structure (WBS) facilitates the assimilation of data in a format useful for preparing future estimates and comparability studies. IPTs can refer to the standard elements to ensure that they have considered buying all the elements typically required for a system.

Work Breakdown Structure

The FAA Standard Work Breakdown Structure may be found on FAST at http://FAST.FAA.gov. WBS diagrams and definitions that reflect the breakdown structure are available online for use by the cost estimators in developing the life cycle costs required for investment analyses and studies. These documents continue to be refined as the WBS is used.

Program Work Breakdown Structure

The Program Work Breakdown Structure (PWBS) is the total WBS for the program. To define all of the effort needed for the total program, the government IPT includes the PWBS in the solicitation. As such, the Statement of Work (SOW) in the solicitation should clearly relate to the PWBS to avoid confusion between the two descriptions of the effort.

Contractor Work Breakdown Structure

The company that wins a contract will extend the PWBS to lower levels of detail as required to accomplish the SOW. This extension of the PWBS is called the Contractor Work Breakdown Structure (CWBS). The CWBS extends to whatever level the contractor deems necessary to manage the work effectively.

In the case of associate contractors, each will develop a CWBS from the PWBS provided in the RFP. For example, the air-to-ground/ground-to-ground switch manufacturer’s CWBS will address only those WBS elements applicable to their contract.

Organizational Breakdown Structure

The WBS is primarily product oriented. There are some summary level functions such as Systems Test and Evaluation and System/Project Management, but focus is on products like airframe, data, support equipment. The contractor will have some sort of Organizational Breakdown Structure (OBS) by which human resources are managed. A very common form of OBS is the traditional functional form, where an organization is disaggregated into engineering, manufacturing, etc. There are other forms of OBS, and a contractor is free to manage human resources according to their judgment. However, functional breakouts of the WBS should not show up in the CWBS. Functional costs will show up as costs are accumulated through the CWBS, but the WBS itself is primarily product-oriented.

The Integration of the OBS and the WBS: A Key Management Point

To manage work with a WBS approach the contractor integrates the OBS with the CWBS. The contractor will assign responsibility for each piece of work represented by each element in the WBS. That responsible manager will manage resources in accordance with the company OBS and policies in order to accomplish the WBS element of work.

Application of the WBS to an Estimate

The following provides several general thoughts on this subject and provides references to other handbook areas that address this topic.

- The WBS should be used as the method of insuring that all portions of the program are considered in the estimate.

- The WBS is extremely useful in assigning portions of the estimating effort to team members who may be specialists in certain areas. The same thought carries through if multiple services or commands are partial participants in the estimate.

- For the estimator, the WBS becomes a tool for structuring the cost estimate. During the investment analysis phase, before the program is developed, the WBS will be described at a fairly high level and will not include a CWBS. Once a program exists, the estimate typically will proceed into a lower level of detail.

- Actual costs incurred during the development and production of a system are the source of invaluable data to support cost research and engineering or analogous estimating methodologies. Using a standard WBS to collect these actual costs simplifies the task of estimators of future systems.

It is against this structured hardware element framework that a program's costs are estimated, budgeted, collected, and reported. Therefore, it is the estimator's primary reference in identifying the program elements to be estimated. Within this reference, the estimator's task is to identify those WBS elements that capture the estimate's scope and represent the appropriate level of detail, given its purpose and data availability.

In the event that no PWBS exists, the estimator's task becomes more involved. The reference is still to WBS elements, but now the estimator is an active participant in constructing it for the program. With the guidance provided in the FAA Standard Work Breakdown Structure and knowledge of the program to be estimated, the estimator can contribute significantly to WBS formation. Once the WBS is constructed, the estimator will proceed with normal cost element selection for the estimate.

4.5.2 Choosing the Method Best Suited to Each Cost Element

In any estimate, it is typical to employ a variety of estimating methods. A program early in development that has not been defined in detail technically may use parametric methods to estimate the majority of its content. Even so, for those elements that have adequate technical definition, the estimating methodology may make use of analogy or of catalog pricing for off-the-shelf items.

A program entering production typically will use an engineering methodology that relies on the use of actual recurring costs incurred during the manufacture of development articles. While grass roots methods may be predominant in this case, the estimator also may employ parametrics or analogies to estimate items such as electronic components. Historical factors are often the preferred estimating method for cost elements like program management, systems engineering, support equipment, data, and training.

For estimates on one-of-a-kind systems such as those in space programs, methodology selection becomes limited. Since each article tends to represent a significant technological advance over predecessor systems, detailed engineering methods have no application. Consequently, parametric and some analogy techniques are used almost exclusively to estimate the cost of these special programs.

Combining discussions in this and the previous section, the following summarizes the steps leading to estimating methodology selection.

- Step 1. Know in detail the composition of each estimating methodology, its preferred application, and the models and techniques that are available to assist in its application.

- Step 2. Gain a full understanding of the system to be estimated through a comprehensive characterization of its technical and programmatic parameters.

- Step 3. Establish an estimating framework from selection of those WBS cost elements that capture the estimate's desired scope and level of detail.

- Step 4. Analyze each element to determine the depth of its technical definition, relationship to technology, and analogy to other articles.

- Step 5. Identify the methodology that is best suited to estimate the cost of each element.

4.5.3 Risk and Uncertainty Analysis

The steps outlined in the preceding section will allow the estimator to intelligently select the most appropriate estimating methodology for each cost element. In addition to this, a prudent estimate will include a risk analysis.

Prudence calls for risk and analysis because uncertainty increases with the distance into the future that projections are made; consequently, the risk of producing forecasts that deviate from actual outcomes increases. To account for uncertainty, the FAA investment analysis process requires a sensitivity analysis and risk assessment of the minimum, most likely, and maximum expected cost.

The estimate planning process should identify the preferred risk analysis strategy. Typically, the risk analysis process will involve identifying the cost drivers, identifying a range of input values to allow for the uncertainty in the cost drivers, and performing sensitivity analysis to highlight the magnitude of effects resulting from possible changes in these cost drivers. In the planning process, the cost drivers can be identified, assumptions can be made about risk, and cost risk models can be chosen. Chapter 8 discusses risk and uncertainty analysis in detail.

4.5.4 Identifying Crosscheck Methods for the Cost Drivers

It is a good practice to crosscheck the results generated by the primary estimating tools with alternate methodologies. The process of crosschecking simply involves the application of an estimating approach other than that selected as the primary method.

Typically a crosscheck is used for those cost elements that contribute heavily to the total estimate or that have a high cost risk. Major cost elements, often referred to as cost drivers, need cross-checking since inaccuracy in these areas can have a significant impact on the estimate.

In the case of a parametric estimate, an acceptable high-level crosscheck would be to demonstrate that the development program estimate is similar to the actual costs incurred on an analogous program. Another crosscheck would be to determine that the estimated average unit production cost is reflective of those for predecessor systems after normalizing for quantity buy differences. This type of gross crosscheck for early program estimates is intended to convey that the primary estimating method generated results that appear reasonable in view of experience on similar programs.

This does not mean necessarily that there will always be a close tolerance between the estimated program and those serving as crosschecks. The estimated program may possess characteristics that require its estimate to be higher or lower than the predecessor program. When significant differences do exist, however, it is the estimator’s responsibility to understand them and determine their acceptability. If it is acceptable due to program characteristic differences, then the estimator must be able to present and document this rationale. If it is unacceptable, a complete review of the estimate and the validity of the crosscheck program is required.

If the estimator employs analogy as the primary estimating methodology, then a parametric estimate may be selected as the crosscheck method. When actual program costs become available, an engineering methodology may be used to estimate remaining development and production costs with analogy and/or parametric methods serving as a check of the engineering estimate results.

Other forms of crosschecks involve the use of historical factors to test the reasonableness of an estimate conducted using another method. For example, a typical estimating methodology for support equipment is to use analogies and/or catalog prices. You can convert this estimate into a factor, for example, as a percentage of prime mission hardware. This factor can then be compared to other factors computed on the same basis for predecessor programs. If all factors fall into an acceptable range, the crosscheck validates the primary estimating method. This technique is applicable to data, training equipment, systems engineering, program management, and other costs that can be estimated in detail and then converted to a factor of an appropriate program element like recurring hardware.

Regardless of the crosscheck methodology used, its purpose is to demonstrate that alternate methods generate similar results, thus increasing confidence in the estimate. As a program matures and its technical definition becomes more refined, and actual costs become available, estimates of the remaining program become more accurate. In the same vein, the results of primary and crosscheck methods should become closer as the program matures. When wide margins exist, the estimator must investigate how to correct unacceptable out-of-tolerance conditions or how to explain what makes the variance acceptable.

4.5.5 Cost Estimating Checklist

The foregoing discussion shows that the formation of a competent estimate is an involved process. The omission of one or several of the steps could introduce inefficiencies and errors in the estimating process. To avoid this, a comprehensive Detailed Estimate checklist is included in Appendix 4A.

4.6 Developing the Estimating Plan

To approach an estimate effectively, an estimating plan should be developed. The estimating plan introduces structure to the task, provides management an exposure to the approach adopted for the estimate's conduct, and serves as a contract between the estimator and requester. The following sections provide a general discussion of those plan aspects that require emphasis - the estimating team, approach, and timetables

4.6.1 Developing the Estimating Team

Up to this point, for the sake of simplicity, the text has assumed that one estimator would accomplish the estimate. This generally will not be the case. An estimating team is more likely to be assembled for the purpose of performing the estimate. The exact size and composition of the estimating team will depend on the type of procurement (non-developmental versus developmental), and the time and resources available to produce the estimate. An FAA estimating team would consist primarily of members from the line of business with the need, the Investment Analysis Staff, and IPTs who have candidate solutions. Ideally, the estimating team should have people with expertise in estimating all cost elements. This seldom is the case. Therefore, the team leader must assign available resources efficiently, ensuring a balance of technical and estimating expertise.

When making team assignments, it is important to recognize that each estimate is a learning experience. Therefore, individuals should be used in a manner that not only ensures a competent estimate, but also broadens the experience base of each estimator. A common approach in building a team is to assign experienced estimators the responsibility over major areas of the estimate with less experienced estimators working under their control. In addition, it is a good idea to give estimators an opportunity to participate in areas outside their current experience. This can be achieved by assigning an individual primary responsibility for an area within their experience base and a secondary responsibility for a portion of an unfamiliar area.

Structuring the optimal estimating team involves careful consideration of the capabilities of available resources in light of the estimating task. Responsibilities of participating organizations should be assigned formally at appropriate levels of management, via correspondence that clearly states the estimating task and schedule for its accomplishment and review. Beyond this, each team member's area of responsibility should be made known to all members of the Investment Analysis Team.

4.6.2 Planning the Estimating Approach

The scope, ground rules and assumptions, inputs required for analysis, and estimating methods are the core of the estimating approach. As the approach evolves, it is important that management has a full understanding of the approach to avoid confusion and unnecessary revisions to the estimate after it is completed. Management should be informed of any assistance required in gathering data and of clarification needed to refine the set of ground rules and assumptions.

4.6.3 The Estimate Timetable

The estimator must be afforded adequate time to develop a competent estimate. Constraints on time and resources required to conduct the estimate are a condition that could jeopardize the team's ability to deliver a quality product.

Once the requester establishes the task, the estimator should understand the due date. A detailed schedule leading to this date can then be evolved. Earlier, the estimator was cautioned on the devastating impact over-optimism could have on program schedules. This same caution applies to estimate schedules. Consequently, the estimator should create a schedule with realistic milestones that provide margin for delays. The schedule should also recognize travel time to briefing locations and reworks directed by review authorities. Since these delays and activities always consume time, it is appropriate to consider them in the schedule.

Frequently, estimators are willing to compress the estimate schedule to meet a due date. Compression is risky if additional resources are not available to perform the effort that would have been accomplished by fewer estimators over a longer period. The key point to remember is that the estimator's acceptance of the schedule constraint does not remove the requirement to deliver an estimate that is complete and possesses a high degree of competence. Therefore, the estimator should always strive for approval of a reasonable schedule. If this is not possible, the constraint should be highlighted under ground rules and assumptions as a condition that curtailed the estimating team's depth of analysis and the estimate's confidence level. Once the estimate timetable has been established, its milestones will be reflected in the Investment Analysis Plan.

4.7 Summary

This concludes the discussion of how to plan for a cost estimate. The planning stage is an important one. It is during the estimate planning that the estimators will discuss key estimate considerations such as estimating constraints and methodologies. The estimators also will characterize the system and obtain the WBS.

4A. DETAILED ESTIMATE CHECKLIST

Administrative

- Is this a totally new estimate or an update of a prior estimate?
- What is the purpose of the estimate?
- What is the scope of the estimated program?
- Who performed the estimate? Position, title, and grade?
- How many manhours were required to deliver the estimate?
- Has anyone else reviewed it? If so, what were the findings?

Basis for Estimate Assessment

Depending on the specific program, the assessment should address either the estimate as a whole or the lowest level cost elements used to build up the estimate. The depth of the review will vary depending on the complexity and importance of the estimate and the time available for the review. When time for the review is limited, the reviewer should identify the largest cost elements quickly and focus his attention on them - searching to insure that no large cost elements are missing. At the very least, the reviewer should address the following questions:

- Completeness:
  - ⇒ Are all pertinent costs included in the estimate? (e.g., GFE, support equipment, test centers, management reserve, warranty, contractor support)
  - ⇒ Have the latest available actual costs, proposals, etc., been used to develop or check the estimate?
  - ⇒ Has the estimate been summarized by appropriation and fiscal year?

- Reasonableness:
  - ⇒ Are the methods used to develop all cost element estimates appropriate?
  - ⇒ Is the estimate developed from proper historical costs using accepted methods and logical approaches?
  - ⇒ Are the assumptions, including learning curve slopes, production rates, usage rates, etc., reasonable?

- Consistency:
  - ⇒ Is the scope of the cost estimate defined clearly and is it consistent with the directed program? How does it differ from direction?
  - ⇒ Are all differences between the previous and current estimates identified and explained adequately so they can be understood fully?

- ⇒ Is the estimate consistent with the latest schedule estimate?
- ⇒ Have the appropriate inflation rates been used?

- Documentation:
  - ⇒ Is the estimate documented in a clear and complete manner?
  - ⇒ Are the latest actual data values and sources clearly shown in the documentation?
  - ⇒ Can the estimating methods used to develop the estimate or update previous estimates be followed easily?
  - ⇒ How does the estimate compare with the approved program funding?

- General:
  - ⇒ To what extent were contractor estimates used as a basis for the estimate?
  - ⇒ What adjustments were made to the contractor estimates?

NOTE:
Planning wedge estimates should be identified clearly as such and supported by the source and best available basis for the wedge values used, such as continuing at same level of effort, increased over prior year because...etc.

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

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.

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

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.

Specialized Sources of Cost Data

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.

Construction

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.

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.

> 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 1921-1 (*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

<u>Simple Index</u>

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

SIn/o = Pn/Po (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.

Composite Indices

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)	(3)	(4)	WEIGHTED PRICE (Step 1)		
		PRICE		QTY	(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

$$WAPI_{n/o} = [(\sum (P_n Q_o) / \sum (P_o Q_o)] * 100$$

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.

<u>Government Indices</u>

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. Manufacturing and Wholesaling: Misc. Industrial

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. Transportation

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.

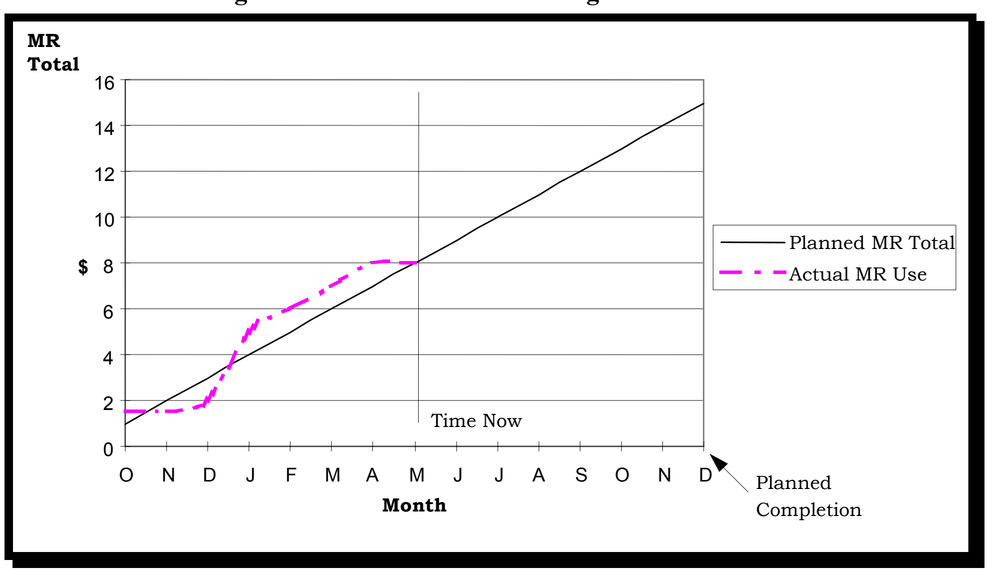
Budget at Completion (BAC) is the total of BCWS over the life of the program. It is in effect the "spend plan" for the contract and should be established as quickly as possible after contract award. The latest DoD guidelines require the government program manager to review the spend plan for the contract 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.

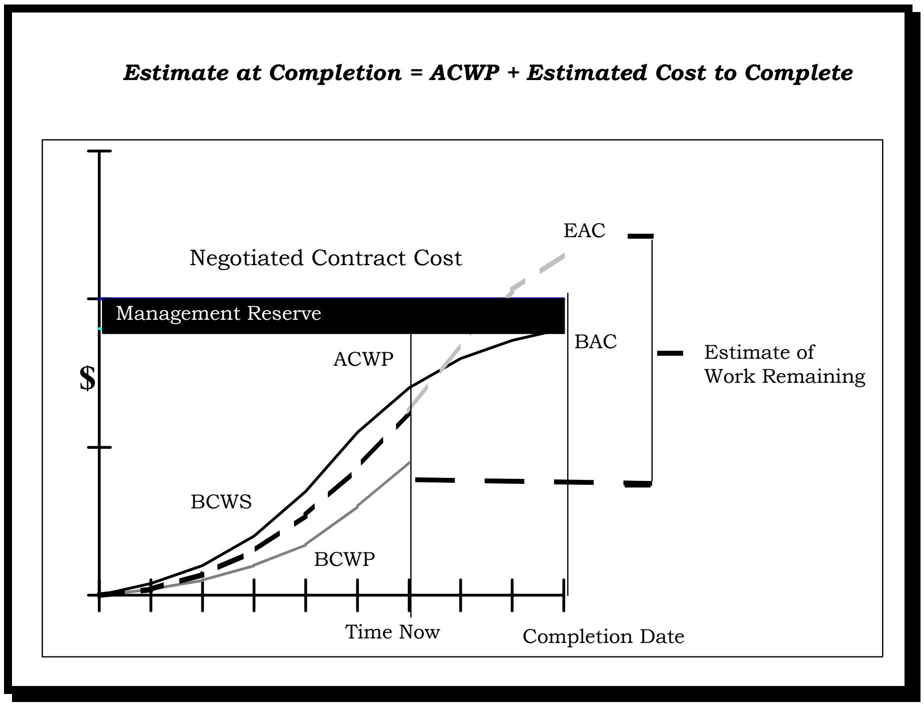
Simple projections of plotted BCWS, BCWP, and ACWP data extended with straight lines are indicative of the possible path of the use of the contract dollar. There are models available which will temper the straight-line projections to take advantage of experience gained on analogous programs or on an 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

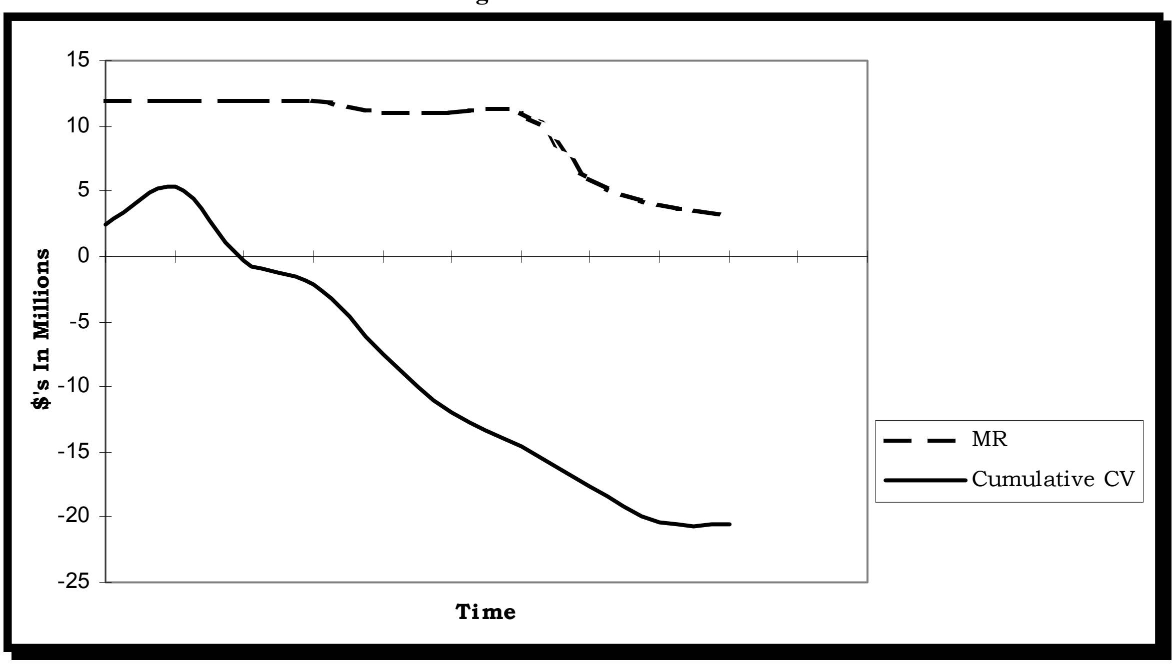
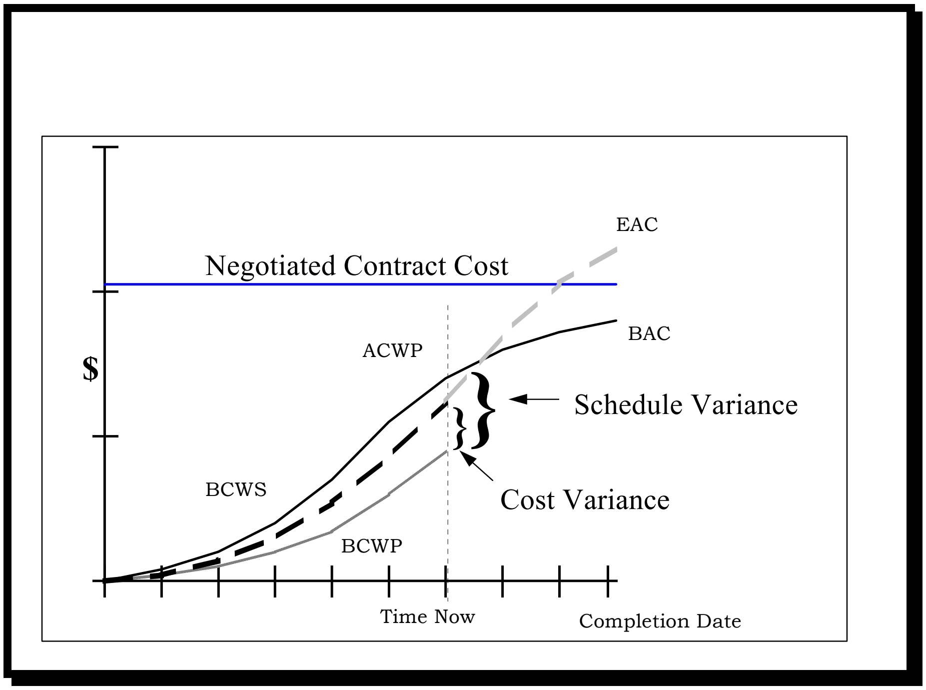


Figure 5B.4 is the Cumulative Performance chart. This chart plots BCWS, BCWP, and ACWP on a cumulative basis from the beginning of the contract and illustrates the total contract and current status. The example shown indicates a contract that is behind schedule and is overrunning cost, with both the 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



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.

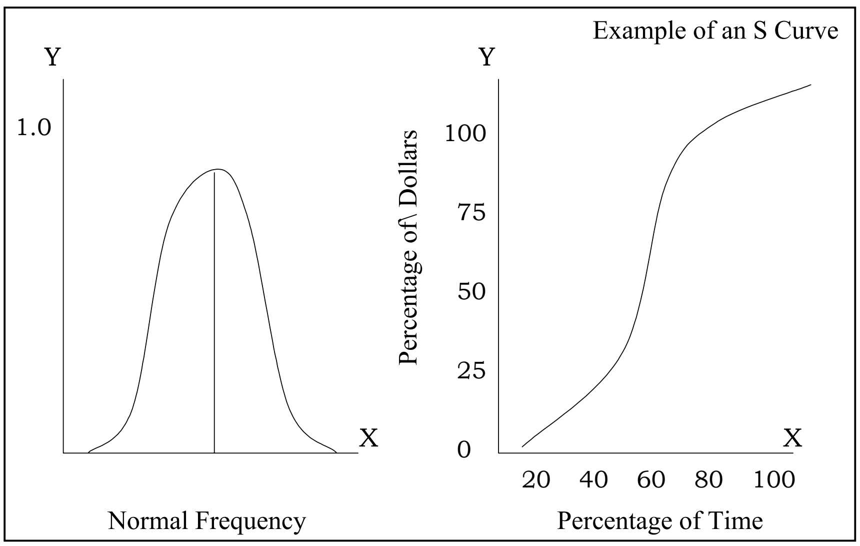


Figure 6.1 Example of an S-Curve

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.

7.0 DOCUMENTING AND PRESENTING THE COST ESTIMATE

7.1 Introduction

The FAA places great emphasis on both the importance of complete and understandable documentation of estimate results, as well as the approach employed to develop the estimate. The FAA's documentation philosophy is premised on the recognition that it is absolutely vital to be equipped with documentation that supports total recall of the estimate's detail in the absence of the team that conducted the estimate. The FAA further recognizes that the recall ability is of major assistance to future estimating or research teams, since often the original effort and its ingredients serve as a point of departure for the current effort. This requirement for total recall or estimate replication is driven by the need for the FAA cost community to be responsive to its management and their queries regarding original cost estimate assumptions, ground rules, methodologies, and techniques when program revisions, cost growth, or other perturbations occur. To do anything less than high quality, complete documentation will cause all the effort, creative thinking, and data that formed the estimate to be lost for future reference.

The FAA understands that review of study results by various levels of management occurs at the presentation level rather than the documentation level. Consequently, the estimating team must be equipped with a presentation package that is:

- Crisp and complete
- Easily comprehensible in a short time period by audiences unfamiliar with the estimate
- Addresses the important details of the estimate
- Conveys to the presentation recipient the competence that underlies estimate results

This chapter addresses the subjects of cost estimate documentation and presentation in detail. Documentation contents, format, and the process by which it occurs are discussed in Section 7.2. The aspects of cost estimate presentation are contained in Section 7.3.

7.2 Cost Estimate Documentation

The common theme conveyed in the various directives pertaining to cost estimate documentation is that of estimate replication. The requirement to develop the cost estimate document in a manner that allows an independent cost estimator to understand the methodology adequately to reconstruct the estimate in detail is the keystone to high quality cost estimate documentation. The remainder of this section provides:

- Visibility into the various aspects of cost estimate documentation in order to satisfy the replication criteria, and

- An efficient process for developing high quality documentation.

Throughout this discussion, emphasis is given to the FAA prerequisite not only to document the methodology employed in developing the estimate, but also to fully document the rationale for having selected a particular methodology.

7.2.1 Documentation Content

The following content structure encompasses the cost estimate documentation requirements for the FAA. The cost estimator must understand, however, that every estimate will not be documented to this level of detail. Documentation must be tailored to align with the size and visibility of the program estimates. Consequently, when documenting smaller programs or projects, this tailoring provision would be employed to downscope the content structure provided below. Specifics of this downscoping would be dictated by the size and nature of the program or project involved. However, the requirement for enough detail to support replication must be sustained by the tailored documentation.

Introduction

This portion of the cost estimate document will provide the reader a thumbnail sketch of the program estimated, who estimated it, how it was estimated, and the data used in developing the estimate. The introduction is a highly valuable overview for managers and an extremely useful reference for estimators attempting to determine the applicability of the document's main body to a current estimate or research study.

To ensure that it fulfills these objectives the introduction should address the following areas:

- Purpose of the Estimate. State why the estimate was done, whether it is an initial or updated prior estimate and, if an update, identify the prior estimate.

- Direction. Identify the requesting organization, briefly state the specific tasking, and cite relevant correspondence. Copies of tasking messages can be included here, in the main body, or as an appendix to the documentation package.

- Team Composition. Identify each team member, his or her organization, and area of responsibility.

- Program Background and System Description. Characterize significant program and system aspects and status in terms of work accomplished to date, current position, and work remaining. Include information such as detailed technical and programmatic descriptions, pictures of the system and major components, performance parameters, support concepts, contract types, acquisition strategies, and other information that will assist the document user in fully understanding the system estimated (reference Chapter 4, Section 4.3 for a discussion which will assist in preparing this documentation section).

- Scope of the Estimate. Describe acquisition phases, appropriations, and time periods encompassed by the estimate. Further, if specific areas were not addressed by the estimate, state the reason (e.g., this estimate was accomplished to support a development budget update; therefore, production costs were not addressed).

- Program Schedule. Include the master schedule for development, production, and deployment, as well as a detailed delivery schedule.

- Ground Rules and Assumptions. List all technical and programmatic conditions that formed the basis for the estimate. Chapter 4, Section 4.4 provides a list of those aspects of an estimate for which ground rules and assumptions generally are established.

- Inflation Rates. Simply state which set of inflation rates were used for the basic estimate. It is not necessary to identify in this section other rates that may have been used to normalize historical data, since they will be described in the main body. A detailed table portraying the rates used can be included either in the main body or as an appendix to the documentation package.

- Estimate Summary. Identify the primary methodology and techniques that were employed to construct the estimate, along with a general statement that relates the rationale for having selected these particular methodologies and techniques. Also, briefly describe the actual cost data and its sources that were used to develop or verify the estimate. The final portion of this section should portray estimate results by major cost element, in both constant year and current year dollars. A bottom-line track to the previous estimate also should be included, if applicable. For each major cost element, a page reference to the main body of the documentation where a complete description of its estimate can be located should be included.

- Main Body Overview. Provide an overview of how the document's main body is organized and describe any of its aspects that may facilitate its use.

The introduction section not only should provide a complete summary of the cost estimating effort, but also contain directions (including page numbers) on where to go in the report to get further details. This feature is a great help to reviewers; especially those who only want to pursue large dollar value items or some other selected items.

It should be remembered that many higher-level reviewers will read only the introduction. If accomplished properly, this section alone can do much to establish the credibility of the estimate. Therefore, it is critical that the introduction be written well and summarize the entire estimate completely. This can be done best by having one person responsible for writing the entire introduction. This assures a consistent style and lessens the probability of omissions or double coverage. In an ideal situation, the team leader should be responsible for preparing the introduction since he generally is free from specific estimating responsibilities (as well as the corresponding documentation preparation).

Main Body

This portion of the documentation should describe the derivation of the cost estimate in sufficient detail to allow a cost estimator, independent of the original estimating team, to replicate the estimate. The rule for developing this part of cost estimate documentation is clear - providing too much detail is better than not providing enough. Developing this portion of the document properly requires that documentation be written in parallel with developing the estimate. Said another way, as numbers are crunched, the rationale behind the number crunching must be written down.

The main body should be divided into sections using the content areas and titles shown below. Following these guidelines, pertaining to the document's main body content structure, will allow the estimating team to develop a comprehensive document efficiently.

Estimate Description

Provide a detailed description of the primary methods, techniques, and data used to generate each element of the estimate. For each primary approach employed, the rationale for having selected it, along with the crosscheck approach used for substantiation, must be included to convey the competence of estimate results. The descriptions contained in this section will, at a minimum, address the specific topics contained in Table 7.1. It should be noted that, in some cases, not all of the topics identified in Table 7.1 will be used in performing the estimate.

The discussion in this portion of the documentation package should follow a logical flow that moves from cost element to cost element as depicted in the work breakdown structure (reference Chapter 4, Section 4.5.1) for the program being estimated. Where appropriate, functional breakouts should be made to assist in describing how the estimate was developed. The actual timephased estimate, in constant year dollars for each cost element, should be included with the description of how it was developed. Each of these cost elements will become an input to the timephased estimate summarization that will be provided in both constant year and current year dollars at the end of this section. If the estimate is an update to a prior estimate or an Independent Government Cost Estimate (IGCE), a track between the two (IGCE and program office estimate in the case of an IGCE) should also be provided at the end of this section along with an explanation of differences. This explanation must address not only where the differences reside, but also why they exist.

Every cost element should be documented in a consistent, four subsection format. These subsections include - a fiscal spread in constant year dollars (sometimes a useful option is to include two lines, one for constant year dollars and one for current year dollars), a description of each cost element content, a summary of estimating and fiscal year spread procedures, and a detailed description of the basis for the estimate.

Table 7.1 Topics Addressed Under Estimate Description

TOPIC	REQUIRED DESCRIPTION
Data	Show all data used, its source (e.g., actuals on current contract/analogous program), and normalization procedure.
Labor Rates	Identify direct and indirect labor rates as industrial averages or contractor specific, their content, and how they were developed.
Labor Hours	Discuss how functional labor hours were developed (e.g., contractor proposal, build-up from analogous program, engineering assessments).
Material/Subcontracts	Depict the material, purchased parts, and subcontracted items that are required, and the development of their cost (e.g., vendor quotes, negotiated subcontracts, catalog prices).
Cost Improvement Curves	Include method used to develop T1 values and describe the curve selected in terms of its slope, source, and relevance to the cost element and program being estimated. Any unique aspects of curve application must be included in this section.
Factors and Cost Estimating Relationships (CERs)	Provide the basis, development, and/or source of all factors and CERs used for areas such as support equipment, data, training, ECO, etc. This discussion must include a description of how the factor was applied (e.g., against recurring manufacturing labor costs) and its relevance to the program being estimated.
Cost Models	Describe all models used and their relevance to the estimate, along with complete details regarding parametric input and output (include detailed runs here or as an appendix to the documentation package) and any calibration performed to ensure the model served as an appropriate estimating tool for the cost element and program involved.
Inflation Index	Document the specific indices and computations used in the estimate including those employed to normalize historical data. A detailed table portraying the rates used can be included either here or as an appendix to the documentation package.
Timephasing	Identify/describe the approach used to phase the estimate.
Sufficiency Reviews and Acceptance	Discuss the process used for reviewing an existing cost element estimate to determine its sufficiency and acceptability for incorporation into the estimate. This process should be applied to existing government and contractor estimates that are accepted as throughput to the estimate.
Estimator Judgment	Document the logic and rationale that led to specific conclusions reached by the estimator regarding various aspects of the estimate.
Risk and Confidence	Show the details of all risk analysis conducted and how it formed the basis for reaching conclusions regarding estimate confidence.

Conclusion

This would be included in the case of IGCE documentation, and would express the team's determination regarding the reasonableness of the program office estimate.

Appendices

These should be used to append any pertinent information that, due to size, would be disruptive to the introduction and/or main body of the documentation package. Appendices can include a copy of estimate briefing charts, model runs, inflation rates, tables, etc.

References

Source documents/data should be identified where used in the documentation package, with its citation (author, title, date, page numbers, etc.) listed in the reference section. This is discussed in detail in the following section.

7.2.2 Documentation Format

Documentation must be organized logically with clearly titled, easy to follow sections. The following considerations will contribute toward achieving high quality, useable cost estimate documentation:

- The documentation package should include the program name, reason for the estimate, the identity of both the tasking organization (and office symbol) as well as the organization that accomplished the estimate, and the "as of" date.
- A table of contents should be included that identifies the titles of each numbered section and subsection along with page numbers.
- Pages should be numbered either sequentially or sequentially within each section.
- Where the same data or method is used repeatedly, it should be described in detail at the point of original use, and referenced by page number thereafter.
- All terms and acronyms should be defined fully at the point of first use.
- All figures and tables should be identified by numbers and clear descriptive titles (the numbering and titling convention used in this handbook would be appropriate for cost documentation).
- Cross-references should be used to assist the reader in understanding where areas addressing the same subject are located in the document.
- The first time documented information is used, its source should be cited and added to the reference list contained at the end of the documentation package. When the same source is used thereafter, only the reference number needs to be cited.

The guidelines provided above are general in nature and should be tailored to the specific documentation effort at hand. A key cost estimating activity required during the investment analysis phase is to produce an Investment Analysis Report (IAR). The *FAA Acquisition Management System Investment Analysis Process Guidelines*, revised July 1998, describes the investment analysis process within the FAA AMS. Appendix G of this manual provides specific guidelines for documenting an IAR.

7.2.3 Documentation Process

The FAA has adopted the perspective that documentation is not a final chore but rather one of the most important aspects during compilation of the estimate. Integral to this perspective is the fact that the only correct way to document is parallel to the estimate itself. Because of this, it is critical that the subject of documentation and its accomplishment be a topic during the estimate's initial planning phase. With this early emphasis on estimate documentation, the team is organized to write down clear, orderly notes as the estimate progresses. This ensures that the data, analysis, and rationale that underlie the estimate are captured at their freshest moment rather than depending on recollection weeks later.

To carry out the documentation process effectively, the team leader should develop an outline from the guidance provided in Section 7.2.1. This estimate specific outline will provide a road map that depicts to the team the planned structure and content of the final documentation package. With this blueprint and the documentation requirements established in this chapter, the estimator can develop notes that will form the basis for the estimate's documentation. If accomplished properly, the time to clean up and refine the estimator's notes into final documentation form will be minimized.

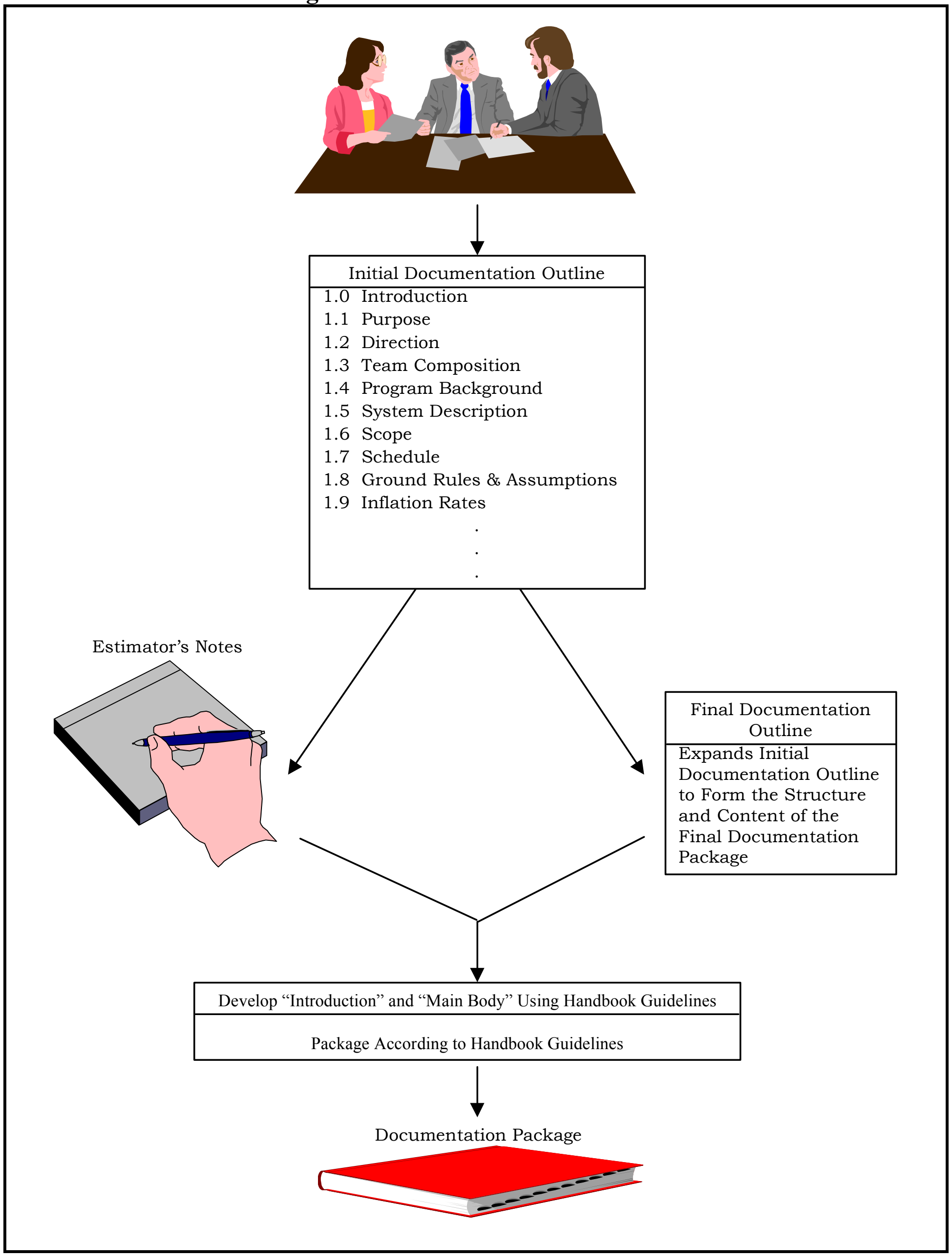
Any departure from this process constrains the team's ability to portray accurately its rationale for having selected the methodology, techniques, and data that form the foundation upon which the estimate’s results were developed. By following this real-time documentation process, two distinct benefits accrue immediately:

- The team is postured to convey readily its reasons for having selected the specific rationale that underlies study results, and

- The draft product is produced in a manner that minimizes time invested while maximizing the quality and timeliness of study documentation and delivery to review authorities.

Figure 7.1 provides a flow diagram of the documentation process.

Figure 7.1 Documentation Process



7.3 Cost Estimate Presentation

The foregoing sections concentrated on the preparation and importance of cost estimate documentation. Equally important is cost estimate presentation, since the review of estimate results by various levels of management typically occurs at the presentation level rather than at the documentation level. The estimating team's first formal opportunity to convey in a short time what was accomplished over a period of months is the estimate presentation.

7.3.1 Presentation Content and Format

It is inefficient to expend valuable resources and time to generate a highly competent product that contains the correct approach and accurate answers, but fails to convey these results due to a less than competent presentation. For this reason, the estimating team must be equipped with a presentation package that is:

- Crisp and complete
- Easily comprehended, in a short time period, by audiences unfamiliar with the estimate
- Addresses the important details of the estimate
- Conveys to the presentation recipient the competence that underlines estimate results

To assist the estimating team in achieving this objective, a briefing package must be developed which:

- Ensures all key aspects of the estimate are addressed in a logical manner
- Accommodates estimate results regardless of the nature, range, or depth of the study
- Enhances estimate comprehension by allowing review authorities to concentrate on content, not format

The key to developing an effective briefing is to capture the estimating details in a manner that conveys the estimate's contents and competency to the presentation's recipients in an easily understood way. The most difficult transition for the estimator is moving from the detailed study to an understandable presentation of its results. An effective briefing format channels the appropriate level of information into distinct compartments that are addressed easily by the presenter and comprehended by the recipient. In preparation for questioning that penetrates beneath the level of information presented, the briefing can include a series of indexed backup material that supports the key elements of the primary briefing package. These allow the presenter to be responsive to detailed probes by the review authorities.

As with the documentation guidelines, these presentation guidelines are general in nature and should be tailored to the specific presentation effort at hand. The FAA provides specific guidance for building an Investment Analysis Briefing, which can be found in Appendix H of the *Acquisition Management System Investment Analysis Process Guidelines,* revised July 1998.

7.3.2 Briefing the Cost Estimate

While an effective briefing package enhances the cost estimate review and approval process, it must be employed by a team that is fully prepared to articulate its contents professionally. Proper briefing preparation requires hours of study to ensure that the presenter and team members are intimately familiar with the briefing content. Guidelines for briefing the estimate are listed below.

- Part of team homework is being acquainted with the recipient’s background. This will assist in anticipating questions, developing backup material, and drawing analogies between various presentation aspects and the recipient's experience.

- The presenter should be able to visualize and articulate every chart in the primary deck.

- Each team member must be prepared to respond intelligently to questions within their area of responsibility.

- To facilitate responses, each team member should follow presentation progress with their personal copy of the briefing, annotated with notes of explanation and backup material references.

- It is unacceptable for a team member to be inattentive or non-responsive when called upon for assistance by the presenter.

- Similarly, it is unacceptable for the presenter not to call on team members when in need of assistance. Accurately responding to questions should be a team effort.

- A presenter who can only read the charts is not really prepared for the briefing. The recipient can also read. Charts are an outline against which the presenter articulates the estimate's story. This articulation should occur in a manner that keeps the recipient attentive and makes the experience meaningful, as well as interesting.

The presentation must be the team’s finest hour, or the time and effort expended on the estimate will be for naught. The development of an effective briefing package, combined with team homework and briefing techniques, are essential ingredients to the successful presentation of the estimate's approach and results. Other helpful tips to facilitate briefing development, practice, and presentation are listed below.

- Use the most recent successful estimate briefings as guides. Preferred formats change over time.

- Have one person, not the briefer, assigned to work with the graphics shop.

- Number charts, especially back up charts, for quick retrieval.

- Have a dry run in front of an internal peer group. Do not practice in front of the Director.

- Be prepared for both single and double screen presentations.

- Be prepared for both front and back projection facilities.

- Schedule enough lead time for all necessary briefing reviews and the changes that can be expected as the result of them.

- During trips, keep the briefing charts with the briefer.

- Have one or more team members assigned to take detailed notes about audience comments and direction during briefings.

- Make provisions for chart flippers in advance, especially at FAA Headquarters.

- Anticipate questions, and conduct a limited amount of sensitivity analyses to be prepared for them.

7.4 Summary

The discussion throughout this chapter focused on the benefits of high quality documentation and presentation, and offered a systematic approach for developing such products. None of the discussion regarding systemization should be interpreted either as a rote or mechanical approach to developing documentation and presentation packages, or as intended to stifle creativity. In fact, a disciplined approach to documentation and presentation frees the estimator's time for creating the estimate.

Beyond the estimate, however, it is not necessary to create new approaches to documentation and presentation each time a task is undertaken. This constant change in format is needlessly time-consuming and generates confusion in the system. The FAA structured approach to post-estimate activity allows the team to achieve efficiently the bottom-line objective of portraying the competency that is inherent to the estimate.

All documentation resulting from an investment analysis and its accompanying cost estimate is stored for historical purposes, including the IAR, the JRC Briefing, and information supporting all phases of the analysis. The FAA's Corporate History Management System, which houses this documentation, is being refined to support consistency in the structure of cost analysis and to provide reference material for development of future cost estimates.

8.0 COST RISK AND UNCERTAINTY

8.1 Introduction

Risk and uncertainty exist in cost estimating because a cost estimate is a prediction of the future. There is a chance that the estimated cost may differ from the actual cost. Moreover, the lack of knowledge about the future is only one possible reason for such a difference. Another equally important cause is errors resulting from historical data inconsistencies, cost estimating equations, and factors that typically are used in an estimate. For instance, the standard error of the estimate (discussed in Section 9.5.5 of Chapter 9) and the limitations of historical data (covered in Section 5.2.2 of Chapter 5) are both examples of error sources. Thus, when viewed in its totality, a cost estimate can include a substantial amount of error. Once this is recognized, the question becomes one of dealing with those errors, which is what the subject of risk and uncertainty is about.

The rest of this section discusses the purpose of both risk and uncertainty analysis and provides useful definitions. Section 8.2 provides general background information and a discussion on the nature of risk and uncertainty. Section 8.3 reviews the typical approaches that have been proposed and applied in dealing with the uncertainty problem. Section 8.4 provides a summary of models and methods currently being employed. The main purpose of this section is not to provide a detailed description of each model or method, but rather to show how cost estimation approaches in the previous section were implemented by field practitioners. Qualitative indices are covered in Section 8.5.

8.1.1 Purpose of Risk and Uncertainty Analysis

In general, people associate one number with an estimate. The use of one number rather than a range of numbers probably has its origins in the need to put one value in a budget request. The budget request quickly becomes a very practical document, with organizational obligations made based on approved budgets. Obligations involve payment to individuals or entities; and payment is made in discrete dollars and cents, not ranges of estimated amounts. However, estimates are prepared long before actual obligations are incurred; and by the time the estimate turns into a payment for services rendered, it often has grown from the original amount. Significant cost growth generally is viewed as an indicator of poor planning, mismanagement, underestimation of cost, and/or incomplete/inadequate identification of requirements. After all, during the investment analysis phase, the choice of the best alternative is made based on a comparison of cost estimates. If cost growth on one alternative is significantly higher than it might have been on another, the original choice could be called into question. Therefore, decision makers require a way of measuring the inherent risk and uncertainty in an estimate.

8.1.2 Common Terms and Definitions

A prerequisite to discussing risk and uncertainty analysis requires that certain terms and definitions be provided. Table 8.1 lists these terms and definitions.

Table 8.1 Risk and Uncertainty Analysis Definitions

TERM	DEFINITION
Risk	A situation in which the outcome is subject to an uncontrollable, random event stemming from a known probability distribution.
Uncertainty	Occurs in a situation in which the outcome is subject to an uncontrollable, random event stemming from an unknown probability distribution.
Engineering Change Orders (ECO)	That amount of money in a program specifically set-aside for uncertainty. ECO generally is referred to as the money set-aside for "known-unknowns."
Management Reserve (MR)	This term represents a value within the negotiated contract target cost that the contractor has withheld at the management level for uncertainties. The contractor is required to track and report to the government the application of MR. Generally, MR is referred to as the money set-aside for "unknown-unknowns."
Monte Carlo Analysis	Simulation technique, which varies all relevant input parameters to arrive at the potential range of outcomes expressed in terms of probability distributions.
Sensitivity Analysis	Estimating technique in which a relevant non-cost input parameter is varied to determine the probable cost.
Most Likely Cost	The most likely or most probable estimate of the cost that ultimately will be realized for a program, project, or task.
Standard Error of the Estimate	Represents a measure of the variation around the fitted line of regression, measured in units of the dependent variable.
Budgeting to Most Likely Cost	The most likely or most probable estimate of the cost that ultimately will be realized for a program, project, or task. Inherent in the estimate should be all funding necessary to ensure that the program can be managed properly in an environment of undefined technical complexity, schedule uncertainty, and the associated cost risk.
ECO Funding	ECO is the best estimate for contract changes, based on historical precedence (e.g., safety of flight, correction of deficiencies, and value engineering). ECO is a reserve for known-unknown contract changes and does not include reserves for requirements creep. ECO is an identifiable and traceable element of cost. ECO applies to both development and production and varies by both program and fiscal year.

8.2 Classical Treatments

This section covers several aspects of risk and uncertainty that set the stage for the later sections that deal more with approaches and actual practice. As a result, the focus here is to examine the nature of risk and uncertainty.

8.2.1 Risk versus Uncertainty

The terms risk and uncertainty often are used interchangeably. However, in the more strict definitions of statistics they have distinct meanings. Reviewing these definitions helps clarify the problem confronting the cost estimator. Three reports were consulted for the following definitions. They were Frank Husic's *Cost Uncertainty Analysis,* Paul Dieneman's *Estimating*

Cost Uncertainty Using Monte Carlo Techniques, and Gene Fisher's *Cost Considerations in Systems Analysis.*

The traditional view of risk is a situation in which the outcome is subject to an uncontrollable random event stemming from a known probability distribution, e.g., drawing an ace of spades. There is only one chance in 52. In drawing one card from the deck, the outcome is not known, but the probability associated with each outcome is known. The probability of drawing an ace of spades with replacement is 1/52, and the probability of drawing a spade with replacement is 13/52, etc.

Uncertainty is a situation in which the outcome is subject to an uncontrollable, random event stemming from an unknown probability distribution. That is, there is insufficient information available to form an objective view of the outcomes and their associated probabilities.

In most cost estimating situations, it is impossible to collect enough data to generate anything like a frequency distribution; in many cases five or six data points is a bonanza. The general conclusion is that cost estimating is much more in the realm of uncertainty than risk. Therefore, in the interest of both clarity and simplicity, the remainder of this chapter will use only the term uncertainty.

8.2.2 Elements of Uncertainty

The term cost growth seems to represent an inherent aspect of almost any government acquisition. It usually is measured by comparing the estimated cost of an item with its final actual cost. In this respect, cost growth is a monetary realization of the uncertainty that existed at the time the estimate was made. If all the events and circumstances that occurred between estimate and final cost were known at the time of the estimate and the source data/estimating techniques were sound, there would have been no uncertainty and, hence, no cost growth. The time element in the comparison of estimated to actual cost is critical; the earlier an estimate is made, the less is known about the item and the more opportunity there is for change. In terms of the acquisition cycle, the system cost estimate developed during the investment analysis phase has more uncertainty than the system estimate developed during the solution implementation phase. The reason for this is that at the beginning of a program there are several aspects for which only general statements can be made. As the program progresses, these aspects become clearer and more refined; as a result, uncertainty is reduced. That is, the known-unknowns are becoming known with the passage of time and experience.

This relationship of uncertainty and the acquisition cycle is shown in Figure 8.1. In the figure, the vertical lines represent the most likely cost (the point estimate). Panel A depicts the situation just described; all variables affecting the system are known but their magnitudes are originally uncertain. Again, as the program progresses, the measure or value of these variables becomes known, the uncertainty is reduced, and the probability of the point estimate increases. Panel B illustrates, basically, the same situation as A, except that the point estimate is increasing with time. The reason for the increase is due to factors and changes that could not be anticipated. These are the so-called unknown-unknowns. Past experience indicates that most programs resemble more panel B than panel A situations, which means the uncertainty surrounding an estimate is a composite of known-unknowns and unknown-unknowns.

Figure 8.1 System Cost Uncertainty and the Acquisition Cycle

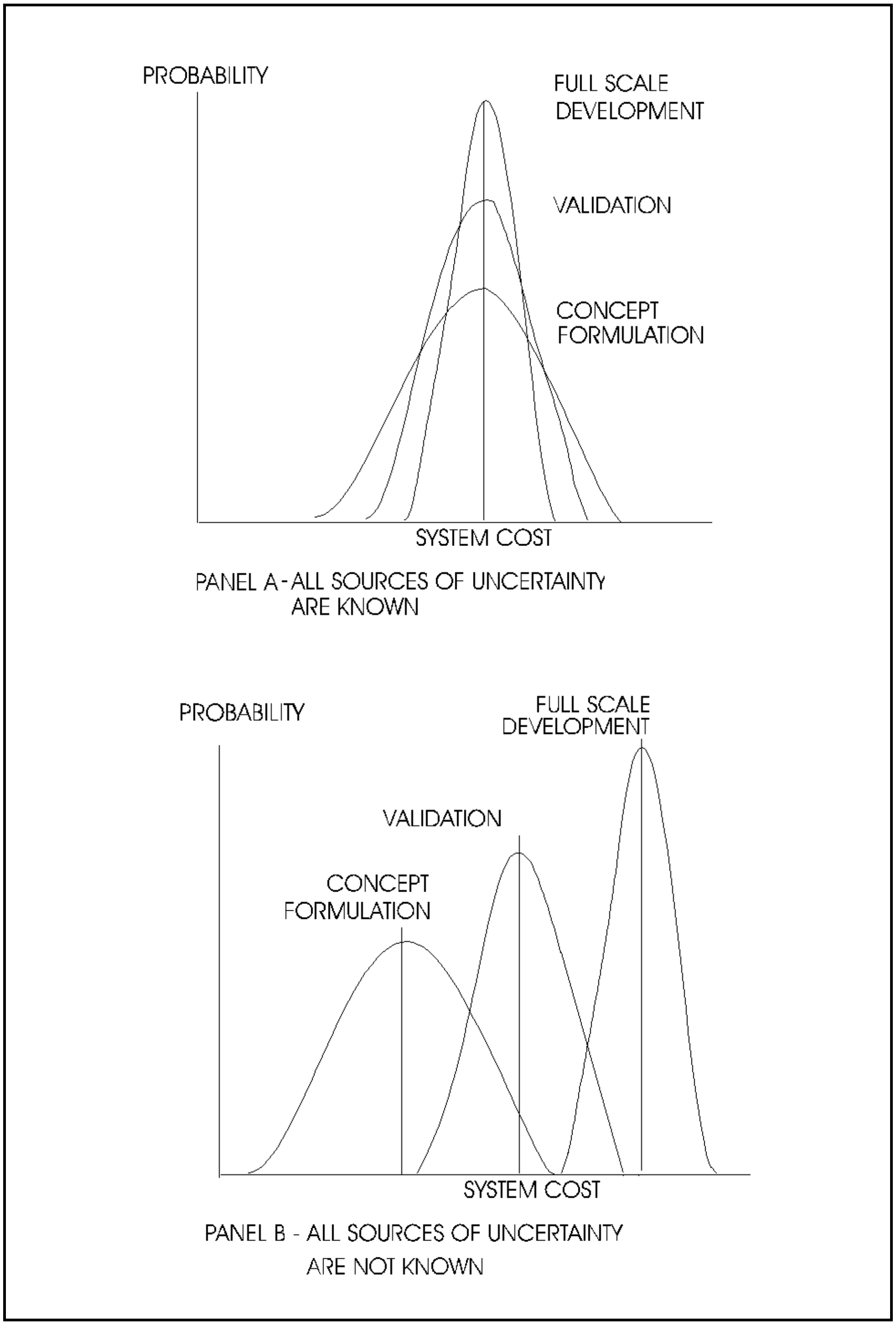


Table 8.2 provides a listing of one researcher's (John D. Hwang) findings about the economic, technical, and program factors causing these uncertainties. Generally, these sources of uncertainty are categorized as requirements uncertainty and cost estimating uncertainty.

Table 8-2. Sample List of Factors Causing Uncertainty

• Current/Future State of Technology	• Present Defense Systems Capabilities
• Defined Threat or Proposed Change/Innovation	• Production Facilities and Factory Test Equipment
• Desired Date for Operational Capability	• Production Hardware Including Necessary Spares
• End Item Interfaces Defined	• Quality Assurance and Test Requirements
• Equipment Schedules Delivery Dates	• Recommended Changes to System Design
• Estimated Production Rates/Quantities/Deliveries	• Reliability, Maintainability, Evaluation Criteria
• Expected Operational Environment	• Required Training Equipment and Facilities
• Field Requirements for Trained Personnel	• Subsystem Specifications
• Fiscal Information/Available Resources	• Support Facilities/Equipment on Hand
• Identified/Approved Engineering Design Changes	• System Operational/Functional Requirements
• Maintenance and Logistics Plans	• System Performance Demonstration Plans
• Material Sources and Market Prices	• System Performance/Design Requirements
• Mission Objectives and Priorities	• Test and Evaluation Concepts
• Mission Responsibility Assignment	• Test Facility, Support Equipment, Instrumentation
• National Objectives and Strategies	• Test Measurements, Data, Variables, Parameters
• Necessary Technology Advance and Risk Assessment	• Test Objectives, Environment, Expected Results
• Operational Plans Instructions and Manuals	• Tooling Design Jigs and Fixtures
• Performance Envelopes/Design Constraints	• Training and Personnel Requirements
• Personnel Subsystem Evaluation Plans	• Training Course Materials

Requirements uncertainty refers to the variation in cost estimates caused by changes in the general configuration or nature of an end item. This would include deviations or changes to specifications, hardware characteristics, program schedule, operational/deployment concepts, and support concepts.

Cost estimating uncertainty refers to variations in cost estimates when the configuration of an end item remains constant. The source of this uncertainty results from errors in historical data, cost estimating relationships, input parameter specification, analogies, extrapolation, or differences among analysts.

This form of categorization has been employed in the study of weapon system cost growth. According to Leroy Baseman's article in the *Journal of Cost Analysis*, in the 1960s and later in the early 1970s, requirements uncertainty accounted for about 75 percent of cost growth with the remaining 25 percent attributed to cost estimating uncertainty. By 1983, the percent attributed to cost estimating uncertainty had dropped to around five percent, and current information indicates the percentage will be even smaller in the future. Thus, cost growth today is not so much a matter of cost estimating error. Instead, it is a matter of how the end item originally estimated is different from the item finally produced due to changes in technology, national strategy, deployment concepts, operations procedures, or other end systems.

8.2.3 Point Estimates versus Interval Estimates

Development of a cost estimate usually involves the application of a variety of techniques to produce estimates of the individual elements of the item. The summation of these individual estimates becomes the singular, best (and most likely) estimate of the total system and is referred to as a point estimate. In and of itself, the point estimate provides no information about uncertainty other than it is the value judged more likely to occur than any other value. A confidence interval, on the other hand, provides a range within which the actual cost should fall, given the confidence level specified.

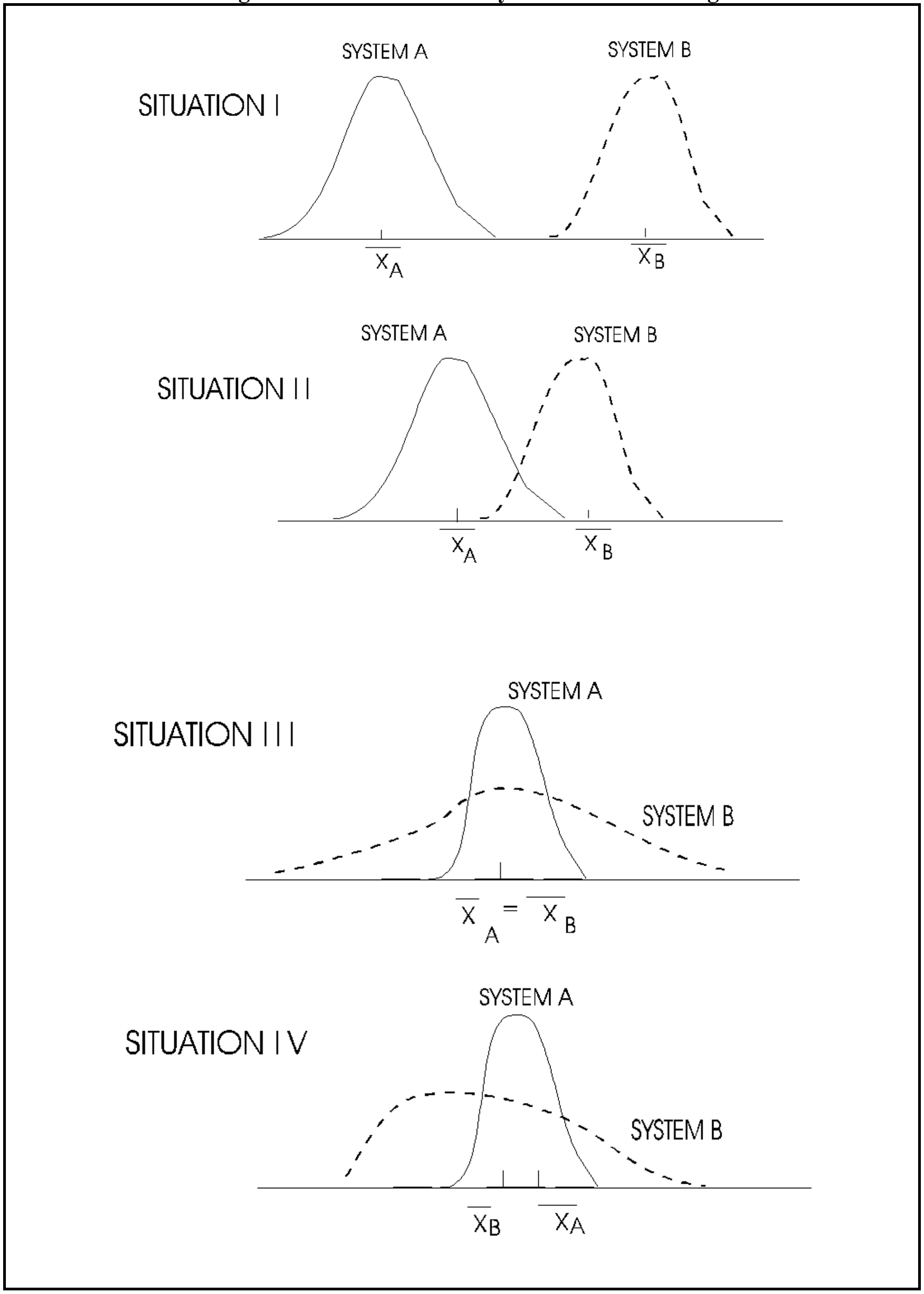
For example, suppose an estimating team has provided a point estimate for a system of $10M. Also, because of the way the estimate was built, the standard deviation has been estimated at $2.5M, and the distribution of cost is assumed to be normal. The interval estimate for the hypothetical system would be $5M to $15M, at the 95 percent level of confidence. This tells the manager that there is a 95 percent probability that the actual cost of the system will be between $5M and $15M, but the exact amount is unknown.

8.2.4 Uncertainty in Decision Making

The point estimate provides a best single value, but with no consideration of uncertainty. In contrast, the interval estimate provides significant information about the uncertainty but little about the single value itself. However, when both measures are taken together, they provide valuable information to the decision maker.

An example of the value of this information is in situations involving choice among alternatives, as in the case of source selection or systems analysis studies. For instance, suppose systems A and B are being evaluated; and because of equal technical merit, the choice will be made on the basis of estimated cost. According to Paul Dieneman, in his report *Estimating Cost Uncertainty Using Monte Carlo Techniques*, if the choice is made solely on the basis of the most probable cost, the decision may be a poor one (depending upon which of the four situations in Figure 8.2 applies.)

Figure 8.2 Cost Uncertainty In Decision Making



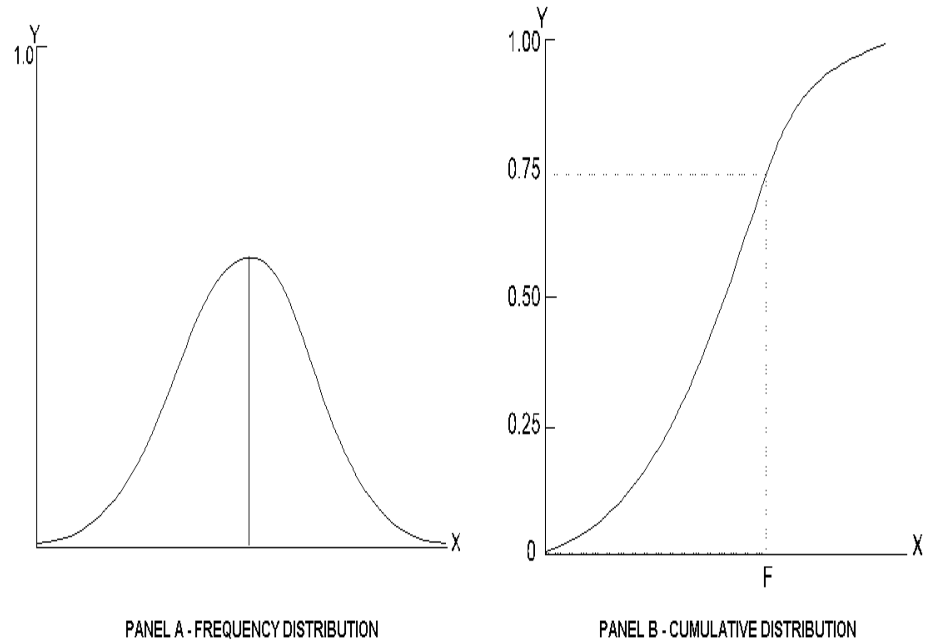
In situation I, there is no problem in the choice, since all possible costs for A are lower than B. A's most probable cost is the obvious choice. Situation II is not quite so clear because there is some chance of A's costs being higher than B's. If this chance is low, A's most probable cost is still the best choice. However, if the overlap is great, then the most probable cost is no longer a valid criterion. In situation III, both estimates are the same, but the uncertainty ranges are different. At this point, it is the decision maker's disposition toward risk that decides. If the preference is a willingness to risk possible high cost for the chance of obtaining a low cost system, then B is the choice. If the preference is to minimize risk, then A is the appropriate choice. Finally, situation IV poses a more complicated problem, since the most probable cost of B is lower but with much less certainty than A. If the manager uses only the point estimates in this case, the most probable choice would be the less desirable alternative. In the preceding situations, uncertainty information was a method used to select between alternatives. A quite different use of uncertainty information is when a point estimate must be adjusted for uncertainty, as in the case of establishing a budget.

8.2.5 Budget Realities

Establishing the funding level for a program or system is one of the primary purposes of developing an estimate. Unfortunately, the budgeting process is not designed to accommodate an interval estimate, which means that a single monetary value must be chosen. The program manager will, in most cases, not select the point estimate as the budget since it does not reflect any adjustments for uncertainty or circumstances beyond the realm of the cost estimate (such as affordability, availability of funds, the cost and relative priority of other systems/items competing for funds, and the manager's disposition toward taking a chance). Since it is likely that the choice will be somewhere between the point estimate and the upper level of a conservative interval estimate, the selection of a value suitable to external constraints and the cost uncertainty of the estimate becomes an obvious concern. Such a selection must be made by the manager, but the estimator can assist in the decision by providing uncertainty information for various budget values.

One particularly effective method of portraying the uncertainty implications of alternative choices is to depict the estimate and its related uncertainty in the form of a cumulative probability distribution, as shown in Figure 8.3. The utility of this approach is the easy-to-understand, convenient manner in which the information is presented to the decision maker. In the figure, panel A shows the cost estimate as it might normally be depicted with the most likely value (point estimate at the center); panel B shows the same information in the form of a cumulative curve. It is easy to see, for instance, that the selection of the funding level, F, is at the 75 point, which means that there is only a 25 percent chance of actual cost exceeding this funding level. The manager can see the implications of a particular choice immediately.

Figure 8.3 Distribution Forms



This completes the discussion of the nature and makeup of uncertainty. Before proceeding on to the next section, which covers the methods of dealing with uncertainty, there is a point that needs to be made. Rarely are there ever enough data available to generate a useable frequency distribution that could be employed like those in the examples used in this section. However, estimators do try to approximate such distributions through the use of some of the techniques discussed in the next section.

8.3 Dealing with Uncertainty

When actually treating uncertainty in an estimate, several approaches are available, ranging from very subjective judgment calls to rather complex statistical approaches. This section is not intended to be an exhaustive discussion of every possible approach or variation of an approach, but rather to provide an insight into the more fundamental and traditional techniques that form the basis for current field use. The order of presentation of these techniques is intentional, because it tends to portray the evolution that has taken place in terms of the tools used to handle uncertainty.

Before beginning actual discussions of the uncertainty approaches, there are a few points for an estimator to keep in mind. First, to the extent that actual historical cost information has been used in developing the point estimate, data already include the realities of both requirements and cost uncertainty. This leads to a natural question of why there is any need to treat uncertainty separately. The need appears to come from the view that a point estimate includes an inherent amount for expected uncertainty. However, there is a bias toward caution by adding an amount to the point estimate to cover uncertainties over and above what might be expected. Other than lacking the specific precision of statistics, this is not any different from adding some number of standard deviations to the mean to arrive at a higher specified level of confidence.

A second point to keep in mind is whether cost uncertainty or requirements uncertainty, or both, are to be treated. Several of the approaches discussed here require the estimator to provide a highest and lowest possible value. The point becomes one of knowing whether these values presume a fixed baseline and, therefore, only reflect cost uncertainty, or whether they reflect possible variations of the baseline itself. Whatever the case, it must be communicated clearly so that the decision-maker knows exactly what is included in, or excluded from, the estimate.

8.3.1 Subjective Estimator Judgment

This is perhaps one of the oldest methods of accounting for uncertainty and, in some respects, is the basis for most other approaches. Under this approach the estimator merely reflects upon the assumptions and judgments that were made during the development of the estimate. After evaluating all the "ingredients," a final adjustment is made to the estimate, usually as a percentage increase. This yields a revised total cost, which explicitly recognizes the existence of uncertainty. The logic to support this approach is that the estimator is more aware of the uncertainty in the estimate than anyone else, especially if the estimator is a veteran and has experience in systems or items similar to the one being estimated. One method for assisting estimators is to use a questionnaire, which provides a yardstick of their uncertainty beliefs when arriving at their judgment. The following questions, drawn from John D. Hwang's *Analysis of Risk for the Material Acquisition Process Part I: Fundamentals*, provide some examples:

- What cost is as likely to be greater than or less than the actual cost (this gives the median or 50 percent probability level)?

- What is the greatest imaginable cost of the project (this gives the 100 percent probability level)?

- What cost is just as likely to be above median as it is to be below the greatest amount (this gives the 75 percent probability level)?

- What cost is just as likely to be above the cost from the preceding statement as it is to be below the greatest amount (this generates the 87.5 percent probability level)?

This questionnaire device is equally applicable to a single cost estimator or team of estimators. Regardless of how subjective judgment is determined, there comes a time where the complexity and sophistication of the item is beyond the estimator's subjective assessment abilities. One method to overcome this is to use the expert judgment/executive jury technique discussed in the next paragraphs.

8.3.2 Expert Judgment/Executive Jury

A variant of estimator subjective judgment is a technique wherein an independent jury of experts is gathered to review, understand, and discuss the system and its costs. The specific objective from their collective deliberation is some measure of uncertainty that can be quantified into dollars and used to adjust the point estimate cost. The strengths of such an approach are related directly to the diversity, experience, and availability of the group members.

The use of such panels or juries requires careful planning, guidance, and control to ensure that the product of the group is objective and reflects the best, unmitigated efforts of each member. Approaches have been designed to contend with the group dynamics of such panels. One classical approach is the Delphi technique, which originally was suggested by RAND. With this technique, a panel of experts is drawn together to evaluate some particular subject and submit their answers anonymously. Next, a composite feedback of all answers is communicated to each panelist, and a second round begins. This process may be repeated a number of times, and ideally, convergence toward a single best solution takes place. By keeping the identities anonymous rather than in a committee session, the panelists can change their minds more easily after each round and provide better assessments, rather than defending their initial evaluation. The principle drawback of Delphi is that it is cumbersome, and the time elapsed in processing input may present some difficulty to respondents as to their reasons for the ratings. However, it is possible to automate the process with online computer terminals for automatic processing and immediate feedback. Other group dynamics schemes have been proposed as alternatives to Delphi; but, as with Delphi, there has been no definitive analysis of how well they work.

8.3.3 Sensitivity Analysis

Another common approach is to measure how sensitive the system cost is to variations in non-cost system parameters. For instance, if system weight is a critical issue, then weight would be varied over its relevant range, and the influence on cost could be observed. Analysis of this type helps to identify major sources of uncertainty. It also provides valuable information to the system designer in terms of highlighting elements that are cost sensitive, areas in which design research is needed to overcome cost obstacles to achieve better program performance, and areas in which system performance can be upgraded without increasing program cost substantially. The traditional criticism of this procedure is that it does not reveal the extent to which the estimated system cost might differ from the actual cost. That is, it tends to address uncertainty of requirements more than cost uncertainty.

8.3.4 High/Low Analysis

Another approach, which has been used to express cost uncertainty, requires the estimator to specify the lowest and highest possible values for each system element cost, in addition to its most likely value. These sets of input values are then summed to total system cost estimates. The most likely values establish the central tendency of the system cost, while the sums of the lowest possible values and highest possible values determine the uncertainty range for the cost estimate.

Although this approach has a logical appeal, it tends to greatly exaggerate the uncertainty of system cost estimates because it is unlikely that all system element costs will be at the lowest (or highest) values at the same time. While the high/low approach is plausible, its shortcoming is that it restricts measurement to three points, without consideration to intermediate values or their likelihood. The approaches described in the next paragraph provide solutions to this shortcoming.

8.3.5 Mathematical Approaches

If the individual cost elements can be regarded as random variables and their distributions can be determined, then the system cost can also be expressed as a probability distribution around an expected value. This is the basis for the approaches covered in this section. What these approaches do is to overlay the high/low approach with probability distributions for each cost element. Doing so requires the solution of two distinct problems. The first is how to determine the probability distribution for each cost element. The beta and triangular distributions are both described as solutions to this problem. The second is how to combine the individual cost elements and their measures of uncertainty into a total estimate of cost and uncertainty. The summation of moments and Monte Carlo simulation are described as solutions to this problem.

<u>The Beta Distribution</u>

This distribution is particularly useful in describing cost risk because it is finite, continuous, can easily accommodate a unimodal shape requirement ($\alpha > 0$, $\beta > 0$), and allows virtually any degree of kurtosis and skewness. Kurtosis characterizes the relative peakedness or flatness of a distribution as compared to the normal distribution. Skewness characterizes the degree of asymmetry of a distribution around its mean. S. Sobel, in *A Computerized Technique to Express Uncertainty in Advanced System Cost Estimates*, described a few of the many shapes of the Beta as shown in Figure 8.4. Per H. W. Darrwachter et al. and Gerald R. McNichols, the Generalized Beta Family of Distributions is defined over an interval (a, a+b) as in Equation 8.1.

Equation 8.1

$$f(x;\alpha,\beta,a,b) = \left(\frac{\Gamma(\alpha+\beta+2)}{\Gamma(\alpha+1)\Gamma(\beta+1)b} \right) \bullet \left(\frac{(x-a)}{b}^{\alpha} \right) \bullet \left(1 - \left(\frac{(x-a)}{b}^{\beta} \right) \right)$$

$$a \le x \le a+b$$

Where:

$a \le x \le a+b$ *defines an interval*

α, β *are the shape parameters of the Beta Distribution (values follow)*

Γ *is the Gamma Distribution (see Appendix 8-A for values to use)*

The following transformation is frequently used as in Equation 8.2.

Equation 8.2

$$f(x) = K \bullet \left(\frac{(H-L)^{\alpha} \quad (H-X)^{\beta}}{(H-L)^{(\alpha+\beta+1)}} \right)$$

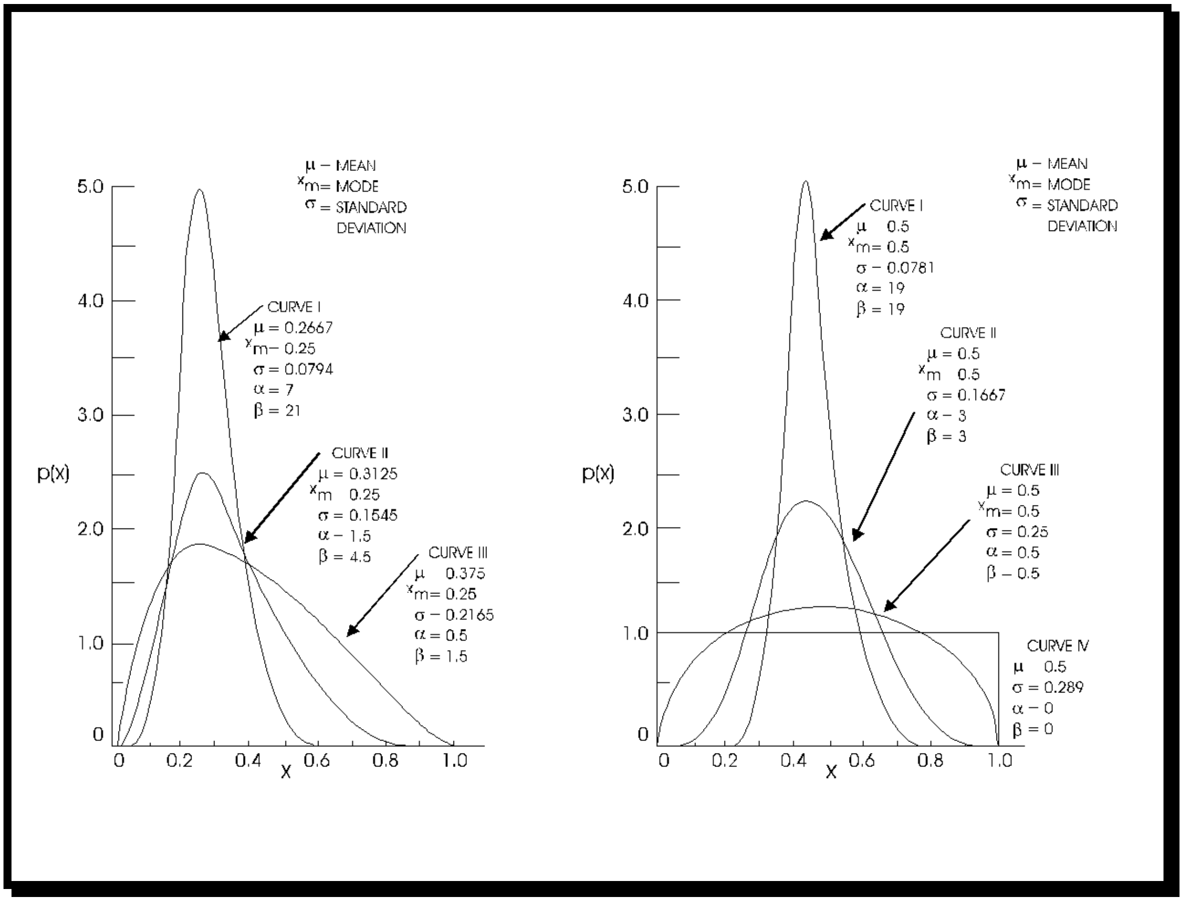
Where:

L = *Lowest value*

H = *Highest value*

$$K = \frac{\Gamma(\alpha+\beta+2)}{\Gamma(\alpha+1) \bullet \Gamma(\beta+1)}$$

Figure 8.4 Beta Distribution Shape Examples

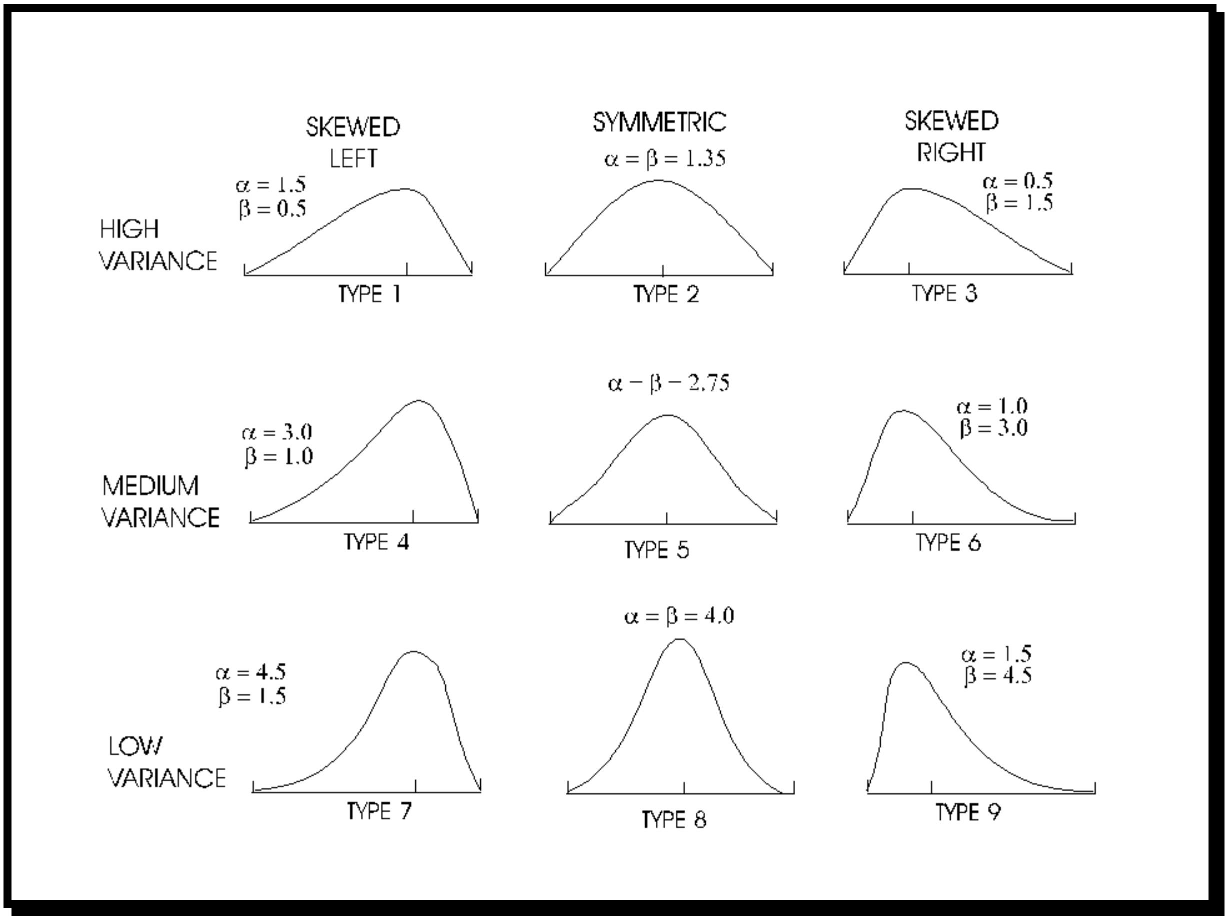


The values of α and β are the shape parameters, and each combination produces a unique shape. However, the process of deriving the appropriate values for a particular shape can be quite involved. Fortunately, a few observations about α and β lead to a rather useful approach in approximating the appropriate values. In the case of skewness, when α and β are equal the distribution is symmetric; when α>β the distribution is negatively skewed; and when α<β the distribution is positively skewed. Similarly, variance (kurtosis) can be categorized as high, medium, or low, based upon the magnitude of α and β. When these notions of skewness and kurtosis are combined, the result is nine combinations as shown in Table 8.3. These nine types tend to be fairly descriptive of most situations an estimator might confront. For that reason, Paul F. Dieneman translated them into the specific beta distributions shown in Figure 8.5.

Table 8.3 Beta Shape Combinations

Combination Type	Skewness	Kurtosis
1	Negative	High
2	Symmetric	High
3	Positive	High
4	Negative	Medium
5	Symmetric	Medium
6	Positive	Medium
7	Negative	Low
8	Symmetric	Low
9	Positive	Low

Figure 8.5 Beta Probability Distributions for Uncertainty Analysis



The advantage of the figure is that estimators can choose the distribution which best approximates their subjective view of the cost element uncertainty without having to derive α or β. Although the nine distributions do represent a rather restrictive set of options, the selection generally is considered sufficient from the standpoint that an estimator probably cannot distinguish among more variations accurately. These nine shapes have been adopted as a kind of standard by several researchers and practitioners. Also, it should be noted that these nine limit the location of the mode to the first, second, or third quartiles of the distribution range. The estimator should be conscious of these locations when specifying the high and low values relative to the most likely (point estimate) value. If these conditions are unsatisfactory, others can be developed by varying α and β (the ratio of α to β locates the mode within the range of the distribution). The value of this approach is that the estimator uses the point estimate as the most likely value and specifies a lowest possible value and highest possible value consistent with the distribution shape, based upon subjective judgment of variability.

At this point, the cost element can be described by its expected value and variance as shown in Equations 8.3 and 8.4.

Equation 8.3

$$\overline{X} = L + \frac{(H-L)(\alpha+1)}{(\alpha+\beta+2)}$$

In the case where the estimator specifies only the lowest and highest value and the chosen distribution, the most likely value (MO) can be calculated as in Equation 8.5:

Equation 8.1

$$S^2 = \frac{(H-L)^2(\alpha+1)(\beta+1)}{(\alpha+\beta+3)(\alpha+\beta+2)^2}$$

Equation 8.2

$$MO = \frac{\alpha(H) + \beta(L)}{(\alpha+\beta)}$$

Triangular Distribution

An alternative approach to assigning a distribution shape to a cost element is the triangular distribution. Like the Beta, it can take on virtually any combination of skewness and kurtosis, but the distribution represented by a triangle rather than the smoother curve of Beta, as shown in Figure 8.6. Albin D. Kazanowski wrote in *A Quantitative Methodology for Estimating Total System Cost Risk*, about the triangular distribution. The triangular distribution is specified by the lowest, most likely (usually the point estimate), and the highest value. Any point within the range of the distribution can be chosen to locate the mode and the relationship among the three values specifies the amount of kurtosis. Given the selection of the values and the triangular shape inherent to those values, both the mean and the variance can be calculated as in Equations 8.6 and 8.7.

Equation 8.3

$$\overline{X} = \frac{1}{3}(L + ML + H)$$

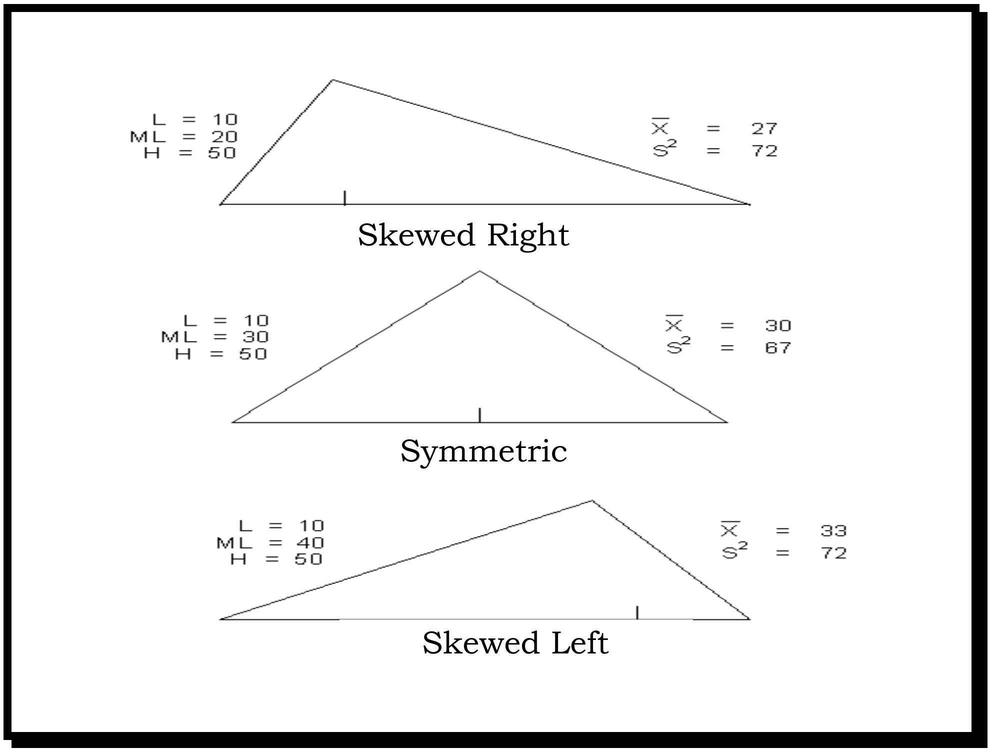
Equation 8.4

$$S2 = \frac{1}{18}[\,(H-L)2 + (ML-L)\ (ML-H)\,]$$

Where:

L = Lowest likely value
ML = Most likely value
H = Highest likely value

Figure 8.6 Triangular Distribution Examples



In contrast to Beta, the triangular distribution is much easier to use and produces equally satisfactory results. For this reason, the triangular generally is preferred over the more common Beta distribution.

Once distribution shapes have been identified for each cost element (or grouping of elements), the next step is to find the expected value and measure of uncertainty for the total system cost.

The Summation of Moments

This method takes the approach of measuring or describing a distribution through the use of moment statistics. According to Paul G. Hoel in *Introduction to Mathematical Statistics*, the first moment is the mean (x) and the second, third, and fourth moments (about the mean) take the form of Equation 8.8.

Equation 8.5

$$M_r = \frac{1}{n} \sum_{i=1}^{n} (X_i - \overline{X})^r$$

Where r is the rth moment around the mean.

As can be seen, the second moment is the variance. The third and fourth moments do not have any particular name, but they are used to calculate two measures that provide additional insight into the shape of a particular distribution. Those measures are: 1) the coefficient of skewness, which provides a measure of symmetry, and 2) the coefficient of kurtosis, which measures the peakedness or height of a distribution.

Coefficient of skewness = M3/(M2) 3/2

Coefficient of kurtosis = M/(M2) 2

The relevance of moment statistics to the development of a measure of total system cost uncertainty hinges upon one fact. That is, the moment measures for each cost element can be summed to produce the moment measures for the total system (or item) cost, when the variables (cost elements) are independent. (If, for some reason, independence among variables does not exist, then the covariance of the interdependent variables must be incorporated in estimating the moment of the sum.) For instance, the system mean is the sum of the individual element means; the variance (second moment) of the sum of independent variables is equal to the sum of the variances, etc. In fact, some authors use only the first and second moments to arrive at a measure of uncertainty. That is, with both the mean and variance of the total system cost determined through the summation process, the standard deviation is computed directly and the total cost portrayed as either a normal probability distribution or cumulative density distribution, as shown in Figure 8.3.

According to E. H. Yates, et. al. and Edward L. Murphy, Jr., the critical assumption in this approach is that even though the individual cost element distributions may not be normal, the total cost distribution will be. The basis for this normality assumption is both the central limit theorem and a sufficiently large number of cost elements (a minimum of thirty). This particular approach is shown in Figure 8.7. However, it is possible that if the variance of the distribution for an individual cost element is an order of magnitude greater than others, it may dominate the resulting aggregate distribution, which then may take on any of the non-normal characteristics of the dominant cost element. When this, or any other condition occurs which might jeopardize the central limit assumption, the approaches described in the next paragraphs offer possible solutions.

A more specific approach, advocated by several researchers and authors, is to take advantage of all four moments at the total system cost level by computing the mean, variance, and coefficients of skewness and kurtosis. These four measures can be analyzed then to determine the approximate distribution shape, without being limited to the central limit theorem and the normal assumption. One such method is to compare the characteristics of the estimated total system cost distribution with those of known distributions, such as shown in Table 8.4. According to J. J. Wilder, in *An Analytic Method for Cost Risk Analysis*, "If the correspondence is close enough (we leave that to the judgment of the analyst), we can conclude that the matching distribution is a good model of the unknown distribution, and use the appropriate density function for our calculations." There are other approaches to identifying the proper distribution, based upon moment statistics. However, they are beyond the scope of this chapter.

Figure 8.1 Summation of Moments--Central Limit Theorem Assumption

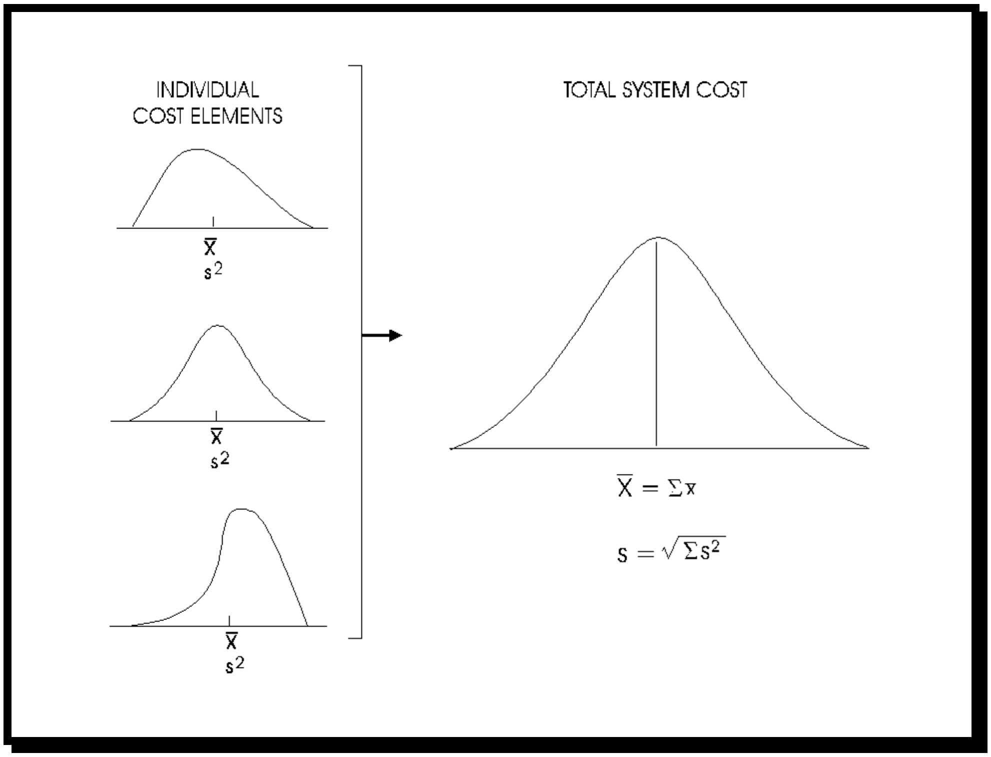


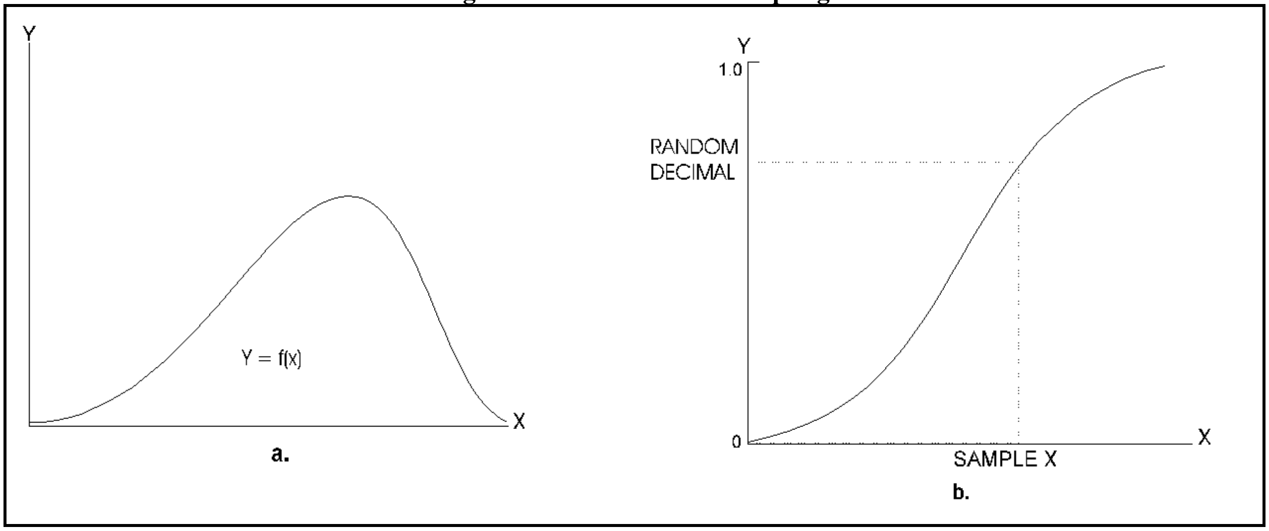
Table 8.4 Characteristics of Known Variables

Distribution	Skewness	Kurtosis
Uniform	0	1.8
Triangular	-.565 to +.565	2.4
Beta	Any Value	1.8
Normal	0	3

Monte Carlo Simulation

An alternative to the summation approach is to use the Monte Carlo Simulation Technique. With this approach, the distribution defined for each cost element (using beta, triangular, or an empirical distribution) is treated as a population from which several random samples are drawn. For example, a single cost element has been estimated and its uncertainty described as shown in A of Figure 8.8. From the probability density function, Y=f(X), a cumulative distribution is plotted, as shown in B of Figure 8.8. Next, a random decimal between zero and one is selected and located along the Y axis. By projecting horizontally from this random decimal location to the cumulative curve, the corresponding value of X can be determined. This value is considered as one sample of X for this specific cost element. A different random decimal is chosen for the next cost element and repeated until all cost elements have been sampled once. The sample values are summed to a total cost, and then the entire process is repeated again. This procedure is repeated several times (100-1000). The result is a normal distribution of random total costs that can be described by its mean and standard deviation and portrayed in the same manner as Figure 8.3 (Paul F. Dieneman, *Estimating Cost Uncertainty Using Monte Carlo Techniques*.)

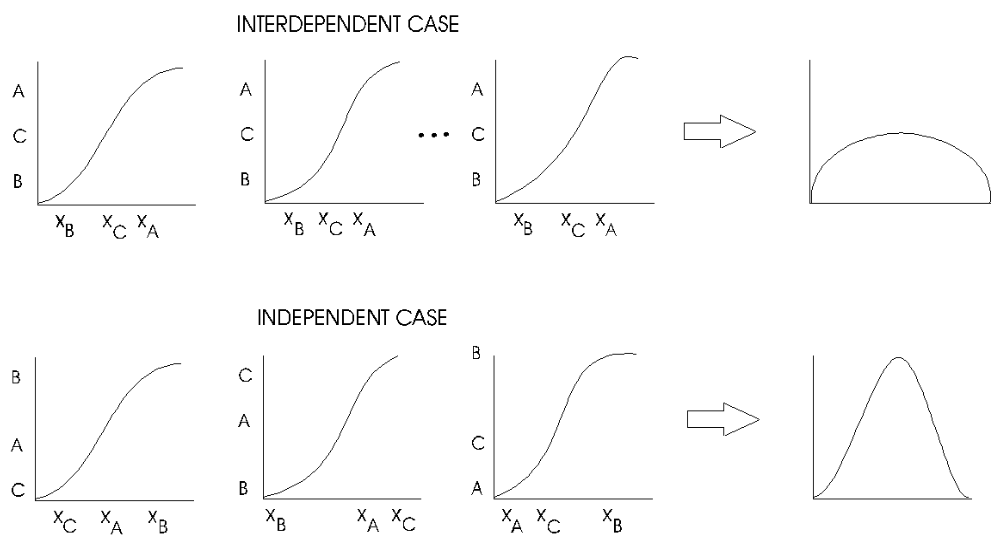
Figure 8.2 Monte Carlo Sampling



Again, the question of independence versus interdependence arises. The previous discussion of Monte Carlo assumed total independence. The opposite extreme is to assume total interdependence. A solution for this is to use the same random decimal for one pass through each of the cost elements. The sum of these observations is uniformly additive and results in a flatter, more rectangular distribution than in the independent case. The process for sampling in both the independent and interdependent cases, along with the resulting total cost distribution shapes, is illustrated in Figure 8.9.

Realistically, it is quite unlikely that a total system cost consists either of completely interdependent or independent cost elements. Nor does there appear to be a consensus on which assumption to make. One position holds that the only estimating errors meeting the criteria of randomness are cost uncertainties; and therefore, the assumption of independence is reasonable for cost uncertainty only. Interdependence appears to be more of a concern when cost and requirements uncertainties are considered jointly, or when requirements uncertainty is considered alone. That is, requirements variations tend to be viewed more like bias errors than the noise normally associated with randomness. (E. H. Yates et. al., *A Method for Deriving Confidence Estimates in Cost Analysis*)

Figure 8.3 Independent and Interdependent Assumptions for Monte Carlo Simulation



This concludes the discussion of the methods for dealing with uncertainty. The discussion was not intended to be exhaustive, but rather to provide an insight into the how and why of selected methods in prominent use. Section 8.4 discusses two commercially available software packages that can be employed for cost risk simulation.

8.4 Cost Uncertainty Models

@RISK Simulation Software

@RISK is an analysis and simulation direct add-in to standard spreadsheet programs (Microsoft EXCEL or Lotus 1-2-3) allowing the analysis of business and technical situations impacted by risk. The user replaces uncertain values in the spreadsheet with @RISK functions that represent a range of possible values, such as total profits or outputs. @RISK recalculates the spreadsheet hundreds or thousands of times, each time selecting random numbers from the @RISK functions entered. The result is a distribution of possible outcomes and the probabilities of getting those results.

@RISK employs both the Monte Carlo and Latin Hypercube simulation techniques to combine all the uncertainties identified in a system model. Risk analysis in @RISK is a quantitative method that seeks to determine the outcomes of a decision as a probability distribution. Thirty-seven different types of distributions are supported including: tbeta, binomial, chi square, Pareto, triangular, and Weibull. Up to 32,000 user-defined iterations per simulation are possible.

High-resolution graphics are used to present the output distributions from the @RISK simulations. Histograms, cumulative curves, summary graphs for cell ranges, zooming, and graphic overlays are all supported.

@RISK is available through Palisade Corporation of Newfield, New York, (607) 564-9993 or www.palisade.com. A demonstration and tutorial is available for download.

Crystal Ball Simulation Software

Crystal Ball is a fully integrated add-in program for Lotus 1-2-3 for Windows, Microsoft EXCEL for Windows or Microsoft EXCEL for Macintosh. Crystal Ball works with information the user provides about the uncertain inputs to the spreadsheet model. These assumptions are the cells that would be modified in a manual "what-if" analysis. For each assumption, a range of possible values (or a probability curve) is defined that reflect what is known about that value. There are 16 pre-defined curves, as well as a custom distribution capability that allows the user to assign probability distribution functions (PDFs) to cells in the spreadsheet. With a Graphical User Interface, Crystal Ball gives users the capability to perform risk analysis based on Monte Carlo simulations or Latin Hypercube sampling. As such, Crystal Ball has many similarities to the @RISK product discussed above. The Crystal Ball analyses are summarized in a graph showing the probability for each result. The capability to produce customizable charts, trend charts, overlay charts, and sensitivity charts is also provided to aid further analysis of the data.

Crystal Ball is available through Decisioneering, Inc., of Denver, Colorado, (800) 289-2550 or www.decisioneering.com. A free evaluation copy is available for download.

This concludes the discussion of uncertainty models. Again, the use of any model requires a clear definition of what uncertainty is to be treated and how the specific model satisfies the requirement.

8.5 Qualitative Indices of Uncertainty

Up to this point, the methods of treating uncertainty have all resulted in a quantitative adjustment or refinement of the point estimate. However, the use of qualitative indices has been proposed as a method of communicating a cost estimate's goodness, accuracy, or believability. Most of the indices are based upon the quality of the data and the quality of the estimating methodology.

For instance, John D. Hwang proposed the rating scheme using a two-digit code with ratings of l to 5 for data and for methodology, with a l representing highest quality and a 5 representing lowest quality. Thus, a rating of 1,1 would reflect that the estimate was the result of the highest quality level for both. The complete scoring system is shown in Table 8.5.

Table 8.5 Two Digit Confidence Index

Rating	Methods	Rating	Data
1	The basic method used to perform this analysis is exceptionally well documented and time tested; one or more other techniques have been used to verify the estimate provided.	1	Very complete, well-authenticated, highly relevant data, such as recent contractor actual costs, official catalog prices, etc. have been used.
2	The basic method used to perform this analysis is well documented, but no double-check or authentication has been possible.	2	The data used generally are relevant and from a reputable source; however, they are incomplete, preliminary, or not completely current.
3	The basic method used to perform this analysis has been documented, but has not been widely used or approved.	3	The data used have been obtained from official or standard sources; however, notable inconsistencies, lack of currency, or gaps in data reduce the confidence in the estimate.
4	A highly arbitrary method of analysis has been used.	4	The data used to make the estimate are highly suspect, of doubtful relevance, very sparse in quantity, and characterized by major inconsistencies.
5	The analysis is almost pure guesswork, and little or no confidence can be placed in it.	5	An almost total lack of current, reliable, relevant data makes the cost estimate completely uncertain.

The value of such qualitative indices appears to be their use as a sort of broad gauge for the manager to use in understanding the makeup of uncertainty. That is, such a qualitative index could be used to get a feel for what portion of the uncertainty is related to cost and what portion to data.

8.6 Summary

This chapter examined the terms, concepts, and approaches involved in analyzing cost risk and uncertainty. It should be clear from the chapter discussion that a consideration of risk and uncertainty is an integral part of the estimating process. For a more detailed discussion of cost and uncertainty analysis, read *Improving Cost Risk Analyses* by Fred Biery, David Hudak, and Shishu Gupta. This article can be found in the Spring 1994 edition of Society of Cost Estimating & Analysis' *Journal of Cost Analysis*.

8A. GAMMA FUNCTION TABLE

The values of the Gamma function used in the Beta distribution can be found using the following table. Note that (n+1) is equal to n (n), which allows the determination of gamma values greater than those contained in the table. For integer values, the gamma value can be found in (n)=(n-1)!

and for half integers by (m)=(m-1)! (π) -- $\frac{5}{2} \bullet \frac{3}{2} \bullet \frac{1}{2} \bullet \pi$.

Values of Γ(n) = $\int_0^\infty$ e-zxn-1dx; Γ(n+1) = n Γ (n)

n	**Γ(n)**	**n**	**Γ(n)**		**Γ(n)**	**n**	**Γ(n)**
1.00	1.00000	1.25	.90640	1.50	.88623	1.75	.91906
1.01	.99433	1.26	.90440	1.51	.88659	1.76	.92137
1.02	.98884	1.27	.90250	1.52	.88704	1.77	.92376
1.03	.98355	1.28	.90072	1.53	.88757	1.78	.92623
1.04	.97844	1.29	.89904	1.54	.88818	1.79	.92877
1.05	.97350	1.30	.89747	1.55	.88887	1.80	.93138
1.06	.96874	1.31	.89600	1.56	.88964	1.81	.93408
1.07	.96415	1.32	.89464	1.57	.89049	1.82	.93685
1.08	.95973	1.33	.89338	1.58	.89142	1.83	.93969
1.09	.95546	1.34	.89222	1.59	.89243	1.84	.94261
1.10	.95135	1.35	.89115	1.60	.89352	1.85	.94561
1.11	.94740	1.36	.89018	1.61	.89468	1.86	.94869
1.12	.94359	1.37	.88931	1.62	.89592	1.87	.95184
1.13	.93993	1.38	.88854	1.63	.89724	1.88	.95507
1.14	.93642	1.39	.88785	1.64	.89864	1.89	.95838
1.15	.93304	1.40	.88726	1.65	.90012	1.90	.96177
1.16	.92980	1.41	.88676	1.66	.90167	1.91	.96523
1.17	.92670	1.42	.88636	1.67	.90330	1.92	.96877
1.18	.92373	1.43	.88604	1.68	.90500	1.93	.97240
1.19	.92089	1.44	.88581	1.69	.90678	1.94	.97610
1.20	.91817	1.45	.88566	1.70	.90864	1.95	.97988
1.21	.91558	1.46	.88560	1.71	.91057	1.96	.98374
1.22	.91311	1.47	.88563	1.72	.91258	1.97	.98768
1.23	.91075	1.48	.88575	1.73	.91466	1.98	.99171
1.24	.90852	1.49	.88595	1.74	.91683	1.99	.99581
						2.00	1.00000

NOTE:
For large positive values of x, Γ(x) approximates Stirling's asymptotic series

$$\text{xze-z}\sqrt{\frac{2\pi}{x}}\left[1+\frac{1}{12x}+1/288x^2-\frac{139}{51{,}840}\text{x3}-\frac{571}{2{,}488{,}320}\text{x4}+\ldots\right]$$

9.0 PARAMETRIC ESTIMATING

9.1 Introduction

Chapters 9, 10, and 11 discuss extensively the three main estimating methodologies: parametric, analogy, and engineering, respectively. The reader was introduced to these estimating methodologies in Chapter 3, Section 3.3 in the context of the cost estimating process. This chapter provides a full and detailed treatise on parametric estimating.

How a cost estimator develops parametric estimates and evaluates their quality in both a statistical and intuitive sense is provided herein. The chapter begins with a brief overview of parametric estimating (Section 9.2), followed by a history of this type of estimating (Section 9.3). Section 9.4 discusses parametric estimating in greater detail. Section 9.5 explains how the statistical relationship between the cost to be predicted and the cost predictor or cost driver is developed. It also presents the statistical measures that allow the cost estimator to assess the quality of the parametric estimate and the likely accuracy of the estimate. The limitations of parametric estimators are discussed in Section 9.6. Section 9.7 delves into a special type of parametric estimate in wide use in estimating: the learning or cost improvement curve.

9.2 Overview of Parametric Estimating

Parametric estimating is the process of estimating cost by using mathematical equations that relate cost to one or more physical or performance characteristics of the item being estimated. A simple example of a parametric estimate is the use of square footage to estimate building costs. Square footage is a physical characteristic of a building that has been shown through statistical analyses of building trends to be one way of estimating building costs. (Rodney D. Stewart, *The Cost Estimator's Reference Manual*, page 225)

Parametric estimates are often used in the early phases of a system's life cycle. At that stage of the life cycle, basic physical or performance characteristics may be available, but detailed designs may not be. Thus, parametric approaches may be the only option. Even later in a system's life cycle, however, a parametric approach might be used, for instance for certain elements of a detailed estimate.

Parametric estimating equations are often called Cost Estimating Relationships or CERs. In the rest of this chapter, the two terms are used interchangeably. A discussion of the history of parametric estimating will shed some light upon its usefulness.

9.3 History of Parametric Estimating

Parametric estimating resulted from the need for an alternate method of estimating costs early in the development cycle. In the 1950s, the Rand Corporation first began to pursue methodically the development of statistical techniques for estimating the costs of military hardware in the early design phases. The approach worked well for estimating the cost of airframes early in the design process. This technique further evolved as learning curve theory was mated to parametric estimating. The result of joining parametric estimating and cost improvement curve methods was to allow the estimating of design through production costs early in the development cycle. Parametric estimating was at that time a relatively radical departure from more traditional detailed estimating techniques. The estimating community, however, had discovered in CERs a useful method of producing early life cycle estimates without the time-consuming and input-intensive detailed methods previously in use. Parametric methods enjoy widespread use today. The greater availability of computers helped spur the use of CERs because of the greater ease of doing statistical analyses and handling large amounts of data on a computer. (*Cost Estimator's Reference Manual* by Rodney Stewart, page 227-228)

9.4 Cost Estimating Relationships (CERs)

A CER predicts the cost of some part of a program or of the entire program based on specific design or program characteristics. A CER may be used, for example, to predict the cost of an entire spacecraft based on its in-orbit weight. Software costs are often estimated with a CER based on how many lines of program code are written. One of the oldest relationships uses the weight and speed of an airplane to provide a prediction of the airframe's cost. Another type of CER relates the cost of one program element to another. For example, modification costs often are estimated based on the dollar size of airplane flyaway cost. Equation 9.1 presents an example of a CER, drawn from H.E. Boren and J. Dryden in *A Computer Model for Estimating Development and Procurement Costs of Aircraft.*

Equation 9.1

$$ML = 0.63 \times Wt^{0.68} \times S^{1.21}$$

Where:
ML = Non-recurring manufacturing labor hours
Wt = Airframe unit weight in pounds
S = Maximum speed at best altitude in knots

When using a CER, the cost is unknown, but there is some information about the size, shape, or performance of the piece of equipment to be costed or some information on the dollar size of other cost elements that enables the cost estimator to estimate the unknown cost based on the known information. When developing or using CERs, cost estimators must be aware of the data upon which it was based. Differences between the historic programs and a new program for which a cost estimate is needed may be significant and could render the CER useless, or at least require a major adjustment to the estimate or database. Assumptions and inherent limitations associated with the CER should be addressed prior to its use. Arguments for its validity should be included in the cost estimate documentation.

CERs have been developed for nearly every major commodity type and cost element and are applied to estimate costs in all phases of a system's life. CERs come in several different functional forms based upon a variety of cost drivers. The next two sections discuss the different types of CERs and their uses.

9.4.1 Types of CERs

CERs can be divided into several classes depending on: 1) the kind of costs to be estimated, 2) the cost drivers chosen to predict costs, 3) the complexity of the estimating relationship, and 4) the aggregation level of the CER. Other classifications are surely possible, but these will be addressed in this section.

<u>CERs Based on the Kind of Costs to be Estimated</u>

The kind of costs to be estimated can be grouped into the three phases of a program's life cycle:

- Research, Engineering and Development (RE&D)
- Production
- Operating and Support (O&S)

These distinctions are important because the kind of costs to be estimated will guide the cost estimator in the search for cost drivers to use in the estimating relationship. O&S cost estimates must consider both equipment characteristics and the support and logistic structure. When estimating maintenance costs, the reliability and maintainability of the equipment are important, but so is the level of maintenance support (e.g., field level, depot level, etc.). The level of maintenance support is a function of the established maintenance concept for that piece of equipment. In contrast, CERs in RE&D generally use equipment characteristics as primary cost drivers and usually are not based on how the equipment is to be developed. Cost estimators, who are estimating production costs, also must estimate cost/quantity relationship curve effects. Sometimes these effects are built into CERs.

<u>CERs Classified by Type of Cost Driver</u>

CERs also are classified by the type of cost driver. Over the years, cost estimators have discovered a variety of quantitative cost drivers to apply to CERs. The most common variable for hardware remains weight and for software, the most common variable is its size. Other system attributes, such as physical, technical, and performance characteristics, also are used. Besides weight, physical characteristics include volume, length, number of parts, and density. Examples of technical parameters (factors that produce performance) include system or subsystem power requirements and scan rate. Performance characteristics include speed, range, accuracy, reliability, etc.

Physical, technical, and performance characteristics are not the only variables that have been used to develop CERs. Cost estimators recognize that hybrid variables like hard drive speed to memory size ratio, the system environment, the system mission and function, and the technological level of the system in relation to the state-of-the-art, can all play an important role in determining costs. There is almost no end to possible quantitative cost drivers.

Cost estimators have long recognized that technology - specifically the degree of technical advance sought in a new system - can affect a system's cost dramatically. However, measuring how far the proposed system is beyond state-of-the-art can be difficult. Currently, cost estimators use several approaches. One approach is to use time as a proxy for technological advance. Thus, a CER may include the year development begins or the date of first flight as a proxy for the technological advance cost driver. 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 cost estimator, along with system engineers, selects a level of technical advance or system complexity. This can be represented by a continuous variable running from 0 (off the shelf, no new technology) to some number N (brand new technology, major advances in the state-of-the-art); or this variable can be represented by a binary variable, where 1 indicates a major technical advance is required, and 0 indicates no technical advance. Other approaches to quantifying technological advances are possible and should be investigated. To pursue this, the cost estimators must learn as much as possible about both how the system works and what technological improvements will be implemented to increase system performance.

Table 9.1 provides an example of possible Information Technology (IT) cost drivers that a cost estimator might consider when developing an IT CER.

Table 9.1 Potential Airframe Cost Drivers

<u>Physical</u>

- Software size
- Number of servers
- Length of communications links
- Number of sites
- Number of positions

<u>Performance</u>

- Processor speed
- Communications link speed
- Memory capacity

<u>Environment</u>

- Levels of maintenance planned
- Support concept

<u>Time</u>

- Date of first operational site

<u>Technological Advance</u>

- Level of technical advance required

Another type of cost driver commonly used in building CERs is the use of one cost element to predict the cost of another element. For example, Engineering Change Orders (ECOs) may be estimated as a percent of the cost of the prime mission equipment. Such cost-to-cost CERs are often used to estimate portions of O&M costs and non-hardware acquisition costs. They are sometimes referred to as factors.

CERs Classified by Complexity of the Estimating Relationship

Equation 9.2

$$ECO/MR = 0.10 \times (TFSDC)$$

CERs can be simply two variable equations, or they can be complicated multivariate equations. J. Gibson, in *The ASD ECO Model User's Guide* presents the simple CER relating ECOs/Management Reserve (ECO/MR) during full-scale production (FSD) to total FSD costs (TFSDC) in Equation 9.2. An example of a more complex CER is presented in Equation 9.3, from B. W. Boehm and B. K. Clark's 1997 briefing *An Overview of the COCOMO 2.0 Software Cost Model*.

Equation 9.3

$$ESLOC = ASLOC \times ((AA+SU)/100 + 0.4 \times DM + 0.3 \times CM + 0.3 \times IM)$$

Where:
ESLOC = equivalent new software size of reused software
ASLOC = size of the software being adapted in Source Lines of Code (SLOC)
AA = rating of the assessment and assimilation of the adaptive software
SU = rating of the current programmers' software understanding of the adaptive software
DM = percent of design modification
CM = percent of code modification
IM = percent of the original integration effort required for integrating the reused software

CERs Classified by Aggregation Level

CERs can also be classified in terms of the aggregation level of the estimate. For instance, CERs can be developed for the whole system, major subsystems, other major non-hardware elements (training, data, etc.) and components. The aggregation level of the costs to be estimated should be matched by the aggregation level of the cost drivers, as shown in Figure 9.1. For instance, system costs may be estimated as a function of total system weight, while a particular subsystem will be estimated by that subsystem's weight.

Figure 9.1 Matching Aggregation Levels of CERs

COST		COST DRIVERS
System	←	System Level Characteristics
Subsystem	←	Subsystem Level Characteristics
Component	←	Component Level Characteristics

9.4.2 Uses of CERs

CERs are used to estimate costs at many points in the acquisition cycle when little is known about the cost to be estimated. As more cost information becomes available, more detailed methods (e.g., engineering methods) of costing become feasible. CERs are of greatest use in the early stages of a system's development. CERs can play a valuable role in estimating the cost of a design approach, especially when conceptual studies and broad configuration trade-offs are being considered.

In the source selection process, CERs can serve as checks for reasonableness on bids proposed by contractors. Many contractors use CERs to help formulate their bids.

Even after the start of the development and production phases, CERs can be used to estimate the costs of non-hardware elements. For example, they can be used to make estimates of O&S costs. This may be especially important when trying to determine downstream costs of alternative design, performance, logistic, or support choices that must be made early in the development process.

9.5 Developing CERs

As discussed earlier, a CER is a mathematical equation that relates one variable such as cost (a dependent variable) to one or more other cost drivers (independent variables). The objective of constructing the equation is to use the independent variables about which information is available or can be obtained to predict the value of the dependent variable that is unknown. A classic CER uses airframe weight, which can be estimated early in an airplane's development, to predict airframe cost, which is not known until much later in the program's life.

To make an estimate using CERs or to assess CERs developed by others, the cost estimator must have an understanding of basic statistics, including the meaning of such terms as mean, standard deviation, correlation, and so on. The reader is referred to Appendix 9B for a refresher on basic statistics.

In most of the discussion of basic statistics in Appendix 9B, the concern is with estimating characteristics of single variable probability distributions. Measures of central tendency (mean, median, and mode) are discussed, as well as two measures of dispersion (range and standard deviation). Two variable distributions are also examined. Scatter diagrams are discussed as a means of exploring the relationship between two variables. The correlation coefficient is introduced as a measure of the strength of the association between two variables. These are subjects the reader should understand before proceeding to the discussion of how to develop a CER, which is based upon statistics.

The purpose of this section is to describe the mathematical steps required to construct a CER and introduce several related statistics used to evaluate the quality of the CER. The discussion presented here assumes the reader has read, or is otherwise familiar with, the material presented in Appendix 9B. Although the discussion in this handbook is limited to simple CERs (i.e., a single independent and a single dependent variable), the generalization to multiple, independent variables is briefly discussed. Further discussion can be found in more advanced CER texts.

The classical CER example that relates airframe weight to airplane cost is an example of a simple relationship developed from a set of two-variable data. Suppose two measurements were taken on n airframes, where Xi denotes the weight of airframe i and Yi denotes the cost of airplane i. Then one would obtain a set of n pairs of measurements:

$$\begin{array}{c}(X1, Y1)\\ (X2, Y2)\\ .\\ .\\ .\\ (Xn , Yn)\end{array}$$

Table 9.2 displays hypothetical cost and weight measurements for 10 airframes. This data will be used to demonstrate the techniques discussed in the remainder of the chapter

Table 9.2 Sample Airframe Cost and Weight Data

Airplane	Cost [1]	Weight [2]
727	5.07	9.2
MD-95	7.67	14.8
DC-10	24.01	26.5
DC-9	20.27	18.4
767	13.0	16.4
737	4.04	12.1
MD-80	9.23	12.3
L1011	13.69	16.1
747	17.58	17.6
757	10.99	17.3

(1) Cumulative average cost of the first 100 airplanes produced, in millions of FY 1981 dollars.
(2) Weight in thousands of pounds.

The objective in developing a CER is to determine the relationship, if any, between X and Y (e.g., airframe weight and airplane cost). If such a relationship is found, it can be used to predict the costs of a new airplane if the cost estimator has some information on the new airplane's weight. One way to proceed is to construct a functional relationship between X and Y. This procedure is called regression analysis.

The first step in regression analysis is to hypothesize a relationship, usually involving one or more parameters, between the independent and dependent variables. This is discussed in Section 9.5.1. Once a relationship is selected, a curve fitting technique is required to determine the specific values of the parameters. The method of least squares curve fitting is discussed in

Section 9.5.2 and several simple nonlinear models are described in Section 9.5.3. Measures of "goodness of fit" and confidence intervals are presented in Sections 9.5.4 and 9.5.5, respectively. More general methods of regression are provided in Section 9.5.6. A note on computer packages to assist in constructing CERs is given in Section 9.5.7.

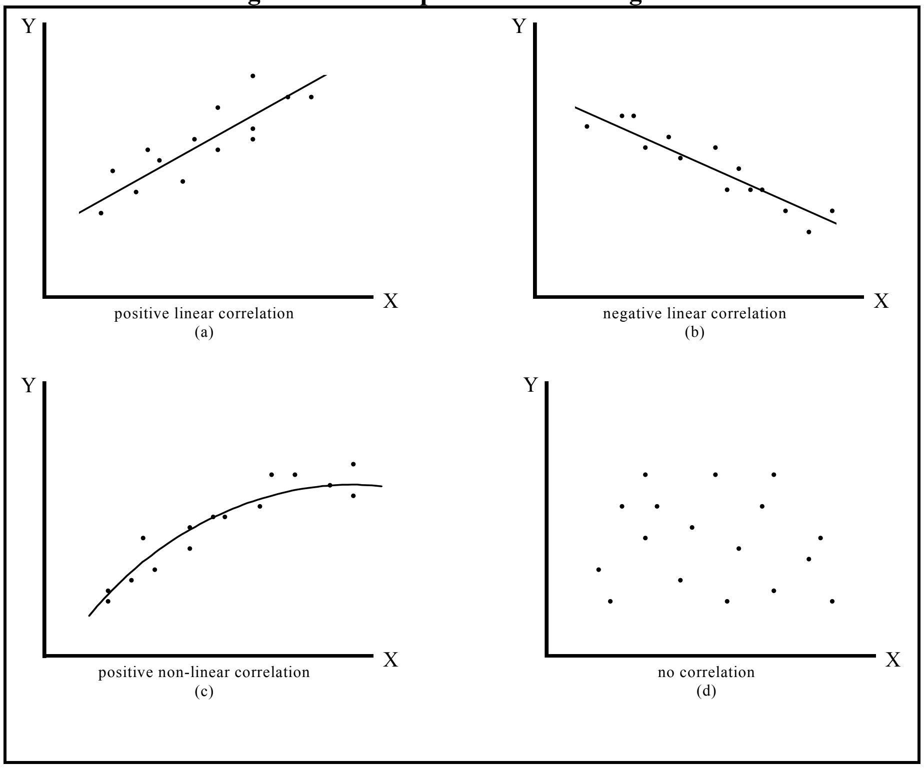
9.5.1 Hypothesizing Functional Relationships

There are essentially two approaches to hypothesizing a functional relationship between the independent and dependent variables in a regression analysis.

The first approach is to hypothesize a relationship on the basis of a priori assumptions. For example, it is reasonable to hypothesize that airframe costs increase as airframe weight increases (at least within a certain range of weight). However, it would not be plausible to assume there is a relationship between sunspots and airplane costs. The cost estimator must review what factors might cause costs to increase and measure them directly or indirectly. The weight relationship seems reasonable because the more material that the airframe comprises, the more one would expect an airframe to cost. Other relationships might be hypothesized for which there is no direct measure. For example, the airframe's technology level could affect costs, but there is no direct measure of technology. Hence, the cost estimator may resort to an indirect measure such as time. Once the cost estimator has a list of hypothetical relationships, the cost estimator should determine what kind of relationship is expected. Is the relationship expected to be positive (as weight increases cost increases) or negative? Determining this before collecting and analyzing the data enables the cost estimator to judge the reasonableness of the estimating relationship from an intuitive sense.

The second approach is to construct and study a scatter diagram of the two variables. For example, the relationship between the X and Y variables presented in Figure 9.2 (a and b) clearly suggests a linear relationship. Figure 9.2 (c) suggests a non-linear relationship and Figure 9.2 (d) suggests that X and Y are not related at all.

Figure 9.2 Examples of Scatter Diagrams



In practice, it is best to employ both approaches. That is, after hypothesizing one or more functional relationships between the independent and dependent variables, the cost estimator should plot the data on a scatter diagram. If the scatter diagram does not confirm the hypothesized relationship, the cost estimator should rethink the a priori notions and try to explain the discrepancy. There is no simple, direct way of determining a functional relationship; the process requires good judgment and experience that are gained only through repeated use of CERs. Once the relationship has been hypothesized and the data collected and normalized, the cost estimator should use curve-fitting techniques to specify the relationship in mathematical terms.

9.5.2 Curve Fitting Techniques

Two methods for fitting a curve to a set of bivariate data are described in this section. The first method is visual inspection of the scatter diagram and drawing a suitable curve through the data points. This approach has several advantages - it is easy and quick to do, no calculations are required, and consideration can be given to outliers. The principal disadvantage of this approach is that the location and shape of the curve through the data points is based upon individual, subjective judgment.

The second approach is the least squares method. This method has the disadvantage that all data points are given equal weight. The cost estimator cannot give less weight to outliers except by excluding them from the sample altogether. However, the advantages are significant. The approach results in selection of a best-fitting curve according to a precise definition. Least squares avoids the subjectivity inherent in the graphical approach, and the estimated regression equation facilitates predictions (there is no need to refer to a graphical representation).

Equation 9.3

$$\sum_{i=1}^{n}\left(Y_i - \hat{Y}_i\right)^2 = \left(Y_1 - \hat{Y}_1\right)^2 + \left(Y_2 - \hat{Y}_2\right)^2 + \ldots + \left(Y_n - \hat{Y}_n\right)^2$$

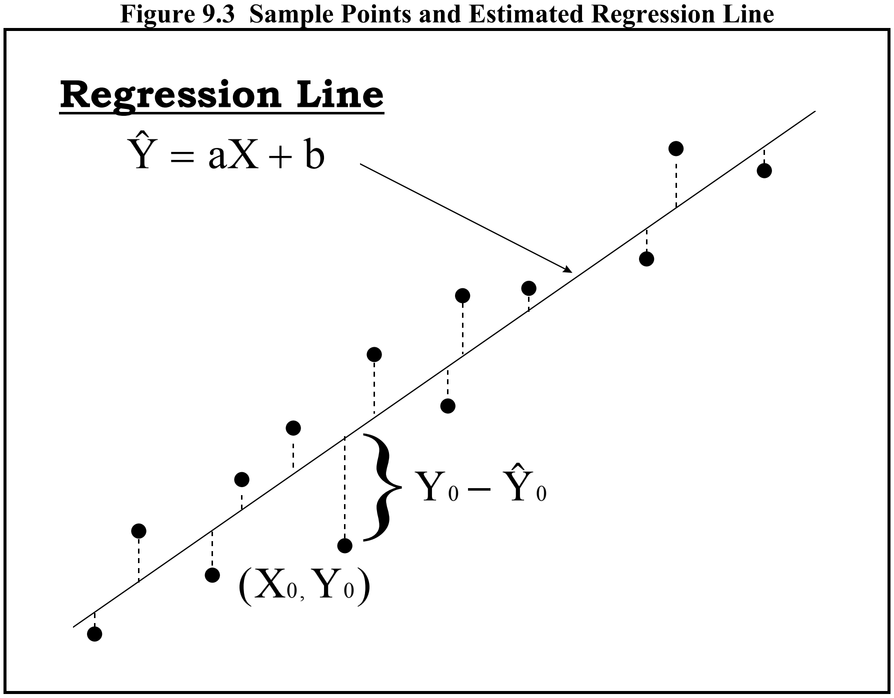
Where:

$\hat{Y}$ = The expected value of Y which is generated by the regression equation

Y = Observed values of Y, i.e., data points

This figure depicts a scatter diagram in which an estimated regression line has been drawn through several plotted data points. The vertical distance from the estimated curve to the observed value (X_0, Y_0) is given by $\hat{Y}_0$-Y_0. If there are n data points, similar distances can be obtained for each of the n (X,Y) pairs. The least squares curve through the plotted data points is defined to be the one that minimizes the sum of the n squared vertical distances, i.e., the curve that minimizes Equation 9.4. To illustrate the least squares method, refer to Figure 9.3.

Figure 9.3 Sample Points and Estimated Regression Line



Equation 9-4

$$\hat{Y} = aX + b$$

The least squares curve is a straight line of the form of Equation 9.5 where b is the Y-axis intercept and a is the slope of the curve. The least squares method gives rise to unique values of the two parameters b and a. Once these parameters are found, the regression line is completely specified. The formulas for estimating b and a are derived in the addendum to this chapter and displayed in Worksheet 9.1.

The parameters of the regression line can be found by performing the computations indicated in Worksheet 9.1. For example, suppose the cost estimator had cost and weight data on the ten airframes presented in Table 9.2. A completed sample worksheet is given in Worksheet 9.2 that illustrates the computations that the cost estimator would need to make.

Worksheet 9.1 Worksheet for Computing Regression Line Parameters

X_i	Y_i	X_iY_i	X_i^2	Y_i^2 *
X_1	Y_1	X_1Y_1	X_1^2	Y_1^2
X_2	Y_2	X_2Y_2	X_2^2	Y_2^2
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
X_n	Y_n	X_nY_n	X_n^2	Y_n^2
ΣX_i	ΣY_i	ΣX_iY_i	ΣXi^2	ΣY_i^2

$$\overline{X} = \frac{\sum_{i=1}^{n} X_i}{n} \qquad a = \frac{\sum_{i=1}^{n} X_i Y_i - \frac{\left(\sum_{i=1}^{n} X_i\right)\left(\sum_{i=1}^{n} Y_i\right)}{n}}{\sum_{i=1}^{n} X_i^2 - \frac{\left(\sum_{i=1}^{n} X_{ii}\right)^2}{n}}$$

$$\overline{Y} = \frac{\sum_{i=1}^{n} Y_i}{n}$$

$$b = \overline{Y} - a\overline{X}$$

* This column will be used in subsequent computations (see Section 9.4.4).

The estimated regression line and data points are plotted in Figure 9.4. Note that airframe cost (Y-axis) can be estimated by inspection of the regression curve at any given airframe weight (X-axis). Alternatively, the regression equation computes the airframe cost, given any airframe weight within the range of the data. For example, for a weight of 22,000 pounds, the regression equation developed in Worksheet 9.1 and applied in Worksheet 9.2 yields a predicted cost of \$20.19 million.

$$Y = -9.29 + 1.34X = -9.29 + 1.34 \times (22000 \div 1000) = \$20.19 \text{ million}$$

Worksheet 9.2 Completed Worksheet for Airframe Example

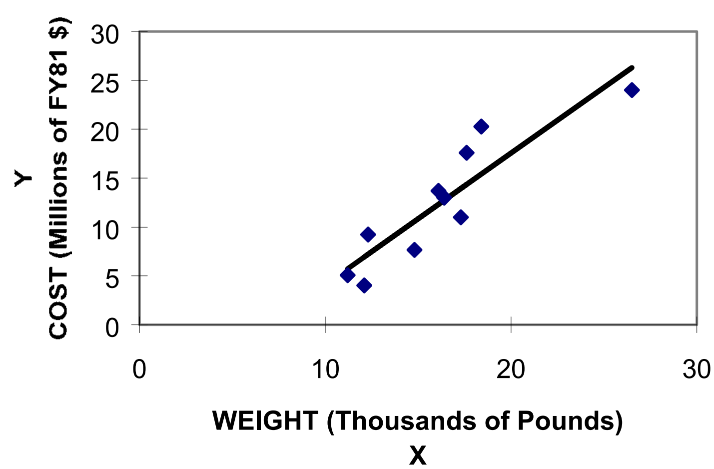
X_i Weight (lbs ÷ 1000)	Y_i Cost ($M)	X_iY_i Weight × Cost	Xi_2 Weight Squared	Yi_2 Cost Squared
11.2	5.07	56.8	125.4	25.7
14.8	7.67	113.5	219.0	58.8
26.5	24.01	636.2	702.3	576.5
18.4	20.27	373.0	338.6	410.9
16.4	13.0	213.2	269.0	169.0
12.1	4.04	48.9	146.4	16.3
12.3	9.23	113.5	151.3	85.2
16.1	13.69	220.4	259.2	187.4
17.6	17.58	309.4	309.8	309.0
17.3	10.99	190.1	299.3	120.8

$\Sigma X_i=162.7$ $\Sigma Y_i=125.6$ $\Sigma X_iY_i=2275.0$

$\Sigma X_i^2=2820.3$ $\Sigma Y_i^2=1959.6$

$\overline{X}=16.3$ $\overline{Y}=12.6$ a=1.34 b=-9.29 n=10

Figure 9.4 Sample Data and Estimated Regression Line for Airframes



9.5.3 Simple Non-Linear Relationships

Although this handbook is limited to the development of CERs using simple linear regression techniques, this does not preclude consideration of certain non-linear relationships. By applying appropriate variable transformations, some non-linear relationships can be converted into equivalent linear relationships. In addition to treating simple linear relationships of the form $\hat{Y} = aX + b$, the curve fitting techniques discussed can be applied easily to the non-linear relationships listed in Table 9.3. For example, if the scatter diagram suggests that an exponential relationship might exist, then the cost estimator should first transform all the Y data values by taking their logarithms. The least squares method can then be applied to the transformed data in order to estimate the curve parameters. However, in this case, the least squares estimate of a represents the logarithm of a (log a), and b represents log b in the exponential curve.

Table 9.3 Simple Non-linear Curves and Variable Transformations

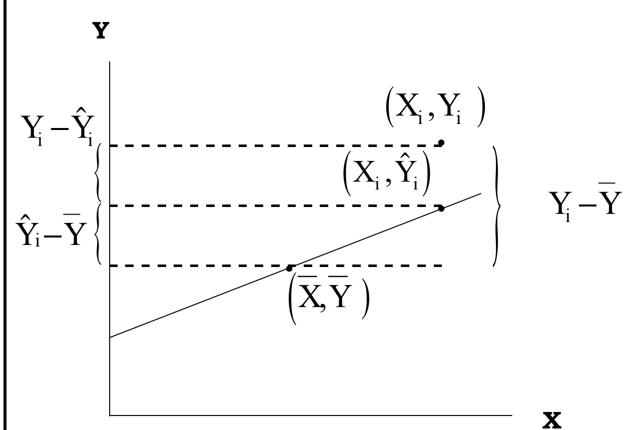
Curve Type	Curve Formula	Equivalent Curve Formula	Req. X-Values	Transform Y-Values	Least Squares Estimator Of Intercept b=	Least Squares Estimator F Slope a=
Hyperbolic	$Y = \frac{1}{aX + b}$	1/Y = aX + b	None	1/Y	b	a
Exponential	$Y = ba^X$	log Y = log b + X log a	None	log Y	log b	log a
Geometric	$Y = bX^a$	log Y = log b + a log X	log X	log Y	log b	a

9.5.4 Determining the Goodness of Fit

In the univariate statistics discussed in Appendix 9B, the standard deviation is introduced as one measure of dispersion. All the variability in a random variable is captured in the standard deviation, regardless of the source. In regression analysis, however, the variability in the dependent variable Y is correlated with the independent variable X.

Figure 9.5 depicts a single observed data point (X_i,Y_i), the plotted point ($\overline{X}, \overline{Y}$) computed from the data, and the fitted regression curve. The total deviation of Yi from $\overline{Y}$ is the sum of the deviation of Yi from $\hat{Y}_i$ and $\hat{Y}_i$ from $\overline{Y}$, or mathematically as shown in Equation 9.6.

Figure 9.5 Partitioning of Total Deviation



Equation 9.5

$$\left(Y_i - \overline{Y}\right) = \left(Y_i - \hat{Y}_i\right) + \left(\hat{Y}_i - \overline{Y}\right)$$

The second term in the right hand side of Equation 9.6 ($\hat{Y}_i - \overline{Y}$) is explained by the relationship between Y and X, that is, by the regression of Y on X. The first term in the right hand side, ($Y_i - \hat{Y}$), is due to random variation and, hence, is unexplained. By squaring both sides of Equation 9.6 and applying the summation operator over all n data points, Equation 9.7 is obtained.

Thus, the total variability in Y, given by the left hand side of Equation 9.7, is partitioned into a component that is attributable to the relationship between the dependent and independent variables (explained), and a component that is attributable to random variation (unexplained). The ratio of the explained portion of variability to the total variability provides a measure of the goodness-of-fit of the regression equation to the sample data. This ratio, called the coefficient of determination, is denoted by R2. Hence,

Equation 9.6

$$\sum_{i=1}^{n}(Y_i - \overline{Y})^2 = \sum_{i=1}^{n}(Y_i - \hat{Y})^2 + \sum_{i=1}^{n}(\hat{Y}_i - \overline{Y})^2$$

$$R^2 = \frac{\text{Portion of variation due to regression}}{\text{Total variation}}$$

Equation 9.7

$$R^2 = \frac{\sum_{i=1}^{n}\left(\hat{Y}_i - \overline{Y}\right)^2}{\sum_{i=1}^{n}\left(Y_i - \overline{Y}\right)^2}$$

Recall that $\hat{Y}$=aX+b and b=$\overline{Y}$ -a $\overline{X}$ (refer to Table 9.3). By substituting into the numerator of Equation 9.8 for $\hat{Y}_i$ and $\overline{Y}$, Equation 9.8 can be written as Equation 9.9, given the two mathematical relationships below it.

Equation 9.8

$$R^2 = \frac{a^2\sum_{i=1}^{n}\left(X_i - \hat{X}\right)^2}{\sum_{i=1}^{n}\left(\hat{Y}_i - \overline{Y}\right)^2}$$

Given:

$$\sum_{i=1}^{n}\left(X_i - \overline{X}\right)^2 = \sum_{i=41}^{n}\left(X_i^2 - 2X_i\overline{X} + \overline{X}^2\right) = \sum_{i=1}^{n}X_i^2 - n\overline{X}^2 = \sum_{i=1}^{n}X_i^2 - \frac{\left(\sum_{i=1}^{n}X_i\right)^2}{n}$$

$$\sum_{i=1}^{n}\left(Y_i - \overline{Y}\right)^2 = \sum_{i=1}^{n}Y_i^2 - \frac{\left(\sum_{i=1}^{n}Y_i\right)^2}{n}$$

Recalling the expression for a, from Worksheet 9.1, Equation 9.9 can be written as Equation 9.10.

The coefficient of determination ranges between zero and one. Since R2 is the fraction of variation explained by the regression, as R2 approaches one, the "goodness of fit" increases. If all the plotted data points are close to the regression line, then R2 will be close to one (R2 equals one when all data points fall on the regression line). As the points become more scattered, R2 will move closer to zero. Using the previous airframe example and Worksheet 9.2, R2 can be computed as follows.

Equation 9.9

$$R^2 = \frac{a\left\{\sum_{i=1}^{n} X_i Y_i - \frac{\left(\sum_{i=1}^{n} X_i\right)\left(\sum_{i=1}^{n} Y_i\right)}{n}\right\}}{\sum_{i=1}^{n} Y_i^2 - \frac{\left(\sum_{i=1}^{n} Y_i\right)^2}{n}}$$

Since R2=0.814 (close to one), the estimated regression line fits the data reasonably well. The fraction of variation left unexplained is,

$$1 - R^2 = 1 - 0.814 = 0.186.$$

$$R^2 = \frac{(1.34)\left[2275.0 - \frac{(162.7)(125.6)}{10}\right]}{1959.6 - \frac{(125.6)^2}{10}} = 0.814$$

The sample correlation coefficient r, discussed in Appendix 9B, is the square root of the coefficient of determination (R^2). The difference between the two lies in their interpretation. In correlation, r estimates the population correlation coefficient, ρ. In regression, however, the independent variable X is assumed to be non-random. R^2 is simply a measure of the goodness-of-fit of the regression line.

The confidence one can place in whether a valid relationship exists depends on the computed R^2 value and the number of data points. Tables for using the t statistic to assess both the slope a and intercept b can be found in many college level statistics books. Although the quality of the relationship is measured by testing the confidence one can place in the a value, the intercept b should be tested to assess the CER's usefulness in providing high confidence forecasts.

9.5.5 Estimating Confidence Regions

There are several statistical techniques for estimating confidence regions around predicted values. They vary depending on the amount of data available and the data distribution assumptions. Many textbooks, such as R. C. Owen's *Two-Variable Linear Regression Analysis for Introductory Quantitative Analysis*, describe the use of the Standard Error of the Prediction (SEP). SEP is most applicable for cost estimating activities where data availability is limited. Even more textbooks describe the Standard Error of the Estimate (SEE). However, its use is limited to situations where more data are available and the value of the independent variable for which an estimate is desired is near the mean of the data values. The SEE will give a deceptively narrow prediction confidence interval; therefore, the SEP is a more appropriate measure for cost estimating.

In cost estimating, the typical situation involves a CER developed using a small database (less than 20 data points) and input values that are not close to the mean of the independent variables. This leads to very wide confidence limits for the predicted values of the dependent variable. Cost estimators generally will be better off trying to use a second estimating method to support their estimates rather than attempt to prove statistically that their cost estimate has a high probability of lying within narrow bounds. Therefore, predictive confidence intervals often are not used in cost estimating.

9.5.6 Generalization of Simple Regression Analysis

Thus far the discussion has been limited to CER development using simple regression analysis: a single independent variable and a single dependent variable. For many cost applications, knowledge about a single key cost driver is all that is required to predict certain cost elements.

In other applications, however, a single independent variable may not be adequate to predict cost reliably. For example, more than one cost driver may be required to describe the manufacturing cost of a component. In these instances, it is useful to broaden simple regression techniques in order to accommodate additional cost drivers. This more general form of regression is called multiple regression because there are multiple independent variables that are used to predict the value of the single dependent variable. Thus, the functional relationship between the independent variables, denoted Xi, and the dependent variable, denoted Y, may have the following linear form if there are p independent variables:

$$Y = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + ... + \alpha_p X_p$$

Where α_0 represents a constant and the α_i (for $i = l,...,p$) are the coefficients of the independent variables (analogous to a in the simple regression case). The α_i can represent the relative importance, or weight, of each of the independent variables, provided the X_i are commensurable.

An important assumption of multiple regression is that the independent variables are truly statistically independent of each other (i.e., r=0 for all pairs of independent variables). If this is not the case, which it frequently is not, a condition called multi-collinearity is said to exist. However, some multicollinearity can be tolerated. Moderate to severe multicollinearity (values of r over 0.7) will cause problems in using the prediction equation for cost trade studies, where one wants to see how costs vary as a function of individual variables. However, multicollinearity (high r values) can be tolerated when making a single point estimate.

The computations involved in multiple regression are more difficult than those for simple regression; therefore, multiple regressions should be performed using current computer software packages. More advanced textbooks, such as N. Nie et. al.'s *SPSS: Statistical Package for the Social Sciences,* should be referenced for more detailed discussions on multiple regression.

9.5.7 A Note on Computer Applications

Today, there are many regression analysis packages available which can compute the various parameters and statistics used in regression analysis easily. Most computerized statistical packages perform simple and multiple regression, and many of them provide useful information on significance test computations and interpretations. Thus, if CERs are to be used frequently, the cost estimator should investigate how to access and use a statistical package rather than perform the calculations by hand. In addition, many hand calculators have special functions to perform simple regression.

9.6 Limitations of CERs

Like all estimating techniques, CERs have their limitations. The cost estimator must be fully aware of these limitations to properly convey the degree of confidence one should have in the cost estimate. This section addresses the major limitations associated with using CERs.

9.6.1 Quality and Size of the Database

Credible CERs demand quality data and enough data to estimate the relationship. Quality data means actuals (e.g., actual historical costs, actual weight, speed, etc.). When the cost estimator does not work with actuals, care must be given to estimating and interpreting the CER. Of course, actuals are not always available, forcing the cost estimator to rely on cost data from contractor bids and/or other projections. If a cost estimator were to use the airplane cost CER developed in Section 9.5, the cost estimator probably would not have actual airplane weight, only an estimate of the weight. Unfortunately, actual weight is not available until the airplane is produced and even historical actuals may contain measurement errors and anomalies. Moreover, historical data is often quite time consuming to collect. These factors place limits on the quality of the data available to build CERs. As a result, the cost estimator must be sensitive to these issues.

The size of the database also places limitations on CER credibility. In general, the more data points the cost estimator has, the more confidence the cost estimator will have in the CER and its predictions. Larger values of n will usually result in smaller values of SEE and SEP. For small values of n, the size of the confidence intervals becomes unacceptably large. Thus, the cost estimator must be aware of quantity and quality of the data used to assess the quality of the CER properly. Sample sizes of 30 or more are valuable because they allow one to assume a normal distribution in situations where the Central Limit Theorem is applicable.

9.6.2 Past Costs as Predictors of Future Costs

When using a CER, the cost estimator makes the assumption that information from the past is a good predictor of the future. Therefore, CERs assume that relationships that held true in the past will remain roughly the same in the future. Put another way, one is assuming that all factors affecting costs (e.g., productivity, material type, etc.) will affect future costs in approximately the same way they affected past costs. A CER prediction further assumes that the future program will have several management and technical problems, just as the programs in the historical database.

These assumptions may be unrealistic for two reasons. First, historical relationships between costs and cost drivers can change as technology changes. For example, the increased use of composite materials that are lighter and stronger, but which cost more than previously used metals, offer the prospect of reversing the positive airplane cost/weight relationship. Technology can thus alter the validity of CERs derived historically. Second, it is more than likely that management has learned from previous successes and failures. Managers are trying actively to ensure that a new program will not repeat past management and technical problems.

The cost estimator must consider whether technological changes (including changes in manufacturing technology) may invalidate a CER. Likewise, the cost estimator must review how management practices and acquisition strategy are likely to alter historical cost-to-cost driver relationships. Additionally, studies (Daly, Gates and Schuttling, *The Effect of Price Competition on Weapon System Acquisition Costs*; Kratz, L. A., *Dual Source Procurement: An Empirical Investigation*) show that competition during the production phase reduces unit costs; thus, if the program is to be dual-sourced, the cost estimator may have to consider the effects of competition in the cost estimate.

One way to make these adjustments would be to develop a CER using only a select portion of the data (assuming there is enough data). To develop the CER only those programs that were subject to competition would be included. More advanced regression techniques such as weighting schemes might also be used. It is important to remember that there are some built-in assumptions when using past costs as predictors of future costs, and the cost estimator must be careful when interpreting the results.

9.6.3 Cause and Effect versus Correlation

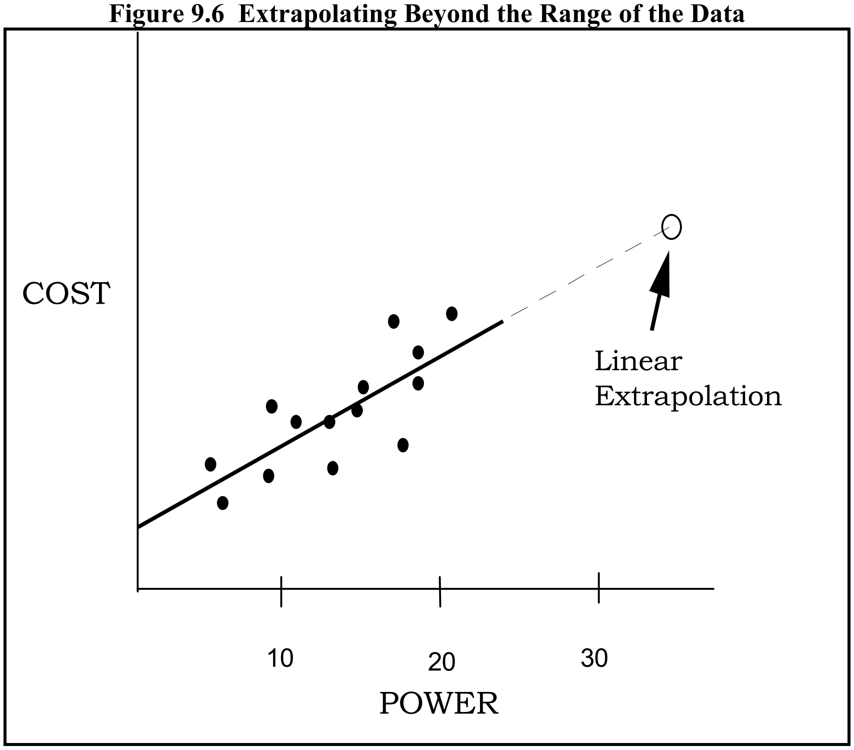
Section 9.5.4 described the computation and meaning of the coefficient of determination, R^2. The square root of that statistical measure, r, shows the degree of association between the independent variable and the dependent variable. The higher the value of r, the closer the association between the two variables. A high r, however, does not imply there is a cause and effect relationship between the two variables. The cost estimator must provide that interpretation. When doing so, the cost estimator must think through what imputing a cause and effect relationship between the two variables really means. Thus, the cost estimator must ask this question of all potential cost drivers: How do I expect this cost driver to affect cost? One might possibly find a relationship between cost and sunspots, but what cost estimator really expects the occurrence of sunspots to drive cost?

Some relationships that may appear plausible at first glance, in actuality are implausible. For instance, if a cost estimator wanted to examine the hypothesis that a large number of air traffic controllers at an airport indicates better air space management, the cost estimator might regress the number of controllers per airport against the number of flight delays per airport. The resulting regression might show that the greater the number of controllers, the greater the number of flight delays. Does this mean more controllers result in poorer air traffic services? Not likely, instead other explanations could also account for the high R^2. Large airports have more flights and thus more delays. Another reason might be that larger airports tend to be located in northern areas where there is more inclement weather. When thinking through this example, the cost estimator concludes that the number of flight delays at an airport may not be the best measure of good air traffic service. The lesson here is to think through the estimating problem before performing the regression because a high correlation does not imply necessarily a cause and effect.

9.6.4 Going Outside the Range of Data Applicability

CERs are derived from a set range of data. Using the CER to extrapolate well beyond that range must be done with great care. For example, in Figure 9.6 cost estimates of power requirements for cooling a site's existing ADP between 5 and 20 kilowatts can be developed with some confidence. A cost estimate for cooling the site after receiving new ADP with power requirements of 35 kilowatts is subject to more uncertainty. Can the cost estimator be sure that the linear cost/power relationship that held for lower power requirements continues at much higher power levels? Clearly, the cost estimator should consider carefully whether such extrapolation is feasible. Some input from knowledgeable engineers could provide valuable guidance on whether to extrapolate the CER.

Figure 9.6 Extrapolating Beyond the Range of the Data



9.6.5 Tests of Reasonableness

When using any kind of an estimating relationship, the cost estimator should check to ensure that the relationship, cost drivers, and results of a CER are intuitively plausible. The statistics generated in a regression analysis are helpful in this regard. For example:

- Correlation coefficient, r. This statistic should have the same algebraic sign as the regression coefficient a (the slope of the regression line). In other words, if the slope of the regression line is positive, the correlation coefficient should be positive.

- Standard Error of the Estimate (SEE) and Standard Error of the Prediction (SEP). SEE and SEP confidence bounds can be drawn around the regression line to give the cost estimator a sense of the uncertainty associated with the CER.

- Other statistics. The F-statistic and t-statistic (not discussed in this handbook) are useful in establishing the uncertainty associated with the regression coefficients b and a (α_0 and α_i). Refer to any basic statistics book for a discussion of these.

The cost estimator also must examine the relationship form carefully. The relationship between the cost drivers (independent variables) and the cost to be predicted (dependent variable) may be linear within a specified region, but curvilinear at extreme values of the independent variable. For example, component cost may be linearly related to power requirements within a certain range; however, at some threshold, costs may go up at an increasing rate. The cost estimator should try as many functional relationships as feasible.

In addition to statistical evaluation, other things can be done by the cost estimator to ensure a quality estimate and a reliable CER. For example, the estimator can:

- Make a "test" estimate for some recent system that was not included in the database and check to see if the CER's "test" estimate is in agreement with the actual system cost.

- Perform sensitivity analysis with the CER and show that all results are logical and reasonable.

- Have independent technical experts review and endorse the selection of the cost driver variables used and the reasonableness of sensitivity analysis results.

- Show that the model produced good estimates for those systems in the database most like the new system.

- If possible, gather enough historical data points so the new system's variable values are within the ranges of those in the database (i.e., avoid the need for data extrapolation).

Finally, the cost estimator must recognize that some cost estimating problems are not amenable to simple regression analysis and that more advanced statistical techniques need to be applied (e.g., multiple regression, multivariate techniques) and perhaps even some non-statistical techniques (e.g., expert judgment, elicitation techniques). In the final analysis, the intuition, experience, and judgment of the cost estimator are indispensable components in developing reliable cost estimates.

9.7 Introduction to Cost Improvement Curves

This section addresses the application of cost improvement curves to the cost estimating process. Cost improvement curves have been called by many names including learning curves, progress curves, cost/quantity relationships, and experience curves. Specific types (i.e., mathematical models) of cost improvement curves often have been named after the men who proposed them or companies that first used them. They include Wright, Crawford, Boeing, and Northrop curves. All of these names refer to one of two mathematical models generally agreed to describe best how costs or labor hours decrease as the quantity of an item being produced increases. These two models are described most accurately as the unit curve and cumulative (cum) average curve. The differences between the two models can be important and will be described later in Section 9.7.2. The differences are important because there are times when use of one model clearly is preferred over the other. The two models use what look like identical equations. However, because of the differences in the definition of the cost or hour term, they compute different total cost or hour values for identical first unit (T_1) and slope values.

The primary purpose of this section is to provide an introduction to basic cost improvement curve theory. While the theory is applicable equally to labor hours and costs - more exactly constant dollar costs - only costs will be addressed in the computation discussions presented in this section.

Throughout this section, the term total production costs will be used. Used herein, it means total recurring production costs; that is the total cost for activities and material requirements that are common to every production unit. Recurring costs do not include non-recurring costs, such as basic and rate tooling, which must be added in most cases to get a true total production cost.

At the outset it must be pointed out that cost improvement curve theory has been found to be a useful estimating tool in the past. However, it is based on observations, most of which do not fit either the unit or cum average curve equations exactly. No one can describe totally the cause and effect mechanisms that produce the cost decreases forecast by the theory. There are many uncertainties associated with cost estimates for future activities. While cost improvement curve analysis methods have been, and will continue to be, useful cost estimating tools, their use is also a source of estimate uncertainty. It is prudent financial management to review actual data from time to time, after the estimate has been made, to determine if cost reduction projections are being met. Section 9.7 provides brief historical, theoretical, and application information on cost improvement curves.

9.7.1 Brief History

Since the first paper on cost improvement curves in the airplane industry was published in the 1930s, much has been written on the subject. Louis E. Yelle, in *The Learning Curve: Historical Review and Comprehensive Survey*, provides over 90 references published before 1967. The most important fact derived from Yelle's research is that in the past, costs have been observed to go down in a somewhat predictable manner as the quantity increased. This has resulted in industry personnel planning and managing to assure the predicted cost reductions are achieved, and the government, as a buyer, expecting to see such reductions in the prices it pays for systems. Much has been written on what causes costs to decrease. It is agreed widely that the decreases result from many things including - job familiarization by workmen doing repetitious jobs, general improvement in tool design and usage, production control improvements, improved materials flow, reduced scrap, design fixes and simplification, and many other factors. On the other hand, very little is known about the relative magnitude of the reductions associated with each of the many individual sources of improvement or exactly how each component of improvement can be predicted. It is important for an estimator to study the process to which learning is being ascribed before accepting the learning curve as a reasonable estimating approach. For instance, if a company has experienced 85 percent learning curves historically, but recently has automated its process significantly, it is not to be expected that the process will involve as much learning, since machines do not learn. In this section the word learning is used to describe everything being done to reduce costs. Since factors well beyond the usual definition of learning are involved, quotes will be used to indicate this special meaning of the word learning.

9.7.2 Brief Theory of Cost Improvement Curves

As already mentioned, cost improvement curve theory states that as the quantity of items produced doubles, costs decrease at a constant rate. This constant rate will depend on many factors related to the process being modeled. Equations 9.11 and 9.12 describe the learning curve concept.

Equation 9.10

$$Y_x = T_1 \bullet X^b$$

Where:
Y_x = The cost required to produce the Xth unit
T_1 = The theoretical cost of the first production unit
X = The sequential number of the unit for which the cost is to be computed
b = A constant reflecting the rate costs decrease from unit to unit

In reviewing Equations 9.11 and 9.12, it is important to note that the form of the equations is the same. Both plot as straight lines when the variables are transformed into their logarithmic form. They differ only in the definition of the Y term. Equation 9.11 describes the basis for the unit curve. It is used to describe or model the relationship between the cost of individual units. Equation 9.12 describes the basis for the cumulative average or cum average curve. It is used to describe the relationship between the average cost of different quantities of units. The significance of the cum in cum average is that the average costs are computed for the first X units. Therefore, the total cost for X units is the product of X times the cum average cost. Unfortunately, there is no easy way to get the exact total cost of the first X units produced using the unit curve theory without a computer, although there are approximation formulas.

Equation 9.11

$$\overline{Y}_x = T_1 \bullet X^b$$

Where:
$\overline{Y}_x$ = The average cost of the first X units
T_1 = The theoretical cost of the first production unit
X = The sequential number of the last unit in the quantity for which the average cost is to be computed
b = A constant reflecting the rate costs decrease from unit to unit

Both the unit and cum average cost improvement curve equations describe and model the observation that costs decrease a constant percent every time the quantity doubles. This is reflected in the curves through the b value, a constant reflecting the amount of the decrease for every doubling of quantity. The b value for both curves is computed by Equation 9.13.

As an example using the unit curve, if the first unit cost 100 and the second unit cost 90, or 90 percent of unit 1, the unit curve would have a 90 percent slope, and the S value would be 0.9. The resulting b value would be the log 0.9/log 2 or -.045758/0.30103, or -0.15200. The b value is determined in the same way for the cum average curve. However, using the same first unit (T_1) value and slope, one will always get lower cum total costs using the cum average curve because of the difference in how Y_x and $\overline{Y}_x$ are defined. In the example above where the first unit cost 100 and the second 90, the total cost for the two is 190, based on use of the unit curve. Using the cum average curve the $\overline{Y}_x$ for the same T_1 value (100), slope value of .9, and x value of 2, would yield a total cost of 2 times 90, or 180.

Equation 9.12

$$b = \frac{\log S}{\log 2}$$

Where:
S = The cost/quantity slope expressed as a decimal value.

Since these two models of how costs decrease with quantity are clearly different, a cost estimator must always know which type of curve is required. If provided historical slope data, a cost estimator must know which curve type was assumed to derive the given slope values.

One other piece of theory is important to the applications of cost improvement curve theory. It is that when a procurement, whether new or continuing after a design change, consists of some elements being produced for the N^{th} time and other elements being produced for the M^{th} time, where N and M are not equal, the total cost of the total unit can be estimated using the sum of values computed from two cost improvement curves. The theory extends to any number of curves as long as the T_1, slope, and quantity values for each are appropriate for the items or fraction of the total item applicable to each curve. This is often the case where two or more systems use the same engine or some other major component.

9.7.3 Importance of Cost Improvement Curves to Cost Estimating

Cost improvement curves have long been recognized in the airframe industry and widely used by industry and government cost estimators. Subsequently, cost improvement curves have been applied to almost all production cost estimates, especially where the quantity of production units involved justified planning and tooling activities greater than those used to produce prototype items. Cost improvement curves can be applicable to production quantities as small as two units if the product is not machine made.

Cost improvement curves are one of the most widely understood concepts of all cost analysis tools. Therefore, cost estimators can expect questions from various levels of management on all aspects of their use in developing a cost estimate. Where quantities exceed 100 units, a change of only a few percent in the slope value can make a large change in the total procurement cost value. Many managers know this and may challenge the slope values used to argue for higher or lower estimates. The cost estimator must be prepared to defend all cost improvement curve methods, assumptions, and input values used to develop an estimate.

9.8 Summary

This chapter has dealt with the subject of parametric estimating, often used interchangeably with the term CER. Parametric estimating is the process of estimating cost by using mathematical equations that relate cost to one or more physical or performance characteristics of the item being estimated. Since physical or performance characteristics of a system are known early in a system's life cycle, parametric estimating methods are particularly needed for early life cycle estimates, although they are used throughout the life cycle. The use of parametric methods has gained increasing acceptance because of the inherent advantages of the methods; they can generate complete estimates with little detail and relatively small time investment.

9A. Least Squares Formula Derivation

The derivation of the least squares formulas for estimating b (y-intercept) and a (slope) is given below.

- Step 1: Observe Equations 9A.1 and 9A.2 and note that the "F" in Equation 9A.2 must be minimized.

Equation 9A.1

$$\sum_{i=1}^{n}\left(\hat{Y}_i - Y_i\right)^2 = \sum_{i=1}^{n}\left(b + aX_i - Y_i\right)^2$$

Equation 9A.2

$$F = \sum_{i=1}^{n}\left(b + aX_i - Y_i\right)^2$$

- Step 2: Square the expression ($b + aX_i - Y_i$) in Equation 9A.1 and apply the summation operator to get Equation 9A.3.

Equation 9A.3

$$F = nb^2 + 2ba\sum_{i=1}^{n} X_i - 2b\sum_{i=1}^{n} Y_i + a^2\sum_{i=1}^{n} X_i^2 - 2a\sum_{i=1}^{n} X_i\sum_{i=1}^{n} Y_i + \sum_{i=1}^{n} Y_i^2$$

- Step 3: Take the partial derivatives of F in Equation 9A.2 with respect to b and a. Then, set these partial derivatives equal to zero to get Equations 9A.4 and 9A.5.

Equation 9A.4

$$\frac{\partial}{\partial\ b} = nb + a\sum_{i=1}^{n} X_i - \sum_{i=1}^{n} Y_i = 0$$

Equation 9A.5

$$\frac{\partial}{\partial\ a} = b\sum_{i=1}^{n} X_i - \sum_{i=1}^{n} X_i^2 - \sum_{i=1}^{n} X_i Y_i = 0$$

- Step 4: Multiply Equation 9A.3 by (ΣXi), and Equation 9A.4 by n. Subtract the resulting equations to generate Equation 9A.6.

Equation 9A.6

$$a\left[n\sum_{i=1}^{n} X_i^2 - \left(\sum_{i=1}^{n} X_i\right)^2\right] - n\sum_{i=1}^{n} X_i Y_i + \left(\sum_{i=1}^{n} X_i\right)\left(\sum_{i=1}^{n} Y_i\right) = 0$$

- Step 5: Solve Equation 9A.6 for a to generate Equation 9A.7.

Equation 9A.7

$$a = \frac{\sum_{i=1}^{n} X_i Y_i - \frac{\left(\sum_{i=1}^{n} X_i\right)\left(\sum_{i=1}^{n} Y_i\right)}{n}}{\sum_{i=1}^{n} X_i^2 - \frac{\left(\sum_{i=1}^{n} X_i\right)^2}{n}}$$

- Step 6: Solve for b in Equation 9A.5 to get Equation 9A.8.

Equation 9A.8

$$b = \frac{\sum_{i=1}^{n} Y_i - a\sum_{i=1}^{n} X_i}{n} = \overline{Y} - a\overline{X}$$

9B. Basic Statistics for Cost Estimators

Introduction

This is a basic statistics reference for cost estimators.

Probability Distributions

Very few things in life are certain. Just as the actual outcome of a good horse race seldom can be predicted with confidence, the actual cost of an airplane seldom can be predicted to the dollar. Moreover, knowing the cost of one system or cost element in the Work Breakdown Structure may not provide much insight into the cost of another system or cost element because of the differences in technology, manufacturing process, labor skill, etc. How then does the cost estimator assess the uncertainty inherent in a cost prediction?

The cost estimator will not be able to specify with certainty the cost of a given element of the total system cost. The uncertainty, however, can be captured in the form of a probability distribution (sometimes referred to as a frequency distribution) on that cost element. A probability distribution gives two basic pieces of information:

- The possible values or range of values that the cost element might assume; and
- The likelihood that each of these values will be realized.

Figure 9B.1 depicts several probability distributions. In constructing a probability distribution, the only mathematical requirements are:

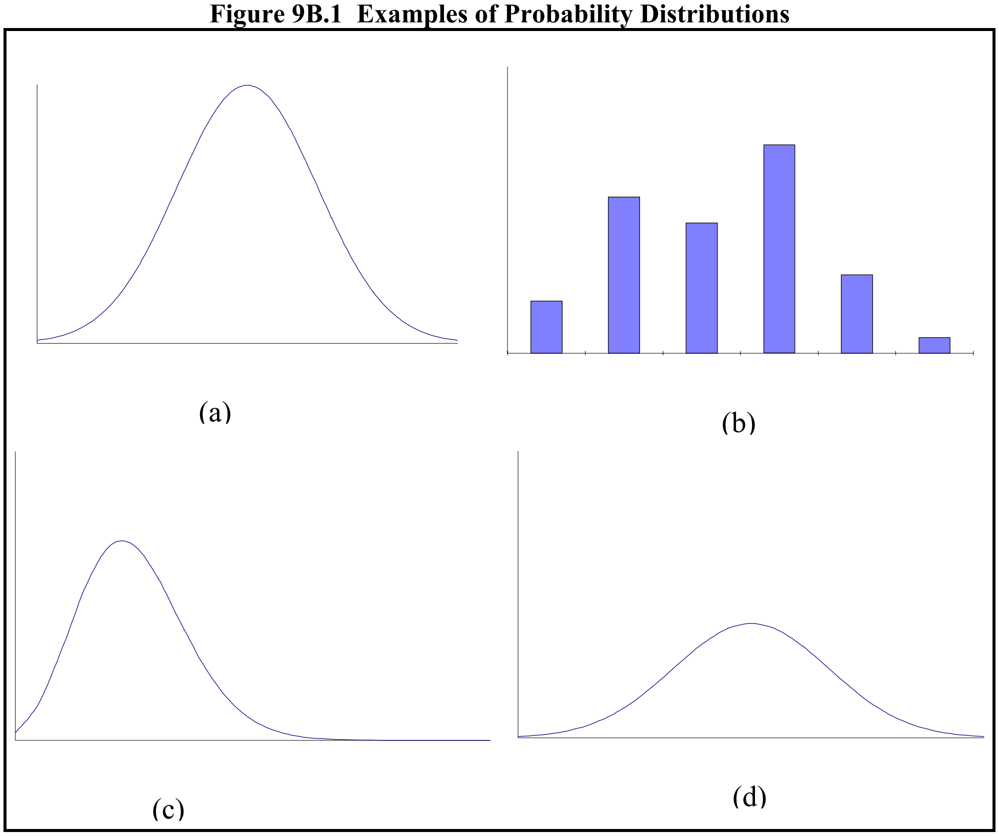
- That the probability assigned to each possible value (given by the height of the curve) be non-negative; and
- That the area under the curve sum to one.

The possible shapes are limitless. The height of the curve above the X-axis represents the relative likelihood that the cost value lying immediately below it will be realized.

Graphically, probability distributions may be depicted as smooth curves or histograms. Figure 9B.1, parts (a), (c), and (d) depict smooth curve distributions, and part (b) depicts a distribution in histogram form. The difference between smooth curve and histogram forms lies largely in how the distribution is constructed. In the histogram form, the cost estimator groups data into specific intervals (e.g., cost intervals) and centers each of the histogram bars on the midpoints of the intervals. For example, if 20 of a total of 100 cost observations fell in the interval $100,000 to $150,000, the cost estimator would assign a probability of 0.2 (20/100) to a histogram bar centered at $125,000. Smooth curve distributions may be generated from histograms by drawing a smooth curve through the midpoint of the top of all the histogram bars.

Smooth distributions also may reflect certain shapes that correspond to specific analytical distribution forms. By knowing the distribution's parameters, one can simply plot the distribution. For example, part (a) of Figure 9B.1 depicts a normal, or bell-shaped, probability distribution. Normal distributions provide the basis for many statistical estimation theories.

Figure 9B.1 Examples of Probability Distributions



Another important property of probability distributions is symmetry. Symmetry must always be measured relative to some point, line, plane, or other geometric reference. The symmetry in a probability distribution is specified relative to the mean. Figure 9B.1(a) depicts a symmetrical distribution as does Figure 9B.1(d). Skewness is a property of asymmetrical distributions. Roughly speaking, a skewed distribution is one that has a long tail at one end. Figure 9B.1(c) depicts a distribution that is skewed to the left.

Most of the information contained in a distribution is reflected in its shape. Two characteristics of shape are:

- a tendency for data values to concentrate around certain values, or
- a tendency for data values to disperse.

The next two sections are devoted to discussions of measures of central tendency and measures of dispersion. When two or more variables are under consideration, other statistics become important. Since CERs seek to exploit the relationship between two or more variables (e.g., cost and weight), the last section discusses a measure of association between two variables.

When using statistical methods, a cost estimator needs to understand whether his data constitute a population or a sample. A population consists of all the data of a specified type. A sample consists of part of a population, selected at random from the entire population. Some statistical formulas vary depending on whether the data being used is a population or a sample. As a general convention, Greek letters are used for population parameters and English letters for sample parameters.

Measures of Central Tendency

When analyzing historical cost data, it is often observed that while costs may vary over some range, there is a tendency for observations to cluster around certain values. In a sense, this clustering locates the middle of the distribution. It is desirable to identify the value corresponding to the center of distribution, but this depends on how this middle value is defined. Different definitions give rise to different measures. In this section, three measures of central tendency are given - mean, median, and mode.

Mean

The most commonly used measure of central tendency is the mean or arithmetic average. The mean of a probability distribution has a geometric interpretation. It represents the middle of the distribution in the sense that it is the center of gravity. If the distribution were balanced on a fulcrum, the X value corresponding to the point of balance would be the mean value, denoted by $\overline{X}$.

For a given set of n values $X_1, X_2, \ldots X_n$ (e.g., number of lines of computer code written by each of n programmers during a single hour), the mean is their sum divided by n, the number of values in the set. The mean is expressed mathematically in Equation 9B.1.

Equation 9B.1

$$\overline{\mathbf{X}} = \frac{1}{n}\sum_{i=1}^{n} X_i$$

where $\sum$ is the summation operator

CASE STUDY 9B.1. CALCULATING THE MEAN

Nine programmers picked at random were given the same programming task. After one hour, their coding sheets were collected and the following results were noted:

Programmer (i)	Lines of Code Written (Xi)
1	22
2	21
3	34
4	18
5	22
6	12
7	22
8	28
9	21

The mean number of lines of code written for this group of nine programmers is computed as:

$$\overline{X} = \frac{1}{n}\left(X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 + X_9\right)$$

$$\overline{X} = \frac{1}{9}\left(22 + 21 + 34 + 18 + 22 + 12 + 22 + 28 + 21\right)$$

$$\overline{X} = \frac{200}{9}$$

= 22.2 lines per hour

Median

Another measure of central tendency is the median or middle value of the probability distribution. The median is that value that bisects the probability distribution into two areas of equal size. The median is equivalent to the 50th percentile. This means that 50 percent of the probability lies above the median and 50 percent lies below. In other words, one is just as likely to observe values above the median as below it.

The median is frequently a more useful measure of central tendency than the mean, especially if the distribution is highly skewed. Highly skewed distributions tend to force the mean away from the median. The greater the separation between the two, the more important the choice of measure becomes. If the cost estimator has reason to believe that exceptionally high (or low) values experienced in the past are very unlikely to repeat themselves in the future, then the median may be the better choice. On the other hand, if widely divergent values are expected to persist into the future, the mean may be more appropriate, since it implicitly gives more weight to outlying values. A good guideline is to use the more conservative estimate (i.e., the one leading to a higher cost estimate).

CASE STUDY 9B.2. CALCULATING THE MEDIAN

To calculate the median, it is first necessary to arrange the data in ascending order. Continuing our previous example, the data arrange as follows:

Programmer (i)	Lines of Code Written (Xi)
6	12
4	18
2	21
9	21
1	22
5	22
7	22
8	28
3	34

Since the median is the middle value of the frequency distribution and 22 lines of code is the middle value, then 22 is the median of this distribution.

In the example above, the number of data points was odd (n=9). The reader may ask how one goes about finding the median when the number of data points is even. The answer is that one averages the two middle values. For example, if a tenth data point is added corresponding to 19 lines of code, the data would display as follows (in ascending order).

Programmer (i)	Lines of Code Written (Xi)
6	12
4	18
10	19
2	21
9	21
1	22
5	22
7	22
8	28
3	34

The median is computed as:

$$\text{Median} = \boxed{\frac{X_9 + X_1}{2} = \frac{21+22}{2} = 21.5}$$

Suppose now that another, especially bright programmer is added who writes 72 lines of code in one hour. The new mean for this frequency distribution of eleven data points is:

$$\boxed{\overline{X} = \frac{1}{11}\left(12+18+19+21+21+22+22+22+28+34+72\right) = 26.5}$$

The median is now 22. But which of these two measures of central tendency is more appropriate to use? Note that only three programmers out of eleven wrote more lines than the mean value of 26.5. The new mean value is heavily influenced by the large number of lines of code written by programmer 11. That is, programmer 11 is an outlier. Since this programmer has exceptional capability, the mean is biased and does not represent the preponderance of programmers. Therefore, the median (22) gives a better indication of the center of the frequency distribution.

Mode

The last measure of central tendency to be discussed in this chapter is the mode. The mode is simply the most frequently observed value, that is, the X-value corresponding to the highest point in the frequency distribution. The mode cannot be computed algebraically and must be determined by inspection of the frequency distribution. In the previous example, the mode is 22 since this value occurs most often.

Some distributions will have more than one mode (bimodal distribution). That is, there are two X-values around which data values tend to cluster. Other distributions may not have a mode at all if there are no repeated data values.

The normal probability distribution, which will be discussed in a later section, has the property that the mean, median, and mode all have the same value.

<u>Measures of Dispersion</u>

The last section was devoted to a discussion of measures of central tendency. The propensity for data values to concentrate around certain X-values. This section is devoted to just the opposite - the tendency for data values to spread. Two measures of dispersion are discussed below - range and standard deviation.

Range

The range is a simple statistic that represents the difference between the extreme values of the distribution. It is computed by taking the arithmetical difference between the largest and smallest data values.

CASE STUDY 9B.3. CALCULATING THE RANGE

Continuing our programming example, the largest value was 72 lines of code per hour; the smallest was 12 lines. The range is computed as follows:

Range = 72 - 12 = 60 lines of code per hour

The range is of limited value as a measure of dispersion because it does not depict the shape of the distribution - merely the range of values over which observations have been taken. Moreover, the value of the range has no meaning except in relation to the magnitude of the mean (or other measure of central tendency). For example, a range of 1,000 lbs. is small in the context of comparing airframe weights but large in the context of comparing the weight of avionics boxes. The standard deviation, which is discussed next, provides an answer to this measurement problem.

Standard Deviation

The standard deviation provides a standard measure of the degree of dispersion in a probability distribution. It is defined according to the formula in Equation 9B.2 for a sample, and Equation 9B.3 for a population.

Equation 9B.2

$$s = \sqrt{\frac{\sum_{i=1}^{n}\left(X_i - \overline{X}\right)^2}{n-1}}$$

Equation 9B.3

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n}\left(X_i - \mu\right)^2}{n}}$$

To compute the standard deviation of a sample, first compute the sum of squared deviations of the individual observations from the mean (this is the numerator under the radical). Then, divide this result by (n-1). Finally, take the square root.

CASE STUDY 9B.4. CALCULATING STANDARD DEVIATION

The standard deviation of the number of lines of code written per hour is computed by:

- Step 1: Compute the sum of the squared deviations from the mean $\left(\overline{X} = 26.5\right)$ as shown in Worksheet 9B.1.

- Step 2: Divide the result obtained in Step 1 by (n-1).

$$\frac{\sum_{i=1}^{n}\left(X_i-\overline{X}\right)^2}{n-1} = \frac{2588.75}{10}$$

- Step 3: Take the square root of the result obtained in Step 2.

$$\sqrt{\frac{\sum_{i=1}^{n}\left(X_i-\overline{X}\right)^2}{n-1}} = \sqrt{258.875} = 16.09$$

Worksheet 9B.1. Computation of Sum of Squared Deviations

$(X_1-\overline{X})^2$	=	$(12-26.5)^2$	=	210.25
$(X_2-\overline{X})^2$	=	$(18-26.5)^2$	=	72.25
$(X_3-\overline{X})^2$	=	$(19-26.5)^2$	=	56.25
$(X_4-\overline{X})^2$	=	$(21-26.5)^2$	=	30.25
$(X_5-\overline{X})^2$	=	$(21-26.5)^2$	=	30.25
$(X_6-\overline{X})^2$	=	$(22-26.5)^2$	=	20.25
$(X_7-\overline{X})^2$	=	$(22-26.5)^2$	=	20.25
$(X_8-\overline{X})^2$	=	$(22-26.5)^2$	=	20.25
$(X_9-\overline{X})^2$	=	$(28-26.5)^2$	=	2.25
$(X_{10}-\overline{X})^2$	=	$(34-26.5)^2$	=	56.25
$(X_{11}-\overline{X})^2$	=	$(72-26.5)^2$	=	2070.25
$\sum_{i=1}^{n}\left(X_i-\overline{X}\right)^2$			=	2588.75

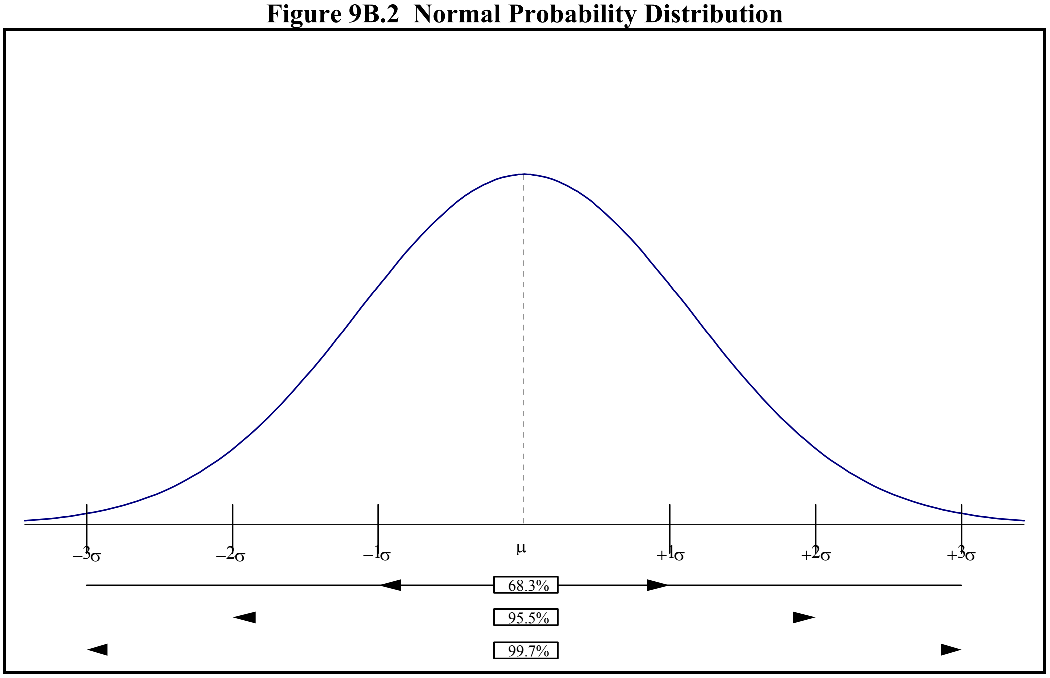
Thus the standard deviation in the example above is 16.09 lines of code per hour. Note that the standard deviation is expressed in the same units as the variable being analyzed.

The standard deviation provides a standard measure of dispersion. Knowing the standard deviation allows one to assign probabilities that observations will occur in various intervals over the full range of the distribution. This is true regardless of the nature of the probability distribution. However, confidence limits depend on the population's distribution and on whether one is dealing with a population or a sample.

Figure 9B.2 depicts a normal probability distribution with a mean of μ and a standard deviation of σ. Many natural phenomena obey the normal probability law and, hence, have normal probability distributions. The normal distribution is symmetrical about its mean. Note in Figure 9B.2 that the mean, μ in the normal distribution is also the mode and the median. The only other parameter needed to define a normal distribution completely is the standard deviation, σ.

As stated above, the assumption that the data follow a normal distribution allows one to make some assertions about the probability that observations will fall within a specified interval. In the case of a normal distribution, 68.3 percent of the observations will fall within one standard deviation of the mean, 95.5 percent within two standard deviations of the mean; and 99.7 percent within three standard deviations. (Normal probability tables exist in most statistics texts.) One can also specify the probability that an arbitrary value of X_0 or less will be observed if μ and σ are known. This is important since frequently one would like to know whether a specific observation constitutes a likely or unlikely event.

Figure 9B.2 Normal Probability Distribution



If two normal distributions have the same mean but different standard deviations, the one with the larger standard deviation has greater dispersion. This is true in the case of normal distributions but not necessarily true in the case of asymmetrical distributions. Two distributions can have the same mean and standard deviation but widely differing shapes. Only by looking at either the entire distribution or more detailed statistics (which are beyond the scope of this handbook) can one gain a full appreciation of the uncertainty contained in the distribution. Hence, the standard deviation (as a single measure of uncertainty (or risk)) must be used with caution.

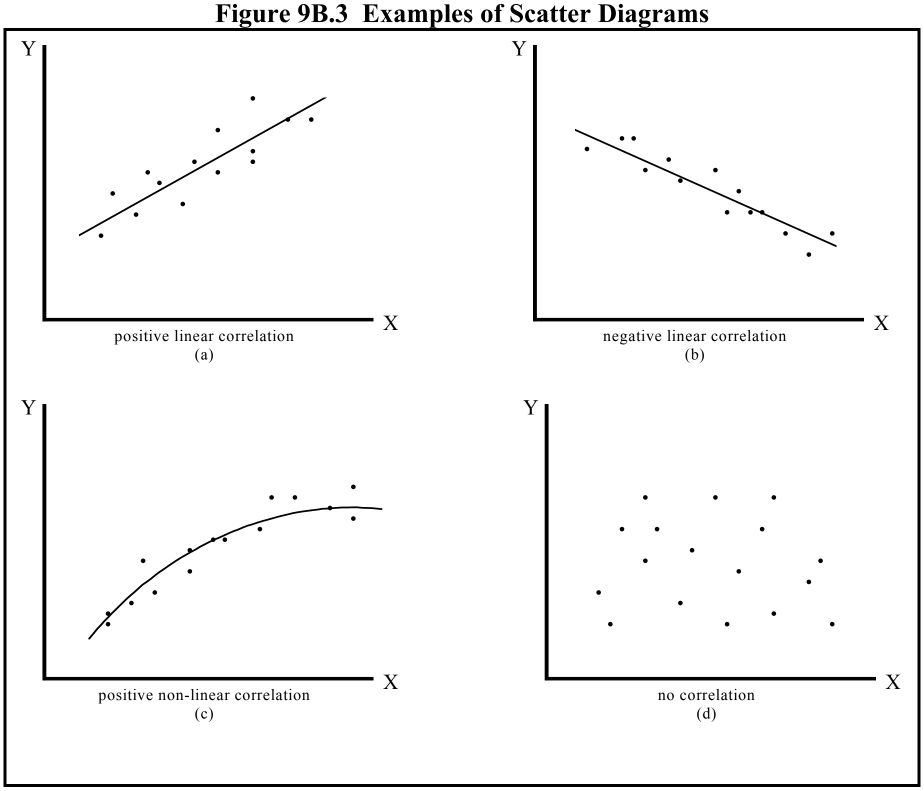
A Measure of Association

In cost estimating, cost estimators attempt to find relationships between two or more variables. Some of these relationships are deterministic (certain) in nature. For example, the relationship between programmer labor cost and labor hours is deterministic if a single labor rate is used for all programmers. If labor hours are known, then labor costs can be stated with certainty.

Other relationships are probabilistic (uncertain) in nature. For example, the relationship between lines of code written and software labor costs depends on the difficulty of the coding task and the proficiency of the programmer. If only given the number of lines of code written, one cannot assert with certainty the programming cost. However, one can measure the strength of the association between these two variables.

A good way to represent the relationship is by means of a scatter diagram. Let X_i represent the number of lines of code written by programmer i and Y_i represent the cost incurred. If there are n programmers, then there are n points (X_i, Y_i) which, when plotted, yield a scatter diagram of these two variables. Figure 9B.3 depicts four possible scatter diagrams that might result from plotting the n points. (There are other possibilities as well.)

Figure 9B.3 Examples of Scatter Diagrams



Part (a) of Figure 9B.3 depicts a situation in which Y tends to increase in proportion to X; this situation reflects positive or direct linear correlation. Part (b) depicts negative or inverse linear correlation (i.e., as X increases, Y tends to decrease proportionately). Part (c) depicts a situation where Y tends to increase as X does, but at a non-proportional or decreasing rate; this situation characterizes positive non-linear correlation. Finally, part (d), depicts a situation in which there is no apparent correlation between X and Y.

In essence, cost estimators need a measure that captures the strength of the association between X and Y. The correlation coefficient provides such a measure.

Correlation Coefficient (r)

The sample correlation coefficient (r), is an estimator of the population correlation coefficient (ρ). The correlation coefficient is a unitless measure of the degree of linear association between two random variables. The formula for computing the sample correlation coefficient follows.

Equation 9B.4

$$r = \frac{\sum_{i=1}^{n} X_i Y_i - \frac{\left(\sum_{i=1}^{n} X_i\right)\left(\sum_{i=1}^{n} Y_i\right)}{n}}{\sqrt{\sum_{i=1}^{n} X_i^2 - \frac{\left(\sum_{i=1}^{n} X_i\right)^2}{n}} \bullet \sqrt{\sum_{i=1}^{n} Y_i^2 - \frac{\left(\sum_{i=1}^{n} Y_i\right)^2}{n}}}$$

The sample correlation coefficient can vary between -1 and +1, inclusive. If r = +1 (-1), the correlation is said to be perfectly positive (negative) which means that all sample data points lie on a straight line.

CASE STUDY 9B.4. CALCULATING THE COEFFICIENT OF CORRELATION

Suppose that in addition to the number of lines of code written by each of the nine programmers, the number of months of programming experience was also identified. The data set now appears as follows:

Programmer (i)	Lines of Code Written (X_i)	No. Months of Experience (Y_i)
1	22	16
2	21	18
3	34	22
4	18	15
5	22	33
6	12	9
7	22	40
8	28	38
9	21	30

Worksheet 9B.2 illustrates the computations required to obtain the sum of squares and cross products. Substituting into equation 9B.4 gives the following result:

$$r = \frac{5156 - \frac{(200)(221)}{9}}{\sqrt{4742 - \frac{(200)^2}{9}} \bullet \sqrt{6403 - \frac{(221)^2}{9}}} = \frac{244.89}{(17.25)(31.24)} = 0.454$$

Thus, there is a mild positive correlation between programmer productivity and experience. This suggests that there are other variables that are just as important as experience (e.g., education, motivation, intelligence, etc.). The amount of confidence one can place in the correlation between two variables depends on the value of r and the sample size.

Worksheet 9B.2. Computation of Correlation Coefficient (r)

X_i	Y_i	X_i^2	Y_i^2	X_iY_i
22	16	484	256	352
21	18	441	324	378
34	22	1156	484	748
18	15	324	225	270
22	33	484	1089	726
12	9	144	81	108
22	40	484	1600	880
28	38	784	1444	1064
21	30	441	900	630
200	221	4742	6403	5156

$\Sigma X_iY_i = 5156$ $\Sigma Y_i^2 = 4742$
$\Sigma X_i = 200$ $\Sigma Y_i^2 = 6403$
$\Sigma Y_i = 221$ $n = 9$

A calculated r value of 0.454 is low; therefore, the data associated with it could not be used to make high confidence estimates. The F and t statistics should be used to assess a confidence measure of the relationship between the variables. The F and t statistics are discussed in most statistical texts and can be computed by nearly all statistical computer packages.

10.0 ANALOGY ESTIMATING

10.1 Introduction

This is the second of three chapters providing extensive discussions on one of the three main estimating methodologies - analogy estimating. The reader was first introduced to analogy estimating in Chapter 3, Section 3.3 in the context of the estimating process. This estimating methodology is discussed in detail within this chapter.

10.2 Brief Description

Analogy cost estimates also are called analog, analogous, or comparative cost estimates. Such estimates generally are characterized by use of a single historical data point serving as the basis for a cost estimate or portion thereof. A program cost estimate identified as an analogy cost estimate consists of more than one, and often many, analogy estimates each for one of several elements within the total estimate. While data limitations sometimes force cost estimators to use analogy-estimating methods, it must be pointed out that many believe basing an estimate (or a portion of the estimate) on a single historical cost data point creates considerable risk. One definition of analogy cost estimating, per the *Glossary of Financial Analysis Terms* published by the Systems Analysis Division, Department of the Navy, in 1981, includes the phrase, “based on historical data too limited to allow statistical estimating.”

Because estimates are based on extrapolation of a single data point, the comparison or extrapolation process is critical. Often, cost estimators must seek assistance from technical specialists to make the needed comparisons. This help is necessary to develop appropriate quantitative factors or judgments describing complexity, technical, performance, or physical differences between the new item and the item for which cost data are available. Judgments are also needed with respect to the significance of the cost differences found. These judgments often require technical knowledge beyond that of most cost estimators.

Use of analogy estimating methods is advisable when the new system is primarily a combination of existing subsystems, equipment, or components for which recent and complete historical cost data are available. Analogy methods are most useful in situations where rapidly advancing technology and acquisition strategies cause a parametric cost model database to become antiquated quickly. When properly completed and documented, analogy estimates provide a good understanding of how the program description affects the estimate produced. Since analogy cost estimates usually can be prepared quickly (especially if calculated at or near the system level), these methods often are useful as a check of an estimate prepared by other methods.

The fact that a new system rarely is comprised of entirely new subsystems makes analogy estimating methods valuable. Most new programs consist of modified or improved versions of existing components, combined in a new way to meet a new need. When analogy cost estimating methods are employed, the new system is broken down into components that can be compared to similar existing components. The basis for comparison can be in terms of capabilities, size, weight, reliability, material composition, or design complexity.

Analogy cost estimating usually requires the services of technical specialists. However, these estimates should not be confused with what are called “specialists estimates,” “engineering judgment estimates,” or “expert opinion estimates,” whereby an expert is asked to provide a cost estimate, not primarily a technical comparison of an old and new system or component.

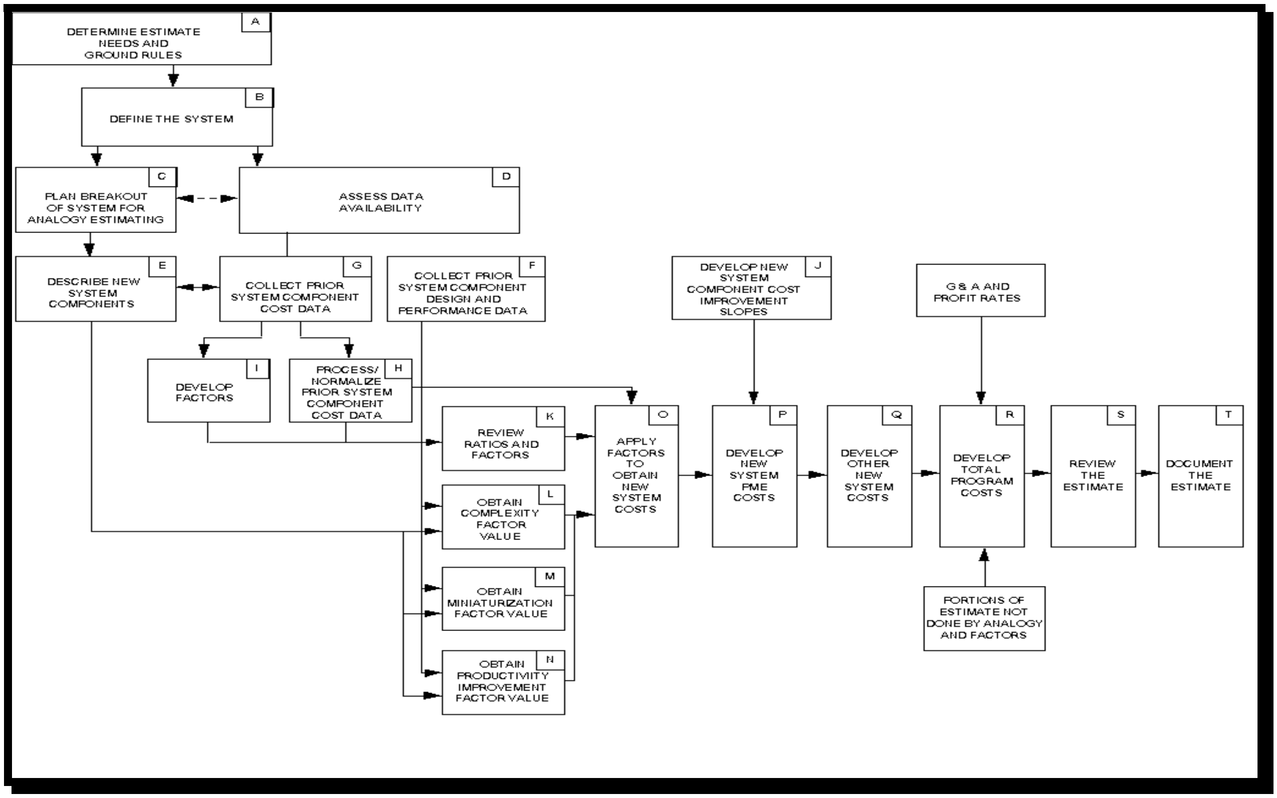
If both production and development program cost estimates are required, analogy estimating methods allow several approaches. The first approach (described in Section 10.3) calls for preparation of separate development and production estimates, each based on data related specifically to development and to production. Alternative approaches use analogy methods to develop production cost estimates for the first unit (or some specified average lot cost) and use historical production to development cost ratios to estimate the development costs. When feasible, the development of separate analogy estimates is preferred.

10.3 Key Analogy Estimate Activities

Figure 10.1 depicts typical key activities involved in making an analogy estimate. Each block represents an activity. Arrows indicate the usual sequence of activities. Dashed lines indicate interactive activities. Some activities must be repeated for each of several system components. Factors are likely to be developed once and used for all or most components. Many analogy estimates are less complex than indicated by Figure 10.1, especially if only one cost element is included. When only a single item is involved, the critical activities (L, M, and N) need to be performed only once. There also is reduced work associated with activities A through F and J. Many activities shown in Figure 10.1 are not unique to analogy estimates.

Typical key activities are described in the remainder of Section 10.3. Each block in Figure 10.1 has a letter in the upper right corner to key it to its associated paragraph in the following text.

Figure 10.1 Analogy Cost Estimating Process



10.3.1 Activity A. Determine Estimate Needs and Ground Rules

Cost estimates differ widely from detailed life cycle cost estimates, which cover activities occurring over periods up to 20 years, to simple estimates for a one time purchase of a single piece of equipment hardware of an existing design. In essence, estimates differ by level of detail or accuracy required. Some estimates need to be as accurate as possible, while others can be less accurate as long as they can be used as an equitable basis for comparing among several alternatives. In addition, some estimates need to be detailed so that costs can be tracked and managed at a lower level. Ground rules and assumptions (e.g., inflation rates to be used, buy quantities, schedules, interactions with other programs, test requirements, etc.) must be defined. The possible requirement for a sensitivity analysis should also be addressed. To facilitate creation of an estimate, estimate objectives, assumptions, and ground rules should be documented at the outset and agreed upon by all, especially program management. Subsequent changes to those plans should also be coordinated with program management.

10.3.2 Activity B. Define the System

Defining the system includes determining:

- Design or physical parameters such as weight, size, material type, and design approach

- Required performance characteristics such as speed, range, computation speed, reliability and maintainability
- Interface requirements with other systems, equipment, and organizations
- Unusual training, operations, and support requirements
- Unusual testing or certification requirements
- Level of technology advance, if any, required
- Known similar systems

10.3.3 Activity C. Plan Breakout of System for Analogy Estimating

Generally, the system to be estimated should be broken down into hardware or activity components. While the total new system may not be similar to a prior total system, many of the components of the new system (e.g., the power supply, computer, or antenna) may be like components of prior systems. The overall objective of this activity is to break out the overall system into components in such a way that:

- Good comparable components from past programs can be identified
- Relatively complete cost and descriptive data on the components from past programs are available
- Technical experts who have or can quickly obtain a good understanding of the differences between the old and new system components are available

The level of detail selected provides both a complete and sound basis for capturing all of the costs. An example of a poor breakout is one where both component and assembly costs are expected to be significant; however, only historical analogy component cost data are available, but historical analogy assembly cost data are missing.

As indicated in the chart, this activity is best done interactively with the next activity (D) to best achieve the overall objectives described above.

10.3.4 Activity D. Assess Data Availability

Three types of data are required:

- Quantity, design, and performance characteristics of the new system components
- Quantity, design, and performance characteristics for components of one or more prior systems

- Cost data for the prior system components.

Since all three of these items for any component must be obtained, cost estimators must assess the availability of the information listed above before making final system component breakout decisions or risk the chance of later finding that the data is not available at the breakout level selected. The technical specialists assisting in the estimate may have to be involved in assessing the availability of component description data.

10.3.5 Activity E. Describe the New System Components

If plans for the breakout are sound, the next step is to describe each of the new system components in terms most comparable to prior system components and which are more likely to reflect cost differences (e.g., weight rather than color). It is important that similar information can be found for the prior system components. This activity is best done in close coordination with the early phases of collecting prior system data, Activity F, to assure that adequate comparable design and performance data will be available.

10.3.6 Activity F. Collect Prior System Component Design and Performance Data

It is generally best to gather data on several characteristics for each component. It is better (but not mandatory) that this data be measurable. The data must be in terms comparable with the information known about the new system. In areas where technology is changing rapidly, such as microelectronics, it is best not to rely on weight or size data. The more recent the prior data the better, since the new system will more likely use similar manufacturing technology. Wherever possible, data should be gathered for several prior system components that are similar to the new system component. Subsequent analysis may show that one prior system component is a better basis for estimating the cost of the new system or that several may be considered in arriving at an estimate for the new system component.

10.3.7 Activity G. Collect Prior System Component Cost Data

As in collecting prior system component design and performance data, it is better to have data on several prior systems. Of course, the prior system component cost data must be for the same items for which the design and performance data was collected. It is desirable to obtain separate cost values for both development and production. In gathering the cost data, it is critical that all cost data collected are defined clearly. Things that should be known about cost values include:

- Exactly what is included in the cost (e.g., software, etc.)
- What year dollars the cost values are in and when the work included in the costs was completed
- What general and administrative (G&A) costs and profit were included in the values
- Where in the sequence of units bought were the items to which the cost values apply

- A breakout of recurring and nonrecurring production costs
- Cost improvement curve slope values experienced during production of the prior system components

The work required to obtain this information will vary widely from estimate to estimate. Analysis of production lot cost data to establish prior system recurring cost first unit (T_1) and slope values probably will be required. The impact of prototyping may have to be assessed. Contracts and the Work Breakdown Structure (WBS) dictionary may have to be reviewed to determine exactly what costs should fall into the full-scale development (FSD), production, recurring, and nonrecurring categories. When prior costs are spread over several years, either: 1) an average year of acquisition value must be established to convert the historical data to the desired constant year, or 2) the costs associated with individual years must be identified and each converted to the desired constant year. The work required to get costs to a constant year must be accomplished before the analysis required to establish slopes and T_1 values. An important part of this step is to assemble all historical financial data in terms of cost only. Therefore, if the available historical data contain G&A and profit, it must be identified, often from contract documents, and removed.

10.3.8 Activity H. Process/Normalize Prior System Component Cost Data

The objective of processing the prior system component cost data is to obtain the following:

- All cost values in a common constant year
- A breakout of all nonrecurring costs from recurring costs
- T_1 values for recurring costs
- A breakout of FSD and production costs, if a developmental program
- Recurring production cost improvement slopes and curve types
- Knowledge of prototype to first production unit cost improvement curve step functions, if any, associated with prior system component production
- Knowledge of anything unusual about prior system costs or uncertainties concerning the cost values obtained
- Nonrecurring to recurring cost ratios

10.3.9 Activity I. Develop Factors Based on Prior System Costs

Sometimes, extrapolating cost elements from past systems to future systems is more logical than using design and performance differences as a basis. One example is program management. Program management is generally estimated as a percent of total prime mission equipment hardware costs. Support equipment, training, and data generally are handled in this manner also.

While such factors may be available (having been developed during other estimates), the prior system data to be used for the estimate should be analyzed to develop such factors. It is always prudent to check the factors developed with similar ones used for other estimates and reconcile any major differences.

10.3.10 Activity J. Develop the New System Component Cost Improvement Slope Values

This is applicable only if there is recurring production or production of multiple prototypes involved. The most logical source of curve slopes is the slope of the prior system as described in Activity H.

10.3.11 Activity K. Review Ratios and Factors

When preparing analogy estimates, cost estimators generally need to rely on judgments made by engineers and other technical specialists. Specialists must be selected because of their knowledge of both the new and prior programs. They should understand design, materials, and manufacturing technology. They also may know reasons why past programs may or may not be representative of work on the new system. Therefore, it is valuable to have them review the ratios and factors developed in Activity H and Activity I as a precaution against using factor or ratio values from a prior system which are not representative of the usual or projected circumstances.

The break between completing Activity K and starting Activity L essentially divides the analogy estimating process into two major parts. Activities A through K can be viewed as getting ready to conduct the estimate. The remaining activities can be viewed as preparation of the estimate itself. If several estimates are needed for different designs or levels of performance, the work involved in Activities A through K will have to be repeated.

10.3.12 Activity L. Obtain Complexity Factor Values

This activity is the foundation of analogy estimating methodology. It must be done carefully and result in an understandable and traceable reason for each complexity factor developed. In essence, the cost estimator is asking a technical specialist who knows both the prior system and the new system the following question. “Assuming no special miniaturization requirement and no manufacturing technology differences (i.e., productivity improvement differences between production of the prior and new system), what should their relative complexity be (i.e., cost ratio)?” This relative complexity should be based on the design and performance differences between the prior and new system. This is not an easy question to answer. Technical specialists generally do not think of complexity as a number directly related to cost differences. In addition, the cost estimator must insist that the technical specialist provide justification for his answer in terms that others can understand, such as the ratio of number of circuit cards, radiated power ratio, weight ratio, etc. If possible, multiple complexity judgments should be obtained and combined in a logical manner to arrive at a single best complexity value to be used for the estimate.

10.3.13 Activity M. Obtain Miniaturization Factor Values

For some applications such as aircraft, missiles, and space systems, the smaller the subsystem is for a given level of performance, the more costly it is to produce. Sometimes stringent weight and space constraints are placed on subsystems. These constraints can increase costs. The guidance of technical specialists is required to determine if the new system can be expected to cost more due to weight and volume constraints and, if so, how much more. The question of "how much more" should be presented in terms of the ratio of the expected cost of the new system to the expected cost of designing a new system with the same level of performance but with no space and weight constraints. If no added costs are expected, this ratio will be 1.0. All ratios not equivalent to 1.0 should be supported with rationale that is understandable to both the cost estimator, and those who will review the estimate.

10.3.14 Activity N. Obtain Productivity Improvement Factor Values

Just as inflation drives costs up over time, productivity improvements should drive costs down, or at least somewhat offset inflation cost increases. In many cases productivity improvements are not obvious because the product changes so much that the productivity improvement cost benefits get lost or do not materialize. This is true with respect to automobiles. One really does not know what it would cost to build a 1960 Chevy today because new Chevys are very different than 1960 models. However, in agricultural products, such as wheat, corn, etc., where the product is about the same as it was 60 years ago, the constant dollar cost per unit is way down due to productivity improvements. Spectacular decreases in costs per unit of computing capability have been seen in recent years.

Technical specialists should be asked if there has been significant productivity improvement between production of the prior and new systems. If the answer is yes, a judgment is required to assess the cost ratio of producing the new system, using the anticipated manufacturing technology and material costs, to those associated with the prior system. A significant productivity cost improvement will result in a ratio of less than 1.0. A value of 1.0 indicates no significant productivity change. Sound reasons for the ratio selected should be provided.

It is very desirable to obtain separate factor judgments for complexity, miniaturization, and productivity changes because reasons provided to justify each individually should be easier to understand. However, as a practical matter, the technical specialists may argue that they can only give factor values that combine two or even all three factors. The cost estimator will have to decide what course of action is best. However, it is essential that the factors used in any combined factor be identified clearly with respect to which of the three factors are taken into consideration. In addition, the cost estimator must assure that each of the factor areas has been addressed.

10.3.15 Activity O. Apply Factors to Obtain New System Costs

The factors developed in Activities L, M, and N are applied to T_1 values and nonrecurring costs for both FSD and production, as applicable. They are not applied directly to the ratios developed in Activity H and Activity I because these ratios will be applied to new system costs to which the factors have already been applied. In applying the factors, the Equation 10.1 is used.

Equation 10.1

$$C_N = C_P \bullet F_C \bullet F_M \bullet F_P$$

Where:
C_N = The equivalent cost for the new system
C_P = Any T_1, FSD, or production nonrecurring cost for the prior system or system component
F_C = Complexity factor ratio
F_M = Miniaturization factor ratio
F_P = Productivity component ratio

Where two or more factors are combined, the equation will change accordingly.

10.3.16 Activity P. Develop New System PME Cost Estimates

The T_1 values developed in Activity O must be combined with cost improvement curve slope values developed in Activity J to arrive at total recurring costs for each component. Nonrecurring costs should be developed in Activity O or be based on recurring to nonrecurring cost ratios developed in Activity H. Recurring and nonrecurring costs are added to develop total prime mission equipment (PME) costs for each WBS component (or aggregation of components) addressed. FSD and production estimates must be prepared separately, unless one is to be developed based on the other. Costs for the various components or groups of components involved are summed to get the total new system PME cost for FSD and the specified production quantity of interest.

10.3.17 Activity Q. Develop Other New System Costs with Factors

When making analogy cost estimates, comparisons generally are made between prior and new equipment based on characteristics of the equipment. A common approach is to use the differences in characteristics to extrapolate from the PME costs of prior systems to the PME costs of the new system. When this is done, other elements of cost such as Systems Engineering (SE)/Program Management (PM), spares, support equipment, training, and data must be added to complete the estimate for the new system. To do this, a cost estimator must use the costs developed in Activities O and P and the factor values developed in Activities H and I. Other sources, such as company history, can be used to develop all non-PME costs for the new system. The costs produced to this point generally cover all costs for a contractor to carry out work on the new system.

10.3.18 Activity R. Develop Total Program Costs

Completion of Activities P and Q should provide cost data that can be summed to get the total cost for a contractor to provide the new system. Profit and G&A costs must be added to obtain the total contract prices. Appropriate profit and G&A rate data generally can be obtained either from forward pricing rate agreements for the company involved or from recent history of similar programs. To arrive at the total program costs, all other costs not associated with the prime contractor must be added. This generally includes mission support, Government Furnished Equipment (GFE), and costs to use government test facilities. If the program has several contractors, the total program cost must combine the costs associated with all contractors.

10.3.19 Activity S. Review the Estimate

Because analogy cost estimates require complexity value judgments, which significantly affect the final results, they should be reviewed before preparing final documentation. This review is best performed by other cost estimators or supervisors experienced in analogy cost estimating and, if possible, an engineering supervisor familiar with the equipment. To prepare for such a review, it is often desirable to perform some sensitivity analysis to show how sensitive the estimate is to the various key complexity value judgments.

10.3.20 Activity T. Document the Estimate

Analogy cost estimate documentation has much in common with documentation required for any cost estimate. However, since the final product is tied so critically to the comparison of the prior and future system, the basis for complexity factors given must be discussed clearly in a way that is logically persuasive. Where complexity judgments by technical specialist are used, the specialists and their qualifications should be identified. The same type of information is desirable to support miniaturization and productivity judgments.

The inclusion of a figure like Figure 10.1 in the estimate documentation helps the reader more clearly understand how the estimate was developed. All factors, ratios, slopes, and T_1 values used, for prior and new equipment, should be included and identified clearly. Pictures or drawings also can be helpful to illustrate important design characteristics or differences.

10.4 Additional Guidance

Generally, technical specialists find it difficult to make, and often balk at making, complexity, miniaturization, and productivity improvement judgments. Their concepts of complexity are not necessarily in terms that are directly proportional to cost differences. The cost estimator can sometimes help the technical specialist by providing the relative component costs of several past systems and asking for a relative cost or complexity judgment for the new system with respect to these several past systems.

Some engineers believe that as the complexity ratio from the prior to future system increases, the quality of the analogy decreases. It follows that as the complexity ratios increase much above 2.0, the quality of the estimate is reduced due to the quality of the analogy (unless very convincing rationale is provided to support high complexity values).

While it is desirable to divide a system into components for analogy estimates, little can be gained by breaking out the system below the highest level for which good data are available and for which the technical specialist can make sound complexity judgments.

Where subcontractors were used on past programs and may be used in the future, past subcontract cost values are used with subcontractor G&A and fees included in the analysis. Adjustment might be made in the final estimate, since it generally is not appropriate for the prime contractor to charge a G&A fee for subcontract work. However, it is customary for prime contractors to earn a profit for the value of the subcontracted work.

10.5 Summary

This chapter provides the cost estimator with an overall analogy estimating process, along with detailed explanations for each activity within the process and the interrelationships among activities. Although analogy estimating was described as a very rigorous process, two critical limitations must be kept in mind. First, is the requirement for a detailed technical definition of both the analogous system as well as the system being estimated. Expert judgment becomes the mainstay of this approach and, at the same time, a limitation. Without access to sound expertise, this methodology is difficult to employ. Secondly, once the technical assessment has identified the analogous system, actual cost data on that system must be acquired. Without this, the transition from the analogous system to the current system cannot be made.

11.0 ENGINEERING ESTIMATING

11.1 Introduction

This is the last of three chapters providing extensive discussions on one of the three main estimating methodologies. The reader was first introduced to engineering (also know as detailed engineering estimating) in Chapter 3, Section 3.3 in the context of the estimating process. Engineering estimating methods are important because they result in the most detailed estimates. Specifically, engineering estimating methods generally involve a more detailed examination of the new system and program. A full and detailed treatise on engineering estimating is provided within this chapter.

When talking about an engineering estimate, it is prudent to clarify whether this is a detailed estimate prepared by bidders or a cost estimate prepared by government personnel (hereafter referred to as an in-house engineering cost estimate). The two tend to be quite different estimates, even on the same program. Section 11.2 will address bidder- or contractor-prepared engineering estimates to help cost estimators understand how contractors prepare estimates, so they will be better prepared to use and evaluate such estimates. Section 11.3 will address in-house estimates and differences between detailed in-house prepared engineering estimates and those prepared by contractors.

The process of developing engineering estimates often calls for techniques described in other chapters of the handbook. This chapter will show how methods (including those described elsewhere in the handbook) are integrated into engineering estimates. All available system descriptions and applicable historical cost data must be considered in a logical manner when arriving at an estimate. In the case of engineering estimates there generally are more data available upon which to base an estimate than there are available for a parametric or analogy estimate. For instance, a firmer, more complete description of the new program for acquiring the end item usually is available. Often the converse is true for parametric and analogy cost estimates.

Nothing in the definition of engineering estimates limits the scope of the estimate with respect to cost element contents. However, engineering estimates prepared by contractors usually do not include such elements as other government costs and engineering change costs that must be included in most government budget estimate submissions.

Most significant estimating efforts are a combination of several methods. The best combination of methods is the one which makes the best possible use of the most recent and applicable historical data and system description information and which follows sound logic to extrapolate from historical cost data to estimated costs for future activities. The smaller the extrapolation gap in terms of technology, time, and activity scope the better.

11.2 Engineering Estimates Prepared by Contractors

11.2.1 Brief Description

As discussed in Section 11.1, engineering estimates prepared by contractors differ substantially from engineering estimates performed by government personnel in at least two important ways. First, the contractor-prepared estimate is based on input from work units that will do the work and that have performed similar work in the past. Second, contractors are able to bring more detailed program description data such as tooling plans, make or buy plans, etc., to the cost estimating process. It is not unusual to see contractor engineering cost estimates documented in at least two volumes. One volume most likely would be called the Cost Estimate or Financial Plan with the other volume being called something like the Engineering Estimate or Substantiating Data. The second volume is primarily time (direct labor hours) and material estimates prepared by the organizations that would do the work.

The activities described in Section 11.2.2 are consistent with the brief descriptions provided in this section. However, not only do different contractors do things in different ways, procedures will vary by individual contractor depending on the availability of cost data on similar programs, vendor proposals, and the degree of design and program description uncertainty. Therefore, the activities described in Section 11.2.2 must be viewed only as representative - not the only type, combination, or sequence of activities that can be encountered with respect to contractor-prepared engineering estimates.

11.2.2 Key Activity Descriptions

Most contractor-prepared engineering cost estimates that are seen by government cost estimators were prepared for cost proposals. Such estimates are described here.

<u>Activity A. Understand Program Requirements</u>

An initial and critical activity is to understand the program requirements clearly and completely. This understanding is gained by a complete review of several documents describing what is to be done, how it is to be done, and the contractors' responsibilities with respect to getting it done. These documents include:

- Proposal instructions
- Statement of Work (SOW)
- Lists of deliverables
- Data lists
- Specifications
- MIL Standards
- Federal Acquisition Regulation (FAR) clauses
- Contract requirements

For most programs, especially major programs, contractors will be in direct contact with government personnel at bidders' briefings or through the buyer to get further clarification on the program requirements.

Activity B. Prepare Program Baseline Definition

This critical activity includes company preparation of detailed plans and documents describing how they plan to complete required work. These preliminary plans and documents can include:

Technical descriptions	Production illustrations
Manufacturing, tooling, and facility plans	Government Furnished Property (GFP) lists
Quality assurance plans	Master equipment lists
Test plans	Support equipment lists
Logistics plans	Tool lists
Training plans	Special test equipment lists
Management plans	Schedules
Contractor support plans	Facility layouts
Associate contractor agreements	Model contract
Make or buy plans	
Hardware drawings and descriptions	

Activity C. Prepare Ground Rules and Estimating Instructions

The early publication of cost estimate ground rules and instructions is important to assure that the many people involved in the preparation of the cost estimate clearly understand and correctly carry out their roles. Subjects addressed include, but are not limited to:

- Quantity and schedule information
- Estimate formats to be used
- Escalation rate assumptions
- GFP availability assumptions
- Man-month to man-hour conversion factor

The estimating instructions usually define major cost groups and list their components. Table 11.1 is an example of such instructions.

Table 11.0 Cost Element Group Definitions

Term	Definition
Direct Material	Includes raw materials like lumber and oil, as well as processed materials (sheet metal), purchased parts (nuts and bolts), and purchased equipment (tools). This category also includes subcontracted items or items produced outside of the company, which could be major sub-components of an end item.
Direct Labor	The effort of hourly or salaried employees, usually expressed in labor hours or labor years. Direct labor typically is broken out by functional category, such as engineering, quality assurance, and manufacturing.
Overhead (Indirect)	A cost which, because of its incurrence for common or joint

	objectives, is not readily subject to treatment as a direct cost to one contract or product. Such indirect cost is incurred to benefit the total direct cost or business base of a contractor. The character of overhead thus requires estimating, budgeting, and control techniques that take into account the total business base of a contractor. This term is synonymous with indirect costs. It could include such costs as the Engineering Department head office expenses.
Direct Travel	Includes all travel by direct personnel in support of contract tasks.
Other Cost Elements	Fringe benefits, direct charges, state taxes, cost of facilities capital, and inter-divisional support.
General and Administrative (G&A) costs	These are indirect costs necessary for maintaining an ongoing business entity. They typically include a company's general and executive offices, the cost of staff services such as legal, accounting, and similar expenses related to the overall business.

Activity D. Develop Required Matrices and Checklists

Control matrices relate WBS tasks to contract line items. Matrices and checklists are prepared to assure that all required work is considered during preparation of the estimate. Also, matrices are used to show organizational responsibilities with respect to WBS tasks.

Activity E. Develop Functional Organization Task/End-item Estimates

This is the most important activity in the company-prepared engineering cost estimating process. Most of what was done in Activities A through D was done to assure that this activity is complete and valid. Many people in several functional organizations must estimate the time in hours, days, or months to carry out their responsibilities with respect to each of many WBS tasks and end items. These estimates are primarily direct labor values but may also include some material and subcontract cost estimates. Elements of costs estimated in this manner include:

- Engineering direct labor
- Tooling fabrication labor
- Basic factory labor
- Manufacturing engineering labor
- Quality assurance labor
- Facilities engineering

How this activity is done differs substantially from how the equivalent activity is done in the in-house engineering estimate. This is because the in-house team is not supported with man-hour estimates made by people who will do the work and who have done similar work before.

Activity F. Use Other Program History

The availability and use of other program historical cost and description data are essential for developing and substantiating sound estimates of direct labor, appropriate factor, and future costs. Most companies will have a computerized system for bringing such data quickly to bear on the preparation of estimates for future work. These computer programs often include procedures for entering descriptive data on the new system and for generating an estimate automatically based on this input and the historical data in the system.

Activity G. Compile Estimate Data

This activity consists of aggregating all the time and material cost data provided by the functional organizations in accordance with the proper contract line item number (CLIN), SOW, and WBS breakouts needed both to show the estimate detail required and to properly apply rates and factors. To an extent, this activity is the dividing line where primary estimating activities pass from the functional organizations to the pricing or financial specialists. Often these time and material estimates and the rationale supporting them are documented in a separate volume or volumes from the information prepared by company pricing or financial specialists.

Activity H. Develop Rates and Factors

Many rates and factors are used to develop a contractor-prepared engineering estimate. For major programs these rates are different and must be provided by year over the entire life of the program. The development of these rates is subject to strict rules enforced by various audit agencies. Ideally, contractor estimates are based on rates and factors already approved by a government audit agency. If not, the usual process of reviewing a contractor's estimate is to have the rates and factors used audited by one of the organizations. The primary criteria for acceptable rates and factors is that they were developed using accepted accounting procedures, appropriate recent historical data, and reasonable assumptions about the future with respect to inflation, plant loading, wage contract settlements, etc. Many rates and factors are used which differ from contractor to contractor depending on individual accounting systems. Some of the rates and factors that could be used and that are defined in the example in the appendix to this chapter include:

- Direct labor pay rates for all categories of direct labor
- Overhead rates covering all categories of direct labor
- Facilities Capital Cost of Money (FCCOM)
- Overtime premium factors
- Tooling material cost per tooling fabrication hour
- Engineering operations cost per hour of engineering direct labor
- Sustaining engineering cost per factory labor hour
- Tooling and production planning cost per factory labor hour
- Quality assurance cost or hours per factory labor hour
- Program financial control cost per hour
- Fringe benefit cost factor of direct labor costs
- Other direct charge factors (e.g., freight) of material costs
- General and administrative factor of labor and overhead

A detailed discussion concerning the construction of Wrap Rates, used by government personnel in estimating, is included as an appendix to this chapter (Appendix 11A: Wrap Rate Construction).

<u>Activity I. Incorporate Supplier Proposal Prices</u>

Most major prime contracts for government equipment result in many subcontracts for goods and services. For common items, costs can be obtained from catalogs. For one of a kind items or services, the prime contractor usually asks for quotes from one or more suppliers. Since such subcontracts will not be negotiated and signed until after the award of the contract to the prime, the contractor-prepared engineering estimates generally use the vendor quoted price, less an assumed negotiation decrement (based on past experience).

<u>Activity J. Compute the Estimate</u>

Because of the large volume of data involved, the need to present the cost estimate in several ways, and the need to incorporate last minute changes, all prime contractors use computers to compute, organize, format, and print their engineering cost estimates. The computations are consistent with the ground rules, instructions, matrices, and checklists discussed in Activities C and D. They reflect all the data generated in Activities E, F, G, H, and I.

<u>Activity K. Summarize the Cost Estimate</u>

The results of the cost estimate computations must be summarized in several ways, according to decision maker needs.

<u>Activity L. Review the Estimate</u>

Several levels of review usually are required for all contractor-prepared major program engineering estimates. Special scrub teams look at details, while a higher-level corporate team may perform the last review. Unfortunately, these review teams have been known to raise or lower estimates in the past, especially in response to a Best and Final Offer (BAFO) request, without having to supply all the desired supporting rationale for the new estimate. As a result, some of the input data described in Activities E, H, and I may need to be changed without sound rationale to arrive at the desired estimate.

11.2.3 Additional Guidance

Since the role of a government cost estimator is to use or evaluate a contractor-prepared engineering estimate, the additional guidance that follows will be directed to that end. The following guidelines have proven useful in the past with respect to evaluating contractor prepared engineering estimates:

- Quickly find out what the high cost areas or items are, and focus attention on them.
- If the evaluation is part of a source selection, compare WBS element and CLIN costs among contractors to spot unusually high or low costs quickly for further investigation.

- Probe to see whether major and poorly substantiated changes were made to the cost estimate during the contractor's review or BAFO preparation process.

- If the contract has been awarded and the purpose of the Government review is to update the estimate, check the final negotiated subcontract price against those proposed.

- Use audit reports to check the validity of the rates and factors used by the contractor.

- In high cost areas, make sure the contractor has provided all cost estimate substantiating information requested.

Perhaps the most important guidance that can be given to improve government review of contractor-prepared engineering cost estimates is to require the submission of cost data and substantiating information in a format that is clear, complete, and ready for evaluation. This is not always easy, but several requirements are common to most review needs. They include:

- Requirements that data be totaled in each table, both down and across, if appropriate.

- Requirements that the contractor make it easy to track totals from low-level breakout sheets to higher levels of aggregation.

- Requirements for CLIN/WBS and other information matrix summary sheets to help convey how the estimate aggregates to a total cost.

- Requirements for summary sheets containing the rates and factors used to prepare the estimate.

- Requirements for man-hour summary sheets by WBS for direct and subcontracted work by labor type, if appropriate, to assess the level of effort proposed.

- Requirements that the contractor track cost estimate changes and justify the basis for the change fully.

- Requirements for fiscal phasing of costs, but only at the highest level of aggregation that will meet anticipated analysis needs.

11.3 In-House Engineering Estimates

11.3.1 Brief Description

To many, engineering is synonymous with detailed with respect to cost estimating. Generally, the most common level of detail always contained in an engineering estimate is a breakout of functional labor categories such as engineering, manufacturing, quality control, and tooling. In most engineering estimates one also can expect to find a breakout of major subcontracts and material items.

By definition, an in-house engineering estimate almost always is prepared by government personnel or by cost analysis support contractors and not by the contractor who can or will do the work. The other type of engineering estimate (where contractors prepare the estimate) was described in the previous section. Many, but not all, in-house engineering estimates are prepared to forecast out year costs for systems in production or for which prototype production cost data are available. It is less common, but possible, to do a detailed estimate for a future system by using cost estimating relationships (CERs) or analogy estimating techniques to develop detailed labor and material estimates that can be summed into an engineering-like estimate containing a minimum of detail.

It generally is more time consuming to develop detailed engineering estimates than to develop other types of estimates. However, where detailed and pertinent historical data are available, this approach more completely takes such data into consideration. It is more appropriate when the design is stable.

11.3.2 Major Differences Between Contractor and In-House Engineering Estimates

In-house engineering estimating processes differ from the contractor-prepared engineering estimating process described in Section 11.2 in several important ways. For an in-house estimate:

- Typically fewer people are available to help prepare the estimate
- Fewer product and program description details are developed and used in the process of developing the estimate
- Specialists responsible for doing the work do not estimate functional labor requirements; therefore, labor requirements usually are estimated at or near the total functional level (i.e., in far less detail)
- Supplier proposals are not available, unless the work is on contract, so material costs most likely will be based on historical costs and not broken out at as low a level

These differences can cause in-house and contractor estimates to vary from each other significantly, especially prior to production when not as much actual data is available. When the program is in production, the differences between the estimates should not be so significant. In such circumstances, actual man-hour, material, and subcontract cost data for prior production provides an excellent basis for projecting the costs associated with future production. Government cost estimators usually obtain the necessary data through visits to the prime contractor and one or more of the major subcontractors.

11.4 Summary

To apply the engineering methodology, the program to be estimated must be well defined and capable of being broken down to a fairly low indenture level. As a result, engineering estimates generally are more detailed than either parametric or analogous estimates. The key disadvantage and limitation of this approach is that a great deal of time may be required to define all of the discrete activities, tasks, and/or operations at a low enough indenture level to estimate labor and material.

11A. Wrap Rate Construction

This appendix contains a discussion of the mechanics of wrap (wrap-around) rate construction. The majority of this handbook has been concerned with methods of predicting those comprehensive quantifiable elements (e.g., labor hours, material dollars, other direct costs, etc.) that produce the total costs of the particular effort being estimated. These quantified elements must be converted to program dollars through the use of various multipliers (e.g., labor rates, overhead rates, G&A rates, etc.). The conversion of quantifiable elements to program dollars can be accomplished by first calculating each individual element of cost (e.g., labor dollars, overhead dollars, G&A dollars, profit dollars, etc.) and then adding the individual results to arrive at a total bottom line program cost. This approach dictates a tremendously laborious computational effort and is very susceptible to mathematical errors. Substantial reduction in computational time is achieved through use of wrap rates.

A wrap rate is a rate that encompasses all direct labor, overhead, general and administrative expenses, profit, Facilities Capital Cost of Money (FCCOM), and other costs as appropriate. When applied to estimated hours, the wrap rate will yield total program dollars for each representative functional area. Each specific element of the wrap rate will be discussed below and a computational example is presented. The addendum will conclude by addressing precautions the cost estimator should exercise when dealing with wrap rates.

The major elements that compose a wrap rate are presented below:

- Direct Labor Rate. Typically, the direct labor rate is that composite rate charged by each functional area (e.g., engineering, tooling, quality assurance, manufacturing), on a per hour basis, to accomplish their respective tasks. The importance and significance of the direct labor rate being a composite will be addressed when the precautions of wrap rate usage are discussed.

- Overhead Rate. Overhead is a cost which, because it is incurred for common or joint objectives, is not readily subject to treatment as a direct cost. Such indirect cost is incurred to benefit the total direct cost or business base of a contractor. The distribution of indirect costs applicable to any one project is accomplished through the use of a rate per hour or percentage (i.e., overhead rate) applied to direct hours or costs. The kind and quantity of indirect cost elements are functions of how each individual contractor's accounting system is structured.

- Other Costs. Other costs can consist of myriad items such as allocated material, factored labor, travel, computer time, overtime premium, fringe benefits, and support services. The kind and quantity of other cost items included in a wrap rate is a function of how each individual contractor's accounting system is structured to provide the kinds of cost information needed for its cost estimating system to be effective.

- General and Administrative (G&A) Expenses. General and Administrative expenses are indirect expenses, including corporate office costs, staff services such as legal, accounting, marketing, public relations, financial, and similar expenses related to the overall business. These costs are allocated through the application of factors/percentages to the combination of direct labor, overhead, and other costs.

- Facilities Capital Cost of Money (FCCOM). Facilities Capital Cost of Money factors are typically applied to various labor and/or overhead accounts (engineering, manufacturing, G&A, etc.) and allow the contractor to recoup the cost of money (interest) incurred as a result of his investment in capital facilities. As such, FCCOM factors function in the same manner as ordinary engineering or manufacturing overhead rates. The purpose of FCCOM factors is to reward contractors for facility investments, motivate increased productivity, and reduce costs through the use of modern manufacturing technology.

- Profit. Profit is the excess of revenues from the sale of goods over the related costs thereof.

A wrap rate computational example for a production estimate follows. For simplicity of presentation, the following assumptions are made:

- A Forward Pricing Rate Agreement (FPRA) is in existence such that there are no disputes between the contractor and governmental agencies with regard to projected labor, overhead, FCCOM rates, or factors. If an FPRA is not in existence, it falls to the estimator to evaluate the relative merits of the contractor and government positions with respect to projected rates and factors. One area frequently requiring analysis is the projected future business volume of the contractor. The evaluation can, of course, result in acceptance of either position or development of an independent third position.

- Wrap rates will be calculated at the labor functional level, and composite direct labor rates reflecting the same have already been calculated.

- Other costs consist of overtime premium and computer time. Both are factored from direct labor dollars.

General and Administrative rates are listed in Table 11A.1. The composite direct labor rates, by function, are given in Table 11A.2. Overhead rates and other cost factors are given in Table 11A.3 and Table 11A.4, respectively.

Table 11.0A.1 General and Administrative Rates

	G&A Rates
CY84	7.7%
CY85	8.9%
CY86	9.5%
CY87	9.0%

CY=Current Year

Table 11A.2 Composite Direct Labor Rates (CY$)

Function	CY84	CY85	CY86	CY87
Engineering	14.44	15.25	15.56	15.64
Tooling	10.81	11.34	11.57	11.64
Quality Assurance	10.47	10.99	11.20	11.27
Manufacturing	10.07	10.56	10.76	10.83

Table 11A.3 Overhead Rates (CY$)

Function	CY84	CY85	CY86	CY87
Engineering	14.15	13.88	14.16	14.23
Tooling	20.76	23.25	23.72	23.86
Quality Assurance	20.10	22.53	22.96	23.10
Manufacturing	19.33	21.65	22.06	22.20

Table 11A.4 Other Cost Factors

Function/Items	CY84	CY85	CY86	CY87
Engineering:				
Overtime Premium	5.0%	7.0%	6.5%	6.1%
Computer Time	1.0%	2.0%	1.5%	1.9%
Tooling:				
Overtime Premium	8.0%	9.0%	9.0%	9.0%
Computer Time	N/A	N/A	N/A	N/A
Quality Assurance:				
Overtime Premium	N/A	N/A	N/A	N/A
Computer Time	N/A	N/A	N/A	N/A
Manufacturing:				
Overtime Premium	8.0%	9.0%	9.0%	9.0%
Computer Time	0.5%	0.6%	0.6%	0.8%

Facilities Capital Cost of Money (FCCOM) factors are given in Table 11A.5. A profit rate of 12.0 percent, exclusive of FCCOM, is assumed.

Table 11.0A.5 FCCOM Factors

Function	CY84	CY85	CY86	CY87
Engineering	.04304	.04014	.05111	.05210
Manufacturing	.18000	.18010	.21680	.20987
G&A	.00985	.01121	.01486	.01652

Based on the information given, wrap rates for engineering would be calculated for each year as follows in Worksheet 11A.1.

Worksheet 11A.1 Calculating Wrap Rates

Wrap Rate Elements			CY84
Direct Labor Rate..............................			$14.44
Overtime Premium ($14.44 × 0.05).....	+	0.72	
Computer Time ($14.44 × 0.01)..........	+	0.14	
Overhead Rate[1]..................................	+	14.15	
Subtotal	=		$29.45
G&A ($29.45 × 0.077)........................	+	2.27	
Subtotal	=		$31.72
Profit ($31.72 × 0.12).........................	+	3.81	
FCCOM[2]			
(ENGR: $14.44 × 0.04304)...........	+	.62	
(G&A: $2.27 × 0.00985)[3]..............	+	.02	
TOTAL PRICE WRAP RATE	=		$36.17

TABLE FOOTNOTES:

1.) Overhead rates are expressed frequently as a percentage of direct labor. If expressed as a percentage, overhead is applied in the same manner as overtime premium and computer time in the example ($14.44 × 0.98 = $14.15).
2.) FARs and Cost Accounting Standard 414 prohibit application of contractor overheads, G&A, and profit to FCCOM costs. Therefore, FCCOM is the last element calculated in a wrap rate.
3.) Note that G&A cannot be applied to the FCCOM cost element but the G&A cost element can serve as the base from which the FCCOM cost element is factored.

Repeating the above calculations (as applicable) for each functional category and each calendar year generates the wrap rates presented in Table 11A.6.

Table 11A.6 Calendar Year Wrap Rates (Current Year$)

Function	CY84	CY85	CY86	CY87
Engineering	36.17	37.86	38.81	38.85
Tooling	39.15	43.47	44.60	44.67
Quality Assurance	36.89	40.91	41.95	42.01
Manufacturing	38.33	42.45	43.90	43.94

The rates contained in Table 11A.6 reflect calendar year values. To use these rates for production cost estimating purposes, the calendar year rates must be composited to establish fiscal year buy rates. This conversion is accomplished through the use of an effort distribution profile. The effort distribution profile indicates how much effort will fall in each year of the period of performance. Table 11A.7 displays assumed effort distribution profiles for each of the functional labor categories.

Using the expenditure profile in Table 11A.7 and the calendar wrap rates in Table 11A.6, the fiscal year-buy wrap rates for FY84 and FY85 were calculated. Table 11A.8 depicts these rates. These current year buy wrap rates also could be expressed as current year-wrap rates by applying applicable inflation indices directly.

Table 11.0A.7 Effort Distribution Profiles

Function	YEAR 1	YEAR 2	YEAR 3	TOTAL
Engineering	45%	40%	15%	100%
Tooling	30%	60%	10%	100%
Quality Assurance	40%	33%	27%	100%
Manufacturing	31%	39%	30%	100%

Table 11A.8 Fiscal Year Buy Wrap Rates (TY$)

Function	FY84	FY85
Engineering	37.24*	38.39
Tooling	42.49	44.27
Quality Assurance	39.58	41.55
Manufacturing	41.61	43.46
* Sample calculation for FY84 Engineering		

Worksheet 11A.2 Constructing Wrap Rate

CY	CY RATE		DISTRIBUTION %		FY RATE	
84	36.17	×	0.45	=	16.277	
85	37.86	×	0.40	=	15.144	
86	38.81	×	0.15	=	5.022	
					37.243	≈ $37.24

The wrap rate example (Worksheet 11A.2) demonstrates the process for construction of wrap rates. As with any process, the steps or procedures used to arrive at the end result (e.g., a wrap rate) can be modified, rearranged, or otherwise manipulated and still achieve the same final result. When developing a wrap rate, the cost estimator should strive to mirror the structure of the contractor's accounting system. By doing so, the cost estimator ensures that the goal of a wrap rate is achieved - to capture total program costs associated with each functional hour of labor.

There are three major variables that impact wrap rate formulation:

- The structure of the contractor’s cost accounting system
- The estimating approach or methodology employed by the cost estimating team
- The selection of an appropriate composite direct labor rate

Each of these variables has been touched on previously, but further elaboration is required, along with cautions to the estimator.

The first variable to impact wrap rate formulation is the contractor's cost accounting system. Many contractors, in an effort to reduce the size of their overhead accounts, have incorporated numerous rates and factors into their estimating systems. An example is development of machine maintenance hours as a factor of fabrication labor. The kind and quantity of rates and factors are potentially endless, with some contractor's estimating systems so intricate that computer programs are required to generate their wrap rates. The cost estimator should recognize also that at a gross level all accounting systems function in the same manner basically, but at lower (i.e., more specific) levels, however, each contractor's accounting or estimating system is uniquely his own. Because each contractor's accounting system is unique and wrap rate formulation is a mirror of that system, the cost estimator is cautioned to be thoroughly familiar with the mechanics of the accounting system before attempting the development of wrap rates.

The second variable to be considered in wrap rate formulation is the estimating approach or methodology being employed by the cost estimating team. A contractor could estimate quality assurance man-hours as a factor of fabrication hours within the manufacturing function. The cost estimating team also could choose to use a factor or instead to do a detailed man-loading estimate. Should the estimating team select the man-loading approach, the manufacturing wrap rate formulation must exclude the quality assurance factor to ensure that no double counting of effort occurs. In this case, the team must construct a separate wrap rate for quality assurance so that the detailed man-loading estimate could be converted to dollars. Again, the cost estimator must be thoroughly familiar with the estimating approaches being used before attempting the development of wrap rates.

The third variable is the selection of the appropriate composite direct labor rate to be used in the wrap rate. This is critical because all wrap rates start with a composite direct labor rate. Four different types of composite labor rates are possible. Composite labor rates can be developed by:

- Functional cost category (engineering, manufacturing, etc.)
- Labor type within each function (fabrication, assembly, test)
- Cost centers, departments, or organizational units
- Job classification

Composite labor rates also can be developed on a plant wide basis, a commercial versus government business basis, a program basis, or on a particular procurement (i.e., contract) basis. The basis of selection of the most appropriate composite direct labor rate is primarily a function of the scope of the estimate. For example, if the estimate were very narrow in scope (e.g., involving only engineering tasks) then composite labor rates by labor type would be appropriate. In the vast majority of cases, composite labor rates by functional cost category are most appropriate.

Finally, a couple of major points must be made based on the above discussion. First, in those situations where a cost estimator is either given a wrap rate or uses a wrap rate developed by someone else, extreme caution is recommended. The concern is the proper application of the correct wrap rate. This concern has its origins in the fact that there can be multiple wrap rates, each being referred to by the same generic name. For example, an engineering wrap rate for XYZ Corporation could be based on either plant wide data or just one specific contract. The wrap rate could be at the functional level or for one job classification within the engineering function. The wrap rate also could be for either a calendar year or a fiscal year. Because so many types of wrap rates are possible, an estimator should never use a wrap rate without specifically knowing how it was developed to ensure that its application is proper. The second major point to be made is that comparison of different contractor wrap rates is hazardous at best. Meaningful comparison of contractor wrap rates is nearly impossible due to the unique intricacies of each contractor's accounting system, compounded by the multitude of wrap rates that can be generated based on the selection of a composite direct labor rate.

In closing, to avoid potential pitfalls resulting from incorrect wrap rate formulation, it is recommended that the cost estimator develop wrap rates with input from the staff cost/price analyst personnel. These personnel have cognizance over the contractor for which the wrap rates are being developed. They are particularly knowledgeable of the contractor's cost accounting system structure, due to their daily monitoring of contractor activities.

12.0 COST MODELS

12.1 Introduction

This chapter introduces the concept of cost models in general terms and describes considerations for the utilization of a model. A few specific hardware cost models are presented as examples; however, they are not intended to constitute a complete list, but only to identify some of the more frequently used models which are considered representative of the capabilities available. Cost estimating models are discussed in other areas of this handbook. Section 8.4 of Chapter 8, "Cost Risk and Uncertainty," describes two models used for cost estimate risk analysis. Section 13.5 of Chapter 13, "Operation and Support Cost Estimates," describes the types of O&S cost models and provides an overview of some selected models.

12.2 Categories

This chapter will discuss two general categories of models: cost accounting models and CER models. Both manual and automated methods are available, although the use of automated methods is pervasive even with simpler models today.

12.3 Examples of Hardware Cost Models

The following sections describe three popular cost hardware models in use today. Since there are few commercial hardware cost models available, the two most widely used are discussed in general terms in this section without creating a separate appendix. DoD and NASA have developed many special application hardware cost models (e.g., space launch vehicles), however, those models/CERs applicable to the FAA generally are contained in DoD's ACEIT tool, discussed in Section 12.3.3. Section 13.5 of Chapter 13 identifies a number of O&M cost models.

12.3.1 PRICE Cost Models

Key inputs to the PRICE H Model are:

- Weight: tells the model the size of the product being estimated.
- Manufacturing complexity: a coded value that characterizes product and process technologies and (optionally) the past performance of the organization.
- Platform: a coded value that characterizes the quality, specification level, and reliability requirements of the product application.
- Quantities: the number of prototypes and production items to be estimated.
- Schedule: the dates for the start and completion of the development and production phases may be specified. The model will compute any dates that are not specified. Only the date for the start of development is required.

- Development costs: effort associated with drafting, design engineering, systems engineering, project management, data, prototype manufacturing, prototype tooling, and test equipment.

- Production costs: effort associated with drafting, design engineering, project management, data, production tooling, manufacturing, and test equipment.

12.3.2 SEER Cost Models

The System Evaluation and Estimation of Resources (SEER) models are used to estimate development, production, and operating/support costs of hardware, software, and integrated circuit programs. The SEER estimating models were developed by GA SEER Technologies as a computerized system for producing life cycle cost estimates and schedules for acquisition programs involving a wide variety of hardware and software content. The models estimating capability is derived from parametric equations, produced by cost analysis of previous programs, and a knowledge base of cost data that aids the analyst in producing estimates of programs in the concept phases where detailed data is not always available.

<u>Hardware Cost Estimating Model (SEER-H)</u>

The SEER family of models includes the basic hardware cost estimation model (SEER-H) and a hardware life cycle cost model. The hardware cost model estimates hardware cost and schedules and includes a tool for risk analysis. The hardware model is sensitive to differences in hardware technologies ASIC, MCMS, exotic materials, miniaturization, etc., and to different acquisition scenarios (e.g.,make, modify, customer-furnished, purchased, off-the-shelf, etc.). It is also sensitive to differences in electronic versus mechanical parameters and makes estimates based on each hardware item's unique design characteristics.

Key inputs to SEER-H are weight, volume, material composition, complexity of form/fit, production process, electronic parameters, mission description and quantity/schedule.

12.3.3 Automated Cost Estimating Integrated Tools (ACEIT)

ACEIT is an estimating system consisting of a suite of tools designed to assist cost analysts in arriving at cost estimates, conducting what-if? studies, developing cost proposals and evaluations, conducting risk and uncertainty analysis, and developing cost estimating relationships (CERs). Its primary purpose is financial management. Although ACEIT can be set up to estimate any type of program (hardware, software, O&S, etc.), it has been primarily used to estimate hardware programs. ACEIT is a Joint Service system, sponsored by the Air Force Materiel Command (AFMC) Electronic Systems Center and the U.S. Army Cost and Economic Analysis Center (CEAC). The result of government-sponsored efforts, the ACEIT suite of applications is available to U.S. government organizations with no charge for use (but there is an annual maintenance and support fee). The ACEIT system is a computer based cost model that allows the estimator to start from the ground up with the WBS elements. The system enables the estimator to define the estimate, build the estimate, and to document the estimate using either built in methodologies or one of their own. This is a combination accounting model and CER model. For government users, a CER database is provided to aid the estimator in developing his or her model.

12.4 Summary

The goal of this chapter was to outline the concept of cost models. Accordingly, cost models were defined. CER and cost accounting models are the most common categories of models. There are several models available within each category. Section 12.3 of this chapter described three hardware cost models. Chapter 13 contains examples of operating and support (O&S) cost models. Models are very useful; however, calibration and validation of the model being used is necessary. The estimator can use models to simplify greatly a complex estimating task, provided the estimator is careful in choice of model and understands the model composition and the data input required. In short, a cost model is a tool - the estimating process remains the same.

13.0 OPERATIONS AND MAINTENANCE COST ESTIMATES

13.1 Introduction

Operating & Maintenance (O&M) costs are addressed separately in this chapter because they are generally the largest category of life cycle cost and complexities of estimating them are considerable. This category of life cycle cost has a number of unique estimating characteristics that warrant separate treatment. One of the unique characteristics is that O&M costs occur over many years. (The actual number of years depends on the life cycle of the item being operated and supported.) Predicting trends in material, parts, and personnel costs and benefits over long periods of time is difficult and makes the O&M estimate more sensitive to assumptions than other types of estimates.

The objective of this chapter is to provide an introduction to the complexities of O&M estimating. There is a discussion of the typical O&M Work Breakdown Structure, a general introduction to typical O&M estimating methods, a brief discussion of O&M cost drivers, and a discussion of O&M models. It is beyond the scope of this chapter to discuss specific factors and relationships that have been developed for O&M cost estimating. While myriad exist, their use will vary by the acquisition category and phase of the life cycle. Furthermore, the FAA IAS has been given the mission to develop databases and methods for consistent estimating, and the estimator will need to refer to them for assistance when an actual estimating task is at hand.

O&M cost estimating is much like other kinds of estimating - estimators must follow the general estimating process. The choice of methodologies is the same as for other estimates - analogies, parametric models, and detailed engineering estimates. However, there are some unique aspects to O&M estimating that justify a separate chapter. This chapter has been divided into sections that cover the topics necessary for a basic understanding of O&M cost estimating. The remainder of this section provides a definition for O&M cost estimating. Section 13.4 discusses unique aspects of O&M estimating and addresses types of O&M cost models. Section 13.5 provides selected model descriptions and information on how to choose a model.

13.2 Integrated Logistics Support Discipline

One of the major reasons that O&M cost estimating is particularly complex is that it is affected heavily by the Integrated Logistics Support (ILS) discipline. The FAA AMS defines ILS as "the functional discipline that deals with the relationship of supportability requirements to the operational requirements, and their consideration in the design of products." (FAA AMS, Appendix E) The discussion in this chapter gives an overview of important concepts that allow an estimator to use tools and data in a more educated manner. The use of an ILS management approach means that early in the planning stages of an acquisition, whether it is developmental or off-the-shelf, the ILS requirements are still being defined. At that early planning stage, there are trade-offs between design and ILS characteristics that will affect the total life cycle costs. This presents the estimator with a great challenge, and a need to understand ILS concepts in order to estimate their impact on life cycle costs to support trade-off analyses during the investment analysis phase. The estimator must understand the ILS parameters and how they affect all elements in the life cycle cost estimate, from acquisition to operations to support costs.

13.3 O&M Work Breakdown Structure

System O&M costs are the added or variable costs of personnel, material, facilities, and other items needed for the operation, maintenance, and support of a system during in-service management. For cost estimating purposes, the convention has been to include only those variable costs associated with system activation and steady-state operation. Disposal costs are expenses associated with discarding the system (excluding salvage value) and are seldom estimated and included as part of O&M costs. Table 13.1 shows the typical O&M cost elements. Of course, the precise WBS will vary with the system being estimated, as will the split of direct and indirect costs in the O&M WBS. The WBS in Table 13.1 is based on the ILS elements listed in the FAA AMS. It also uses input from *FAA Order 1810.3, Cost Estimation Policy and Procedures*, which breaks down operating and maintenance costs more clearly into the two categories of operations cost and maintenance cost. It defines operations costs as those costs that are required to operate the system. Maintenance costs are those costs required to support and maintain the system. All costs must be captured in a life cycle cost estimate, so the WBS contains other cost categories to account for the fact that any given estimate may include unique costs. The estimator also must attempt to capture all direct and indirect costs.

Table 13.0 Typical Operating & Maintenance Cost Elements

WBS Element		WBS Sub-element
Operations		Operations Personnel Support Personnel Other Costs • Supply Support • Operational Facilities • Travel and Transportation • Training and Training Support • Computer Resources Support • Other
Maintenance		Maintenance and Logistics Personnel (Depot, Line, and Contractor Support) Maintenance Personnel Other Costs • Supply Support • Maintenance Support Facilities • Packaging, Handling, Storage and Transportation and Travel • Training and Training Support • Computer Resources Support • Technical Data • Spares • Support Equipment and Spares

Table 13.0 Typical Operating & Maintenance Cost Elements, Cont'd

WBS Element		WBS Sub-element
		Direct and Indirect Other Costs • Utilities • Consumable materials and supplies • Operational facilities • Equipment leases • Communications • Travel • Other

The following paragraphs discuss the O&M WBS and typical estimating methodologies. The reader must bear in mind that estimating methodologies for O&M estimates are the same as those for acquisition programs.

Estimates using analogies, parametric tools, and engineering methods are really no different in O&M estimating. The cost driving variables are different, and they will be discussed in a later section of this chapter.

13.3.1 Operations Costs

Operations Personnel Costs

Operations personnel costs are the wages and benefits paid to the full complement of system operators. For the FAA, system operators are typically air traffic controllers. With the current modernization effort underway at FAA, automation is causing reductions in controller needs. A typical question that an estimator will need to ask is what the impact of a proposed investment will be on operator productivity. System utilization rates and the change in operator productivity can then be translated into the number of operator hours required over the life cycle of the system. A wage and benefits rate is then applied to the estimated hours to generate the total costs of operations personnel. This is a typical approach to estimating personnel costs.

Support Personnel

Controllers have supervisors and a support staff whose costs need to be included in the O&M estimate. The support staff includes programmers, administrative staff, and weather coordinators. The methodology for estimating their costs is the same as for operations personnel, although it is also possible to estimate these personnel costs as an overhead rate applied to the operating personnel workyears.

Other Operating Costs

These include supply support, such as consumable materials and supplies (e.g., fuels and office supplies), travel and transportation costs, training and training support costs, and computer resources support. They also include the costs of operational facilities (e.g., leases, equipment leases, energy consumption, and telecommunications costs).

The other operating costs typically are estimated by multiplying a historical factor by an estimate of usage. For instance, travel costs might be estimated by multiplying the number of miles traveled by an average historical travel cost. Facilities costs may be estimated by a dollar per square foot algorithm.

In the training cost area, training facilities, consumables, personnel, and other costs must be included. The number of operations personnel trained, the amount of time they spend in training, and the costs of their travel to and from training must also be considered as part of the annual training cost. As in many other categories of O&M costs, these types of costs typically are estimated using historical factors. Adjustments, of course, may be required if new equipment is easier to maintain or use.

Energy costs usually are computed by multiplying a cost factor (representing the unit cost of energy in some measure of energy consumption such as kilowatt-hours) by the consumption of energy. Energy consumption needs of new equipment typically are estimated by using existing or analogous equipment and by discussions with technical personnel to adjust for the characteristics of the new equipment. Other regular utility costs related to general facilities and not specific equipment are more of an overhead nature and usually have an established usage pattern.

The types of factors used commonly in O&M estimating are based on costs incurred year to year. An organization should collect these costs in a central cost estimating database and update it as cost information becomes available. Of course, historical rates need to be adjusted for changes that might affect them. For example, consider communications costs. The rapid communications technology changes at FAA mean that historical factors probably will need to be adjusted significantly. With a good O&M cost factor database, the cost estimator's task is simplified.

13.3.2 Maintenance Costs

Maintenance and Logistics Personnel

As with the operations cost category, the maintenance cost category includes direct and indirect personnel costs, and other direct and indirect costs.

The maintenance personnel category of support costs includes the costs of personnel at the depot and at the operating level who are performing maintenance, as well as the costs of supervisory and support personnel. Specifically, maintenance personnel costs include the pay and allowances of personnel performing maintenance at depot and operational facilities.

Repair and maintenance performed at the depot is more complex than that performed at the operating organization. Maintenance activities performed at the depot include:

- Overhaul, conversion, progressive maintenance, modernization, conversion, interim rework, modification, and repair of equipment, and
- The manufacture of parts and assemblies required to support the above.

The number of work hours personnel will spend on maintenance is typically estimated based on some maintainability and repair measure such as mean time to critical maintenance. The result is then multiplied by the average hours spent repairing or maintaining the equipment. A personnel cost factor which captures pay and benefits is then applied to the estimated personnel hours. This is a typical method for estimating direct personnel costs.

Maintenance data like this are collected routinely to help plan maintenance schedules. The FAA IAS should capture maintenance data like this to assist in the cost estimating process. This will facilitate the estimating of such costs for systems in the in-service management phase greatly, providing excellent actual data if the data are captured and maintained properly.

For new programs being considered during IA, the existence of a good database will facilitate estimating and will reduce the time required to estimate. Estimating methods will be very similar to methods used for acquisition - the estimator may use a top-level parametric approach or an analogous system as the basis for the estimate.

Logistics Personnel

Logistics personnel costs include the costs of personnel involved in logistics support, procurement, inventory management, technical data support, and the shipping and handling costs for sending items from the organizational level to the depot and back. These costs often are estimated using historical cost factors and parts condemnation rates.

Other Maintenance and Logistics Costs

The following costs reflect other support cost categories that may be of a direct or indirect nature.

- Supply support such as consumable materials and fuels consumed during maintenance
- Facilities expenses (e.g., leases, utilities, etc.)
- Telecommunications
- Packaging, handling, transportation, and travel
- Computer resources support
- Technical data support
- Replenishment spares,
- Support equipment and spares

- Other.

Most of these categories of cost are the same as those found in the operations section. Some of the costs are unique to the support area such as replenishment spares, replacement support equipment, technical data maintenance and support, equipment maintenance and spares.

<u>Replacement Spares for Programs including Support and Test Equipment</u>

Replacement or replenishment spares costs make up the largest portion of sustaining investment costs for many systems. According to the Air Force Cost Analysis Improvement Group, replenishment spare parts include those repairable components, assemblies, or subassemblies required to resupply initial stock or increased stock for reasons other than support of newly fielded end items. Replenishment would include additional stockage due to usage increases.

Replenishment spares cost estimates typically are based on condemnation, which is based on historical maintenance data. Replacement support and test equipment estimates usually are based on factors that capture experience on similar systems.

In summary, O&M cost estimates generally have some reliability and maintainability measure or system usage rate at their core that allows the estimating of number of personnel required to operate and maintain the system. Other costs are often measured by the use of historical factors applied to the baseline estimate of number of operations and support personnel. These historical factors are types of cost estimating relationships, and can range from very simple to quite complex relationships. The O&M estimate requires good usage rate data, as well as logistics and maintenance data. Over time, as an organization gains experience with its systems and services, this type of data can be captured and refined to the point where O&M estimating becomes relatively routine, such as during the in-service management phase. How well an organization tracks, collects, and maintains data on operating and support costs will make a significant difference in the quality of its O&M estimates.

13.4 O&M Cost Estimating

O&M cost estimating is accomplished by applying many of the same estimating principles and methods used in acquisition cost estimating. There are, however, unique aspects of O&M cost estimating that this section explores.

13.4.1 Unique Aspects of O&M Estimating

In O&M estimating, the estimator will find:

- An O&M Cost Estimating Structure (CES) which differs substantially from the acquisition product oriented WBS

- Heavy reliance on predictive models which tie maintenance and manpower considerations together for long range estimates of costs

- Requirements for 10 to 20 years of projected operational use data to use most models effectively

- Need to consider system constraints extending beyond system hardware (i.e., maintenance manpower, operational environment, spares pipeline times, etc.)

13.4.2 O&M Cost Drivers

When preparing an O&M cost estimate (as part of a life cycle cost analysis or as a stand-alone entity), a number of factors unique to the O&M estimate influence the range and magnitude of the costs to be estimated. Regardless of the scope of the estimating task, six factors always should be considered: equipment life cycle, equipment characteristics, system usage, system activation and deactivation, maintenance concept, and relevant cost elements.

The estimator must determine the quantitative and qualitative impact that each of these factors has on the system being estimated. This process is an important part of defining the system in the planning process. Each of the six factors will be discussed in detail in the following sections. Table 13.2 defines common O&M terms to help the reader understand this discussion.

Table 13.0 O&M Terms and Definitions

Term	Definition
Availability	A measure of the degree to which an item is in an operable and executable state at the start of a mission, when the mission is called for at an unknown (random) time.
Condemnation Spare	A spare obtained to replace an item that is rendered inoperable as a result of the prime equipment operation.
Corrective Maintenance	All actions performed, as a result of failure, to restore an item to a specified condition. Corrective maintenance can include localization, isolation, disassembly, interchange, reassembly, alignment, and checkout.
Cost Driver	An item whose share of O&M costs is disproportionately high.
Line Replaceable Unit (LRU)	An on-equipment replaced item that is repaired at a maintenance level higher than that of the flight line.
Maintainability	The measure of the ability of an item to be retained in, or restored to, a specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair.
Mean-Time-Between Demands (MTBD)	A measure of the system reliability related to demand for logistics support. For a particular interval, the total functional life of a population of an item divided by the total number of item demands on the supply system.
Mean-Time-Between Failure (MTBF)	For a particular interval, the total functional life of a population of an item divided by the total number of failures within the population. A basic (usually contractual) measure of reliability for repairable items.
Mean-Time-Between Maintenance-Action (MTBMA)	A measure of the system reliability related to demand for maintenance. For a particular interval, the total functional life of a population of an item divided by the total number of maintenance actions (preventive and corrective).

Table 13.2 O&M Terms and Definitions, Cont'd	
Mean-Time-Between Removals (MTBR)	A measure of the system reliability related to demand for logistics support. For a particular interval, the total functional life of a population of an item divided by the total number of items removed from that system during a stated period of time. The time is defined to exclude removals performed to facilitate other maintenance and removals for product improvement.
Mean-Time-To Repair (MTTR)	A basic measure of maintainability. It is the sum of corrective maintenance times at any specific level of repair, divided by the total number of failures within an item repaired at that level, during a particular interval under stated conditions.
Not-Repairable-This Station (NRTS)	All reported unscheduled maintenance actions that must be sent to a depot or Special Repair Activity (SRA) for repair.
Reliability	The duration or probability of failure-free performance under stated conditions. Reliability is quantified as the probability that an item can perform its intended function for a specified interval under stated conditions.
Repair Cycle Time	The time span (in calendar days) that begins with the removal of an unserviceable item and ends when the item is made serviceable and ready for use.
Repair Level	Level at which maintenance is performed on an item - organizational, intermediate, and depot.
Scheduled Maintenance	Maintenance performed at prescribed points in time to retain an item in a specified condition by providing systematic inspection, detection, and prevention of incipient failures.
Shop Replaceable Unit (SRU)	An off-equipment replaced item, usually part of an LRU. It can be repaired at a repair shop, but usually is repaired at the depot.
Spare Backorders	Spares orders not filled for lack of spares.
Spare Pipeline	The inventory of spares required to meet an established system availability requirement. Inventory is a function of item reliability, repair cycle time, and the established availability requirement.

Equipment Life Cycle

Every item of equipment has an expected useful life determined by one of three factors - technological considerations, mission requirements, or physical characteristics. From a technological standpoint, systems are useful up to the point where technology makes them obsolete. Physical characteristics (e.g., the inherent wear-out mechanisms in systems) eventually make support and repair impractical. For O&M cost estimating, the useful life of a system or an equipment item is considered to be the shortest of its technological, mission, and physical life. Incidentally, the value picked is commonly referred to as economic life. *OMB Circular A-76*, *Appendix C,* provides suggested economic lives for selected assets. In addition, the FAA's Special Topics paper, *Choice of Economic Service Life (ESL) for FAA Analysis Purposes,* dated September 29, 1998, provides guidance on this topic. The FAA paper is available on FAST.

Equipment Characteristics

Defining the system includes determining a number of equipment characteristics that impact O&M costs, such as:

- Design and physical parameters such as weight, size, design approach, degree of modularity (e.g., LRU, SRU)

- Required performance characteristics such as reliability and maintainability, availability, redundancy levels, etc.

- Required interfaces with other systems, equipment, and support equipment

- Unusual training, operations, and support requirements

- Unusual testing or certification requirements

- Required level of technology

- Known, similar systems

Equipment characteristics such as reliability, maintainability, size, and weight often are used in parametric O&M cost estimation, since they are strongly related to O&M costs. MTBF, a measure of system reliability, is used to predict the frequency at which maintenance and supply actions will occur. MTTR, a measure of system maintainability, is used to predict the duration of repair actions. Together, reliability and maintainability information form the basis for determining recurring labor and material costs associated with maintenance and supply.

A number of cost estimating relationships (CERs) use physical attributes such as size and weight in the estimation of inventory and transportation related costs. Examples of such costs are the costs of packaging inventory for shipment between operational and maintenance facilities, handling assets before and after shipment, shipping assets between facilities by various modes of transportation, and storing the assets prior to use.

System Usage

System usage, or usage rate, is defined as the expected or planned use of the asset per unit of time. This rate is expressed in terms of operating hours per month or year, and in most cases reflects steady-state operations. When developing usage rates for a system, the estimator should consider anticipated surges. Surges are intermittent additional usage requirements over and above steady-state rates. An increase (decrease) in usage produces a corresponding increase (decrease) in total O&M cost. Most O&M cost elements vary linearly with usage. For instance, the number of system operator hours will vary linearly with usage. However, there are elements that are more independent of usage. Fixed costs such as item management, facilities, and technical data are constant regardless of usage. Semi-variable costs, such as maintenance personnel, may vary only as specific thresholds are exceeded.

System Activation and Deactivation

FAA's program phases are investment analysis, solution implementation, in-service management, and disposal. Although program phases generally are considered sequential, sometimes overlap occurs, especially between solution implementation and in-service management. During the solution implementation phase, systems normally are deployed on an incremental basis, and activation of systems takes place shortly thereafter. Activation of all systems can take as little as a few months or as long as five to ten years, depending on the program. The start of the activation period generally is considered the beginning of the in-service management or O&M phase. During the activation period, O&M costs increase with the total number of systems activated. This ramping up of O&M costs continues until all systems are activated, concluding the activation period. From this point on, O&M costs level off until the end of the system's economic life. As systems are deactivated during retirement, O&M costs ramp down until all systems are deactivated. Certain cost elements are applicable only during the activation phase; initial transportation and facility construction/preparation are two such examples.

Maintenance Concept

The maintenance philosophy, or maintenance concept, defines the means of maintaining a system or equipment item. It includes maintenance levels to be used with major functions accomplished at each level, basic policies, and primary logistic support requirements. The maintenance concept usually is defined at program inception and is refined over the system design and development phase. The maintenance plan formally documents the maintenance concept, defining in detail the procedures and resources necessary for the support of a system.

Determining the maintenance concept of the system under study requires answers to the following questions:

- Is there a warranty?
- Is the system under a two-level or a three-level maintenance policy?
- Are there any special maintenance activities?
- Does the system receive Interim Contractor Support (ICS)? At intermediate-level? At depot? For how long?

A major component of maintenance concept definition is the structure of maintenance levels to be used in support of the system. Maintenance, both corrective and preventive, may be accomplished at the site where the system is used (organizational level), and/or at a depot or manufacturer's plant facility (depot level). Tasks and functions are divided among any or all of these levels; division is primarily dictated by task complexity, personnel skill level requirements, and special facility needs. Each acquisition program has an Integrated Logistics Support Plan that should identify the maintenance levels.

Also important to the O&M cost estimating process is quantifying the type and level of maintenance resources required for the system. The principle maintenance resources are spares; petroleum, oils and lubricants (POL); support equipment maintenance manpower; facilities; and computer resources.

Once the estimator has defined the major characteristics of the system, the O&M estimator will continue following the normal estimating process. After a plan is in place, the estimator will lay out the estimating structure, which involves outlining the expected O&M cost elements. Then, the estimator will select methodologies and conduct data research and normalization. This step also includes, as the reader may recall, risk analysis.

13.4.3 O&M Risk Analysis/Trade-off Analysis

O&M risk analysis differs from other cost estimating risk analyes because the cost drivers differ. Knowing the cost drivers and understanding their relationship to cost is important in O&M estimating because decision makers, at least early in the life cycle, require information regarding design and O&M cost trade-offs. It is very common to do sensitivity analysis on the key cost drivers to see the trade-off of design factors on cost.

As an example of a cost trade-off, consider the cost sensitivity of an advanced fire control system to both reliability (as measured by MTBF) and maintainability (as measured by repair times). The cost trade-off analysis may show that a shortfall in field reliability of 33 percent (from 33 to 22 hours) will yield a 50 percent increase in maintenance and spares cost ($100 million increase). Conversely a doubling of the repair times at the baseline reliability value will result in only a $15 million (7.5 percent increase) in maintenance and spares cost. Thus, it can be concluded that reliability represents a greater cost risk than maintainability. From this analysis, decision makers might conclude that they should place emphasis on monitoring and improving reliability since greater potential cost savings can be obtained.

Trade-off analyses are also important to logistics decisions impacting the maintenance concept and investments in support resources, such as spares and support equipment. Perhaps the most common trade-off analysis is Level of Repair (LOR) type analysis, also commonly known as two- versus three-level maintenance analysis. Trade-off analysis often involves varying a set of parametric values in order to determine break-even values. For example, equipment reliability (as measured by MTBF) can be varied over a wide range of values while varying the investment cost in support equipment (e.g., quantity of testers at intermediate-level). Two- versus three-level analysis can be conducted under these conditions to determine the equipment MTBF break-even value where one maintenance policy becomes more costly. In general, the lower the support equipment investment, the higher the system MTBF needs to be for a two-level policy to be cost effective.

13.5 O&M Cost Models

Many cost models are used to perform analysis of O&M costs. Most are designed to fulfill a particular need. Some cover life cycle costing overall, while others are devoted wholly to acquisition costing, O&M costing, or a mixture of both. Since describing all O&M related models is beyond the scope of this chapter, the models described in the next section are representative types of models. Section 13.5.2 gives the reader tips on how to find O&M cost models and Section 13.5.3 describes some commonly used models. Finally, Section 13.5.4 gives tips on cost model selection.

In *O&S Cost Estimating - A Primer*, Thomas May warns that "one of the major pitfalls that trap many cost analysts is placing too much emphasis and time on developing a highly complex model that is peculiar to their program."" Fortunately, the cost estimator can often short cut the analysis process by fitting data into existing O&M models. The following sections review general types of O&M models and introduce commonly used models. The focus is on DoD-developed models because this is where much of the activity in estimating major systems acquisition costs has been and therefore where most of the cost models have been developed. It should be emphasized, as mentioned before, that existing cost models generally have been created for specific uses or systems. The following discussions simply provide the estimator with insight into what to look for in building models.

13.5.1 Types of O&M Cost Models

There are three general categories of models used in O&M estimating – the engineering model, the parametric model, and the simulation model. Of course, as in any kind of estimating, it is typical to use a combination of estimating methods. For instance, many engineering models require input that might be the output of a parametric model.

Engineering Model

An engineering model contains a set of equations used to aggregate elements of O&M costs. Costs may be computed by multiplying item costs by quantity, or by applying factors to system parameters, gross costs, and requirements. These models are useful when estimating O&M costs for an entire system; they may sometimes be used to aggregate subsystem O&M costs developed by the more complex parametric models discussed later. An example of an equation you might find in an engineering model follows.

$$WR = [EQL(LH/\ YR)] \bullet (ELE\text{-}Dollars/LH)$$

Where:

PWR = Annual site electrical costs
EQL = Average equipment load in kilowatts per hour
LH/YR = Average electrical load hours per year
ELE-Dollars/LH = Cost of electricity per load hour

Parametric Model

This type of model uses CERs developed from an analysis of historical data of similar systems. The available models range from those that use simple factors to those that employ sophisticated

CERs. The more complex models employ equations relating O&M cost elements to parameters that describe the design, performance, operating or logistics characteristics, or environment of a system. The CER type of model is particularly appropriate at early program stages when only top-level system data are available.

In the case of a factor-based model, factors are developed that relate known input costs or parameters to costs being estimated. The following is a sample equation drawn from a well-known factor based O&M estimating model.

$$TAH = (T\&E\ MH) \bullet (T\&E\ RATIO)$$

Where:
(maintenance programs)
= 0.035 (communications programs)

TAH = Man-hours to system-test modified software
T&E MH = Man-hours to test software in lab
T&E RATIO = 0.030 (controller programs)
= 0.050

More complex analytic models should be used only when there is both a detailed system definition and substantial operational data. Some analytic models work best for specific subsystems rather than an entire system. Below is an example of an equation found in an analytic model.

$$FMC_i = \sum_{m=1}^{12} \left[\left(NCUM_{(k,m)} \bullet OH \bullet NQ_i \right) / \left(\left(1\text{-}OFP_i \right) \bullet G_{(k,m)} \bullet MTBF_i \right) \right] \bullet RRS_i \bullet SBR$$

Where:
FMC_i = Annual maintenance cost for a unit i (where unit i is an LRU, SRU, or sub-SRU)
$NCUM_{(k,m)}$ = Cumulative number of systems installed by month of year k
OH = Average operating hours per month per system
Nq_i = Quantity of unit i required in system
UFP_i = Expected fraction of removals of unit i that will be unverified failures
$G_{(k,m)}$ = Ratio of the system MTBF achieved in month of year k to the initial system
MTBF $MTBF_i$ = Mean Time Between Failure of unit i
RRS_i = Average labor in man-hours required to isolate a failure to unit i, remove it, replace it, and verify the corrective action
SBR = Standard base labor rate in dollars per man-hour

Source Model: Life Cycle Cost Analyzer (LCCA).

Simulation Model

A simulation model uses computer simulation to determine the impact of a system's characteristics, operational constraints, basing concept, maintenance plan, and support resource requirements on operations and support costs. These models generate statistical results based on hardware parameters such as reliability and maintainability. Simulating the system life through analytic models and statistical distributions generates computed O&M costs. These models assume that system performance and maintenance can be simulated with statistical distributions, and require the user to input parameters for the distributions.

O&M estimates often are very detailed estimates simply because of the nature of operations and maintenance, such as the requirement for numerous spares and piece parts. Also, the common predictive models, used heavily for O&M cost estimating, make use of detailed input parameters, thereby producing detailed output.

13.5.2 Finding Information on O&M Cost Models

There are many O&M cost models available, particularly in the DoD. The estimator should research some of the following sources in the search for a good model to use.

The Supportability Investment Decision Analysis Center (SIDAC) is an Information Analysis Center sponsored by the Air Force Materiel Command to increase the effectiveness of logisticians, engineers, and managers engaged in the support of DoD systems. SIDAC has composed a 600-plus page compendium of supportability models, titled *The Supportability Model Catalog.* This two-volume set features detailed information on over 100 active models, including the model's history, scope, mission, reliability, etc. Also enclosed is a list of over 50 models that are considered to be obsolete. Information concerning SIDAC can be obtained from http://www.sidac.wpafb.mil/reprt.html #model.

The Defense Logistics Studies Information Exchange (DLSIE) has the mission of collecting, organizing, storing, and disseminating information relating to the DoD logistics study effort and logistics management documentation. The principal method of disseminating information relating to the current logistics studies effort is through the *Annual DoD Bibliography of Logistics Studies and Related Documents.* DLSIE also produces the *Annual DoD Catalog of Logistics Models.* See http://www.sidac.wpafb.mil/data_sys/dlsie.html for DLSIE information.

13.5.3 Selected Model Descriptions

Table 13.3 Summary of O&M Cost Models

Name of Model	Type of Model	Outputs	Inputs

Logistics Support Cost (LSC) Model http://www.sidac.wpafb.mil/models/catelog/modcat.html	Engineering with CERs	Hardware estimated: primarily avionics Costs estimated: depot maintenance, spares, transportation costs, subsystem to system level	SRU and LRU reliability and maintainability factors
Life Cycle Cost Analyzer (LCCA) http://www.sidac.wpafb.mil/models/catelog/modcat.html	Parametric	Hardware estimated: complex avionics, test equipment, electronic warfare systems Costs estimated: Subsystem to system maintenance, spares, supplies, facilities, training	Significant amount of low level reliability and maintainability data
Cost Analysis Strategy Assessment (CASA) Model http://www.logpars.army.mil/casa	Engineering	Hardware estimated: aircraft Costs Estimated: R&D, acquisition, and all O&M cost elements	Detailed data on maintenance characteristics of hardware LRUs and SRUs, extensive detail on maintenance support structure
Standardization Evaluation Program (STEP) Model http://www.sidac.wpafb.mil/models/catelog/modcat.html	Engineering	Hardware estimated: aircraft avionics Costs estimated: three levels of maintenance costs, software maintenance, support equipment maintenance, replenishment spares, packing and shipping costs	Detailed data on maintenance characteristics of hardware LRUs and SRUs, depot attributes, and support equipment attributes

Table 13.3 Summary of O&M Cost Models, Cont'd

Name of Model	Type of Model	Outputs	Inputs
Network Repair Level Analysis (NRLA) Model http://www.sidac.wpafb.mil/models/catelog/modcat.html	Level of Repair Analysis Model, allows quick and easy sensitivity analysis of LRU, SRU, and support equipment costs	Recommended repair level decision and cost of decision	Detailed data on maintenance characteristics of hardware LRUs and SRUs, depot attributes, and support equipment attributes
Cost Estimating for Logistics Support Analysis (CELSA) http://www.logpars.army.mil/alc/webCelsa/celsa.htm	Simulation delphi technique to estimate the cost of doing an LSA program.	Estimated man-hours required to complete a LSA task or subtask.	Type of acquisition, life cycle phases, support concept, type of system/equipment, complexity of system/equipment
Joint Operating and Support Technology Evaluation (JOSTE) Model http://www.sidac.wpafb.mil/models/catelog/modcat.html	LCC and O&M computations for new or existing systems, any acquisition phase, for various technologies	System sensitivity, total LCC, annual costs, detailed subsystem costs	Can transfer external system databases into the model database for analysis, availability, maintainability, repair level

13.5.4 O&M Cost Model Selection

Each O&M model has unique characteristics and level of acceptance for specific uses. Therefore, one of the most critical steps in preparing an O&M cost estimate is that of selecting an appropriate model or methodology.

- Step 1: Determine Needs

The selected O&M cost model generally will be a compromise of more than one model. However, a cost estimator responsible for a total life cycle cost estimate should review the O&M cost estimating requirements and answer the following questions:

- What output values are required?
- What are the input parameters to which the output values must be sensitive? Are the data available to provide this input?
- Are absolute or relative estimates more appropriate for meeting the study objectives?
- What model has been used successfully and accepted recently for similar work?

- What (if any) model was used previously for estimating the O&M costs of the same system?

- Do the O&M activities for the planned system involve any unusual conditions or assumptions?

- Does official direction or precedent exist with respect to what O&M estimating methods must be used?

Prepare a matrix for evaluating each model on each criterion with respect to the analysis needs.

- Step 2: Select Candidate Models
  Review the available O&M cost model description and give a rating with respect to each evaluation criteria. Review the completed matrix to eliminate totally unsatisfactory alternatives and to select an acceptable or best marginal alternative.

- Step 3: Choose Appropriate Model
  Coordinate the model selection with those who will be major users of the analysis results.

- Step 4: Reevaluate Model Choice
  User needs, support concepts, and models change over time. Therefore reevaluate the model being used every few years to insure that it remains the most suitable for the cost estimates required by the program.

- Step 5: Review the completed matrix to eliminate totally unsatisfactory alternatives and to select an acceptable or best marginal alternative.

- Step 6: Coordinate the model selection with those who will be major users of the analysis results.

13.6 Summary

The decision to field a new system requires a commitment to support that system for years into the future. Decisions to develop, procure, and support new systems are based on many factors, one of which is the projected cost of the systems over their operational lifetime. O&M costs normally constitute a major portion of system life cycle costs and, therefore, are critical to the evaluation of acquisition alternatives.

Operations and support costs include all costs of operating, maintaining, and supporting a fielded system. Estimates of O&M costs generally are prepared using previously developed cost models. As a guideline, this chapter has introduced some of the existing models and provided model selection criteria.

14.0 SOURCE SELECTION

14.1 Introduction

Various qualified sources within the United States have the prerequisite experience and facilities necessary to develop, produce, and deliver major air traffic control systems, as well as provide certain technical and administrative services. Each of these sources has an inherent right to compete for programs involving an expenditure of public funds. Competitive procurements generally are preferred because economic theory supports that competition should lead to the best quality good or service provided at the best price. Source selection procedures must be designed to ensure that all competitive companies seeking to perform a service or deliver a specific system to the FAA receive due consideration.

While the FAR details a specific source selection process, the FAA AMS guidelines for source selection are less structured. The FAA AMS policy allows for deviations from the prescribed FAR methods based on the discretion and sound judgment of the source selection official (SSO) and other members of the integrated product team (IPT). The SSO generally acts as the IPT leader unless designated otherwise.

The FAA believes significant reductions in time and cost to field high quality new products and services can be realized best if all elements of acquisition management (policy, processes, people and their proficiencies, and organization) are reengineered dramatically at the same time into a coordinated, integrated system. This chapter describes a new system that allows the FAA to be innovative and creative in the selection of vendors and the management of contracts. Section 15.2 discusses source selection policy in more detail. Section 15.3 defines the role of cost and price analysis in the source selection. The remaining sections discuss competitive source selections, single source selections, commercial purchases, and unsolicited proposals.

This chapter is intended to familiarize the cost estimator with FAA source selection policy, the source selection process, and types of source selections. Generally, the cost and price analyst participates directly in FAA source selections. Unless cost analysis is required, the cost estimator may have little input into this process. However, the cost estimator needs a general understanding of the process in order to contribute when called upon. The *FAA Pricing Handbook* is an excellent source for more detailed information on the role of the cost and price analyst in FAA source selections.

14.2 Source Selection Policy

The FAA should provide reasonable access for firms interested in obtaining contracts. One FAA goal is to procure supplies and services from sources that offer the most advantageous solution to satisfy the agency"s mission need. In selecting sources, the preferred method is to compete requirements for supplies and/or services among two or more sources. Contracting with a single source is also permitted when it is in the best interest of the FAA. The rationale for contracting without competition, or for limiting the number of sources competing, should be documented in writing.

If not previously announced, the IPT should issue a public announcement informing industry of the FAA's procurement strategy prior to or concurrent with issuance of the initial Screening Information Request (SIR). Each SIR should contain the specific evaluation criteria to be used to evaluate offeror submittals. Cost and price considerations should be an evaluation factor in all award decisions. All SSO decisions should be based on the evaluation criteria established in each SIR. The IPT should document the findings of the evaluation. Debriefings should be conducted with all offerors that request them.

The guidelines provided below are intended to provide the contracting officer (CO) and the IPT with latitude to use any method of procurement deemed appropriate to satisfy the agency's mission. The complexity, dollar value, and availability of supplies and services in the marketplace should be considered. The CO should have warrant authority commensurate with the estimated value of the procurement.

Awards should be made to responsible contractors only. To be determined responsible, a prospective contractor must:

- Have adequate resources (financial, technical, etc.) to perform the contract, or the ability to obtain them

- Be able to comply with the required or proposed delivery or performance schedule, considering all existing business commitments

- Have a satisfactory performance record

- Have a satisfactory record of integrity and business ethics

- Be otherwise qualified and eligible to receive an award under applicable laws and regulations

The CO's signing of the contract should constitute a determination that the prospective contractor is responsible with respect to that contract. When an offer is rejected because the prospective contractor is nonresponsible, the CO should make a determination of nonresponsibility. The CO is given great discretion in making this determination.

14.3 Role of Cost and Price Analysis in Source Selection

The purpose of cost analysis and price analysis in the source selection process is to give the CO a sense of the reasonableness of a proposed price. Cost analysis involves the detailed analysis of cost elements that sum up to the total proposed price. In order for the government to perform a cost analysis, the contractor must prepare a detailed estimate of the proposed price. Under cost analysis, cost and price analysts would evaluate every element in the detailed cost estimate supporting the proposal for reasonableness. The rationale is that if the cost of each element is reasonable, the total cost of all the elements should be as well.

Price analysis involves a comparison of the proposed price with another "competitive" price. The CO must first determine that sufficient competition exists and then compare the price of the proposal to a competitive price to determine reasonableness. If a competitive price exists, it is assumed, based on economic theory that the existence of competition is sufficient to ensure a reasonable price to the government. Therefore, the extent of the analysis required under price analysis is limited to finding a competitive price.

FAA policy employs methods of price and cost analysis to determine fair and reasonable prices for procurement of supplies and services. The selection of the type of data requested and the analysis method should be based on the specific requirements of the procurement. When the CO determines that adequate price competition exists, cost and pricing data should not be requested. In situations where we have established catalog or market prices, prices set by law or regulation, and commercial items, cost, and pricing data should not be requested.

The CO has the discretion to require cost and/or pricing data to assure that negotiated prices are fair and reasonable. Cost and pricing data should be requested only when the CO does not have reasonable assurance that the costs or prices are fair and reasonable based on price analysis or other means of evaluation. When considering the degree to which cost and/or pricing data may be required, the CO should consider the cost and schedule burden on both the agency and the contractor associated with providing the information. When the CO determines that adequate price competition exists, cost and pricing data are not required. In situations where adequate price competition does not exist, the decision to require cost and pricing data and the level of data required should be based on the specific circumstances of the procurement. Adequate price competition may exist when:

- Two or more responsible offerors, competing independently, submit priced offers responsive to the agency expressed requirement

- There is a reasonable expectation, based on market research or other assessment, that two or more responsible offerors competing independently would submit priced offers responsive to the solicitation's expressed requirement even though only one offer is received from a responsible responsive offeror

- Price analysis clearly demonstrates that the proposed price is reasonable in comparison with current or recent prices for the same or similar items purchased in comparable quantities, under comparable terms and conditions under contracts that resulted from adequate price competition

If the CO determines that the competition is not adequate to support the determination of price reasonableness, or the otherwise successful offeror's price cannot be determined to be reasonable, the CO may require cost and price data or information other than cost and price data.

The information and data should be sufficient to support a determination of a fair and reasonable price.

14.4 Competitive Source Selection

This section establishes the FAA's guidance for evaluating and selecting sources for the award of competitive contracts. The steps that involve cost and price analysis are in bold and underlined. The competitive source selection process consists of up to five distinct phases, with the screening phase being the cornerstone. The five phases are listed below.

- Planning
- Screening
- Selection
- Debriefing (as requested)
- Lessons learned

With tailoring by the individual IPT, this process will work effectively for both simple and complex procurements, and will allow for the flexibility required to meet the needs of individual, unique procurements.

14.4.1 Planning

Procurement planning is an indispensable component of the total acquisition process. IPTs are expected to use procurement planning as an opportunity to evaluate the entire procurement process, so that sound judgments and decision making will facilitate the success of the overall program. For procurements not covered by an Acquisition Strategy Paper (ASP), the magnitude and character of procurement planning should be appropriate and proportionate to the complexity and dollar value of the requirement.

For procurements not addressed in a program with an approved ASP, the market analysis is to initiate industry involvement, develop and refine the procurement strategy, obtain price information, determine if commercial supplies exist, determine the level of competition, identify market practices, and obtain comments on requirements. The magnitude and degree of formality of the market analysis should be proportionate to the contemplated procurement. Market analysis may be as simple as a telephone call or as formal as a market survey advertisement to learn of industry capabilities. All market analysis, formal or informal, will be appropriately documented.

The plan for each contemplated procurement or class of procurements should address significant considerations of the procurement action. A procurement plan may cover more than one contract and represents the IPT agreement on the conduct of the procurement. For less complex procurements, plans are not required if deemed unnecessary by the IPT.

14.4.2 Screening

Screening is the process by which the FAA will determine which offeror provides the most advantageous solution to the FAA's procurement needs. The number of distinct screening steps for a particular procurement will vary based on the complexity of the procurement. In some cases, only one screening step may be required; while in others, two or more may be required. Screening occurs whenever the FAA issues a SIR and evaluates the offeror submissions in accordance with the stated evaluation criteria. The purpose of the screening phase is to evaluate offerors and identify the offeror who provides the most advantageous solution.

Screening Information Request (SIR)

Once the public announcement has been issued, the SIR may be released. This starts the competitive process. The SIR is any request for documentation/information/offer made by the FAA for the purpose of identifying the offeror that provides the most advantageous solution. Each SIR should include a definition of need, a request for specific information, a closing date stating when submittals must be received in order to be evaluated, evaluation criteria, a statement informing offerors how communications with offerors will be conducted during the screening, and an evaluation/procurement schedule. SIRs fall into one of the following three categories - qualification information, screening information, and requests for offers. The following table defines these three types of SIRs.

Table 14.1 Types of SIRs

Type Of SIR	Definition
Qualification Information	Qualification information, used to qualify vendors and establish qualified vendor lists (QVLs), should only be requested if it is intended that the resultant QVL will be used for multiple FAA procurements. If the FAA does not intend to qualify vendors for future procurements, qualification information should not be requested.
Screening Information	Screening information allows the FAA to determine which offeror(s) are most likely to receive award, and ultimately which offeror(s) will provide the FAA with the most advantageous solution(s). The screening information requested in the SIR should focus on information that directly relates to the key discriminators for the procurement.
Requests For Offers	A request for offer is a request for a binding offer for supplies or services required by the acquisition. The request for offer may take the form of an invitation for bid, a formal solicitation, a proposed contract, or a purchase order. In instances where the FAA is seeking to make a selection on the initial SIR, an invitation for bid, purchase order, or formal solicitation may be used.

Communications with Offerors

Communications with all potential offerors should take place throughout the source selection process. All communications in the screening, selection, and debriefing phases of source selection are coordinated with the CO. The purpose of communications is to ensure that there are mutual understandings between the FAA and the offerors concerning all aspects of the procurement, including the offeror submittals/proposals. Information disclosed as a result of oral or written communication with an offeror may be considered in the evaluation of an offeror's submittal(s).

Receipt/Evaluation of Submittals

Once offerors have submitted responses to a SIR, the IPT will evaluate the submittals in accordance with the evaluation criteria stated in the initial SIR (and evaluation plan, if applicable). In order to be considered for an award, an offeror must submit a response to the initial SIR, unless the IPT determines it is in the best interest of the FAA not to require it.

The evaluation criteria form the basis by which each offeror's submissions are to be evaluated. Once the criteria have been established and disclosed to offerors, they should not be modified without first notifying offerors and allowing offerors currently participating in the process to revise their submissions accordingly. Each SIR should contain the evaluation criteria to be used to evaluate offeror submittals to the initial SIR. Evaluation criteria should be tailored to the characteristics of a particular requirement and should be limited to the key discriminators in the ultimate selection decision only. The criteria should avoid, whenever possible, the inclusion of detailed subcriteria (or subcriteria in general). Further, efforts should be made to ensure that there are no overlapping criteria. Finally, while cost and price considerations need not be considered in screening decisions, cost and price considerations should be an evaluation factor in all award decision(s) and should be considered as soon as practicable.

The evaluation methodology should be set up to allow for maximum flexibility in selecting the offeror(s) providing the most advantageous solution(s). To facilitate such flexibility, the following should be considered in setting up evaluations:

- Relative weighting between criteria is not required (when relative weighting is used, the relative order of importance between criteria should be disclosed)
- Each SIR may incorporate separate and/or distinct criteria that relate to the specific SIR discriminators
- The use of either adjectival rating or numerical ratings are acceptable
- Comparative evaluations between offerors' proposals/supplies are acceptable
- The IPT should be selective/inventive concerning the screening requirements for document submissions (e.g., oral proposals, sample tests, plant visits, etc.)

- Communications with offerors during the evaluation may help clarify submittals, allowing a fuller understanding of the offeror submittals and a more comprehensive evaluation

- Testing of supplies is encouraged to the maximum extent practical ("try before you buy")

- Award of initial offers to other than the low cost and price offer is allowed

The evaluation will be conducted by the IPT in accordance with the stated evaluation criteria (and evaluation plan, if applicable). The IPT (including any additional required evaluators and/or advisors) should be limited in size and dedicated through completion of the acquisition. The IPT is expected to apply sound judgment in determining appropriate variations and adaptations necessary for individual situations, provided these do not constitute a departure from the basic concepts and intent of the evaluation plan and SIR(s). Communications may be considered in the evaluation of an offeror's submittal(s). Verifiable information from outside sources may be considered in the evaluation. Any such findings should be noted in the evaluation report and disclosed to the offeror during the communication process. The IPT should document the results of the evaluation (including applicable recommendations) and brief the SSO if required/requested.

<u>SSO Decision</u>

Based on a review of the IPT's evaluation report, the SSO may either:

- Make a selection decision (see the selection phase below)

- Make a screening decision by screening those offerors determined to be most likely to receive award, thus continuing the screening phase

- Amend and re-open to initial offerors

- Cancel the procurement

To ensure the integrity of the FAA competitive source selection process, all SSO decisions should be based on the evaluation criteria established in the SIR. All offerors that are eliminated from the competition, based on any screening decision, should both be provided the basis for their elimination within five working days of the screening decision and be informed that they may request a debriefing after contract award. Screening decisions may be made without cost and price considerations.

14.4.3 Selection

The selection decision should be based on the stated evaluation criteria including cost and price considerations and will identify the most advantageous solution. The IPT should brief the SSO (if required/requested) on their evaluation findings. The SSO should document the selection decision in the SSO decision memorandum. (In situations where the CO and the Technical Officer are the only IPT members, the evaluation report and the SSO decision memorandum may be one report.) In making the selection decision, the SSO may accept or reject the IPT's recommendations, provided there is a rational basis on which to reject the IPT's recommendation.

Based on the SSO's decision, the CO will execute a contract with the selected offeror. In order to make an award without further communications with the selected offeror, the FAA must have an acceptable binding offer that may be executed without further communication. If the FAA does not have an offer from the selected offeror, communications with the selected offeror will be required prior to award. If after communications, the FAA and the selected offeror cannot come to an agreement, the FAA may select another competing offeror for communications/award without issuance of further SIRs.

14.4.4 Debriefing (if requested)

Once an award has been made, all offerors who participated in the competitive process should be notified of the award and given three working days from receipt of the award notification to request a debriefing. Debriefings are intended to provide meaningful feedback to offerors on their submission. The purpose of the debriefing is to improve the offeror's ability to successfully compete for future FAA business by discussing the strengths and weaknesses of the offeror's submissions. The debriefing should provide the offeror with the following information:

- The SSO's selection decision
- The offeror's evaluated standings relative to the successful offeror(s)
- A summary of the evaluation findings (excerpts from evaluation summary documentation relating to the specific offeror)

The CO should request detailed questions from the unsuccessful offeror so that the FAA can provide meaningful information during the debriefing. Debriefings should be conducted, as soon as practicable, with all offerors that request them.

14.4.5 Lessons Learned

A lessons learned memorandum is a valuable tool that the IPT can use to relay their procurement experiences to other FAA acquisition personnel. Once an award has been made, the IPT must communicate its learning experiences and highlight those issues/processes used that had significant impact on the procurement. Further, the IPT should discuss what it would do differently to ensure a more comprehensive evaluation and/or a timelier award.

14.4.6 Responsibilities

The responsibilities listed below are intended to be guidelines to ensure a successful evaluation by the IPT. The IPT must apportion these responsibilities to fit the needs of specific procurements.

Source Selection Official

The SSO has full responsibility and authority to select the source(s) for award. The SSO's responsibilities are to:

- Approve the evaluation plan, if required
- Ensure that the IPT is constituted properly and includes all necessary disciplines
- Make all screening decisions and selection decisions

Integrated Product Team

The IPT is responsible for the proper and efficient conduct of the source selection process. The IPT's responsibilities and duties are to:

- Draft all SIRs
- Formulate the evaluation plan for the acquisition, if required
- Review existing lessons learned reports that provide meaningful insights into the acquisition
- Ensure an in-depth review and evaluation of each submitted screening document against the FAA requirements and the stated evaluation criteria
- Prepare the evaluation report (including recommendations when applicable), using sound business judgments to assist the SSO in making the down selection and/or award decisions
- Conduct all debriefings
- Exercise oversight of all procedural and administrative aspects of the procurement;
- Select, as required, advisors to assist the IPT in their evaluation;
- Prepare the documentation, at the SSO's request, that provides the SSO's decision rationale; and
- Prepare a lessons learned memorandum after the source selection has been accomplished.

Contracting Officer

The CO's responsibilities and duties are to:

- Ensure that (as applicable) conflict of interest documentation is obtained from all IPT members, and determine, with legal counsel review, if any conflicts of interest exist
- Ensure that IPT members are briefed on the sensitivities of the source selection process, the prohibition against unauthorized disclosure of information (including their responsibility to safeguard proposals and any documentation related to the IPT's proceedings), and the requirements pertaining to conflicts of interest
- Coordinate all communications with industry
- Participate during the screening, selection, and debriefing phases of source selection to ensure fair treatment of all offerors
- Issue, as required, solicitation amendments, letters, SIRs, and SIR amendments to industry
- Control all written documentation issued to industry
- Ensure that the contract is signed by an official with the authority to bind the company
- With guidance from legal counsel, assure that all contractual documents are in compliance with applicable laws and regulations
- Serve as the SSO if specifically delegated
- Execute contract(s)

<u>The Integrated Product Team Leader</u>

The IPT Leader's responsibilities and duties are to:

- Serve as the SSO, unless otherwise delegated
- Assure that the FAA's program needs are acquired through the source selection process
- Assure that the FAA's SIRs include adequate definition of requirement(s)
- Assure that the technical evaluation is performed in accordance with the stated evaluation criteria and that its findings accurately reflect the offeror's capabilities

- Assure that qualified technical evaluators, if required, are chosen to assist the IPT in the evaluation

- Assure team cohesiveness and effectiveness

Other Source Selection Team Members

Advisors may be appointed by the IPT to provide specific guidance to the IPT when essential expertise is not available within the IPT. Also, nongovernment personnel may be used as IPT members, evaluators, and/or advisors. Notice of any nongovernment participation will be provided in the SIR.

14.5 Single Source Procurement Process

The FAA may contract with a single source when it is determined to be in the best interest of the agency and when the rational basis is documented. The decision to contract with a single source may be made as part of the overall program planning. The rational basis may be approved as part of the Integrated Program Plan (IPP) or as a separate document. If an IPP is not required, the single source justification should be endorsed by the IPT and approved by the CO.

Some level of market analysis should be conducted to support each single source decision, except in the case of emergencies. The method and extent of the analysis will be dependent on the requirement.

After the decision to contract with a single source has been approved, a public announcement will be made, except in the case of emergencies. The purpose of the announcement is both to inform industry of the basis of the decision to contract with the selected source and to ensure that the source selected is in the best interest of the FAA.

A basic contract may be modified either to exercise an option, or to satisfy a follow-on procurement for more of the same supplies/services without seeking additional competition, or obtaining additional single source approvals.

The single source procurement process includes planning, negotiations, award, and lessons learned. The actions for an individual phase within the process may vary to accommodate emergencies, complex requirements, and commercial or follow-on procurements. The procurement process should be adapted to the complexity of each of the procurements.

14.5.1 Emergencies

In rare instances, an emergency situation involving loss of life/property or a threat to national security arises, which requires immediate contracting with a single source. In these instances, the CO may give a contractor verbal authorization to proceed, and the process phases may be consolidated or completed after the fact. As a minimum the CO should, as soon as practical:

- Obtain funding certification

- Issue a public announcement
- Document the single source decision

14.5.2 Non-emergencies

For single source non-emergency procurements, planning includes:

- Analyzing the market and determining potential sources
- Developing an independent FAA cost estimate
- Obtaining funding certification
- Obtaining approval of justification for single source, except for follow-on or exercise of options
- Issuing public announcement

For single source nonemergency procurements, negotiation includes:

- Holding communications with the contractor to reach a mutual understanding of: 1) the requirement, 2) probable contract terms and conditions, 3) contract line item number structure, 4) technical approach, 5) level of current cost and pricing data, and 6) bill of material, labor, and overhead rates
- Issuing a proposed contract, draft modification or solicitation
- Receiving and evaluating the contractor's proposal relative to technical qualitative and quantitative evaluation, cost, and price analysis, audit of rates and bill of material. The level of review and analysis may vary depending upon the complexity of each individual procurement
- Developing a pre-negotiation position
- Negotiating the final terms, conditions, and price. Negotiations may continue up to the point of award and may be terminated at any time by the CO
- Awarding the contract or modification

14.6 Commercial Purchases

The term "commercially available" includes supplies, commodities, equipment, material, or services available in existing commercial markets in which vendors compete primarily on the basis of established catalog or market prices.

The FAA may make purchases from the competitive marketplace for commercially available supplies and services using the simplified purchase method described in the following subsections.

14.6.1 Planning

The purpose of procurement planning is to:

- Determine whether commercially available supplies or services meet the FAA's needs
- Identify potential commercial sources
- Publicly announce requirements.

The CO should ensure that the procurement strategy is consistent with the particular requirement. The degree and extent of planning should be dictated by the characteristics of the particular requirement. Market analysis should be simple and straightforward. It may include information based on personal knowledge, historical purchase information, qualified supplies list/qualified vendors list, commercial catalogs, and local telephone directories.

14.6.2 Sourcing Determination

The CO should solicit an appropriate number of vendors both to ensure competition and to obtain a fair and reasonable price.

14.6.3 Screening

The CO should determine the appropriate screening approach, and format for the vendor's responses (e.g., electronic, written, oral, use of commercial or FAA forms). The CO may conduct communications, as appropriate, to determine acceptable prices, terms, and conditions.

14.6.4 Selection Decision and Award

The SSO's selection decision should be consistent with the FAA's needs. The contract file should document the basis for the award decision.

14.7 Unsolicited Proposals

14.7.1 Policy

The FAA may consider and/or accept unsolicited proposals when it is determined to be in the best interest of the FAA, based on the guidance provided herein.

14.7.2 Guidance

Unsolicited proposals are a valuable means for FAA to obtain innovative or unique methods or approaches to accomplishing its mission from sources outside the FAA. Advertising material, commercial item offers, contributions, or technical correspondence are not considered to be unsolicited proposals. A valid unsolicited proposal must:

- Be innovative and unique;
- Be independently originated and developed by the offeror;
- Be prepared without FAA supervision;
- Include sufficient detail to permit a determination that the proposed work could benefit the FAA's research and development, or other mission responsibilities; and
- Not be an advance proposal for a known agency requirement that can be acquired by competitive methods.

14.7.3 Evaluation of Unsolicited Proposals

Unsolicited proposals should be addressed to:

Federal Aviation Administration
Attn.: Office of Acquisitions, Acquisition Policy, and Procedures, Division (ASU-100)
800 Independence Avenue, SW
Washington, DC 20591

Once received, the FAA contact point determines if the unsolicited proposal:

- Contains sufficient technical and cost information; and
- Has been signed by a responsible official or other representative authorized to obligate the offeror contractually before initiating a comprehensive evaluation.

If the proposal meets these requirements, the contact point promptly acknowledges and processes the proposal. If it does not, the contact point provides the offeror an opportunity to submit the required data.

The FAA is not required to perform comprehensive evaluations of unsolicited proposals not related to its mission. If such proposals are received, the FAA contact point promptly replies to the offeror, states how the FAA interprets the proposal, and why it cannot be evaluated.

14.8 Summary

This chapter provides the cost estimator with the basic concepts of source selection within the FAA. A cost estimator must grasp fully the concepts within the FAA source selection process in general, and have a working knowledge of the competitive and single source procurement processes, commercial purchases, and unsolicited proposals.

Glossary of Terms

Absorption: The process of distributing indirect or overhead costs over any defined cost base such as labor hours, labor dollars, material dollars, or total cost dollars so that at the end of an accounting period, the indirect costs will be absorbed totally.

Accelerated Recovery Method: An approach used to account for breaks in production that assumes that production initially will not follow the same cost improvement curve that was experienced in the first production run.

Acceptance Test: A test conducted by the customer or its authorized agency to determine if an item of material or service complies with the terms of the contract.

Acceptance: The act by an authorized customer representative of assent to ownership of existing and identified supplies, or the approval of specific services rendered as partial or complete performance of the contract.

Accounting Calendar: A calendar that sets forth a company fiscal year divided into 12 months, each of which contains either four or five weeks.

Accounting Document: Any form or original record that evidences a financial or property transaction, e.g., voucher, invoice, bill, contract, receipt, order, requisition, procurement directive, etc.

Accounting Period: A definite period of time (month, quarter, year) for which financial transactions are recorded. In government, may be fixed by legislative or other regulatory action. In business, the accounting year may be fixed to coincide with natural annual seasonal cycle of an enterprise. In any case, an arbitrary establishment that designates the date on which a set of accounting records will be closed. See shop calendar.

Accrued Expenditures: Represent charges incurred for goods and services received and other assets acquired, regardless of whether payment for the charges has been made.

Acquisition Cost: The sum total of all development and production cost for a program. Acquisition cost plus ownership cost equals total life cycle cost.

Acquisition Planning: The process by which all acquisition-related disciplines of an acquisition program are developed, coordinated, and integrated into a comprehensive plan for executing the program and meeting the stated requirements within the cost and schedule boundaries. Acquisition planning normally is associated with the initiation of the program at the beginning of solution implementation, but is also important at other times of the life cycle acquisition process.

Acquisition Program: A sponsored, fully funded effort initiated at the investment decision of the life cycle acquisition management process by the Joint Resources Council. An acquisition program is created in response to an approved Mission Need Statement. The goal of an acquisition program is to field a new capability that satisfies requirements, cost, schedule, and benefits stated in an Acquisition Program Baseline. Typically an acquisition program is a separate budgeted line item and may have multiple procurements and several projects, all managed within a single program.

Acquisition Program Baseline (APB): Establishes the performance, supportability and benefits requirements to be achieved by the acquisition program, as well as the cost and schedule boundaries within which the program is authorized to perform. The APB is a formal document approved by the Joint Resources Council at the investment decision, and in effect, is a contract between the user organization that requires the product of the program, and the provider of the product, the Integrated Product Team.

Acquisition Strategy: The overall concept and approach of an acquisition program for acquiring a capability to meet the requirements and perform within the boundaries set forth in the Acquisition Program Baseline. The strategy considers all aspects of a program such as acquisition approach, contracting, logistics, testing, systems engineering, risk management, program management, impact on facilities, human factors, schedules, and cost. The results are documented in the program's Acquisition Strategy Paper during the early stage of solution implementation.

Acquisition Strategy Paper (ASP): A required document that defines the overall approach by which an acquisition program will be executed during the solution implementation phase. It is a high-level, strategic overview of the technical, management, and procurement approach and is approved by the co-leaders of the appropriate Integrated Management Team. (IMT).

Acquisition Workforce: A wide array of disciplines from specialized areas brought together to have overall responsibility for the life cycle of the acquisition system. Skills include operational analysis, contracting, testing, logistics, cost estimating, budgeting, program planning, operational research, risk analysis, and also includes engineering and technical expertise in product lines.

Actual Cost of Work Performed (ACWP): The actual booked or accrued costs of a specific piece of work expressed in dollars.

Actual Cost: A cost sustained, in fact, on the basis of costs incurred as opposed to a standard, predetermined or estimated cost. Actual costs to date include cost of direct labor, direct material, and other direct charges, specifically identified to appropriate cost accounts as incurred, and overhead costs and general administrative expenses reasonably allocated to cost accounts.

Actual Values: Customer reported actual value at the contract level reconcilable to the company book of accounts.

Actuals: The labor hours, material costs, and other costs expended on a program unit or item through a specific period of time. Used interchangeably with actual costs.

Administrative Costs/Expense: Those costs that have to do with phases of operations not directly identifiable with the production, sale or financing of operations. They are costs incurred in connection with policy formation and the overall direction of a business. Salaries of major executives and general services such as accounting, contracting, industrial relations, etc. are included in this category.

Advance Payment: An advance of money made to a contractor prior to but in anticipation of performance under a contract or contracts. This money generally must be deposited in a special account and accounted for separately from other funds. It is to be distinguished from progress payments.

Advance Procurement: An exception to the full funding concept, advance procurement provides the means for funding long lead-time components in advance of the fiscal year in which the related end item is procured.

Advanced Buy: Procurement that provides for obtaining long lead-time components in advance of the fiscal year in which the related end item is to be procured. Advanced buy is an exception to the full funding policy.

Advanced Development: A part of research and development that normally involves hardware designed for test or experimentation, as distinguished from hardware designed and engineered for eventual service use. Subsystems and technology frequently are proved out in advanced development before they are accepted for incorporation in full-scale development. Advanced development effort typically is managed by a laboratory or research organization.

Affordability Assessment: The process of assessing the affordability of each candidate solution developed in the investment analysis phase against all existing programs in the agency's financial baseline for the same years. Standard criteria are used to determine the priority of the candidate program in relation to all others. If the amount of funding available for the years in question is insufficient, offsets from lower priority programs are identified. Affordability assessment also is performed when considering acquisition program baseline changes for existing programs that involve an increase in the cost baseline and the need to reallocate resources.

Agency: (1) Government - refers to a department, commission, board, or other independent office in the executive branch of the government. (2) Public - refers to any part of a Federal, state, or local government that is responsible for carrying out a public program.

Algorithm: A set of ordered procedures, steps, or rules usually applied to mathematical procedures and assumed to lead to the solution of a problem in a finite number of steps.

Allocation: (1) Financial - a method or combination of methods that will result in a reasonable distribution of indirect or overhead costs. In deciding upon appropriate allocation bases for overhead costs, tests of benefits received, equity, and logic are decisive factors. (2) Engineering - the methodical division of a requirement, such as volume, weight, reliability, or maintainability downward to constituent system, subsystems, etc., in such a manner that each is assigned a part of the requirement, which is appropriate to its hardware level and state-of-the-art. (3) Government - an official funding document that represents cash for commitment and obligation.

Allotment/Allotted Funds: (1) An authorization by the head or other authorized employee of a customer agency to incur obligations within a specified amount pursuant to an appropriation or other statutory provision. (2) The amount of funds the government makes available to cover billings from the contractor relative to a given contract.

Allowable: That portion of costs, including overhead, recognized as reimbursable is called allowable for the purposes of costing government contracts.

Analogy Estimating (Comparative): An estimating method that uses actual costs of a similar existing or past program- and adjusts for complexity, technical, or physical differences to derive the new system estimate. Also referred to as analog and analogous cost estimates.

Analysis: A systematic approach to problem solving. Complex problems are simplified by separating them into more understandable elements.

Annual Appropriation: Also known as one-year appropriations. This appropriation generally is used for current administrative, maintenance, and operational programs, including the procurement of items classified as expense. These appropriations are available for obligation for one fiscal year.

Annual Funding: The current congressional practice of limiting authorizations and appropriations to one fiscal year at a time. The term should not be confused with two-year or three-year funds that permit the Executive Branch more than one year to obligate the funds.

Apportionment: A determination by the Office of Management and Budget as to the amount of obligations which may be incurred during a specified period under an appropriation, contract authorization, other statutory authorizations, or a combination thereof.

Appropriation: An annual authorization by an act of congress to incur obligations for specified purposes and to make payments out of the U.S. Treasury.

Assembly And Checkout: Those activities related to assembly, installation, integration, and testing occurring up to the time of turnover of an item to the customer.

Assembly: (1) A number of parts or subassemblies, or any combination thereof, joined together to perform a specific function. (2) Major section of an aircraft, missile, spacecraft, or other structure.

Assumption: A supposition on the current situation, or a presupposition on the future course of events, either or both assumed to be true in the absence of positive proof. In the absence of firm ground rules, assumptions are established to help define the conditions upon which an estimate will be premised.

Attrition: The reduction in a work force caused by loss of personnel and material - may be due to transfer, resignation, layoff, or retirement.

Attrition Rate: A factor, normally expressed as a percentage, reflecting the degree of losses of personnel or material due to various causes within a specified period of time.

Audit: The systematic examination of records and documents and the securing of other evidence by confirmation, physical inspection, or examination.

Audit Report: A report prepared as the result of an audit or examination of the accounts, records, estimate detail, or administrative operating policies, procedures and practices of a corporate entity, contractor, agency, or individual.

Authorization: An annual act of congress that authorizes a specific amount of funding for appropriation based upon a review of program and management considerations to proceed on a project. Must be accompanied by an appropriation to be viable.

Availability: A measure of the degree to which an item is in an operable and committable state at the start of a mission when the mission is called for at an unknown (random) time.

Average Lot Cost: The amount resulting from the division of the costs accumulated against a lot by the number of units in that lot.

Back Order: The quantity of an item requisitioned by ordering activities that is not available for issue immediately, but is recorded as a stock commitment for future issue.

Backlog: Generally, the value of unfilled orders at a particular point in time.

Balance to Complete Estimates: The labor, materials, and costs necessary to complete a program/project from a given point in time. Combined with actuals to derive the total cost.

Base Period: The period of time for which rates and factors were determined for projecting future estimates.

Base Year Costs/Dollars: Dollars that are expressed in the economic condition of a specific year and do not include escalation or inflation for future years. A base year dollar reflects the "purchasing power" of the dollar for the specified base year.

Base Year: Term used to define a year that is (1) the economic base for specific dollar amounts; (2) a fiscal year whose mid-point is selected as a reference point for computing an index; or (3) the starting point for the application of escalation factors.

Base: (1) An area or locality from which operations are projected or supported. (2) The denominator (direct labor hours/dollars, material dollars, units, weight, etc.) used in the development of a factor/rate.

Base/Basic Labor: A term referring to "hands on" or "doing" labor hours. These labor hours form the base for the application of factors for supporting labor functions.

Baseline Changes: Significant changes to, or breaches of, the baseline (cost, schedule, performance, and benefits) (program growth) that cause a need for a "mini" investment analysis and an investment decision by the JRC.

Basic Agreement (Or Basic Ordering Agreement): A written instrument between a procuring activity and a contractor that sets forth negotiated contract clauses that shall be applicable to the procurements entered into between the parties for a specified period of time.

Benefit/Cost Analysis: An analytical approach to solving problems of choice. It requires (1) the definition of objectives; (2) identification of alternative ways of achieving each objective; and (3) the identification for each objective or alternative, which yields the required level of benefits at the lowest cost. It often is referred to as cost-effectiveness analysis when the benefits of the alternatives cannot be quantified in terms of dollars.

Best and Final Offer (BAFO): The final proposal submission after conclusion of negotiations in a source selection acquisition. At the request of the contracting officer, submittals are received from all offerors in the competitive range at a common cut-off date.

Best Time: The highest level of performance expected when the 100 percent efficiency conditions are limited. Best time normally is expressed in the same unit of measure as the standard.

Best-Fit-Line: A line which passes through a group of data point values in a manner which best represents the trend of the data points. The “least squares best fit method” is used frequently to compute this line-of-best-fit.

Bias: An effect that systematically distorts a statistical result. The distortion may be small enough to ignore or large enough to invalidate the results. It may be due to the sample design, the sampling process, or the estimating technique. Analysts try to use unbiased techniques.

Bid Bond: A guarantee furnished by a prospective contractor assuring that he will enter into a contract on which he has bid if it is awarded to him.

Bid Price: A price offered subject to immediate acceptance for a specific amount of goods and/or services.

Bid: Normally implies a response to a customer-initiated request for proposal or quotation that may be competitive or of a sole-source nature. In past years, a bid usually was simpler in documentation requirements than a proposal. However, in current usage the term bid often is used synonymously with a proposal.

Bidders’ Conference: Also known as pre-proposal conference - a conference that may be held to brief prospective offerors after a solicitation has been issued, but before offers are submitted. Generally, the government uses these conferences in complex negotiated acquisitions to explain or clarify complicated specifications and requirements.

Bidding And Proposal Expense: That activity or offer directed toward the preparation and presentation of solicited or unsolicited proposals with the intent of obtaining a customer funded contract for a new or improved product or service, or to obtain contractual support for research and development effort.

Bill Of Material (BOM): A descriptive and quantitative listing of all the materials, supplies, parts and components required to produce a complete end item of material, assembly or subassembly, to overhaul or repair such an item, or to construct or repair a structure or facility item.

Black Box: (1) Electronic, electrical, or electromechanical assembly that is part of a system or subsystem. (2) A generic term for classified hardware.

Block Buy: Buying more than one year's requirements under a single year's contract. A total quantity is contracted for in the first contract year.

Boiler Plate: A popular/slang term used to describe (1) government pre-printed text for use in contracts or RFPs; (2) standard contract clauses as defined in government procurement regulations; (3) standard terms and conditions used in purchase orders; and (4) standard words used in proposals.

Bookkeeping: The recording of financial data for the purpose of accounting, usually under the system known as double-entry bookkeeping and under an accounting system designed by an accountant.

Brassboard Configuration: A pre-prototype working model used to demonstrate the operating functions of a design concept. Brass board hardware generally refers to electronic components and is not constrained to weight and volume parameters specified for the design of the final operational article.

Breadboard: A model constructed to demonstrate the workability or principle of design; a preliminary assembly used to prove the feasibility of a device, circuit, system, or principle with regard to the final configuration.

Breakdown (Price, Cost, Etc.): An orderly listing of the cost categories or elements that constitute the total.

Break-even Point: The unit at which the cumulative product sales equal or recover the cost of the investment required to produce the product.

Budget: (1) A statement, in financial terms, of projected or expected operations of an accounting entity for a given period. (2) The portion of the total cost allocated or assigned to a particular task or set of tasks.

Budget At Completion (BAC): The total of Budgeted Cost of Work Scheduled (BCWS) over the life of the program.

Budget Authorization: An administrative action, normally within the chain of command or management, approving an operating budget for use in execution of a program or programs.

Budget Cycle: (l) The period of time that elapses from the initiation of the budget process to the completion, thereof, for a particular fiscal year. (2) Government - the complete cycle that covers planning, programming, budgeting, enactment and execution phases.

Budget Estimate (or Budgetary Estimate): (1) Government - an estimated fund requirement for any element included in a budget. Collectively, all estimated fund requirements for a particular operating agency or component or consolidation thereof. (2) Contractor - the approximate cost of performing, or completing, the effort required in fulfillment of the contractor's understanding of the job to be performed. Contractor budgetary estimates are not binding contractually, usually have a higher allowance for risk, and are less accurate than contractual bids.

Budget Estimate Submission (BES): The formal submission of a program's financial requirements that becomes the basis for the President's Budget.

Budget Year: The fiscal year that is the subject of new budget estimates.

Budgeted Cost Of Work Performed (BCWP): Also known as earned value, it represents the portion of the work completed with the value in dollars based on the Budgeted Cost of Work Scheduled (BCWS).

Budgeted Cost Of Work Scheduled (BCWS): The amount of money put aside to do 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 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 usually is small and the time period relatively short.

Budgeting: The process of translating approved or negotiated resource requirements (manpower and material) into time-phased financial targets or goals.

Budgeting To Most Likely Cost: The process of including within a budget the most likely or most probable estimate of the cost that ultimately will be realized for a program, project, or task.

Built In Test Equipment (BITE): Test equipment manufactured and assembled as an integral part of the end item or system.

Bulk Material: Material stored and issued by volume, footage, weight, or liquid measurement such as petroleum, bar stock, and lumber.

Calendar Year: The period of time from January 1 through December 31, distinguished from fiscal year.

Calibration: In terms of cost models, a technique used to allow application of a general model to a specific subset of its database. It involves the computation of an adjustment factor to compensate for variations between historical cost and predicted cost.

Call Contract: A contractual arrangement wherein services or personnel are provided on an open contract at the discretion and option of the buyer. Terms and conditions of the contract, which include pricing and scheduling, are predetermined or the methodology for determining them is established. Usually used on spare orders.

Cancellation Ceiling: The maximum amount that the FAA will pay the contractor which the contractor would have recovered as a part of the unit price, had the contract been completed. The amount that actually is paid to the contractor upon settlement for costs not recovered (which can only be equal to or less than the ceiling) is referred to as the cancellation charge. This ceiling generally includes only nonrecurring costs.

Cancellation: The cancellation of the total requirements of all remaining program years of a multi-year contract. Cancellation results when the CO notifies the contractor of non-availability of funds for contract performance for any subsequent program year, or fails to notify the contractor that funds are available for performance of the succeeding program year requirement.

Cannibalize: The art of removing serviceable parts from one item of equipment to install them on another item of equipment to restore the latter to a serviceable condition.

Capital Investment Plan (CIP) Cycle: A five-year capital investment planning period.

Catalog Estimating: An approach, also known as handbook estimating, using handbooks, catalogs, and other reference books that are published with price lists for standard, off-the-shelf items.

Ceiling: The maximum amount on an incentive type contract that usually is expressed as a percentage of the contract target cost.

Certified Tool List: A list of the special tools produced by a supplier. This list is prepared and submitted by the supplier as evidence of completion of tool fabrication or rework. Also, it confirms review and approval of the tools.

Change Of Scope: A customer-directed change pertaining to deliverable items or contract tasks.

Change Order: A written order, signed by the contracting officer, directing the contractor to make changes under a clause of a contract.

Charge Number: The sequence or series of digital and/or alphabetical code numbers designed for controlling and sorting accounting information for cost accumulation, reporting, and management use. The charge number also provides cost information in relation to contract work breakdown structure and organization identity.

Claim: A claim is a written demand or assertion by one of the contracting parties seeking, as a matter of right, payment of money in a sum certain, the adjustment or interpretation of contract terms, or other relief arising under or relating to the contract. A claim arising under a contract, unlike a claim relating to that contract, can be resolved under a contract clause that provides for the relief sought by the claimant. However, a voucher, invoice, or other routine request for payment that is not in dispute when submitted is not a claim. The submission may be converted to a claim, by written notice to the CO, if it is disputed either as to liability or amount or is not acted upon in a reasonable time.

Clarification Request (CR): Used in source selection, a request formally communicated to an offeror to ask for further clarification of information provided in the offeror's proposal.

Closure: (1) Close out of contract on which performance has been completed or deactivation of an installation or facility. (2) The process of finalizing negotiations.

Coefficient of correlation (R): See correlation coefficient.

Coefficient of determination (R^2): A measure used in regression analysis. Values range from -l to +l and are calculated by dividing the variation in Y explained by the regression equation by the total variation in Y. The closer r2 is to +1 or -1, the greater the variation is explained by the relationship between the dependent and independent variables.

Commercial Item: An item or service that has been sold at established catalog or market prices.

Commercial-off-the-shelf: An item or service that has been developed for sale, lease or license to the general public. The item or service currently is available at a fair market value. This is distinct from a commercial item in that it may not have already been sold at established catalog or market prices.

Commitment: (1) An offer or proposal to a customer or a supplier, or acceptance of an offer from the customer, leading to the execution of a contractual instrument or purchase order. (2) A firm administrative reservation of funds, based upon firm procurement directives, orders, requisitions, or requests which authorize the creation of an obligation without further recourse to the official responsible for certifying the availability of funds. (3) A term used in business, where it means a contract or other legal obligation for goods or services to be furnished.

Common Item: (1) An item of material required for use by more than one activity. (2) Sometimes loosely used to denote a consumable item except repair parts or other technical items. (3) Readily available commercial items. (4) Items used by two or more government agencies of similar manufacture or fabrication that may vary between the services as to color or shape (as vehicles or clothing). (5) Any part or component, which is required in the assembly of two or more complete end items.

Common Support Equipment (CSE): Ground support equipment in general use required to support and maintain a particular type or category of equipment or other hardware.

Commonality: The use of identical parts, components, subsystems, or systems to achieve economies in development and manufacture.

Communications: Any oral or written communication between the FAA and an offeror that involves information essential for understanding and evaluating an offeror's submittal, and/or determining the acceptability of an offeror's submittal.

Comparative Cost Estimating: Comparing the job to be done (or portions of it) to all or parts of a previously completed job for which valid and comparable cost and technical information is available. This method of cost estimating can be applied to any level of work, detailed or summary, for estimating the cost-producing elements, or the cost itself. Generally, a proficient cost estimator cannot help but use this method to some extent, consciously or unconsciously, because his experience and natural thought processes force this measurement or appraisal. In comparative cost estimating, complexity factors or ratios may be used and applied to the known costs or cost elements to create the estimates - if enough information is available on the completed program to make a valid comparison of the new with the old program. Other terms, given this kind of estimating, are specific analogy, cost history, estimating by comparison, comparative analysis, key factor estimating, and delta from a previous estimate. See analogy estimating.

Comparative Studies: Studies conducted for the purpose of comparing candidate solutions to a problem normally involving technical, performance, and cost comparisons.

Competition: An environment of varying dimensions relating to buy-sell relationships, which the buyer induces, stimulates or relies on conditions in the marketplace, that cause independent sellers to contend for the award of a contract and/or the sale of the product.

Competitive Negotiation: A negotiated procurement that is initiated by a request for proposals, which sets out the customer (or buyers) requirements and the criteria for evaluation of offers. It contemplates the submission of timely proposals by the maximum number of possible offerors; usually provides discussion with those offerors found to be within the competitive range. Competitive negotiation concludes with the award of a contract to the one offeror whose offer, price and other factors considered, is most advantageous to the customer (or the buyer).

Competitive Range: A technique used in the source selection process to eliminate certain contractors who do not meet minimum requirements. The customer on the basis of technical, management, price considerations, and other salient factors determines the competitive range. Unless exempted by circumstances prescribed by departmental or agency regulations, the contracting officer must conduct written or oral discussions with all responsible offerors who submit proposals within the competitive range.

Completeness: A source selection criteria used to evaluate the responsiveness of the offeror in providing all RFP requirements, SOW items, and traceability of estimates.

Complexity Factor: A judgment or experience factor to evaluate the degree of unknowns, difficulty of design or manufacturing anticipated with a new end item as compared to a similar item.

Component: An article, which is normally a combination of detailed parts, subassemblies, and assemblies, is a self-contained element of a complete operating equipment end item, and performs a function necessary to the operation of that equipment. It is normally a WBS element of the second lower level below a subsystem (that is, below an equipment item).

Composite Cost Per Hour Rate: The total estimated direct hours divided into the total estimated dollars.

Composite Curve: A cost improvement curve calculated from end-item level data that incorporates the influence of all functional cost categories.

Composite Index: An index that measures relative change from the base period for a group of closely related items.

Composite Labor Rate: The weighted average labor rate by skill mix, percentage of effort or time phasing of any group, organization, or project.

Composite Rate: A labor, overhead or other rate that has been weighted to account for a mix of different elements.

Concurrency: The schedule overlap between the development and production efforts of a program.

Concurrent Spares: Those spare parts that can be released and produced simultaneously with end times of the same or substantially the same configuration or model.

Condemnation Spare: A spare obtained to replace an item that is rendered inoperable as a result of the prime equipment operation.

Confidence Level: The degree of probability that actual cost will fall within an expressed interval, e.g., + or –5 percent of the estimated cost.

Configuration: The complete technical description required to fabricate, test, accept, operate, maintain, and support systems/equipment logistically.

Configuration Item (CI): An aggregation of hardware or computer programs or any of their discrete portions which satisfies an end use function and is designated by the government for configuration management. CIs may vary widely in complexity, size and type, from an electronic system to a test meter.

Consideration: (1) That which accrues to a company in return for a benefit passing from the company to another organization or individual outside of the company. It may take the form of money, material, a legal right, goodwill, or other compensation. (2) A negotiation term used to denote that the points and arguments have been included in an offer.

Constant Year Dollars: A phrase reflecting the dollar purchasing power for a specified year. 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. A statistical series is expressed in constant dollars when the effect of changes in the purchasing power of the dollar has been removed.

Constraints: Limitations of any kind to be considered in planning, programming, scheduling, implementing, or evaluating programs or systems.

Constructive Change: During contract performance, an oral or written act or admission by the contracting officer or other authorized customer official, which is of such a nature that it is construed to have the same effect as a written change order.

Consumable Material: Material, which after issue from stock is consumed in use or which, while having continuing life, becomes incorporated in other property, thus losing its identity.

Consumption Rate: The actual or estimated quantity of an item consumed or expended during a given time interval, expressed in quantities by the most appropriate unit of measurement.

Consumption-Type Items: Those items which are either consumed in use or which lose their original identity during periods of use by incorporation into or attachment upon another assembly.

Contingency: An allowance or amount added to an estimate to cover a possible future event or condition arising from presently known or unknown causes, the cost outcome of which is indeterminable at a present time.

Contingency Analysis: Repetition of an analysis with different qualitative assumptions - e.g. how well will equipment perform on different terrain/type of conflict, etc.

Contract (Program) Close Out: The costs associated with the orderly close out of a contract. Includes costs for disposition, scrap, facilities deactivation, etc.

Contract Administrator: The individual duly authorized by the appropriate authority in the department or contractor to administer the contract or a professional employee of a company whose function is the administration of contracts.

Contract Amendments: A contract modification that is accomplished by the mutual action of the parties. See supplemental agreement.

Contract Authorization: A statutory authorization under which contracts or other obligations may be entered into prior to an appropriation for the payment of such obligations.

Contract Bond: A guarantee, backed by cash or other security, of the faithful performance and fulfillment of all the undertakings, covenants, terms, conditions, and agreements contained in a contract. It may include a guarantee of the payment of all labor and material bills incident thereto. These two guarantees may be written separately; the first as a performance bond; the second as a payment bond.

Contract Ceiling: A value established in the contract beyond which the government has no obligation to pay.

Contract Change Notification (CCN): A formal authorization by the contracting officer for a change or variance to an existing contract.

Contract Change Proposal (CCP): A change proposal which may use or have an effect upon end items of operationally configured equipment, but which does not affect the physical, function, performance, maintenance or logistics characteristics of the system, as contracted for acceptance and delivery on an end item or system basis. Examples are changes to program schedule or redirection, data, drawings, documentation, exhibits, etc., which by their nature are not subject to engineering change proposal action.

Contract Data Requirements List (CDRL): A customer listing used to identify and establish the data and documentation required by a contract. Such a list is made a part of the contract.

Contract End Item (CEI): A deliverable equipment or facility that is accepted formally by the procuring agency, in accordance with requirements in a CEI detail specification.

Contract Line Item Number (CLIN): A contract instrument used to administer and control contracts; authorize time limit or content limit portions of a contract; administer funds and appropriations on a contract; procure options for additional quantities or services; and pay contractors for work performed in a contract. Contract line items usually have a numerical designator (i.e., 0001, 0002, 0003, etc.) with sub line items being identified by numerical/alpha designators (000lAA, AB, AC, etc).

Contract Modification: Any written alteration in the specification, delivery point, rate of delivery, contract period, price, quantity, or other contract provisions of an existing contract, whether accomplished by unilateral action in accordance with a contract provision, or by mutual action of the parties to the contract. It includes bilateral actions such as supplemental agreements and amendments, and unilateral actions such as change orders, notices of termination, notices of the exercise of a contract option, and change in payment office or administrative responsibility.

Contract Pricing Proposal: The instrument required of an offeror for the submission or identification of cost or pricing data.

Contract Profit: Covers both profit and fee, target profit, or profit as stated in a fixed price type of contract (FFP, FPI). In a cost form of contract (CPFF, CPIF), it is called fee.

Contract Settlement: An adjustment of a contract termination claim, either by mutual agreement or by unilateral action by the contracting agency pursuant to regulations and contract terms. In its broadest sense a settlement of a contractual dispute.

Contract Technical Services (CTS): Services contracted for by the customer with a manufacturer or commercial concern for the purpose of indoctrinating personnel in new and complex equipment introduced into the inventory; or for advising and instructing personnel in techniques used to install, engineer, maintain, supply, and operate systems and complex equipment when skills within the customer organization or agency are inadequate or not completely operational.

Contract Termination: The cancellation, in whole or in part, of work under a prime contract or a subcontract, thereunder, for the convenience of, or at the option of, the Government. See termination.

Contract Type: Refers to a specific pricing arrangement employed for the performance of work under contract. Specific pricing (or compensation) arrangements, expressed as contract types, including Firm Fixed-Price (FFP), Fixed-Price Incentive (FPI), Cost-Plus-Fixed-Fee (CPFF), Cost-Plus-Incentive-Fee (CPIF), and several others. Among special arrangements that use fixed-price or cost-reimbursement pricing provisions are contract types called indefinite delivery contracts, basic ordering agreements, letter contracts and others.

Contract Underrun/Overrun: The amount by which the estimated final cost is less than/or exceeds the contract target cost.

Contract Work Breakdown Structure (CWBS): The work breakdown structure that addresses only those WBS elements applicable to a specific contract.

Contract: (1) An agreement, enforceable by law, between two or more competent parties, to do or not to do something not prohibited by law, for a legal consideration. (2) Any type of agreement or order for the procurement of supplies and services. It includes unqualified notices of award; contracts of a fixed price, cost, cost-plus-a-fixed fee, or incentive-type contracts. Also may provide for the issuance of job orders, task orders or task letters thereunder; letter contracts and purchase orders. It also includes amendments, modifications, and supplemental agreements to the basic contract.

Contracting Officer: Any officer or civilian employee of a government department or agency who, in accordance with procedures prescribed by each respective department, has been or shall be designated a contracting officer with the authority to enter into and administer contracts and make determinations and findings with respect thereto, or any part of such authority. Sometimes referred to as Procurement Contracting Officer.

Contractor Cost Data Reporting (CCDR): A reporting structure used in pop procurements consisting of specific definitions, requirements, and formats.

Contractor Furnished Property (CFP): Property, other than government furnished and contractor owned property (i.e., acquired by the contractor at the contractor's expense), used by the contractor in the performance of a contract. The contractor at the government's expense acquires CFP.

Contractor: Term used in procurement to denote the party performing the task, service or providing the equipment, hardware, facility, or end item called out in a contract.

Contractor Support: An arrangement whereby a contractor furnishes required material and maintenance of an end item or system pending assumption of supply support by the FAA. Often called interim contractor support (ICS) or contractor maintenance support (CMS). This arrangement covers a specific time or period of years.

Contractual Instrument: A written contract or modifications to the contract. By common usage a portion of a contract as a contract line item, provision, or attachment.

Controlled Item: Any item of material over which proper authority exercises close supervision of distribution, issue, and use because it is scarce, costly, or of highly technical, classified, or hazardous nature.

Coordinates: The two elements of reference of any point on a grid chart. One element, the abscissa (or X), is measured by horizontal distance from a vertical perpendicular axis. The other element, the ordinate (or Y), is measured by vertical distance from a horizontal base line. Abscissas to the right of the vertical axis are positive - to the left, negative. Ordinates above the horizontal base line are positive - below, negative. The point of intersection of the axis, called the point of origin, has the value zero for both abscissa and ordinate. Generally, curves relating to estimating and economic statistics are confined to one quadrant with both abscissas and ordinates positive.

Correlation: Statistical technique used to determine the degree to which variables are related or associated. It does not prove or disprove a causal relationship.

Correlation Coefficient: A mathematical measure of the degree of association between two variables in a series of observations (on the assumption that the relationship between the two variables is a straight line). Its value must lie between +l and -1, either extreme denoting complete dependence of one variable on the other, and 0 denoting no association. A plus sign shows that an upward movement of one is accompanied by an upward movement of the other); and a minus sign shows that an upward movement of one is accompanied by a downward movement of the other. Normally expressed as “r.” See coefficient of correlation.

Cost: The amount paid or payable for the acquisition of materials, property, or services. In contract and proposal usage denotes dollars and amounts exclusive of fee or profit (i.e., cost does not include profit or fee). Although dollars are normally used as the unit of measure, the broad definition of cost equates to economic resources; i.e., manpower, equipment, real facilities, supplies, and all other resources necessary for project, program, or agency support systems and activities.

Cost Account: The lowest level of a work breakdown structure in which work is described and budgeted. Costs are accumulated at this level, normally by functional category.

Cost Accounting: That branch of accounting dealing with the classification, recording, allocation, summarization, and reporting of current and prospective costs. Included in the field of cost accounting are the design and operation of cost systems and procedures; and the determination of costs by department, function, responsibility, activity, product, territory, periods, and other units. Also included are the comparison of costs of different periods of actual with estimated or standard costs and of alternative costs, and the presentation and interpretation of cost data as an aid to management in controlling current and future operations.

Cost Accounting Standards (CAS): Cost accounting principles (standards) established by the Cost Accounting Standard Board for the purpose of achieving uniformity and consistency in the treatment of costs by government contractors and subcontractors.

Cost Accounting System: An accounting system designed to record costs by contract, project, production lot for hardware, or other cost objectives through assignment of specific work order or cost accounts for costs applicable to the cost objective.

Cost Allocation: A method, usually mathematical, of assigning direct or indirect cost equitably to one or each of several of the objectives for which the cost was incurred jointly.

Cost and/or Pricing Data: All facts that, at the time of the price agreement, the seller and buyer reasonably would expect to affect price negotiations. Cost and/or pricing are data requiring certification. Cost or pricing data are factual, not judgmental data, and therefore are verifiable. While these data do not indicate the accuracy of the prospective contractor’s judgment about estimated future costs or projections, they do include the data used to form the basis for that judgment. Cost or pricing data are more than historical accounting data; they are all the facts that reasonably can be expected to contribute to the soundness of estimates of future costs and to the validity of determinations of costs already incurred.

Cost Center: An administrative unit selected for the purpose of controlling costs. The unit has managerial responsibility, usually consists of a related grouping of methods and facilities and is made up of elements having common cost characteristics. Also, it is the basic unit of control in cost accounting. Often referred to as responsibility center.

Cost Contract: (1) A contract, which provides for payment to the contractor of allowable costs, to the extent prescribed in the contract, incurred in performance of the contract. (2) A cost-reimbursement type contract under which the contractor receives no fee.

Cost Control: Application of procedures resulting in early illumination of potential changes in resource requirements and allowing timely surveillance of the usage of funds. This permits action that will keep costs within a predetermined range.

Cost Data: The term given to cost statistics or records of a program that usually have not been analyzed and organized into cost information.

Cost Driver: The characteristics of a system or end item that have a large or major effect on the systems cost.

Cost Effectiveness: The measure of the benefits to be derived from a system with cost as the primary or one of the primary measures.

Cost Estimating: The process of predicting the future cost of something based on information known today. It includes selecting estimating structures, collecting, evaluating and applying data, choosing and applying estimating methods, and providing full documentation.

Cost Estimating Relationships (CER): A mathematical expression relating cost as the dependent variable to one or more independent cost driving variables. The relationship may be cost-to-cost such as using manufacturing hours to estimate quality assurance hours or using manufacturing hours to estimate dollars for expendable material such as rivets, primer, or sealant. The relationship may also be cost-to-non-cost such as estimating manufacturing hours by the use of weight or using the number of engineering drawings to estimate engineering hours. Both weight and engineering drawings are non-cost variables. (NOTE: It generally is accepted that pricing factors, estimating factors, ratios, parametrics, etc. are cost estimating relationships and should be referred to as such).

Cost Estimating Uncertainty: Variations in cost estimates when the configuration of an item remains constant.

Cost Factor: Cost estimating relationship (CER) in which the cost is directly proportional to a single independent variable. A brief arithmetic expression wherein cost is determined by application of a factor such as a percent, e.g., initial spares percent, general and administrative percentage, or a ratio as in pay and allowance cost per man per year.

Cost Growth: Term related to the net change of an estimated or actual amount over a base cost figure established previously.

Cost Improvement Curve Theory: Theory stating that as the quantity of items produced doubles, the costs decrease at a constant rate. Unit cost improvement curve theory describes the relationship between the costs of individual units. Cumulative average theory describes the relationship between the average costs of different quantities of units.

Cost Incurred: A cost identified through the use of the accrued method of accounting and reporting or otherwise actually paid (e.g., cost of direct labor, direct materials, and direct services identified with and necessary for the performance of a contract and all properly allocated and allowable indirect costs as shown by the books of the contractor).

Cost Input: A portion of an estimate received from a supporting functional organization or division.

Cost Model: An estimating tool consisting of one or more cost estimating relationships, estimating methodologies, or estimating techniques used to predict the cost of a system or one of its lower level elements.

Cost Of Money: The cost of capital committed to facilities as an element of contract cost.

Cost Proposal: A submission by a potential contractor, for the purpose of planning or to be used for definitive negotiation, indicating the cost to the procuring agency or buyer for his conduct of a specified extent of work. The proposal, in supporting the proposed cost, includes an amount of detail commensurate with the purpose, coverage, and other characteristics of the proposal. The proposal may or may not be in response to a request for proposal.

Cost Reimbursement: Refers to a family of pricing arrangements that provide for payment of allowable, allocable and reasonable costs incurred in the performance of a contract, to the extent that such costs are prescribed or permitted by the contract.

Cost Reimbursement Contracts: Types of contracts that provide for payment to the contractor of allowable costs incurred in the performance of the contract, to the extent prescribed in the contract.

Cost Risk: An assumption of possible monetary loss in light of the complexity or unknown nature of the job or work to be done. One of the elements to be considered in the negotiation of a fair and reasonable price, as well as in determining the type of contract under which performance would occur. See risk.

Cost Schedule Control System Criteria (C/SCSC): A series of vigorous statements used to determine the quality of a contractor's management information system. C/SCSC is neither a system nor a report.

Cost Sensitivity: Exists when the amount of costs vary greatly with small variation or change in program or end item characteristics.

Cost Sharing: An arrangement under which the two parties share the costs for a program concerned (government/contractor or contractor/subcontractor).

Cost Track (Tracking): (1) A step by step record of the revisions and updates of proposed costs from the original submittal of a baseline estimate to the final agreement on costs. (2) A historical record of selected cost information (estimated or actual) on a system basis with written analysis, which explains variance among cost entries. (3) The flow of cost data from the price summary to detail support data. (4) Establishing and maintaining permanent records of successive cost estimates made for major programs and systems together with the reasons for changes to those tracking cost estimates.

Cost Type Contract: A contract that provides for payment to the contractor of allowable costs in the performance of the contract, to the extent prescribed in the contract.

Cost Underrun/Overrun: A net change due to the contractor's actual costs being under/over target or anticipated contract costs.

Cost Variance (CV): The difference between what was spent and the amount of budgeted work completed. It is expressed as Budgeted Cost of Work Performed (BCWP) - Actual Cost of Work Performed (ACWP).

Cost/Effectiveness Analysis: A method for examining alternative means of accomplishing a desired objective/mission for the purpose of selecting programs, which will provide the greatest effectiveness for the cost. See benefit cost analysis.

Criteria: The standards against which evaluations are performed. Measures used should capture or embrace as closely as possible the purposes sought. May consist of proxy measures for dimensions difficult to measure.

Critical Activities: Those program management, material, engineering, test, manufacturing and quality assurance activities that experience has shown must be subject to formal procedures and discipline to assure that programs and products will be successful and profitable.

Critical Design Review (CDR): Final program technical and configuration review prior to production authorization. Usually signifies a 90 percent drawing release.

Critical Item: Includes items (1) where failure affects safety; (2) where failure will prevent mission accomplishment; (3) which require special handling; (4) which have long lead time, are in short supply, or are expected to be in short supply for an extended period; (5) which are expensive; or (6) which impose high maintenance loads. Special criteria must be established for identification, control, and special handling of critical parts, units, subsystems, or other items from design through final acceptance.

Critical Material: Those supplies and equipment vital to the support of operations, which owing to various causes are (1) not available in sufficient quantity to meet existing requirements; and (2) not anticipated to be available in sufficient quantity to meet future or planned requirements.

Critical Path: The path or a network of a schedule on which the slippage of any event will reflect an equal slippage in the end objective.

Crosscheck Method: An estimating methodology that is different from the estimating approach selected as the primary method. It typically is applied to those cost elements that contribute heavily to the total estimate to ensure that the primary method employed has generated credible results.

Cumulative Average Cost: The cost per unit in hours or money that results when the summation of the costs for the units produced is divided by the units produced.

Cumulative Average Curve: Logarithmic chart of cumulative average values plotted at the last unit of each cumulative quantity.

Current Year Dollars: Dollars that reflect purchasing power current to 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 that will be paid. Also sometimes referred to as actual dollars, then year dollars, inflated, or escalated dollars. See then year dollars.

Cycle: One of the intervals or spaces in time during which one course or round of events of a certain regularly and continually recurring succession of events is completed.

Damages: The amount for which the company will be held liable for contract breaches and acts by employees within the scope of employment.

Data: All graphic and written information, whether technical or non-technical. Data may be in the form of drawings, documents, reports, letters, machine printouts, brochures, and other applicable forms not specifically mentioned. Usually controlled by the Contract Data Requirements List (CDRL) attached to a contract.

Data Item Description (DID): Detailed description of the content of Contract Data Requirements List (CDRL) items including preparation information, reproduction media, delivery requirements, etc.

Data Line Item: One item of data as listed on a data requirements package or CDRL.

Data Management: The element of program management which identifies, plans, directs, and controls data tasks to ensure that total contract data requirements and program data requirements are satisfied.

Data Package: A set of documents furnished by the contractor to the customer upon completion of a statement of work, contract task, or upon delivery of equipment.

Data Reduction: Conversion of a large quantity of detailed data into a small quantity of useful summarized information.

De-Mod: Restoration to the original configuration at the conclusion of a contract or program.

Declared Over/Underrun: The amount of contract cost overrun or underrun that has been reported to the customer.

Defect: A non-conformance to specification/drawing that has not resulted in a failure. A defect might range from an incorrect paint job to a serious flaw. A defect might result in failure eventually, but has not yet done so.

Defect In Material Or Workmanship: (1) Patent Defect - Refers to a special condition or conditions in a product due to faulty workmanship and/or material which might cause its failure or malfunction, and which was or should have been discovered upon inspection. (2) Latent Defect - A defect not discoverable upon inspection, such as a crack in a forging or structural part.

Deficiency: Any condition or characteristic in any supplies or services that is not in compliance with the requirements of the contract at the time of delivery.

Deficiency Report (DR): Used in source selection, a report formally communicated to an offeror to document deficiencies in the offeror's proposal. The DR provides the offeror the opportunity to rectify the deficiency by submitting a proposal modification.

Deflators: A numerical index used to reduce a price level to that comparable with price level at a given different time.

Deliverable Item: Hardware, services, software or other items deliverable to the customer in accordance with the terms of a contract.

Demand: As used in a mission needs analysis, is the projected demand for FAA products, service, and capacity.

Demonstration And Validation Phase: The phase in which the alternatives selected under the conceptual exploration phase are further investigated and definitized. These investigations may involve paper studies or hardware prototypes-or both. The objective of these efforts is an in-depth understanding of the technical and affordability aspects of competing alternatives that will assist in selecting the most viable system for further development.

De-obligation: Downward adjustment of obligations recorded previously. Attributable to contract terminations, price revisions, cost under runs on cost reimbursement contracts and corrections of amounts originally recorded as obligations, or for convenience of the Government.

Deployment Plan: A plan that identifies the bases that will receive operational inventory, the quantity required at each base and the support requirements (e.g., training, data, support equipment) at each base.

Depot Maintenance: The highest level of maintenance that is the responsibility of the logistics agency. This maintenance is performed at organic or contractor facilities and is the "overhaul" level.

Depot: A facility for the receipt, classification, storage, issue, repair maintenance, manufacture, assembly, or salvage of material contract end items, and systems and hardware.

Design: The engineering disciplines and analysis required to transform a concept into released drawings, engineering data, and final hardware.

Design To Cost (DTC): A concept that establishes cost elements as management goals to best balance between life cycle cost, acceptable performance, and schedule. Under this concept, cost is a design constraint during the design, development, and production phases, and a management discipline throughout the system life cycle.

Design To Cost Goal: A unit cost goal to be achieved in the production phase of the life cycle based upon the existing best estimate of quantity, production rate, time frame, and, when available, cost-quantity relationships (learning curves). The DTC goal is expressed in constant dollars and is established not later than entry into full-scale development. Design and production studies are conducted to achieve the goals.

Design To Unit Production Cost (DTUPC): Included in development contracts as the anticipated unit production price to be paid by the Government for recurring production costs and is based upon a stated production quantity, rate, and time frame. The contractor uses this unit cost goal as a design parameter to control system cost. In general, the DTUPC goals should include only those cost elements that are under the control or influenced by the contractor.

Deterministic Relationship: In statistics, a relationship between two or more variables that is certain in nature.

Development: (1) The systematic use of scientific and technical knowledge intended to meet specific product performance requirements or objectives. (2) The design, development, test, and evaluation of a potential new product or service or of an improvement in an existing product.

Development Cost: All costs (government and contractual) required to develop a system before committing it to production.

Developmental Manufacturing: Manufacturing effort to build mockups, breadboards, or help build hardware for use in engineering development, test, and evaluation activities. Also called, developmental support, factory support to engineering, experimental fabrication, manufacturing support to engineering, etc.

Direct Costs: Any item of cost (or the aggregate thereof), which may be identified specifically with any objective, such as a product, service, program, function, or project. These costs may be charged directly to a given contract charge number or they may be charged to a redistribution work order subsequently distributed to contracts over a logical base. Direct costs are the opposite of indirect costs, which are classified as overhead and are distributed to contracts over a base normally composed of direct hours or dollars. See indirect cost.

Direct Estimating: Also known as specialist estimating, an estimating approach that is a judge mental estimate performed by an expert in the area to be estimated.

Direct Labor: That labor that can be specifically and consistently identified or assigned to a particular work order and that bears full overhead.

Direct Material: Includes raw materials, standard, commercial items, purchased parts, purchased equipment, outside production, and subcontracted items required to manufacture and assemble completed products. Also direct material often includes the costs associated with materials or products received from other company divisions under an interdivisional support agreement.

Disclosure Statement (Cost Accounting Standards): Designed to meet the requirements of Public Law 91-379 (Form CASB-DS-l). Persons or firms required to complete and submit the statement describe their contract cost accounting practices by providing data that are responsive to its requirements.

Discount Rate: The interest rate used to discount future costs and benefits to arrive at their present values when one considers the time value of money.

Discounting: A technique for converting forecasted amounts to economically comparable amounts at a common point in time that considers the time value of money. The time value of money is considered by computing present value costs. Present value costs are computed by applying a discount rate to each year's cost in a cost stream. Discount rates usually are developed to approximate closely the current cost of money in the financial marketplace. The purpose of discounting is to determine if the time value of money is sufficiently great to change the ranking of alternatives--a ranking that has been established on the basis of all other considerations.

Discriminating Criteria/Key Discriminators: Those factors expected to be especially important, significant, and critical in the ultimate selection decision.

Disjoint Theory: A part of cost improvement curve theory that contends that the cost improvement rate (slope) in production will be the same as in development but improvement starts over at unit one and at a value less than the first prototype unit.

Distributed/Distributable Labor (Costs): Any costs or labor, which cannot economically be accounted for to a specific task and thus are distributed across all contract tasks as a function of labor or material costs. May also cover costs such as distributed data processing or material costs.

Documentation: The summary and backup data that supports a cost estimate. Cost documentation must support the credibility of the estimate, provide a history of why program cost changed, and provide a database for future estimates. Cost documentation in AFSC is referred to as a “blue book.”

Earned Value: See Budgeted Cost of Work Performed (BCWP).

Economic Analysis: A systematic approach to a given problem, designed to assist the manager in solving a problem of choice. The full problem is investigated; objectives and alternatives are searched out and compared in the light of their benefits and costs through the use of an appropriate analytical framework. Often used to determine the best use of scarce resources.

Economic Life: The period of time over which the benefits gained from a system may reasonably be expected to accrue to the owner. In economic analysis this is the minimum of its physical, technological, or political life.

Economic Lot Size: Size of the batch, which minimizes average unit cost.

Economic Price Adjustment (EPA): A contractual alteration permitted and specified by contract provisions for the upward and/or downward revision of a stated contract price based upon actual experience (future years) as compared to forecasts of selected economic indices at the time the contract was negotiated.

Economic-Order-Quantity (EOQ): That quantity derived from a mathematical technique used to determine the optimum (lowest) total variable costs required to order and hold inventory.

Economic-Order-Quantity Principle: A supply technique used to compute replenishment order quantities of consumable material whereby the cost to order is equated against the cost of carrying the inventory to achieve the most economical procurement, storage and inventory practices. An optimum method for computing operating levels of supply after considering the cost elements involved.

Efficiency: The mathematical reciprocal of a realization factor. A ratio of the standard hour value to the actual hours used. It is expressed as a percent derived by dividing the standard hours by the actual hours. See realization.

Electronic Data Processing (EDP): A general, categorical designation normally used when referring to the entire field of electronic data processing machines, equipment, and software.

End Item: The term used to represent the hardware, software, facilities, or services that are deliverable or supplied to a customer on a contract. It also is defined as a final combination of end products, component parts, and/or material that is ready for its intended use.

Engineering: The effort and costs expended in the scientific exploration, study, analysis, design, development, evaluation, and redesign of a specific task or work breakdown structure element. It includes the preparation of specifications, drawings, parts lists, wiring diagrams, technical coordination between engineering and manufacturing, supplier coordination, test planning and scheduling, analysis of test results, data reduction and report preparation. Also includes the determination and specification of requirements for reliability, maintainability, and quality control. It is a basic functional cost category or cost element.

Engineering Change Orders (ECO) Estimate: The reserve in an estimate for known and unknown contract changes that is over and above allowances for risk.

Engineering Change Proposal (ECP): A proposed change to contract specifications. It applies to changes that affect the physical functional, performance, maintenance, or logistics characteristics of a system as contracted for by the customer.

Engineering Estimate (or detailed engineering estimate): (1) Prepared by contractors - an estimate developed by requesting and collecting estimates from functional organizations within a company or agency for a specific statement of work or task. Usually developed by a combination of many estimating methods and techniques but developed by the "doing" people. (2) Prepared by in-house government analysts - synonymous with the term detailed estimating, the government prepared engineering estimate normally is done at a functional level of detail with regard to labor with a breakout of major subcontracts and material items also included. It normally is prepared to forecast out-year costs for systems in production or for which prototype production cost data are available.

Engineering Labor: Generally that direct labor expended by engineering employees while performing all scientific investigations, technical process, research, development and design, system engineering, testing, logistics, and support to manufacturing processes for a specific product.

Engineering Or Task Change: An alteration in the physical or functional characteristics of a system, contractual tasks, items delivered, to be delivered, or under development, after establishment of such characteristics.

Enhancement: Improvements to augment the design or physical characteristics of a product or system.

Equipment: Property of a more or less durable nature, which may be expected to have a period of service of a year or more after being put into use without material impairment of its physical condition.

Equivalent Labor (Personnel): The required full-time personnel needed to perform a given task on regular time with normal labor loss such as vacations, sick leave, holidays, leave with-pay, leave-without pay, etc. Equivalent personnel is calculated by dividing the total hours (including overtime) by an equivalent personnel factor for the same time period.

Equivalent Labor (Personnel) Factor: A factor used to convert man-hours into the number of full-time employees required to accomplish a specific task within a given time period with normal labor loss such as vacations, sick leave, holidays, etc., without the use of overtime. Factors differ between years, by geographical location, by company and the government as a result of different holiday schedules and vacation patterns. Also referred to as labor conversion factor.

Established Market Price: A current price, established in the usual and ordinary course of trade between buyers and sellers free to bargain, which can be substantiated from sources independent of the manufacturer or supplier, although the obtaining of such pricing data may have to come from the seller.

Estimate: A term describing the resources (labor hours, material costs), travel, computer costs, and other costs which are required to accomplish a contract, task, or work item. Also includes the rates and factors, which are applied to the labor and materials to develop estimated costs.

Estimate Scope: The description of the contents of a particular estimate.

Estimated Actuals: The costs reported to a contract during a contractor's accounting year, consisting of (1) The direct labor and material reported in the period as actuals and not subject to revision; and (2) The applicable overhead and G&A as reported to the contract on approved billing rates. The estimated portion of actuals results because these rates cannot be firm until the close of the accounting year and the completion of the government audit and negotiation of allowable charges to overhead and G&A pools. Contract billings are then adjusted upward or downward to reflect the results of the approved overhead charges and rate negotiations.

Estimated Cost At Completion Or Estimate At Completion (EACS): The current estimate of what the final cost will be for the task, whether it be the total contract or just a portion thereof. It consists of actual costs to date plus the estimate of the balance to complete through contract completion.

Estimated Total Price: Total cost plus fee or profit; synonymous with the term price.

Estimating Methodology: A term referring to the approach(s) used in arriving at a cost estimate. Also referred to as estimating methods or estimating approaches. See analogy estimating, engineering estimating, direct estimating, catalog estimating, man loading estimating, and parametric estimating.

Estimating Plan: Introduces structure to the estimating task by describing the scope of the task, responsibilities of the analysis team, and the schedule for accomplishment of the task.

Estimator: A person who performs the estimating function.

Excess Usage: Material in excess of the net bill of material requirements. See surplus material.

Expenditure: Payments made against a particular contract or other obligation.

Experience Factor: A percentage or ratio expression indicating the results of previous actual performance to indicate the output in relation to input. One statistical form presenting an experience factor is the slope of improvement or learning curve.

Expert Opinion: An estimating method of using experts in engineering, manufacturing, procurement, testing, etc. to brainstorm estimates. Usually conducted on a new concept with little or no definition based solely on expert judgment and similar experiences. This term also is referred to as the Delphi approach.

Facilities Contract: A contract under which industrial facilities are provided by the government for use in connection with performance of a separate contract or contracts for all supplies or services.

Facilities: Property (e.g., buildings, structures, improvements, and plant equipment) for production, maintenance, research, development, or test. A term for an organization whose function is to control, administer, and maintain facilities for a company or agency.

Facility Improvement: Construction necessary to replace obsolete facilities or to expand a facility in order to improve operating efficiency of an installation.

Facility: A physical plant, such as real estate and improvements thereto, including buildings and equipment that provides the means for assisting or making easier the performance of a function (e.g., base, arsenal, factory). A part or adjunct of a physical plant or any item of equipment in an operating entity that contributes or can contribute to the execution of a function by providing some specific type of physical assistance (e.g., railroad, railroad rolling stock, vehicles, access road, railroad spur, ship, pier).

Fact-finding: Post submittal phase of a proposal. This phase allows the customer to (1) review proposal support data; (2) investigate certain areas in more depth; (3) conduct audits of rates, factors, and supplier quotations used in the proposal; and (4) conduct on site surveys and reviews of cost information retained at contractors plants.

Factor: A numerical expression of value, or ratio, expressed as a percentage. A factor is used as a multiplier and which, when combined with, or related to other factors, contributes to produce a result. See cost factor.

Factored Items: Labor or material estimated by the application of a factor to a labor base of hours or dollars.

Factory Support To Engineering: See developmental manufacturing.

Failure Rate: The number of failures of an item per unit of measure. The unit of measure may be time, distance, operating hours, etc.

Federal Acquisition Regulations (FAR): The primary regulation for use by federal executive agencies for acquisition of supplies and services with appropriated funds. It directs the program manager in many ways, including contract award procedures, acquisition planning, warranties, and establishing guidelines for competition.

Fee: Represents an agreed-to amount beyond the initial estimate of costs, in specified cost-reimbursement pricing arrangements. In most instances, fee reflects a variety of factors, including risk, and is subject to statutory limitations. Fee may be fixed at the outset of performance, as in a cost-plus fixed-fee arrangement, or may vary within a contractually specified minimum-maximum range during performance, as in a cost-plus-incentive-fee arrangement.

Field Maintenance: Maintenance authorized and performed by designated maintenance activities in direct support of using activities. It normally is limited to replacement of unserviceable parts, subassemblies, or assemblies.

Field Service Representative: An agent of a manufacturer or commercial concern who provides administration, technical support, or product liaison with a customer or users of the manufacturer's products.

Financial Report: A formal statement, or series of statements, with or without narrative or discussion showing financial condition at a given time or results of transactions or operations for a given period, with or without comparison with budget estimates, standards, past history limitations, etc.

Firmware: A portion of software that has been converted to an actual physical piece of hardware, i.e., a pre-programmed chip.

First Destination Transportation (FDT) Cost: The cost of freight, cart age, and demur rage incurred incident t-o the shipment of material from a procurement source outside the pop supply system to the first point of use or storage for subsequent distribution.

Fiscal Period: An accounting period of a specified time duration.

Fiscal Policy: (1) Government - The policy pursued in connection with legislation or administrative practices relating to taxation, currency, public appropriations, and expenditures, government funds, and similar matters; particularly the intended effect of such legislation and administrative practices upon the economy of the nation. (2) Commercial - The overall financial operating policy of a company with regard to assets, liabilities, cash flow, expenses, indebtedness, stocks, bonds, etc.

Fiscal Year Buy: The procurement of a specific amount of hardware, software or equipment with the funds provided in a specific fiscal year funding. The actual expenditure period for the procurement may cover several fiscal years.

Fiscal Year: Twelve-month period selected for accounting purposes. (1) Government - The fiscal year for most agencies of the U.S. government begins on the first day of October and ends on the thirtieth day of September of the following calendar year. (2) Contractors - The fiscal year of a company can be any time period encompassing a period of one year.

Fixed Overhead Cost: An item of overhead cost (or the aggregate thereof), which is not considered to vary directly as a result of changes in volume of production; as opposed to variable and semi-variable overhead costs.

Forward Pricing Arrangement (FPA): A written understanding negotiated between a contractor and the government to use certain rates (e.g., labor, indirect, materials, etc.) for a specified period of time in pricing contracts or contract modifications.

Forward Pricing Rates: Rates developed especially for pricing new proposals, additions, or changes to existing contracts with the customer.

Fringe Benefits: The cost of benefits furnished to employees. These benefits include sick leave, holidays, employment taxes, vacations, retirement, group insurance, union pension and state workman's compensation insurance, etc. Also included are company contributions to employee savings or personnel benefit plans.

Full Funding: 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

Full Scale Development (FSD) Phase: The phase in the acquisition life cycle during which the selected system is designed, developed, and tested. To ensure that system performance will fulfill mission requirements, several pre production articles will be manufactured and operated. The system configuration that evolves during full-scale development will reflect closely the article committed to quantity production.

Function: Task-oriented blocks of related effort or people necessary to produce outputs (i.e., engineering, tooling, manufacturing, quality assurance, material, program management, etc.).

Functional Baseline: The initially approved documentation describing a system’s or item’s functional, interoperability, and interface characteristics, and the verification required to demonstrate the achievement of those characteristics.

Functional Organization (Functional Cost Category): Areas of responsibility, with their own definite description, (i.e., engineering, manufacturing, material, quality control, etc.).

General Accounting Office (GAO): An agency in the legislative branch of the Federal government. Performs independent audit of Government financial transactions to provide a basis for the settlement of accounts and to determine how well the agencies are managing their financial affairs.

General And Administrative (G&A): Indirect expenses, including a company’s general and executive offices, the cost of staff services such as legal, accounting, public relations, financial and similar expenses and other general expenses related to the overall business. A generic term used to describe expenses that cannot be assigned directly to overheard areas for engineering, manufacturing, material, etc.

General Overhead Accounts Or Costs: Overhead accounts or costs for labor and non-labor not identifiable to specific contract tasks or specific functional areas (e.g., engineering, manufacturing, material).

General Purpose Equipment: Equipment suitable for a wide range of applications and of a standard off-the-shelf configuration. Usually consisting of catalog type equipment such as oscilloscopes, voltmeters, power supplies, etc.

Government Property Administrator: The individual duly designated by appropriate authority, as an authorized representative of the government contract administrator, to administer the contractual requirements and obligations relative to government property.

Government Property: All property owned by or leased by the government including property acquired by the government under the terms of a contract. Government property includes (1) government-furnished property, which is property in the possession of or otherwise made available to a contractor; and (2) contractor-acquired property, which is property procured or otherwise provided by a contractor for the performance of a contract, title to which is vested in the government.

Government-Furnished Material Or Equipment (GFE): Material or equipment provided by the government to a contractor. GFE can range from in-factory test equipment to base ground equipment to hardware within the flyaway cost of the system.

Ground Rule: A condition directed upon an estimating team that provides the basis upon which an estimate is conducted.

Ground Support Equipment (GSE): Equipment designed to support and maintain primary mission equipment in its use.

Hardware: A generic term used to describe aerospace industry equipment consisting of airplanes, missiles, electronic systems, support equipment, and virtually anything else that is manufactured.

Hardware Cost: Costs concerning the major system equipment items of the work breakdown structure exclusively and can encompass contractor, subcontractor, supplier, and government costs.

Historical Cost (Data): An estimating term used to describe a set of data reflecting actual cost or past experience of a product line. Historical data provides insight into actual costs on similar systems from a variety of contractors to establish generic system costs and also helps to establish cost trends of a specific contractor across a variety of systems. Historical cost data provides the raw material of the entire estimating process.

Homogeneous Data: The term used in describing items of data which are similar or essentially alike and therefore comparable, except in the differences that are measured or investigated.

Idle Capacity: The differences between rated capacity and actual level of operation, usually in terms of percentages.

Idle Time: Lost time of employees or machines due to work stoppage from any cause. Idle time is time that is not productive.

Improvement Curve: A graphical representation of improvement curve theory that is used to project resource requirements (e.g., labor hours, labor dollars, material quantity). When used to project cost, it normally is referred to as a cost improvement curve. See cost improvement curve theory.

In-Process Work Packages: The work packages that have been started but not completed as of a reporting cutoff date.

In-Service Decision: A corporate decision to accept a product or service for operational use during the Solution Implementation phase of the life cycle acquisition management process. This decision allows deployment activities, such as installing products at each site and certifying then for operational use, to start.

In-Service Management Phase: This phase of the life cycle acquisition management process is that period of time after a product or service begins operational use, and continues for as long as the product or service is in use.

Incentive: A motivational device used in contracts to induce improved performance. It can be based on technical performance, schedule, cost, or award motivation.

Incentive Arrangement: A negotiated arrangement that structures a series of relationships designed to motivate and reward the contractor for superior performance in accordance with the contract specification.

Incentive Earnings: Earnings resulting from awards made under cost, schedule, or technical performance clauses of incentive contracts.

Incremental Cost: Add-on, alternative, accessory, or choice cost. Takes into account the availability of existing resources when adding a new system.

Incremental Funding Concept: A funding policy that dictates that only funds required to accomplish work and provide for related costs in a given fiscal year are included in the budget request for that fiscal year.

Independent Audit: An audit performed by persons not under the administrative jurisdiction of the major entity being audited. Example, (The General Accounting Office performs independent auditing in the Federal government).

Independent Research And Development (IR&D): Company funded, technical effort which is not sponsored by, or required in performance of, a contract, which consists of projects falling within the areas of: (1) basic and applied research; (2) development; and (3) systems and other concept formulation studies. IR&D investigation and experimentation often lead to the discovery of new facts, the revision of accepted scientific or technical conclusions, and the practical application of such new or revised conclusions to new products through studies, evaluation, and development.

Index Number: A ratio of a value of a subject item to the value of a similar type item for purposes of comparison. Usually expressed as a percent. For example, a price index of an item is the ratio of its price at a given time to its price at some other time, usually previously.

Index: Statistical device for measuring changes in groups of data that serves as a comparative measure, expressed as an index number.

Indirect Cost Pool: A grouping of incurred costs identified with two or more cost objectives but not specifically identified with any final product, program, etc.

Indirect Cost: An item of cost, which is incurred for joint usage, and, therefore, cannot be identified specifically with a single product, service program, function, or project. Usually used synonymously with overhead costs.

Indirect Labor: Labor that cannot be identified to work orders specifically and consistently. Indirect costs are accrued and charged to overhead accounts, the sum of which is applied as burden. The cost of labor that is not applicable directly to a product or service.

Indirect Material: Cost of materials not entering directly into a product. Examples are cleaning fluids, perishable tools, etc.

Industrial Property: As distinguished from government property, means any contractor-acquired or government-furnished property, including materials, special tooling and industrial facilities furnished or acquired in the performance of a contract or subcontract.

Inflation: A rise in the general level of prices. Pure inflation is defined as a rise in the general level of prices unaccompanied by a rise in output (productivity).

Information Other Than Cost or Pricing Data: Any type of information for which certification is not required and that is necessary to determine price reasonableness or cost realism. This includes pricing, sales, or cost information, and cost or pricing data for which certification is determined inapplicable after submission.

Initial Operational Capability (IOC): A term used to signify the operational capability of the first designated unit.

Initial Procurement: The first procurement of an item of fiscal year buy to obtain a specified number of items or system hardware.

Initial Spare Parts: Those spare parts procured through provisioning against a production contract that covers the initial stock age of spares.

Input: (1) Information or variables required by a computer program. (2) Written or verbal data or information requested from a person or functional organization in support of a cost estimating activity.

Inscope Change: Contract change notification from the customer that involves no change in contract cost or fee. Usually called a Class II change.

Inspection (Product): Physical and functional inspection of hardware, the records, and witnessing of test operations to assure that the finished product meets the acceptance requirement of the contract.

Intangible Property: Includes but is not limited to such classes of personal property as patents, patent rights, processes, techniques, inventions, and copyrights.

Integrated Logistics Support (ILS): ILS is the functional discipline that deals with the relationship of supportability requirements to the operational requirements, and their consideration in the design process. The principal elements of ILS are maintenance planning, maintenance support facilities, maintenance staffing, supply support, support and test equipment, training, technical data, and packaging, handling, storage, and transportation.

Integrated Product Development System (IPDS): The implementing arm of the Life Cycle Acquisition Management System, using cross-functional collaborative, empowered, and mutually accountable teams leading teams.

Integrated Product Leadership Team (IPLT): A director-level management team, which oversees the entire IPDS operation. The IPLT resolves high-level, cross-domain issues requiring senior management assistance and support, participates in the establishment and maintenance of IPDS infrastructure, and approves Product Team and Integrated Product Team Plans, focusing on empowerment boundaries and team operations concepts.

Integrated Product Team (IPT): A cross-functional, empowered team with a mission, budget, and other resources for delivering a product or service that meets the needs of its customer or user. The IPT makes binding, team based decisions and ensures the interests of all stakeholders, customers, users, and vendors are represented.

Integrated Program Plan (IPP): The detailed planning document for all aspects of program implementation. It integrates the planning requirements of several previous FAA planning documents including the program master plan, the integrated logistics support plan, the test and evaluation master plan, the program implementation plan, the human factors plan, and the procurement plan.

Integration: (1) The technical and functional activities and interfaces required to accumulate the many facets of a complex system. (2) The overall planning, organizing, and checking process associated with translating RFP costing requirements into a cost proposal. (3) Act of coordinating, summarizing, and documenting the various pieces of a cost estimate. (4) A term often used to describe the effort required for installation of new subsystems in existing systems.

Integration And Assembly (I&A): The term used for the technical and functional activities associated with combining elements into a higher-level element. It includes many of the non-specific efforts such as engineering layouts, testing of components and subsystems, vendor liaison, tooling, and production assembly testing. Generally, I&A activities reside at level 4 of the work breakdown structure for an aircraft system but at Level 3 in most other systems.

Interagency Agreement: A written agreement between the FAA and another Federal agency where (1) the FAA agrees to receive from, or exchange supplies or services with, the other agency and (2) FAA funds are obligated.

Interchangeability And Replaceability: The capability of replacing any part, subassembly, or assembly without affecting form, fit, function, or degradation to quality or reliability of the basic product or end item.

Interdivisional Effort (Support): Effort performed by one division of a company in support of another division. Usually one division is considered the prime and the other the supporting division. As a course of good business, interdivisional support usually is provided on the basis of a documented agreement of the specific work transactions and costs between a prime and supporting division.

Interdivisional Transfers: (1) Price and Cost - these are materials sold or transferred between prime contractor's divisions, subsidiaries or affiliates that are under a common control. (2) At Price - the quoted price covers a standard catalog price item including profit. (3) At Cost - includes support division cost less profit.

Interested Party: An offeror that has a direct economic interest in the procurement.

Interim Contractor Support (ICS) Costs: The costs associated with support provided by the contractor for an interim period of several years prior to the existence of organic capability.

Intermediate Maintenance: Maintenance performed by centralized maintenance facilities that directly support organizations operating the system. Also known as repair level maintenance.

Intra-agency Agreement: A written agreement between the FAA and Office of the Secretary of Transportation or another Department of Transportation operating administration where the requesting organization agrees to provide or exchange supplies or services with the FAA, and FAA funds are obligated.

Inventory: The amount of property on hand at any given time or the act of inspection to determine the physical existence of property.

Inventory Adjustments: Bookkeeping corrections of stock records required to bring book inventories into agreement with physical inventories.

Investment Analysis: Conducted to determine the most advantageous solution to an approved mission need. It involves development of operational requirements, a market search to determine industry capability, analysis of various alternative approaches for satisfying requirements, and an affordability assessment to determine what the agency can afford.

Investment Analysis Plan (IAP): A plan developed by the Director, Investment Analysis Staff, initiated during the investment analysis phase for each new mission need and approved by the Associate Administrator of the Sponsoring Organization. It provides the necessary policies, guidelines, and procedures for completing the particular investment analysis process in a timely and efficient manner.

Investment Analysis Report (IAR): Summarizes the analytical and quantitative information developed during investment analysis in the search for the best means for satisfying mission need. It is the primary information document supporting the investment decision.

Investment Analysis Staff (IAS): A permanent group in a permanent FAA organization that assists and oversees the work of all the investment analysis teams, is responsible for all investment analyses, and is responsible for developing the tools, techniques, and databases to ensure quality performance of investment analysis on behalf of the JRC. The senior member of the staff is the Director, IAS.

Investment Analysis Team (IAT): An ad hoc team assembled for a relatively short time period for each specific investment analysis (i.e., how best to meet a particular mission need), drawing experts from IPTs, sponsor organizations, the IAS, and other organizations to conduct the detailed analysis of alternatives leading to the selection and recommendation of a preferred acquisition solution.

Invitation For Bids: The solicitation document used in formal advertising for bids.

Job Order: A formal instruction to perform certain work according to specifications, estimates, etc.

Joint Resources Council (JRC): The FAA's body responsible for making corporate level decisions. Membership consists of the Associate Administrators representing all lines of business investment areas of the agency (Air Traffic Services, Regulation and Certification, Airports, Administration, Research and Acquisitions, Commercial Space Transportation, and Civil Aviation Security), the FAA Acquisition Executive, the Director of the Office of Financial Services, and Legal Counsel.

Labor Standards: A set of estimated, measured, or computed values used to forecast and evaluate performance. Examples are rates of machine cutting, assembly time, operations per hours, etc.

Laspeyres Index: A Relative of Weighted Aggregates Index, which uses the original base period weights in the calculation.

Latest Revised Estimate (LRE): See estimate at completion.

Lead Time: The time allowed or required to initiate and develop an item or system so that it will be available and ready for use at a given time.

Letter Contract: A preliminary contract with or without a tentative price or specific amount agreed to and with such other basic terms set forth as can be agreed to at the time. It authorizes the contractor to commence work, incur costs, and make commitments pending negotiation and-execution of the final definitive contract. It obligates the customer either to make a final definitive contract within a specific time or to reimburse the contractor for costs incurred under the letter contract. The letter contract is superseded as soon as possible by a final definitive contract.

Letter Of Intent: An obligation instrument that can be used to initiate a letter contract or protect price and availability of long lead items and for other purposes requiring a commitment to contract.

Level-Of-Effort: Normally refers to a constant number of personnel assigned to a given program for a specified period of time.

Life Cycle Acquisition Management Process: A depiction of the series of phases and decision points that comprise the life cycle of products and services.

Life Cycle Acquisition Management System: A fully coordinated set of policies, processes, and computer-based acquisition tools that guide the acquisition workforce through the life cycle acquisition management process from the determination of mission needs to the procurement and life cycle management of products and services that satisfy those needs.

Life Cycle Cost: The total cost to the FAA of acquiring, operating, maintaining, supporting, and disposing of systems or services over its useful life. Life cycle cost includes total acquisition and operational costs, and includes all appropriations (RE&D, F&E, and OPS).

Limit Of Government Obligation (LOGO): A specified amount of funding for a contract through a specific period of time or fiscal year. The LOGO amount limits the government's obligation to fund a contract.

Limited Overhead: Applied in lieu of full burden to certain activities to allocate to such activities an applicable share of employee service expenses and other general and administrative costs.

Line of Business: An informal term used to characterize the seven major organizations of the FAA, headed by Associate Administrators, having major roles and responsibilities in the Life Cycle Acquisition Management System. They are Air Traffic Services, Regulation and Certification, Airports, Administration, Research and Acquisitions, Commercial Space Transportation, and Civil Aviation Security.

Line-Of-Best-Fit: A line which passes through a charting of data point values in a manner which best represents the trend of the data points. The least squares correlation method is used frequently to compute this line-of-best-fit.

Line Replaceable Unit (LRU): An on-equipment replaced item, which is repaired at a maintenance level higher than that of the flight line.

Logistics: The term given to those activities necessary to plan for and to provide support programs, such as logistics and field engineering, publications, supply support, spares, training, administration of logistics functions, and repair coordination.

Logistics Engineering: The application of support planning and analysis techniques to define, optimize, and integrate the logistics support considerations into the program engineering effort.

Logistics Support Analysis: The task of identifying, defining, and quantifying the logistics support requirements to a program or project.

Long Lead (Item): An item for which the contractor requires authorization and funding prior to program go-ahead, but within the same fiscal year, in order to meet contractual end item delivery schedules.

Lot Quantity: The number of parts, assemblies, or end items released on a given work order.

Machine Hour: Operation equal to that of one machine for one hour.

Machine Tool: Those items of production equipment that are power driven, non portable machines used for cutting, abrading, grinding, shaping, or forming metal.

Maintainability: The measure of the ability of an item to be retained in or restored to specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair.

Maintenance, Corrective: All actions performed, as a result of failure, to restore an item to a specified condition. Corrective maintenance can include localization, isolation, disassembly, interchange, reassembly, alignment, and checkout.

Maintenance Planning: An element of integrated logistics support. It is the process conducted to determine, evolve, and establish maintenance concepts and requirements for the life cycle of a product, including both hardware and software.

Maintenance, Preventive (or Scheduled): Maintenance performed at prescribed points in time for the purpose of maintaining equipment and facilities in satisfactory operating condition by providing for systematic inspection, detection, and correction of incipient failures before they become actual failures.

Major Systems Acquisition: A system acquisition program designated by the Acquisition Executive to be of such importance and priority as to require special management attention.

Make Or Buy: Refers to the determinations by management as to which parts, components, or equipment items will be fabricated (manufactured or made) by the company or obtained from outside sources (purchase or buy).

Man-Hour: A unit of work representing the productive effort of one person in one hour. Also referred to as a labor hour or hour.

Man-Month: A unit of work representing the productive effort of one person in one month. Also referred to as a month of labor or labor month."

Man-Year: A unit of work representing the productive effort of one person in one year. Also referred to as a labor year. The actual number of man-hours in a man-year will vary depending on a specific contractor's allowance for vacation, sick leave, holidays, and other non-productive time.

Management Reserve: A term limited to contractors that represents a value within the negotiated contract target cost that the contractor has decided not to distribute to his functional departments initially.

Manloading Estimating: An estimating technique that uses a functional manager or estimator to project the number and type of skilled individuals needed to complete a specific work effort.

Manufacturing: Effort and costs expended in the fabrication, assembly, and functional testing of a product or end item. Includes all processes necessary to convert raw material into finished items delivered to a customer's specification. In most companies it is a basic functional cost category.

Manufacturing Labor: Generally, is that direct labor performed directly on the end item or processing of parts used in the finished product and the functional testing of the product. It normally covers fabrication, assembly, and manufacturing support activities. Sometimes includes tooling and quality control labor.

Manufacturing Plan: The narrative and descriptive information to define the schedules, facilities, tooling, fabrication, assembly, test, personnel, and capital items to conduct a manufacturing operation for a program, project, or product.

Manufacturing Spares: Additional components, parts, or subsystems required to support the manufacturing process and to guarantee delivery of the contract quantity.

Manufacturing Technology (Man-Tech): A program that allows development of new or improved manufacturing/maintenance/inspection systems, processes, techniques, or equipment that will allow for a more efficient production process.

Market Place: The commercial world; the realm of business, trade, and economics; the environment in which buyers and sellers bargain to achieve their separate and mutual ends.

Market Survey: Any method used to survey industry to obtain information and comments and to determine competition, capabilities, and estimate costs.

Market Value: The value of anything as computed on the basis of market quotations or in the absence of quotations, the amount that would induce a willing seller to sell and a willing buyer to purchase.

Master Schedule: The master phasing schedule for a program or project with key milestones and critical tasks.

Material: (1) General - raw, crude, partially processed items, or components, which have not yet been brought into a definite functional shape or configuration. (2) Cost element - consisting of raw material, purchased parts and equipment, subcontract items, and outside production items. (3) Operating - covers the components, parts, assemblies, and supplies used in operations and maintenance.

Material Overhead: The overhead cost which is attributable to purchasing, receiving, storing, warehousing, delivering, or expediting materials. Also called “material burden” and “material procurement (indirect) costs.”

Materials & Workmanship: A type of guarantee extended to customers to cover defects in the manufacturing process.

Matrix: A rectangular array of numbers or notations arranged in rows and columns. Each variable appears in both a row and a column.

Mean: An average of a series of quantities or values; specifically, the quotient of their sum divided by the number of items in the series.

Mean-Time-Between-Demands (MTBD): A measure of the system reliability related to demand for logistics support. It is the total number of system life units divided by the total number of item demands on the supply system during a stated period of time.

Mean-Time-Between-Failure (MTBF): A basic (usually contractual) measure of reliability for repairable items. It is the number of life units during which all parts of the item perform within their specified limits, during a particular measurement interval under stated conditions.

Mean-Time-Between-Maintenance-Action (MTBMA): A measure of the system reliability related to demand for maintenance manpower. It is the total number of the system life units divided by the total number of maintenance actions (preventive and corrective) during a stated period of time.

Mean-Time-Between-Removals (MTBR): A measure of the system reliability related to demand for logistics support. It is the total number of system life units divided by the total number of items removed from that system during a stated period of time. The time is defined to exclude removals performed to facilitate other maintenance and removals for product improvement.

Mean-Time-To-Repair (MTTR): A basic measure of maintainability. It is the sum of corrective maintenance times at any specific level of repair, divided by the total number of failures within an item repaired at that level, during a particular interval under stated conditions.

Measures of Central Tendency: A specific measurement (i.e., mean, median, mode) that depicts the tendency for observations to cluster around certain values.

Measures of Dispersion: A specific measurement (e.g., range, standard deviation) that depicts the-tendency for data values to spread.

Median: An average of a series of quantities or values. Specifically, the quantity or value of that item which is so positioned in the series, when arranged in order of numerical quantity or value, that there are an- equal number of items of a greater magnitude and of a lesser magnitude.

Memorandum of Agreement: A written document between two parties, which calls for the exchange of services or goods and outlines the specific responsibilities of each party. It is used to require either party to provide assistance, equipment, or services that will not result in the obligation of funds. A memorandum of agreement is not to be executed via an exchange of letters, as is allowed for memorandums of understanding, and is not to be used in lieu of a contract or contract modification.

Memorandum of Understanding: A written document between two parties that establishes policies or procedures of mutual concern, or confirms mutual aid and assistance activities. It is not used to require either party to provide assistance that would result in the obligation of funds. An exchange or letters may be used in lieu of a memorandum of understanding, providing the letters contain all essential elements and conditions, but is not to be used in lieu of a contract or contract modification.

Methodology: A term used in estimating to describe the methods used to develop an estimate (i.e., parametric, analogy, engineering).

Metrics: Measurements of indicators of the status of a project or procurement. Metrics is generally quantitative but can be qualitative.

Midpoint: The calculated mean of cumulative average hours or the unit numbers assigned to the quantity of units that make up a release or production block. In improvement curve theory this is the unit number most representative of the cost per unit for the lot. Normally this is the center unit of the lot, but for first lots the nonlinear effects can require more precise estimation. Cumulative average midpoint is the unit number of the unit at which the cumulative average value would occur. Block average midpoint is the unit number of the unit at which the block average value would occur.

Milestone: A date or event that signifies either the start or completion of a task, work item, or activity.

Milestone Billing: A plan, schedule, or table of billing (request for payment) values associated with key milestones and events.

Mission Analysis: Part of the life cycle acquisition management process during which strong, forward-looking, and continuous analytical activity is performed to evaluate the capability of agency assets to satisfy existing and emerging demands for services. It is conducted within the seven lines of business organizations of the agency.

Mission Need Statement (MNS): A formal planning document that defines a mission capability shortfall or technological opportunity the agency should address. Approval of the mission need statement by the Joint Resources Council at the mission need decision initiates investment analysis to determine the best means for satisfying mission need.

Mission Support Costs: An area of other government costs that includes the miscellaneous administrative costs incurred in the day-to-day operations of a program office.

Mock-Up: A partial or full scale replica of an article or its components, usually constructed of cheaper materials than required in the finished product, and used to provide physical interfaces between structure and various systems such as electronics, hydraulics, pneumatics, electrical, etc.

Mode: The most typical item in a series of quantities or values; that is, the quantity or value of that item which appears most frequently in the series.

Model: A representation of the reality of a situation or condition being studied. Consists of a series of equations, ground rules, assumptions, relationships, constants, and variables, which describe and define the situation or condition being studied.

Modification: Changes to an end item or an item of supply for any stated purpose. It is a change in an airframe, component, or equipment that affects performance, ability to perform intended mission, flight safety, production, or maintenance. It may be a block change to upgrade a system in the field or in ships or aircraft.

Modification Request (MR): Used in source selection to communicate formally to a modification to the RFP requirements by an offeror.

Most Advantageous Solution: That solution that is the most advantageous to the FAA, based on the evaluation of price and other factors specified by the FAA. This approach provides the opportunity for trade-offs between price and other specified factors. It does not require that an award be made either to the offeror submitting the highest rated technical solution, or to the offeror submitting the lowest cost/price, although the ultimate award decision may be to either of these offerors.

Most Probable Cost (MPC): The government’s estimate for each competing bidder in a source selection environment. MPC results are used by the source selection authority to determine the winning contractor, and this often becomes the only meaningful measure of the realism of the bidders' cost proposals.

Motion Study: A study of the movements (whether of a part, a machine, or an operator) involved in performing an operation for the purpose of determining the proper movements from the standpoint of maximum economy and minimum operator fatigue.

Moving Average: (1) A continuously revised arithmetic mean of a numerical series of quantities or values for a given period of time, each period being of equal length and expiring at a progressively more advanced date. (2) A forecasting technique used in time series analysis.

Multi-year Contracts: Contracts covering more than one year but not in excess of five years of requirements. Total contract quantities and annual quantities are planned for a particular level and type of funding as displayed in a current five-year development plan. Each program year is budgeted and funded annually and, at the time of award, funds need only to have been appropriated for the first year. The contractor is protected against loss resulting from cancellation by contract provisions, which allows reimbursement of costs included in the cancellation ceiling.

Multi-year Funding: Congressional authorization and appropriation covering more than one fiscal year. The term should not be confused with two-year or three-year funds that cover only one fiscal year’s requirement but permit the Executive Branch more than one-year to obligate the funds.

Multi-Year Procurement: An acquisition strategy that allows authorization of a contractor to purchase materials and parts to support several system buy years, thus achieving savings through economic order quantity procurements.

Negotiation: (1) In its more formal context, negotiation is one of the major methods of procurement. It is employed under certain permissive circumstances prescribed by statute when formal advertising is determined to be unfeasible and impracticable. (2) In its more general context, a bargaining-process between two or more parties, each with its own viewpoints and objectives, seeking to reach a mutually satisfactory agreement on, or settlement of, a matter of common concern. In estimating, the give and take process of final deliberations between a buyer and a seller necessary to finalize a statement of work, program definition, cost estimate and contract for a program or product.

Net Present Value (NPV): The discounted present value of benefits minus the discounted present value of costs. If the results are positive (i.e., benefits minus costs are greater than zero) the project is financially beneficial.

No-year Funding: Congressional funding that does not require obligation in any specific year or years.

Nomenclature: Markings, titles, models, and series numbers used to identify hardware and end items.

Nondevelopmental Item: An item that has been developed previously for use by federal, state, local or a foreign government and no further development is required.

Nonrecurring Costs: Those production costs that generally are incurred on a one time basis and include such costs as plant or equipment relocation, plant rearrangement, special tooling and special test equipment, pre-production engineering, initial spoilage and rework, and specialized workforce training.

Normalized: (1) Database - to render constant or to adjust for known differences. (2) Dollars - various fiscal year costs are inflated/deflated to a common year basis for comparison.

Not-Repairable-This-Station (NRTS): All reported unscheduled maintenance actions, which must be sent to a depot or Special Repair Activity (SRA) for repair.

Not-To-Exceed (NTE) Not-Less-Than (NLT): A corporate commitment to a customer that the value of an estimate plus appropriate contingency allowances will not be exceeded or be less than the firm proposal and estimates which will be submitted at a later date. The NTE or NTL value can be adjusted by changes in the statement of work, requirements, and specifications.

Obligation: The legal reservation of a specific amount of funds associated with a firm contract or other obligating document.

Ogive: Graphic presentation of cumulative hours or costs (or average of period hours or costs) plotted against time. The result is (1) cumulative curve normally “S” shaped; or (2) the average data plotted on a current basis gives the conventional bell-shaped curve, called an “Ogive.”

Operating And Support Costs: The added or variable costs of personnel, materials, facilities, and other items needed for the peacetime operation, maintenance and support of a system during activation, steady state operation, and disposal.

Operating Cost: (1) Total outlay in cash or its equivalent applied in carrying out a specific program or function. (2) A life cycle cost term.

Operational Readiness: Refers to the state of a fielded new system. This state is achieved after the system is tested at the field test site where it is demonstrated that local site personnel have the ability to fully operate and maintain the new system.

Operational Suitability: The capability of a system to be satisfactorily integrated and employed for field use, considering such factors as compatibility, reliability, human performance factors, maintenance and logistics support, safety, and training. The term also refers to the actual degree to which the system satisfies these parameters.

Operations Research: A scientific approach that uses analytic methods to solve operational problems. The objective is to provide management with a logical basis for making sound predictions and decisions.

Optimum: The most efficient/effective use of resources to accomplish a specified task - the best use of time and resource.

Organizational Maintenance: Maintenance performed by the organization that is operating the system. Also known as "base level" and "servicing level."

Other Government Costs (OGC): An aggregated heading of miscellaneous cost elements that typically fall outside of the basic estimate's work breakdown structure.

Out-Of-Scope-Change: A contract change that is considered outside of the contractual statement of work and will result in an adjustment to contract cost and price.

Output: (1) Results of the efforts of B group. (2) Print out of computer tabulation. (3) The energy or work produced by a machine or equipment.

Over Expenditure: Expenditures over (above) the planned or funded levels.

Overhaul: The process of restoring an item of supply to a serviceable condition by completely or partially disassembling the item, inspecting the condition of each of its component parts, repairing, and reassembling it, using serviceable, or new assemblies, subassemblies, and parts as required, followed by inspection and operational tests.

Overhead (Indirect): A cost, which, because of its incurrence for common or joint objectives, is not readily subject to treatment as a direct cost. Such indirect cost is incurred to benefit the total direct cost or business base of a contractor. The character of overhead cost thus requires estimating, budgeting and control techniques that take into account the total business base of a contractor. Accordingly, the overhead applicable to any one estimate or contract is by an appropriate distribution of indirect costs through the use of a rate per hour or percentage applied to direct hours or costs. Indirect is a term that is synonymous with overhead.

Overhead Budget: Management allocation of planned indirect costs to each established overhead pool or organization.

Overhead Pool: A grouping of overhead expenses determined to be applicable to a previously determined distribution base, such as manufacturing or engineering direct labor hours.

Overhead Rates: Indirect dollars per hour or cost-to-cost relationships that mathematically reflect the distribution of overhead costs over a labor or cost base.

Overhead Task: Work done by people charged to an overhead account.

Overrun: Costs in excess of the contemplated or target contract costs.

Overtime: Work in excess of B hours a day or 40 hours a week. Overtime is a resource that is available to management as a means of extending available manpower and talent, but which imposes a premium labor cost to any task to which it is applied. Consists of two types (1) Unscheduled (Bottleneck) - overtime that is necessary to alleviate a temporary behind schedule condition that can have an adverse effect on other organizations if not completed in time. (2) Scheduled (Planned) - overtime expended on a planned basis to provide round the clock support to an activity that cannot be stopped once started (like countdown to a test firing) or to use machines or technical personnel to the maximum on a task.

Ownership Cost: Another term for operating and support costs.

Paasche Index: A relative of Weighted Aggregates Index, which uses weights computed for the period at which the index is being calculated.

Packing: Application or use of shipping containers and assembling of items or packages together with necessary blocking, bracing or cushioning, weatherproofing, exterior strapping and marking of shipping container.

Packing And Crating Costs: The costs to package the company products for shipment to its customers.

Parameter: A characteristic that is considered to be essential in accurately describing a problem, population, or system. The characteristic is used to calibrate, measure, or calculate a series of results or tests. Various types include design, system, equipment, or cost parameter. In costs, it is often hours/pounds, dollars/horsepower, hours/wire, etc.

Parametric Estimating: An estimating technique, which employs one or more cost estimating relationships. It involves collecting relevant historical data at an aggregated level of detail and relating it to the area to be estimated through the use of mathematical techniques.

Part: An item of supply which when joined together with another item normally is not subject to disassembly without disruption or impairment of the design use of the end item.

Part Standard: A selected and defined item (part) for multiple use that has been developed to best satisfy certain design and performance requirements.

Partial Payment: A payment authorized under a contract upon completion of the delivery of one or more complete units called for in the contract, or upon completion of one or more distinct items of service called for in the contract - the payment of an amount less than the amount due. Also a payment made against a termination claim upon prior approval before final settlement of the total termination claim.

Partial Settlement: A settlement of a serviceable portion of a termination claim or settlement proposal, evidenced by a partial settlement agreement.

Partial Termination: The termination of a portion of the work to be performed or services to be rendered under a contract.

Peculiar Support Equipment (PSE): Unique aerospace ground equipment required to support and maintain a special item of equipment, system, or hardware.

People-Capability Maturity Model: A model, which serves as the framework for the life cycle acquisition workforce learning system. This model, adapted from the Software Engineering Institute’s Software Capability Model, is a maturity framework that describes the key elements of managing and developing the human talent of an organization. The model identifies five levels of maturity that an organization must undergo to provide a continuous learning environment. These levels are initial, repeatable, defined, managed, and optimized.

Per Diem: A daily or monthly allowance to cover subsistence, lodging, and local transportation costs while in travel status or temporary additional duty away from one's home location.

Percentage-Time Percentage-Cost (PTPC) Technique: An estimate time phasing technique that illustrates the percentages of total program funds required at various percentages of total program time.

Performance Parameters: Those mission critical performance and life cycle supportability criteria contained in the Requirements Document. They represent the sponsoring organizations’ translation of the capability shortfall in the Mission Need Statement into critical factors the selected solution must contain in its eventual operational state to satisfy the user’s needs.

Performance Measurement Baseline: The timephased budget plan against which contract performance is measured.

Program Evaluation and Review Technique (PERT): A management tool for defining and integrating what must be done to accomplish program objectives on time, and identifying the critical items and flow.

Petroleum, Oil, And Lubricants (POL) Costs: An area of other government costs that includes the cost for the petroleum, oil, and lubricants required in the various tests conducted during the development phase of a program as well as those same costs incurred in initial fueling and acceptance tests during production.

Physical Characteristics: Those descriptors of a system, which are primarily physical in nature such as weight, shape, volume, etc.

Physical Inventory: An inventory of property determined by observation and evidenced by a listing of the actual count, weight, measure, or the sighting of classified documents.

Physical Standard: (1) A quantitative, normal measure (not a dollar cost) of a requirement for raw material, labor time, machine time, etc., in a manufacturing or similar process. (2) A basis of production planning, scheduling and control; a means of determination of material, labor, and machine requirements. (3) A means of projecting workloads in relation to capacity. (4) A basis for determining standard costs for use in cost control and preparation of budget estimates.

Plant Equipment: Property of a capital nature (consisting of machinery, equipment, furniture, vehicles, machine tools, accessory and auxiliary items, and other production equipment, but excluding special tooling) used or capable of use in the research, development, manufacture, and test of products or in the performance of services, or for any administrative or general plant purpose.

Plant Property: Capital assets used in the production of goods and services, but excluding materials used up in producing them.

Point Estimate: An estimate, which measures a single numerical value rather than a range of values.

Preliminary Design Review (PDR): Technical reviews held early in a program to view the acceptability of the concept and initial design information.

Premium Pay: Payment in addition to base pay rates to personnel for hazardous duty, off site, non-normal shifts, or overtime.

Preproduction Period: The time between the beginning of work in preparation for production and completion of the first article.

Preservation And Packaging: Application or use of adequate protective measures to prevent deterioration and damage including the use of appropriate protective wrappings, cushioning, interior containers, etc.

Price: Equals cost plus any fee or profit involved in the procurement of a product or service.

Price Index: A ratio indicating the relationship between prices at two time periods. Labor and materials, within designated industry areas, are the two resources usually considered in determining a price index. The cost-of-living index is a form of price index.

Price Negotiation Memorandum: The document that relates the story of the negotiation. The document has two objectives (1) It establishes the reasonableness of the agreement reached with the successful offeror; and (2) It is the permanent record of the decisions the negotiator made in establishing that the price was fair and reasonable.

Price: Price equals cost plus any fee or profit involved in the procurement of a good or service.

Pricing: The establishment of a sales price. The development and justification of sales price proposals including the selection and projection of rates, ratios, factors, and comparative analyses with present or past programs and market evaluations.

Primary Cost Data: Cost data obtained directly from the originator prior to adjustments, normalization, or other types of manipulations.

Probabilistic Relationship: In statistics, a relationship between two or more variables that is uncertain in nature.

Probability Distribution: Also referred to as a frequency distribution, it conveys in tabular or graphical form the possible values or range of values that an element such as cost might assume and the likelihood that each of these values will be realized.

Probability: The numerical expression of the likelihood or chance of occurrence of a given event. The term is often associated with results of repeated random sampling. It usually is expressed as a proportion that is determined by dividing the total number of items, values, or events of a specific type in a given group (or universe) by the grand total of all possible types of items, values, or events in the same group (or universe).

Process Document: Used as an engineering or manufacturing release to describe processing, sequencing and inspection requirements for manufacture or rework of individual parts or assemblies.

Process Specification: A statement of engineering requirements that are supplemental but subordinate to drawings or other specifications, in which are delineated the means of manufacture and the quality assurance evaluation necessary to assure attainment of engineering design.

Procurement: The act of obtaining raw material, purchased parts and equipment, subcontract and other production items or the obtaining of equipment, resources, property, or services by purchasing, renting, leasing, or other means.

Procurement Contract: A legal instrument used to acquire goods and services for the direct benefit or use of the FAA.

Procurement Contracting Officer (PCO): See contracting officer.

Procurement Schedule: Display by fiscal year of quantities of system peculiar major items/components to be procured for a program.

Procuring Authority: Represents the designated program or project manager, or such other governmental official responsibility for the effective and economical execution of the contract.

Procuring Department: Any department or subdivision that receives, accepts and fulfills orders from another department or subdivision for delivery from stock, manufacture, procurement of material or performance of services.

Product: (1) Any item proposed for sale by a company as a part of their normal marketing or sales function. (2) The service, software, or hardware listed as a deliverable in a contract or purchase order.

Product Assurance: A management discipline which assures that all critical activities are identified; that resources in the form of documented technology, facilities, and qualified people are developed for each activity; and that these resources are applied to each project to achieve customer requirements.

Product Baseline: The initially approved documentation describing all of the necessary functional and physical characteristics of the configuration item and the selected functional and physical characteristics designated for production acceptance testing and tests necessary for support of the configuration item. In addition to this documentation, the product baseline of the configuration item may consist of the actual equipment and software.

Product Configuration Baseline: A description for a contract end item defined by an approved specification and which is established by satisfactory completion of a first article configuration inspection.

Product Cost: The total cost associated with production of a specific quantity of an item.

Product Development: Defined to include all task/project costs incurred in conjunction with the application of scientific or technical knowledge in the development of new products, product components, processes, or improvements. May be developed with a company's own funds, funded by a customer, or combination thereof.

Product Liability Insurance: The purchase of protection against liabilities resulting from product usage.

Product Performance Agreements (PPAS): Contractual agreements that require the contractor to assume a greater responsibility for the field performance of the product.

Product Team (PT): A sub-IPT, with mission, resources, leader, and a complete cross-functional team to execute a sub-element of an IPT's mission.

Production And Deployment Phase: The last phase in a system's acquisition life cycle during which the system, including support and training equipment, data, facilities, and spares, will be produced and deployed for operational use.

Production Break: The time lapse between the completion of a production run and the start of another run for identical units.

Production Cost: Considers the procurement appropriation costs, both contractor and government, associated with the fabrication, assembly, and delivery of a system in the quantities required to support pop objectives. It includes the use able end item, support equipment, training, data, modifications, and spares.

Production Engineering: The application of design and analysis techniques to produce a specified product. Included are the functions of planning, specifying, and coordinating the application of required resources; performing analyses of productivity and production operations, processes, and systems; applying new manufacturing methods, tooling, and equipment; controlling the introduction of engineering changes; and employing cost control techniques.

Production Equipment: Those items of plant equipment located with a manufacturing, processing, assembly, or service establishment and used for cutting, grinding, shaping, forming, drilling, joining, measuring, testing, heating, or treating production materials or work in process.

Production Rate: The maximum number of end items produced in a given time period such as a month or year (i.e., 100 missiles per month).

Productivity: The state of yielding results, benefits, or profits. Productivity rate is a measure of the yielding of result, benefits, or profits; e.g., amount of concrete poured per man-hour.

Profit: Generally characterized as the basic motive of business enterprises; the excess of the revenues from sales of goods to services over the related cost thereof in a given transaction or over a given period of time. The word profit is used in fixed price type contracts versus "fee" in cost type contracts.

Profit Ceiling: The contractual maximum profit usually expressed as a percentage of contract target cost.

Profit Center: The smallest organizationally independent segment of a company which has been charged by management with profit and loss responsibilities and whose operations must, therefore, absorb its indirect costs.

Profit Floor: The contractual minimum profit, usually expressed as a percentage of contract target cost.

Profit Objective: (1) A major goal of a company's sales effort - the difference between sales and cost of sales. (2) In negotiations and procurement, that part of the estimated contract price that the customer and contractor try to negotiate as being appropriate for the procurement at hand.

Program Acquisition Cost: The sum of development and production costs. Construction costs may be included if directly related to the system. Initial spares also are included. Program acquisition cost and program cost often are used interchangeably.

Program Base Year: A fiscal year identified for a specific program that normally represents the year of initial program funding.

Program Cost Estimate (PCE): A program manager's official estimate of the financial resources required to competently conduct the program contained in the Program Management Directive. The PCE is also referred to as the Program Office Estimate (POE).

Program Decision Making: In general, resource decision making in the life cycle acquisition management process is at the corporate level and program decision making is within IPDS. Four decisions are always made at the corporate level, by the Joint Resources Council, the mission need decision, the investment decision, the decision to approve a baseline change, and a new investment decision related to in-service extension.

Program Work Breakdown Structure (PWBS): The total work breakdown structure for a program containing all the effort needed for a total system. The Contract Work Breakdown Structure (CWBS) is a subset of the PWBS. See contract work breakdown structure.

Progress Payments: Payments made to a contractor as work progresses on procurement, completion of a contract, or an end item. The amounts usually are based upon actual expenditures and work performed at a particular state of completion or a predetermined value based on the completion of certain milestones.

Property Loan Agreement: A written agreement under which the FAA provides and/or receives property on a temporary basis, and Federal funds are not obligated.

Proposal: Solicited or unsolicited offers to provide goods or services. Usually consists of a technical, management, and cost proposal plus a model contract. In addition, a separate executive summary document is included in most major proposals.

Proprietary: Data or documents which contain technical or business information developed and controlled by a company and are critical to the company's sales, product growth, or business operations.

Protest: A written, timely objection submitted by a protester to an FAA SIR or contract award.

Protester: A prospective offeror whose direct economic interest would be affected by the award or failure to award an FAA contract, or an actual offeror with a reasonable chance to receive award of an FAA contract.

Prototype: A largely hand-built original or model of a final product that is subject to full service test.

Provisioning: The process of determining the range and quantity of items (i.e., spares and repair parts, special tools, test equipment and support equipment) required to support and maintain an end item of material for an initial period of service.

Purchase Order: An executed document authorizing a supplier to deliver materials, equipment, or perform services, which, upon acceptance, constitutes the purchase contract.

Purchase Request: A document prepared by a requirements office stating the requirement in quantities and delivery dates for material or services and authorizing the procurement office to proceed with acquisition of the material or services.

Purchased Parts: Consists of standard commercial items fabricated by other than the prime contractor, and parts, components, and assemblies produced by others but not to the prime contractor's designs.

Quality Assurance: That function of management relative to all planning procedures, inspections, examinations, and tests required during procurement, production, receipt, storage, and issue that are necessary to provide the user with an item of the required quality. In current usage often includes quality control functions.

Quality Control: The inspection efforts for manufacturing, shops, receiving and shipping, and records necessary to assure that hardware, end items, parts, components, processes, and tests are being fabricated, assembled, and tested in accordance with engineering drawings and specifications.

Quantity Change: A change in quantity of end items to be procured or produced.

Quantity Discount: The effect measured by a decrease in the cost per unit of an item that results from an increase in quantity produced.

Random Sample: A sample selected in such a way that each element being sampled has an equal chance of being selected.

Range: (1) Statistical - The difference between the extreme values (smallest and largest figure or quantity) in a statistical series/distribution. (2) Estimating - The upper and lower possibilities of the forecasted costs of a program or project. Usually considered to be the realistic possibilities, not the extremes.

Rate: (1) In Estimating - The dollar value (actual or estimated) applied to such things as one hour of labor effort, one unit of computer equipment or machine usage. (2) In Manufacturing - The number (quantity) of items being produced in a given time such as a month or year (i.e., 100 missiles per month).

Ratio: A statistical method of comparing the values of two distinct efforts and projecting the result or quotient of this comparison into future efforts being estimated.

Rationale: A term used to explain the logical basis for an estimate. It may be used to show why an estimating method was selected, and how an estimate was developed. It also may be used to document why specific cost history was used and selected; why a given task, job, or estimate is similar to past experience and history; and why the estimate is realistic and credible.

Raw Index: An index that represents the annual compounded inflation from the midpoint of the base year to the midpoint of another fiscal year.

Raw Material: Includes raw stock, minor components, sheet stock, wires, etc., that require further processing into manufactured goods or tools.

RE&D Study Contracts: Customer funded research and development activity, which supports and supplements a company's funded new business effort.

Real Property: Lands, building, structures, utility systems, improvements and appurtenances thereto. Includes equipment attached to and made part of buildings and structures (such as heating systems) but not movable equipment (such as plant equipment).

Realism: Source selection criteria used to evaluate the compatibility of costs with proposal scope and effort.

Realization: A ratio of the standard hour value to the actual hours used. It is expressed as a percent reflecting the relative efficiency of workers in performing a given job.

Reasonableness: Source selection criteria used to evaluate the acceptability of the bidder's methodology.

Reconciliation: A determination or statement of the detailed items required to explain (1) the difference between two or more estimates; (2) the reason an actual value exceeds or is less than the forecasted value; or (3) the balances of two or more related values or accounts.

Recurring: Those elements of cost that occur repeatedly during production and delivery of a system. Includes fabrication, assembly, manufacturing, sustaining engineering and planning, sustaining tooling, acceptance testing of production items, and system engineering/program management.

Recurring Costs: Production costs that vary with the quantity being produced, such as labor and materials.

Refurbish: To restore an item of hardware to its original condition, e.g., refurbishing a flight test airplane for delivery.

Regression Analysis: The association of one or more independent variables with a dependent variable. Under static conditions, the analysis is called correlation. When used for predictive purposes, it is referred to as regression.

Rehabilitation Cost: Cost to restore or improve plant, property, or equipment, which is in a deteriorated condition.

Reimbursable Agreement: A written agreement under which the FAA provides material or services to a requesting party, which agrees to pay for those materials or services, and the requesting party obligates funds or promises to provide funds.

Reliability: The duration or probability of failure-free performance under stated conditions. Reliability is quantified as the probability that an item can perform its intended function for a specified interval under stated conditions.

Repair: The restoration or replacement of parts or components of property necessitated by wear or tear, damage, failure of parts or the like in order to restore it to acceptable operating condition without increasing its value or expected service life.

Repair Level: Level at which maintenance is performed on an item - organizational (flight line), intermediate (base), and depot.

Replacement: The act of replacing a unit with the same or a similar unit with a superior or different unit.

Replacement Cost: The cost of replacing an existing item or group of items of tangible property.

Replacement Factor: The estimated percentage of equipment in use that will require replacement during a given period due to wearing out beyond repair.

Replenishment (Recurring) Spare Parts: Those spare parts procured on other than production contracts. These requirements cover support provided after the initial spare parts procurements and extend throughout the program life of the system or end item of equipment.

*Request For Proposals (*RFP): A solicitation document used in negotiated procurements. It usually contains a description of the items or services to be procured, the terms and conditions, type of contract, schedules, work statement, specifications, listing of the items to be delivered, funding, data requirements, and instruction for the preparation of technical management and cost proposals.

Requirements Document: A formal planning document approved by the Associate Administrator of the sponsoring organization that establishes the operational framework and the cost, schedule, performance, and benefits baselines required by the line of business with the mission need. It translates the mission need into top-level performance, supportability, and benefit requirements that should be satisfied in the final fielded capability. It is prepared in the investment analysis phase of the life cycle acquisition management process.

Research: All effort directed toward (1) increased knowledge of natural phenomena and the environment and (2) the solution of problems in all fields of science. This includes basic research, which has as its goal to increase scientific knowledge rather than its practical application; and applied research, which normally follows basic research and attempts to determine or expand the potential of scientific discoveries or improvements in technology, materials, processes, methods, device, and techniques.

Resources: Consists of facilities, equipment, management, personnel, laboratories, and scientific, technical, and manufacturing capability.

Retrograde Method: An approach used to account for breaks in production that assumes that once production is restarted, learning will proceed down the same cost improvement curve experienced in the earlier production run.

Revalidated Mission Need Statement: The original mission need statement is approved at the mission need decision. Anytime thereafter in the life cycle acquisition management process, there are occasions when the mission need should be revalidated to ensure the program should continue in the same form. This means that the sponsoring organization reexamines the need and determines that the capability shortfall, impact, benefits, timeframe, criticality, and estimate of resources described in the mission need statement essentially are unchanged. If the parameters are unchanged, the sponsor needs to recommend changes to, or cancellation of, the program in its present form.

Rework: Second time effort to rework and repair, replace components, retouch up, disassemble, and reassemble, etc., once the equipment initially has been built, but is rejected by inspection or test. This is particularly applicable to assembly labor where rejections due to workmanship tend to be random and are not related directly to a particular unit.

Rights In Data: Those rights including title, possession, use or proprietary interest in data, which, although not necessarily patentable or copyrightable, give the holder of such rights a competitive advantage or a special consideration.

Risk: A situation in which the outcome is subject to an uncontrollable random event stemming from a known probability distribution.

Run Time: The hour value that is repeated each time a part is produced.

Safety: The relative freedom from damage or risk of injury to people and damage to items. The organization within a company or agency charged with the responsibility to review work conditions, environment, and products for safety. System safety refers to the safe operation of an end item or system in its operational mode.

Safety Analysis: A logical synopsis of a system or part of a system that identifies its hazards and safety features.

Salvage: Property that is in such worn, damaged, deteriorated, or incomplete condition, or is of such a specialized nature that it has no reasonable prospect for sale or use as a unit, or is not usable as a unit without major repairs or alterations. Includes the amount realizable from disposition of such property.

Sampling: Method of obtaining statistics from a large body of data without resorting to a complete data census. Two broad methods of selecting samples are probability sampling (in which sample units are selected according to the law of chance) and non-probability sampling (in which personal choice, expert judgment, or some other non probabilistic rationale is used to select sample units).

Scaling Factor: The decrease of the measure per physical characteristic (as hours per pound) being compared to similar end items but always increasing in the physical characteristic (as weight). For example, as airplanes of a similar type get larger, the hours per pound get less. The scaling factor is the curve that results from plotting the hours per pound against the various weights of the airplanes.

Schedule: (1) A time-display of the milestone events and activities of a program or project. (2) A subsidiary detailed financial or statistical table, generally in support of summary data in an exhibit.

Schedule Changes: Changes in a delivery schedule, completion date, or intermediate milestone of development or production phases of a project or program.

Schedule Variance (SV): The difference between Budgeted Cost of Work Scheduled (BCWS) and Budgeted Cost of Work Performed (BCWP).

Scrap: Property that has no reasonable prospect of being sold except for the possible re-use of its basic material content.

Screening: The process of evaluating offeror submittals to determine either which offerors/products are qualified to meet a specific type of supply or service, which offerors are most likely to receive award, or which offerors provide the best value to the FAA.

Screening Decision: The narrowing of the number of offerors participating in the source selection process to offerors most likely to receive award.

Screening Information Request (SIR): Any request made by the FAA for documentation, information, or offer for the purpose of screening to determine which offeror provides the best value solution for a particular procurement.

Seasonal Variation: In a time series of statistical data, that part of the movement of the data within each year due to the normal recurring effect of a season or seasons.

Second Destination Transportation: Any transportation other than first destination. It includes port-handling charges and charges for freight, cart age, demur rage, and other charges incurred overseas incident to shipment of property.

Secondary Cost Data: Cost data that has been derived from primary cost data through some sort of adjustments.

Selection Decision: The determination to make an award, by the Source Selection Official (SSO), to the offeror providing the best value to the FAA.

Sensitivity Analysis: Repetition of an analysis with different quantitative values for selected parameters or assumptions for the purpose of comparison with the results of the basic analysis. If a small change in the value of the variable results in a large change in the results, then the results are said to be sensitive to that parameter or assumption.

Sequential Theory: A part of cost improvement curve theory that contends that credit can be taken for cost improvement experienced in prototyping by continuing improvement on the same slope with a displacement on the curve at the first production unit. The first production unit under this theory is defined as the last prototype unit plus one.

Service-Life Extension Decision: The decision point during the in-service management phase when the costs and benefits of a major upgrade to extend the service life of an existing asset are weighed against the benefits and costs of meeting the mission need through a new replacement system.

Set-Aside For Small Businesses: The reservation of an acquisition exclusively for participation by small businesses.

Settlement Proposal: A termination claim submitted by a contractor or subcontractor.

Setup: The one time only portion of the job of producing a given quantity of identical parts. Setup involves the preparation of a machine for producing parts.

Share Or Sharing: The sharing of "over or under-run" of target costs at a predetermined ratio under an incentive type contract.

Shop Calendar: A company calendar, which shows the working days, holidays, and weekends. The calendar also is numbered sequentially for the working days. The numbers are used for shop releases and manufacturing events.

Shop Replaceable Unit (SRU): An off-equipment replaced item, usually part of an LRU, which can be repaired at a base repair shop (I-level) but usually is repaired at the depot.

Shop Support: A generic term to cover manufacturing support to a program/project activity. Consisting of secondary support services to a primary manufacturing function producing contract end items.

Short Term Rentals: Rental contracts for property or equipment that may be terminated in one year or less are considered short-term rentals.

Shortfalls: Within the mission needs analysis, refers to the difference between the perceived supply and demand.

Should Cost Estimate (SCE): Performed on production contracts. An estimate of contract price, that reflects a level of contractor economy and efficiency that should be achieved. The SCE's purpose is to develop a realistic price objective for the government to use as its negotiation objective. An SCE does not arrive at its value through a build-up process or by using cost estimating techniques. It starts with the contractor's proposal and seeks to decrease the proposed price by investigating the underlying management, engineering, and manufacturing practices to identify inefficiencies. An SCE is performed by a government team composed of procurement (provides team leadership), contract administration, audit, comptroller, and engineering representatives who conduct in-depth analysis at the contractor's plant. The SCE normally is considered to be a procurement responsibility.

Simple Aggregate Price Index: A composite index that is calculated by taking the arithmetic average of a group of simple index numbers.

Simple Aggregates Price Index: A composite index that is calculated 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.

Simple Index: An index that measures the relative change from the base period for a single item.

Simple Time Determined Penalty: An approach used to account for breaks in production that assumes the beneficial effects of production learning are lost in proportion to the duration of the production break.

Simulation: A model of a set of conditions or an environment of interrelated elements exercised in a manner to gain knowledge of conditions they may develop under various circumstances.

Single Service Procurement: Procurement whereby one government department procures certain supplies to satisfy the requirements of all departments.

Sinking Fund: A fund established by periodic contributions for some specific purpose, e.g., retirement of bonds, payment of mortgage, or replacement of an asset.

Site Activation Costs: The costs incurred to bring a site to operational readiness including facility construction, the installation and checkout of all system and supporting equipment, and acceptance of the site by the operating command.

Slippage: Delay in meeting scheduled objectives under a program. Usually accompanied by a related financial impact.

Small Business: A business, including its affiliates, that is owned and operated independently and not dominant in producing or performing the supplies or services being purchased, and one that qualifies as a small business under the federal government's criteria and standard industrial classification size standards.

Software: Having to do with computer programs and instructions. In a general sense - reports, drawings, sketches, computer programs or tapes, photos, etc., as opposed to hardware.

Sole Source: Characterized as the one and only source, regardless of the marketplace, possessing a unique and singularly available performance capability for the purpose of contract award. (Sometimes used interchangeably with the term single source).

Solution Implementation Phase: Phase of the life cycle acquisition management process that begins after the Joint Resources Council (JRC) selects a solution and establishes an acquisition program. It ends when the new capability goes into service. This phase normally is characterized by three sets of activities: planning solution implementation, obtaining the solution, and deploying the solution. This phase is lead by the Integrated Product Team assigned by the JRC at the investment decision.

Source Selection: The formal procurement process used within pop or a company to (1) call for proposals; (2) evaluate proposals; (3) pass recommendations to higher authority; or (4) award the final contract (decision made by the selection authority).

Source Selection Official (SSO): As a member of the Integrated Product Team, the SSO has full responsibility and authority to select the source(s) for contract award.

Spare: A term sometimes used to denote a portion of spare parts represented by subassemblies and assemblies or major components (like aircraft engines, boosters, etc.); an abbreviated word for spare parts.

Spare Backorders: Spares orders not filled for lack of spares.

Spare Parts: Those items of supply and replacement that are required for the maintenance, overhaul, or repair of a system or associated equipment.

Spare Pipeline: The inventory of spares required to meet an established system availability requirement. The inventory is a function of item reliability, repair cycle time, and the established availability requirement.

Special Test Equipment (STE): All electrical, electronic, hydraulic, pneumatic, mechanical, or other items or assemblies of equipment which are of such a specialized nature that, without modification or alteration, the use of such items or assemblies is limited to testing in the development or production of particular supplies or parts thereof or in the performance of particular services.

Special Tooling (ST): Tools, which are of such a specialized nature that their use is limited to supporting developmental or production manufacturing activities. These tool items are accountable under a contract but not delivered.

Specifications: Federal specifications and industrial trade specifications approved for use by a customer. They include performance, environmental, size, weight, reliability, inspection, safety, health and hygienic, etc. requirements for a deliverable item.

Standard: An established or accepted rule, measure, model, definition, or procedure by which the degree of satisfying a product or act is determined.

Standard Cost: The predetermined cost of each operation or each unit of finished product. It represents the value of direct material, labor, and manufacturing burden, normally required under efficient conditions at normal capacity to process a unit of product. Except for costs attributable to precise and highly predictable operations, actual costs almost always will vary from standard costs due to factors (usually called variances) that affect performance, like employee fatigue, unforeseen interruptions, and other delays.

Standard Deviation: A measure of average dispersion (deviation from the mean) of numbers, computed as the square root of the average of the squares of the differences between the numbers and their arithmetic mean.

Standard Hours: The number of hours a skilled worker should use to complete a given job under ideal or perfect conditions. A standard hour is a means of establishing a relative means of measurement.

Standard Price Variance: Difference between actual costs incurred in connection with acquisition of material and the amount recorded in the inventory accounts at standard unit costs.

Standard Price: A uniform price for any item established by a designated central authority based upon the estimated purchase cost or replacement cost.

Standard Stock Item: An article of the supply system that is approved for procurement, storage, or issue.

Standardization: The practice of acquiring parts, components, subsystems, or systems with common design or functional characteristics to obtain economies in ownership costs.

State Of The Art: The total scientific or technical knowledge available at a point in time when applied to a specific situation or design. It is used as a standard of comparison whereby a design is evaluated in the light of the existing scientific or technical knowledge available at the time.

Statement Of Work: A document stating the confines of the contractual work to be accomplished. The part of an RFP or contract that defines the work which a customer wants performed.

Statistical Cost: Cost derived by the application of statistical methods to data accumulated through a cost reporting and accounting systems.

Statistical Range: The difference between the smallest and largest figure (or quantity) in a statistical series.

Statistical Sample: A limited number of observations selected from a particular area on a systematic, random, or other basis. The sample makes possible, after the application of statistical techniques, a generalization about the area from which the sample was drawn.

Statistics: (1) Descriptive - The collecting, classifying, summarizing, and interpreting of numerical facts and amounts. (2) Inferential - Projection of forecasts based upon sample data.

Status Report: A report reflecting the situation as of a specified date with respect to programs, functions, activities, projects or processes.

Stock: A supply of material maintained on hand or at storage points in a supply system to meet anticipated demands for it. Items issued for actual use are not considered to be in stock.

Stop Work Order: An order from the customer to stop work on a contract. Work may later be resumed or the contract may be terminated.

Storage: The act of storing, or the state of being stored, the keeping or placing of property in a warehouse, shed or open area. Storage is a continuation of the receiving operation and is preliminary to the shipping or issuing operation.

Storage Unit: That part of automatic data processing equipment into which units of information can be copied, stored, and from which the information can be obtained at a later time.

Subassembly: Two or more parts that form a portion of an assembly or end item.

Subcontract: (1) General - any agreement, purchase order, and/or instrument, other than a prime contract, calling for the performance of work or for the making or furnishing of material required for the performance of one or more prime contracts. (2) Estimating - current usage usually covers the procurement of major components or subsystems which require the subcontractor to do extensive design, development, engineering, and testing to meet a prime contractor's procurement specification.

Subcontracted Items: Parts, components, assemblies, and services produced by a subcontractor for a prime contractor.

Subjective Estimator Judgment: An approach to accounting for uncertainty in which the analyst merely reflects back on the assumptions and judgments that were made during the development of the estimate and then applies a final adjustment to the estimate to reflect this subjective measure of uncertainty.

Subsystem: A subset of devices or individual units of hardware that constitute a defined part of a system (e.g., the avionics of an aircraft system, the fire control mechanisms of a ship system, the transmission/receiving elements of an electronic system).

Sunk Cost: The total of all past expenditures or irrevocably committed funds related to a program/project. Sunk costs are generally not relevant to decision-making as they reflect previous choices rather than current choices. Sometimes referred to as prior year costs.

Supplemental Agreement: A contract modification that is accomplished by the mutual action of the parties. The term is synonymous with contract amendment.

Supplier: A company that supplies relatively standard or off-the-shelf hardware, as contrasted to a subcontractor, who generally performs some degree of specialized engineering in producing his deliverable items. The word supplier is synonymous with vendor.

Supply: As used in the mission needs analysis, a determination of the ability of the FAA to provide products, service, or capacity.

Supply System: The organizations, methods, and techniques used to provide supplies and equipment to authorized users, including identification of requirements, procurement, distribution, maintenance, issue, and salvage of material.

Support Changes: A change in the requirements for a support item (e.g., spare parts, training, ancillary equipment, warranty-provisions, Government-Furnished-Property/Equipment, etc.).

Support Equipment: Includes all equipment required to perform the support function except that which is an integral part of the mission equipment. It does not include any of the equipment required to perform mission operation functions. Support equipment includes handling equipment, test equipment, automatic test equipment (when the automatic test equipment is accomplishing a support function), organizational, field, and depot support equipment, tools, and related computer programs, and software. Further, it consists of peculiar support equipment (PSE) that is unique to a system and common support equipment that is in the customer inventory.

Surcharge: Any percentage addition to a material price to cover storage, handling, transportation, and other charges.

Surplus Material: Material in excess of requirements in inventory.

Surplus Property: Idle property no longer required by the using or custodial organization.

Surplus Reserve: A reserve representing the amount set aside or appropriated out of surplus for future planned expenditures or unforeseen contingencies.

Survivability: The measure of the degree to which an item will withstand hostile environment and not sustain abortive impairment of its mission.

Sustaining Engineering: The continuing engineering and technical effort that follows the release of all the drawings and specifications and is required to support fabrication, assembly, testing, and delivery of end items. Specific efforts include the maintenance and updating of drawings and specifications; coordination of material or hardware changes; investigation and analysis of problems; and the proposing of the latest available techniques for the prime purpose of product improvement within the scope of a contract.

Sustaining Tooling: The effort following initial tooling for maintenance, repair, modification, and replacement of the tools used in a program and within the scope of a contract.

Sustainment: Those activities associated with keeping fielded products operational and maintained. Also applies to the planning, programming, and budgeting for fielded products, referred to as sustainment funding.

System: The sum total of prime mission equipment and all the peripheral elements that are necessary to operate and maintain the equipment as a mission-ready unit. The system includes support equipment, spares, supplies, trainers, people, tech orders, and facilities.

System Effectiveness: A measure of how well a system achieves the ends or mission objectives.

System Engineering/Operational Analysis Team (SEOAT): A team of senior level managers representing the agency's lines of business, systems engineering, and other appropriate acquisition functional disciplines responsible for supporting the Joint Resources Council in establishing and maintaining year round prioritization of all ongoing acquisition programs, performing affordability assessments for new proposed acquisition programs, preparing annual budget submissions, and preparing reprogramming of funds recommendations.

System Engineering: An engineering organization that allocates and controls the distribution of system level requirements and specifications to lower level subsystems and equipment items. Also controls system level documents such as specifications, weights, reliability, and program equipment lists.

System Safety: The condition of an assemblage of objects and related personnel, being acceptably free of risk of self-injury or damage, or of injury or damage to other persons or property.

System Safety Engineering: The logical application of scientific methods to the design, development, analysis, testing and use of systems such that the resultant system is acceptably safe.

System Test: Consists of all testing required to develop the system and accomplish planned test objectives, and includes collection of data necessary to evaluate the system. The system test spectrum will be divided into three categories.

Target Cost: A value, established as a result of negotiation within incentive type contracts, used as a cost objective and as a basis for agreement on the target profit and target price. Used as the base point in calculating the cost sharing on incentive contracts.

Task Force: Usually a temporary grouping of personnel formed for the purpose of carrying out a specific mission or project. Sometimes a semi-permanent organization held together for the purpose of carrying out a continuing task.

Task Order: A supplementary contractual and obligating document issued under a master or basic task order contract.

Technical Data: Technical data is an element of integrated logistics support. It is recorded information regardless of form or character (such as manuals, drawings, and operational test procedures) of a scientific or technical nature required to operate and maintain a subsystem/equipment over its life cycle. Computer programs and related software are not technical data; documentation of computer programs and related software are. Also excluded are financial data and other information related to contract administration.

Technical Leveling: The act of helping an offeror to bring its proposal/offer up to the level of other proposals/offers through successive rounds of communication, such as by pointing out weaknesses resulting from the offeror’s lack of diligence, competence, or inventiveness in preparing his proposal.

Technical Representative: An employee representing a manufacturer of equipment and assigned to a base installation or customer facility. He provides technical service on equipment manufactured or sold by his company.

Technical Research: That portion of applied research that is oriented toward the engineering disciplines as opposed to a specific product. This effort would include but not necessarily be limited to maintaining cognizance of the state-of-the-art; developing engineering tools, and software; or providing technical solutions to major customer problems.

Technical Specification: Documents intended primarily for use in procurement which are descriptions of the technical requirements for items, materials, or services including the procedures by which it will be determined that the requirements have been met. Specifications for items and materials also contain preservation, packaging, and marking requirements.

Technical Transfusion: The FAA's disclosure of technical information from one submittal that results in the improvement of another submittal.

Technology Modernization (Tech-Mod) Projects: Efforts that encompass modernization of contractor facilities.

Technology Programs: Those company or customer funded programs that fall within the definition of technical research and customer funded R&D study contracts that are included in a new business program and do not have sale of hardware or services as their end objective.

Telecommunication: Any transmission, emission, or reception of signs, signals, writing, images, and sounds or intelligence of any nature by wire, radio, visual, or other electromagnetic systems.

Terminated Portion Of Contract: That portion of a terminated contract which does not relate either to completed work or material delivered and accepted under the contract, or to any continued portion of the contract.

Termination: A customer-directed cancellation of all or part of a contract. Usually covers two parts. Regular termination covers the short-term aspects of termination consisting of program phase down effort, re-assignment of personnel, final documentation, and initial storage of the contract hardware and data completed up to the termination data. Special termination covers the longer phased aspects of termination such as settlement of subcontractor and supplier claims, continued storage, and disposition of terminated hardware, return of field representatives, and layoff/termination of employees not placed on other programs or projects.

Termination Claim: Any claim or demand by a prime contractor or subcontractor for compensation resulting from termination prior to completion of any contract or subcontract.

Termination for Convenience: The procedure that may apply to any FAA contract, including multi-year contracts. As contrasted with cancellation, termination can be effected at any time during the life of the contract (cancellation is effected between fiscal years) and can be for the total quantity or a partial quantity (whereas cancellation must be for all subsequent fiscal year quantities).

Termination Liability Funding: Obligating sufficient contract funds to cover the contractor's expenditures plus termination liability but not the total cost of the completed end items.

Termination Liability Funding: The funding available to obligate contract funds to cover contractor expenditures plus termination liability, but not the total cost of the completed end items.

Termination Liability: The maximum cost the FAA would incur if a contract is terminated. In the case of a multi-year contract terminated before completion of the current fiscal year's deliveries, termination liability would include an amount for both current year termination charges and out year cancellation charges.

Terms and Conditions: The part of a contract or purchase order which covers the general and special provisions, services, delivery dates, contractual incentives, prices, listings of standards, and specifications included in a contract.

Test: The engineering and manufacturing support activities to provide component, subsystem, and system verification by simulated or real operational use of portions or total end items to determine the acceptability of designs and requirements.

Test Check: To verify selected items in an estimate or record for the purpose of arriving at an opinion of the correctness of the entire data.

Test Equipment: Electrical, electronic, or mechanical items used to support the testing process - usually of a configuration such that it can be used on a repetitive basis to support many tests throughout the system test and evaluation process.

Test Run: To exercise portions of a total series of actions or outputs of a component, subsystem, system, computer, or machine to verify correct operation.

Test Spares: Spare parts used in developmental ground and flight-testing.

Then-Year Dollars: Dollars that reflect purchasing power at the time expenditures are actually made. Sometimes referred to as escalated or inflated costs or current costs. Prior costs expressed in then year dollars are the actual amounts paid out in these years. Future costs stated in then year dollars are projected actual amounts to be paid.

Timephasing: The process of allocating costs to specific government fiscal years.

Time Study: Observing, recording, or calculating the time required to perform each detailed element of an industrial operation and leveling off the results into a practicable, attainable work standard.

Time Variance (Labor): The difference between the standard hours priced at the standard rate and the actual hours priced at the standard rate.

Timephased Procurement: The programming and funding of certain non-recurring elements of a production program in a fiscal year different from that in which the useable end item is funded.

Toe-Up And Toe-Down: The upward (toe-up) or downward (toe-down) trend of a cost improvement curve at the end of a production run.

Tool-Up: The point in a production program when the maximum production rate is achieved; the production tools are in place, checked out, and operating at maximum rate.

Tooling: All jigs, dies, fixtures, molds, patterns, special taps, special gauges, other equipment and manufacturing aids, and replacements thereof, acquired or manufactured by a contractor for use in the performance of a contract. These tools are of such a specialized nature that, without substantial modification or alteration, their use is limited to the production of such supplies or parts; or the performance of such services that are peculiar to the needs of the customer. Sometimes called special tools.

Total Average Labor Cost: Includes all labor hours, productive and nonproductive, averaged over the quantity of units.

Total Contract Price At Completion: Consists of actuals through a specific date plus estimated cost to complete and estimated final fee/profit.

Total Contract Target Cost: The estimated cost set forth in the contract. It is adjusted plus or minus by the negotiated target cost of authorized changes.

Total Obligation Authority (TOA): The amount of funds available for programming in a given year, regardless of the year the funds are appropriated, obligated, or expended. TOA includes new obligation authority, unprogrammed or reprogrammed obligation authority from prior years, and unobligated balances transferred from other appropriations.

Trend: The general tendency of a set of statistical data toward the formulation of a pattern or a line, as related to time or another variable. May be pictured graphically as a curve on a grid chart as opposed to random or no trend data.

Uncertainty Analysis: A systematic analysis of the range of probable costs about a point estimate based on considerations of requirements, cost estimating, and technical uncertainty. The intent of such an analysis is to provide the decision maker with additional information for use in making decisions. Such an analysis is not expected to improve the precision of the point estimate but rather to place it in perspective with respect to various contingencies.

Uncertainty: A situation in which the outcome is subject to an uncontrollable random event stemming from an unknown probability distribution.

Underrun/Overrun: The amount of dollars (plus or minus) that vary from the contract target costs through a given period.

Undistributed Budget: Budget applicable to contract effort, which has not yet been identified to specific CWBS elements.

Unit: Any one part or combination of parts with a specification. Usually used to identify individual end items or major delivered items.

Unliquidated Commitments: Those commitments that are outstanding on the “as of” date of a report.

Unliquidated Obligation: An obligation incurred for which payment has not been made. It may consist of an account payable or obligation for goods and services ordered but not yet received.

Unsolicited Proposal: A quotation or informal bid. Usually generated within a company and not related to a formal customer request for proposal.

User: Internal FAA user of a product or service, such as Air Traffic Controllers or maintenance technicians.

Validation: In terms of cost models, a process used to determine whether the model selected for a particular estimate is a reliable predictor of costs for the type of system being estimated.

Value Analysis: A systematic and objective evaluation of the function of a product and its related cost. Its purpose is to ensure optimum value. As a pricing tool, it provides insight into the inherent worth of a product.

Value Engineering: An engineering function that examines proposed designs, methods, and processes with the objective of identifying lower cost techniques or processes to produce the item more economically without significant loss of performance.

Variable: A characteristic expressed numerically which might differ from one observation to another.

Variable Cost: A cost that changes with the rate of production of goods or the performance of services. As distinguished from fixed costs (which do not change with the rate of production or performance), and semi-variable costs (which are neither entirely fixed nor variable).

Variance: Deviation or difference between a standard or forecasted value and the actual value; stated in terms of cost, rate, time, weight, height, price, usage, etc.

Vendor: See supplier.

Very Small Business: A business that has been in operation for less than three years and whose size is no greater than 50 percent of the numerical size standard applicable to the standard industrial classification code assigned to a contracting opportunity.

Voucher: Any documentary evidence in support of a transaction. A voucher may be a paid check, a receipted invoice, a written requisition for the withdrawal of raw materials from a storeroom, an authorization to place a new employee on the payroll, or a request for repairs. Frequently, a voucher is viewed as an authorization to disburse money; this concept is not all-inclusive.

Weighted Aggregates Price Index: A composite index that uses the quantity used of an item as weighting applied against the price of that item.

Weighted Average Price Index: A composite index that uses the value of an item as weighting applied against the price relative of that item.

Weighted Average: An arithmetic mean of a numerical series adjusted to give appropriate significance to each item in relation to its importance. For example a weighted average purchase price per unit of a number of purchases of a given item is determined as follows: Sum of the cost of all purchases (equals cost times quantity of each purchase) divided by total quantity purchased. An unweighted average, or simple arithmetic mean, would be determined by the sum of the unit price of each purchase divided by number of purchases.

Work Authorization: A company instrument, memo, or document that authorizes work to be accomplished on a contract, project, or program.

Work Breakdown Structure (WBS): A method of diagramming the way that work is to be accomplished by separating the work content into individual elements.

Work Breakdown Structure (WBS) Elements: The individual elements of the work breakdown structure representing the required hardware, software, services and/or data. See work breakdown structure.

Work Load: The amount of work in terms of units, tasks, or products which organizations or individuals perform or are responsible for performing.

Work Measurement: A technique employed independently or in conjunction with cost accounting for the collection of data on labor hours and production by work units so that the relationship between work performed and labor hours expended can be calculated.

Work Order: The internal company authorization to incur costs for the design, development, manufacture, purchase, assembly, test, checkout and/or delivery of products. May also cover a specific or blanket authorization to perform certain work. A work order usually is broader in scope than a job order, although work order often is used synonymously with job order.

Work Package: A segment of effort that is characterized by beginning and ending points clearly defined in terms of accomplishment and can be assigned a value of the hours and dollars required to complete. Work packages are lower levels of the contractors extended work breakdown structure divided into functional packages of effort.

Work-In-Process: Materials upon which some manufacturing operations have been performed and on which additional operations are required prior to completion as finished goods.

Working Capital: Excess of current assets over current liabilities.

Wraparound Rate or Wrap Rate: A total rate per hour that covers direct labor, overhead, fringe benefits, and other costs. Also may include factored labor costs, support services, travel, and material costs. Note: no universal definition exists in the estimating profession to cover the specific items to be included in a wraparound rate.

ACRONYMS

A

ACEIT	Automated Cost Estimating Integrated Tools
ACWP	Actual Cost of Work Performed
AMS	Acquisition Management System
APB	Acquisition Program Baseline
ASP	Acquisition Strategy Paper

B

BAC	Budget at Completion
BAFO	Best and Final Offer
BCWP	Budgeted Cost of Work Performed
BCWS	Budgeted Cost of Work Scheduled
BLS	Bureau of Labor Statistics

C

CASA	Cost Analysis Strategy Assessment
CBA	Cost Benefit Analysis
CCDR	Contractor Cost Data Reporting
CDR	Critical Design Review
CELSA	Cost Estimating for Logistics Support Analysis
CER	Cost Estimating Relationship
CIP	Capital Investment Plan
CIR	Cost Information Report
CLIN	Contract Line Item Number
CO	Contracting Officer
COTS	Commercial Off-the-Shelf
CPI	Consumer Price Index
CPI	Cost Performance Index
CPR	Cost Performance Report
C/SCSC	Cost/Schedule Control Systems Criteria
C/SPCS	Cost/Schedule Performance and Control Specification
C/SSR	Cost/Schedule Status Report
CV	Cost Variance
CWBS	Contractor Work Breakdown Structure

D

DLSIE	Defense Logistics Studies Information Exchange
DoD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
DRI	Data Resources, Incorporated
DSMC	Defense Systems Management College
DTIC	Defense Technical Information Center

E

EAC	Estimates at Completion
ECI	Employment Cost Index
ECO	Engineering Change Order
EPA	Economic Price Adjustment
ETC	Estimate to Completion
EVMS	Earned Value Management System

F

FAA	Federal Aviation Administration
FAA AMS	Federal Aviation Administration Acquisition Management System
FAR	Federal Acquisition Regulation
FASA	Federal Acquisition Streamlining Act
FASB	Financial Accounting Standards Board
FAST	FAA Acquisition System Toolset
F&E	Facilities and Equipment
FCA	Functional Configuration Audit
FCCOM	Facilities Capital Cost of Money
FPRA	Forward Pricing Rate Agreement
FQR	Functional Qualification Review
FSD	Full Scale Production

G

G&A	General and Administrative
GDP	Gross Domestic Product
GFE	Government Furnished Equipment
GFP	Government Furnished Property
GPS	Global Positioning System

H

I

IAR	Investment Analysis Report
IAS	Investment Analysis Staff
IAT	Investment Analysis Team
IC	Integrated Chip
ICE	Independent Cost Estimate
ICS	Interim Contractor Support
IES	Industrial Engineering Standards
IGCE	Independent Government Cost Estimate
ILS	Integrated Logistics Support
IOC	Initial Operating Capability
IPDS	Integrated Product Development System
IPP	Integrated Program Plan
IPT	Integrated Product Team
IRS	Internal Revenue Service
IT	Information Technology

J

JOSTE	Joint Operating and Support Technology Evaluation
JRC	Joint Resources Council

K

L

LCC	Life Cycle Cost
LCCA	Life Cycle Cost Analyzer
LCCE	Life Cycle Cost Estimate
LOR	Level of Repair
LRE	Latest Revised Estimate
LRU	Line Replaceable Unit
LSC	Logistic Support Cost

M

MAIS	Major Automated Information System
MDAPS	Mandatory Procedures for Major Defense Acquisition Programs
MNS	Mission Need Statement
MR	Management Reserve
MTBD	Mean-Time-Between-Demands
MTBF	Mean-Time-Between-Failure

MTBMA	Mean-Time-Between-Maintenance-Action
MTTR	Mean-Time-To-Repair

N

NAILS	National Airspace Integrated Logistics Support
NAS	National Airspace System
NDI	Non-developmental Item
NPV	Net Present Value
NRLA	Network Repair Level Analysis
NRTS	Not-Repairable-This-Station
NTIS	National Technical Information Service

O

OBS	Organizational Breakdown Structure
ODC	Other Direct Costs
O&M	Operating and Maintenance
O&S	Operating and Support
OMB	Office of Management and Budge
OPS	Operations

P

P3I	Pre-planned Product Improvements
PCA	Physical Configuration Audit
PDF	Probability Distribution Function
PDR	Preliminary Design Review
PM	Program Management
PME	Prime Mission Equipment
POL	Petroleum, Oils, and Lubricants
PPI	Producer Price Index
PT	Product Team
PTPC	Percentage-Time Percentage-Cost
PWBS	Program Work Breakdown Structure

Q

QVL	Qualified Vendor List

R

RD	Requirements Document
RE&D	Research, Engineering, and Development
RFP	Request for Proposal

S

SAPI	Simple Aggregates Price Index
SCEA	Society of Cost Estimating and Analysis
SE	Systems Engineering
SEE	Standard Error of the Estimate
SEER	System Evaluation and Estimation of Resources
SEOAT	Systems Engineering/Operational Analysis Team
SEP	Standard Error of the Prediction
SI	Simple Index
SIC	Standard Industrial Classification
SIDAC	Supportability Investment Decision Analysis Center
SIR	Screening Information Request
SOW	Statement of Work
SRA	Special Repair Activity
SRU	Shop Replaceable Unit
SSO	Source Selection Official
SSR	Software Specification Review
STEP	Standardization Evaluation Program
SV	Schedule Variance

T

TFSDC	Total Full Scale Production Costs
TRR	Test Readiness Review

U

V

VAC	Variance at Completion

W

WAPI	Weighted Aggregates Price Index
WBS	Work Breakdown Structure

X

Y

Z