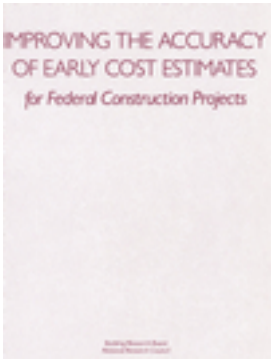

Improving the Accuracy of Early Cost Estimates for Federal Construction Projects

Committee on Budget Estimating Techniques, Building Research Board, National Research Council

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Committee on Budget Estimating Techniques

Building Research Board

Commission on Engineering and Technical Systems

National Research Council

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competencies and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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This report was prepared as part of the technical program of the Federal Construction Council (FCC). The FCC is a continuing activity of the Building Research Board, which is a unit of the Commission on Engineering and Technical Systems of the National Research Council. The purpose of the FCC is to promote cooperation among federal construction agencies and between such agencies and other elements of the building community in addressing technical issues of mutual concern. The FCC program is supported by 14 federal agencies: the Department of the Air Force, the Department of the Army, the Department of Commerce, the Department of Energy, the Department of the Navy, the Department of State, the General Services Administration, the National Aeronautics and Space Administration, the National Endowment for the Arts, the National Science Foundation, the U.S. Postal Service, the U.S. Public Health Service, the Smithsonian Institution, and the Veterans Administration.

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Preface

Concerns regarding the cost of construction have been with us a long time. Shakespeare discusses the problem in Henry IV.

When we mean to build,
We first survey the plot, then draw the model;
and when we see the figure of the house,
Then must we rate the cost of the erection
which if we find outweighs ability,
What do we then but draw anew the model
In fewer offices, or at least desist
To build at all? .
William Shakespeare
Henry IV, Part2, I.iii,1598.

Typically, the blame for cost overruns is attributed to a faulty budget estimate. This is probably due to the normal tendency to judge the quality and level of accuracy of an estimate against bids received and then make the assumption (often erroneous) that the bid is right and the estimate is wrong. The intention of a properly developed estimate is to reflect what the construction “should cost”; a bid reflects what the construction “will cost.”

During the committee deliberations, it became evident at an early stage that many factors influenced the difference between a budget estimate and final constuction costs. In fact, inaccurate budget estimating was found not to be the prime cause for cost overruns on construction projects.

As a result, the committee's work took on additional dimensions looking into not only enhancing estimating techniques, but also studying and making recommendations of other factors likely to influence the differences between budget estimates, bids, and final construction costs.

Time and resources precluded an extensive independent analysis of the federal government agencies abilities and success with budget estimating but considerable help was provided by the agencies by providing cost data input and sharing their experiences with the committee. The committee is particularly appreciative of the input received from the federal liaison members without whose help this study would be far less comprehensive.

As chairman of the committee, I would like to express my thanks to all committee members for their enthusiasm and professionalism in addressing a difficult and complex issue. I would also like to thank the members of the Building Research Board staff whose guidance and assistance we received during the drafting of this report.

Michael R. Morris, Chairman

Committee on Budget Estimating Techniques

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Executive Summary

Cost is a major factor in most decisions regarding construction, and cost estimates are prepared throughout the planning, design, and construction phases of a construction project. All of these estimates are important because they invariably influence the expenditure of major sums. However, estimates made in the early phases of a project are particularly important because they affect the most basic decisions about a project: whether it will be undertaken at all; how large it will be; how elaborate, sophisticated and durable it will be; and how much it will cost (i.e., what the budget will be and, in the case of federal agencies, what the congressional appropriation will be).

Federal agencies, like most organizations with large continuing construction programs, have long recognized the importance of these early estimates, and they have instituted various policies and procedures to help ensure that such estimates are prepared carefully and properly. Yet problems associated with inaccurate early estimates have persisted and manifest themselves in various ways, including: (1) failure to award a construction contract because of excessively high bids, (2) receipt of embarrassingly low bids, (3) design problems, (4) project delays, and (5) facilities with marginal or impaired operations.

Because Congress maintains fairly tight control on federal expenditures, agencies have limited leeway to deal with problems caused by erroneous early estimates. Consequently, agencies periodically look for ways to improve their early estimates. In 1988 the agencies that sponsor the Federal Construction Council asked the Building Research Board (BRB) to review their current practices and, if possible, recommend ways of improving those practices. The study was conducted by the BRB Committee on Budget Estimating Techniques.

PUTTING THE PROBLEM IN PERSPECTIVE

As part of its study the committee investigated the extent, nature, and root causes of the budgetrelated problem experienced by federal agencies on their construction projects. The committee found that agencies do in fact encounter budget-related problems on a significant percentage of their construction projects (approximately 35 percent on average). However, the committee also concluded that, contrary to widespread belief, such problems are not primarily the result of faulty estimating techniques.

Although there is room for improvement in the policies and practices of many agencies regarding the preparation of early estimates, agencies need to recognize that other factors besides estimates contribute to budget-related problems. The committee believes that the keys to a successful project, other than accurate estimates, are (1) accurate definition of user needs, (2) effective management of the design process, (3) well-prepared construction documents, and (4) effective management of the construction phase.

The committee urges agencies to seek ways to

improve their practices and procedures in these areas as they continue to work to improve their estimating procedures.

COMMITTEE RECOMMENDATIONS

The procedures used by most of the federal agencies to prepare early estimates are not necessarily poor or inadequate; in fact, similar procedures are used by many private organizations. The results achieved, in terms of the extent of disparity between early estimates and contract awards, also are in line with the experiences of private companies. However, in view of the importance attached to controlling federal expenditures and the amount of critical attention estimates receive when budgets are exceeded, the committee had expected to see more evidence of emphasis on interagency cooperation and innovative approaches.

On the basis of its review of a variety of ideas for improving the estimating procedures of federal agencies, the committee recommends that agencies:

1. Make a concerted effort to cooperate in the following ways: by developing standard terminology and formats for their budgets and estimates; by cosponsoring cost engineering research and sharing research results, especially research on automated estimating systems; and by pooling and sharing cost data, especially on commonly constructed facilities.
2. Take steps to ensure that the estimators used by private architect-engineer (A-E) firms, as well as the agencies' own estimators, are properly qualified for conceptual estimating.
3. Expand the use of parametric and probabilistic estimating during the early stages of a project.

In view of the fact that a majority of problems associated with budget estimates can be traced to problems other than estimating techniques, the committee urges agencies to seek ways to improve their practices and procedures in the following areas:

1. Ensure that accurate definitions of user needs are prepared and signed off by the responsible parties prior to the development of budget estimates.
2. Place more emphasis on estimating and cost management capability in the selection of A-E's and ensure that sufficient fee allocations are included and sufficient time is provided for adequately performing the required estimating services.
3. Provide effective agency management of the design process to ensure that the A-E's design is within budget. Agencies should employ value engineering and other cost containment techniques and ensure that a well-coordinated and comprehensive set of construction documents are prepared.
4. Provide effective management of the construction phase to maintain time and quality objectives and cost limits.
5. Sponsor conceptual estimating training programs to improve estimating skills. Agencies should ensure adequate salary levels to hire and retain qualified staff.

1

Introduction

Cost is a major factor in most decisions regarding construction, and cost estimates are prepared throughout the planning, design, and construction phases of a construction project. All of these estimates are important because they influence the expenditure of large sums of money. However, estimates made in the early phases of a project are particularly important because they affect the most basic decisions about a project: whether it will be undertaken at all; how large it will be; how elaborate, sophisticated and durable it will be; and how much it will cost (i.e., what the budget* will be and, in the case of federal agencies, what the congressional appropriation will be).

If an estimate made early in the process is seriously in error on the high side, it can result either in a needed and worthwhile project being rejected or in the allocation of excessive money to a project, which takes money away from other deserving projects and invites waste and extravagance. Conversely, if an early estimate is seriously in error on the low side, it can result either in the construction of an inadequate facility or in money being wasted on a fruitless design effort.

Federal agencies, like most organizations with large continuing construction programs, have long recognized the importance of these early estimates, and they have instituted various policies and procedures to help ensure that such estimates are prepared carefully and properly. Yet problems associated with the accuracy and validity of early estimates have persisted; such problems may result in a failure to award a construction contract because of excessively high bids, receipt of embarrassingly low bids, design problems, project delays, and facilities with marginal or impaired operations.

Because Congress maintains fairly tight control on federal expenditures, agencies have limited leeway to deal with problems caused by erroneous early estimates. Consequently, agencies periodically look for ways to improve their early estimates. In 1988 the agencies that sponsor the Federal Construction Council asked the Building Research Board (BRB) to review their current practices and, if possible, to recommend ways of improving those practices. The BRB formed the Committee on Budget Estimating Techniques to conduct the study.

The committee met six times in the course of the project. The first two meetings were devoted to reviewing literature on preparing early estimates and discussing the estimating procedures and practices of federal agencies. Subsequent meetings were devoted to developing a consensus among committee members on the principal issues and reviewing and refining committee and staff-prepared draft material.

*In this report the budget is the amount of money authorized by an official funding authority (e.g., Congress, a board of directors, or top management) to be spent on a project. A budget estimate is a prediction by a professional estimator of what a proposed project will cost. The budget for a project may be significantly different from the corresponding budget estimate.

STUDY SCOPE AND EMPHASIS

Early in the study the committee requested statistics from federal agencies on their experiences with early estimates in order to get a clear understanding of the nature and magnitude of the problem being addressed. However, the agencies reported that they could not provide such information without a costly analysis of records. To fill this statistical gap, a special meeting of the agency liaison members of the committee was held at which information on the experiences of federal agencies with budget estimates was assembled through a modified "Delphi" exercise. The results of this meeting are presented in Appendix A.

In brief, those participating in the exercise estimated that budget-related problems have been experienced on approximately 35 percent of federal projects and that among the factors contributing to such problems were:

- poor definition of user needs, which was estimated to have been a factor almost 60 percent of the time;
- poor design work and/or poor agency management of design, which were estimated to have been factors almost 40 percent of the time;
- poor A-E and/or agency estimators, which were estimated to have contributed to problems more than 25 percent of the time; and
- inadequate estimating procedures and/or data, which were estimated to have contributed to problems almost 20 percent of the time.

These data verified that indeed federal agencies do have serious budget-related problems; however, the data also suggested that the problems are caused by a number of factors besides poor estimating techniques and procedures. Consequently, the committee has included in its report a discussion of various additional factors that contribute to budget-related problems. This discussion is presented in Chapter 2.

In accordance with its original charge, the committee has focused primarily on budget estimating techniques and data. Thus, Chapter 3 of the report describes the current procedures, techniques, and data sources used by federal agencies to prepare early estimates, and Chapter 4 presents the committee's recommendations on steps that agencies can take to improve the accuracy of such estimates.

Descriptions of various budget estimating procedures are presented in Appendix D. The report does not discuss techniques for preparing detailed estimates that are developed in the later stages of a project.

CONSTRUCTION COST ESTIMATING TERMINOLOGY

Different owners use different procedures and processes to administer their construction programs, as illustrated by Appendix B and Appendix C, which describe, respectively, the construction budgeting processes of the Naval Facilities Engineering Command and the IBM Corporation. However, regardless of the owner, most construction projects require the preparation of a number of increasingly detailed cost estimates in the course of the planning, design, and construction phases of a project. One or more of these estimates may be used to establish the budget for a project.

The construction industry and related professions use a variety of terms to indicate different types of estimates. In order to maintain consistency for the purposes of this document, the following terminology will apply. The estimates are listed in the chronological order of their preparation, which means that they are also in ascending order of detail.

Pre-programming estimate. An estimate of the probable magnitude of total construction cost, usually based on single unit costs (such as dollars per gross floor area), for use in the earliest planning phases of a project.

Program estimate.* An expression of probable total construction cost, usually based on a combination of single unit costs and theoretical costs as related to the functional program requirements of the facility and the general design concepts to which the budget and the program of requirements relate.

Concept/schematic estimate. A construction cost estimate based on a proposed scheme and a quantitative analysis of proposed facility components and

*The term "program" may have two different meanings in connection with federal construction activities. It may refer to the totality of construction projects of an agency for a given time period or to the list of requirements for a particular project. (Lists of requirements are sometimes referred to as owner criteria, user needs, or architectural programs.) To minimize confusion, the committee has avoided using the term "program" without a descriptive modifier.

subcomponents using both historical and analytically derived unit costs. Design criteria and scope, including alternates, may be established in relationship to the funding limitations of the program of requirements.

Design development estimate. A construction cost estimate based on quantities derived from a preliminary but definitive set of drawings (frequently about 35 percent complete) and current in-place costs. The design and estimate may be used as the basis for a budget request and/or to verify that established criteria are being followed, that the scope of the project is not being expanded, and that changes in scope are being documented. Some assumptions are made where design documentation is not complete.

Construction document estimate. A construction cost estimate based on a quantitative material take-off using well-developed construction documents. The estimate and the design are used to verify that the authorized budget and scope of the project have not been exceeded. This estimate is normally updated several times until the design is complete.

Pre-bid estimate. A cost estimate based on a final review of the completed construction bid documents.

Federal agencies do not use a consistent and uniform terminology for budgets and estimates, as indicated by the glossary of federal estimating terms presented in Appendix E. However, the committee believes that most agencies would understand the terms defined above, and this terminology is used throughout the report, unless otherwise indicated.

FOCUS OF THE REPORT

This report focusses on early estimates, which include the pre-programming, program, concept/ schematic, and design development estimates. Such estimates are important because they are used in making some of the most basic and important decisions regarding a project. Specifically:

- *Pre-programming estimates* are ordinarily made by an operating element of an agency as part of a request for funding for a new facility or the modification of an existing facility. In most agencies there are many operating elements (commonly called users), and each year each of these elements submits multiple funding requests to agency headquarters. Since funding for construction is always limited, agency headquarters must review these requests and screen out projects that are less critical to or are not in accord with the agency's long-range plans.
- *Program estimates* are ordinarily prepared by the central or regional office of the responsible agency, or by a private A-E firm, based on an analysis of the needs of the user organization and the development of a program of requirements. Some agencies base their funding requests to Congress on a program type estimate.* However, many agencies do not proceed in this manner because they are required by Congress to complete at least 35 percent of the design of a facility before requesting funding for it.† In these agencies, program estimates are mostly used to indicate to the organization designing the facility (almost always a private A-E firm) the approximate cost of the desired facility and to help set the design fee. In theory the program estimate that is given to the design organization is not the final estimate that will be given to Congress. However, in practice design organizations are expected to try to stay within program estimates because agencies usually make preliminary allocations of money to various projects based on program estimates. A major increase in the estimated cost of a project can cause the project to be dropped or adversely affect funding for other projects.
- *Concept/schematic estimates* are prepared by the design organization (usually a private A-E) using the initial design documents as a basis. This estimate is not often submitted to Congress, but instead is used by the design organization to verify the project budgets and to compare alternate schemes.
- *Design development estimates* are prepared by the design organization after analysis of the user's needs, evaluation of alternative designs, and preparation of initial design documents (which frequently corresponds to the 35 percent design point). The design development estimate is used by certain agencies as the basis for funding requests to Congress. Other agencies that base their funding requests to Congress on concept/schematic estimates, use design development estimates as a check to ensure that projects are within budget.

*Some private companies, as discussed in Appendix C, also base funding requests to their top managers or boards of directors on program estimates.

†Agencies follow different policies because their budget requests are reviewed by different congressional committees.

2

Factors Other Than Estimates That Contribute to Budget-Related Problems

As noted in the Introduction (Chapter 1), Congress appropriates money for major construction projects (which include both the construction of new facilities and the renovation or alteration of existing facilities) on the basis of estimates submitted by the responsible agencies. Congress holds the agencies accountable for completing the needed construction work for the amount of money authorized. When for some reason a project cannot be completed with available funding, agency managers are subject to congressional criticism, and often the additional funds needed are taken from other projects.

In the event of a problem, many agency managers and members of Congress tend automatically to blame a faulty estimate. This is a natural and logical reaction since there is a direct and obvious link between estimates and bids. Indeed, this study is a reflection of the concern of the agencies about the accuracy of their budget estimates.* However, while there is certainly room for improvement in budget estimating per se (as discussed in the next two chapters of the report), inaccurate budget estimates are not the sole cause of budget-related problems on federal projects. In fact, they are probably not the major cause. As discussed in Appendix A, and demonstrated especially by Figure A-4, there are a variety of factors causing budget-related problems on federal construction projects. Thus the committee has included in this report a discussion of factors other than the accuracy of early estimates that affect whether a construction project is completed within budget.

This chapter includes a brief review of the design and construction process, a discussion of the keys to a successful project, and committee suggestions on some procedural steps agencies might take to help improve their success rate with construction projects.

ELEMENTS OF THE CONSTRUCTION PROCESS

The ultimate goal of federal agencies when procuring construction is to acquire cost-effective facilities that meet the needs of the users within the budget available (i.e., the amount authorized by Congress). However, major construction projects are complex undertakings that involve many different individuals and organizations and a number of separate steps. Mistakes made in any step by any participant may result in budget-related problems.

The process by which facilities are acquired differs depending on the owner and the type of facility involved. For example, as discussed in Appendix B and Appendix C, the processes followed by the Naval Facilities Engineering Command and IBM Corporation are quite different. However, regardless of the owner, the process typically involves a number of distinct sequential steps culminating with the completion of construction and the recycling of

*A budget estimate is an estimate on which a request to Congress for funding is based. As noted previously, it can range from a pre-programming estimate to a design development estimate, depending on the agency.

cost data, as discussed below and as depicted in Figure 1.

Figure 1 shows the typical construction cycle; the arrow becomes broader to illustrate that both the amount of money being spent and the amount of information available on a project increase with each succeeding step in the process. The figure also illustrates that the process involves a series of steps and that the successful completion of a project is as dependent on the early steps as the later steps. It should be noted that Figure 1 shows the traditional sequential construction process, which is used for the overwhelming majority of federal projects. The process can be shortened by "fast-tracking," which means that contracts covering the early phases of construction are awarded and construction is undertaken before the entire design is completed.

Identification of User Needs

In federal agencies and other large organizations with continuing construction programs, the first step in the facilities acquisition process usually is the identification of a facilities need by an operational element of the organization (i.e., a user). Occasionally, a facility requirement may originate at a high level in the organization; however, responsibility for administering such projects ordinarily is assigned to an operational element.

Most large organizations have a formal procedure by which users notify higher management of the nature and magnitude of their needs for new facilities or for alterations to existing facilities. As a minimum, users ordinarily are required to indicate the size and type of facility needed and the reason for the need, and to provide an estimate of the approximate cost of the project (a pre-programming estimate).

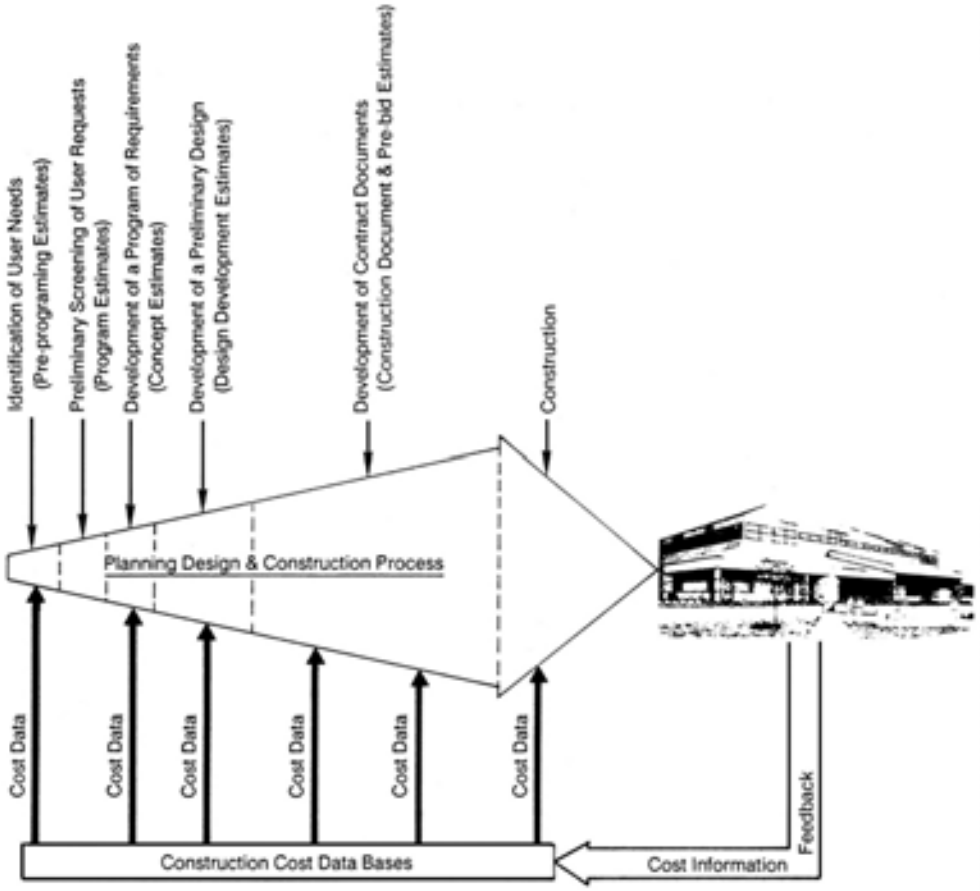

Figure 1 The Design and Construction Process

Preliminary Screening of User Requests

In federal agencies, as discussed in Appendix B, the sum of user requests for funding for facilities each year usually far exceeds the amount of money available. A similar situation exists in most private organizations. Consequently, most federal agencies and private owners have a procedure for screening user requests early in the facilities acquisition process to eliminate proposed projects that are not fully justified, not needed immediately, or not in accord with the long-range plans of the owner. This screening process avoids investing time and money in projects that have little prospect of near-term funding.

Development of a Program of Requirements

Once a project has been tentatively selected for inclusion in an owner's construction program, the next steps are to translate the user's statement of need into a detailed technical description of the facility to be constructed (or the alteration work to be performed) and to develop an estimate of the cost of the project. These steps in the process frequently are referred to collectively as programming.

As noted in the preceding chapter, some federal agencies and many private owners use programs of requirements and associated estimates to seek approval of and funding for their projects from the appropriate authority (e.g., Congress in the case of a federal agency and top management or the board of directors in the case of a private company). Many federal agencies, however, do not do this because they are required by Congress to complete at least 35 percent of the design for a project before including it in a request for construction money.*

Development of a Concept/Schematic Design

The first task of an A-E firm that is awarded a design contract is to develop preliminary design concepts that meet the criteria for the project and to prepare estimates of the cost of different concepts. Then the design firm and the user evaluate the alternatives and select the one that best responds to the program and budget. If the deadline for submitting funding requests to Congress is imminent, agencies may use a concept/schematic estimate as the basis for a request for a construction appropriation. Otherwise, the design effort is continued and the budget request is based on more complete plans and specifications and design development estimates.

Agencies are most likely to treat program estimates as fairly fixed when they have been used to apportion a finite amount of money among a number of projects. In such situations, if the cost of one project increases, an agency must compensate in some way, for example, by cutting the scope of the project or cutting the cost of other projects, which is often a difficult task.

Development of Contract Documents and a Final Estimate

After the design development estimate has been approved by the user, the design organization begins development of contract documents (i.e., working drawings and specifications). These documents, when completed, are used for procurement of the construction and become part of the construction contract.† In the course of preparing plans and specifications, the design organization periodically develops cost estimates to check whether the design is still within budget. If an estimate indicates that construction costs will be over budget, the designer and/or the owner can take various actions to reduce costs, such as performing a value engineering analysis, eliminating some nonessential items, making some items bid alternates, or reducing the size or level of quality of the facility. Estimates based on relatively detailed plans and specifications are called construction document estimates.

*Federal agencies follow different procedures because their funding requests are reviewed by different congressional committees, each of which establishes its own rules.

†If an agency is uncertain about congressional approval of a project, it might defer initiation of work on detailed plans and specifications until funding for construction is assured.

The final estimate that is prepared when the plans and specifications are complete is a 100 percent construction document estimate; it is often referred to as the "government estimate."

Award of a Construction Contract

Some private owners routinely select a construction contractor and award a construction contract before the plans and specifications for a project are complete (e.g., see Appendix C). Other owners, including some federal agencies, occasionally award construction contracts on the basis of incomplete plans and specifications when there is a compelling need to save time. However, most owners, and certainly most federal agencies, ordinarily defer selection of a construction contractor until complete plans and specifications are in hand.

Many private owners routinely select construction contractors through negotiation.* However, most federal agencies and a significant number of private owners usually select construction contractors on the basis of competitive bids. The contract is awarded to the lowest bidder who is "responsive" (i.e., complies with the terms of the invitation for bids) and "responsible" (i.e., is capable of performing the work).

If the lowest bid from a responsive and responsible bidder exceeds the amount budgeted for the project by more than a certain amount stipulated by Congress (e.g., the lesser of 20 percent or $1.5 million for military projects) a contract cannot be awarded, and the project must be re-bid, usually after the design has been modified to reduce costs. Agency managers try very hard to avoid such situations because they are disruptive and embarrassing and because design changes made to reduce costs are often ill-considered.

KEYS TO A SUCCESSFUL PROJECT

Success in construction can mean different things to different people. An architect, for example, may consider any project for which he receives the praise of his client and his fellow practitioners to be successful. A real estate developer ordinarily measures success in terms of the return on his investment. Most construction contractors consider a project to be successful if it runs smoothly and is profitable. The agencies that are responsible for procuring federal facilities generally have three criteria for measuring the success of a project: (1) does the completed facility meet the needs of the user, (2) was the project completed on time and within budget, and (3) did the project run smoothly without excessive change orders or claims. Inasmuch as this report is being prepared under the Federal Construction Council Program, the committee has adopted the success criteria of the federal agencies.

As discussed above, many individuals and organizations are involved in construction projects and countless decisions and actions are taken in the course of a project, all of which contribute to its success or failure. However, the committee believes that the success of a construction project (as defined by federal construction agencies) is especially dependent on five factors: (1) a clear and accurate statement of users needs, (2) accurate estimating, (3) effective management of the design process, (4) well-prepared and coordinated construction documents, and (5) an effectively executed construction effort. While a deficiency in any one factor will not necessarily ensure failure, it will certainly increase the likelihood of difficulties.

The second of the five factors (accurate estimating) is covered in detail in subsequent chapters. The other four factors are discussed below.

Accurate Definition of User Needs

Inasmuch as the ultimate objective of a construction project is to obtain a facility that satisfies the needs of one or more user organizations, a clear understanding of the needs of prospective users obviously is one factor in the success of a project. Until an accurate statement of user needs † has been developed, any design work performed on a project is likely to be of little value, and in the absence of compensating errors, estimates based on erroneous assumptions about user needs inevitably will be wrong.

The importance of having an accurate statement of user needs is recognized by most owners who

*Both federal agencies and private owners procure construction in a variety of ways that are too numerous and varied to discuss here; for example, owners sometimes use "construction managers" in lieu of a general contractor to coordinate and manage projects. Construction managers perform many of the functions of a general contractor, but on a professional services basis.

†As noted previously, statements of user needs are sometimes called architectural programs, programs of requirements, or simply programs.

have continuing construction programs. It is the practice of most federal agencies, for example, to develop a project brochure that includes an analysis of user needs for each major construction project. Nevertheless, owners in general and federal agencies in particular continue to experience difficulties with construction projects due to incomplete, inaccurate, or insufficiently detailed statements of user needs, as discussed in two recent reports prepared under the Federal Construction Council Program (see Committee on Improving Preliminary Planning/Programming in the Building Delivery Cycle, 1986, and Standing Committee on Contract Management, 1982). As noted in the Introduction and as discussed in Appendix A, the agency liaison members of the committee estimated that poor definition of user needs has been a contributing factor about 60 percent of the time when agencies have experienced budget-related problems.

The committee believes that federal agencies still experience problems caused by inaccurate statements of user needs, in spite of their good intentions, for one or more of the following reasons:

- *Insufficient time to perform a proper analysis.* The budget preparation cycle in the federal government requires agencies to submit budget requests by specific dates. If a project is not in the proposed budget for a particular fiscal year as of the cut-off date, chances are it will have to be deferred until the following year. To avoid such situations, agencies sometimes take shortcuts in various phases of the process, including the all-important user-needsdefinition phase.
- *Inadequate analysis.* Developing an accurate statement of user needs for a construction project can be a very difficult and time-consuming task. Sometimes it is not done at all, but more often it is done poorly. It is a difficult task because it requires a thorough knowledge of both construction technology and the user's operations. Since a knowledge of both areas is not generally found in one individual, the development of a statement of needs must be a collaborative effort involving representatives of the user organization and the construction agency, with the latter serving to translate the functional needs of the former into specific facilities requirements. The problem is that, in many cases, neither of the parties fully understands the language and concerns of the other. Consequently, there are numerous opportunities for miscommunications, and the errors that result may not be noticed until detailed drawings have been prepared, or possibly even until the facility is under construction or occupied.
- *Changes in the needs or wishes of the using organization.* Even when ample time and talent have been devoted to developing an accurate statement of user needs, the construction agency may still face problems since users can and frequently do change their minds during design or even during construction. Such changes can be caused by various factors, for example, changes in personnel in the user organization, changes in technology, changes in the basic mission of the facility in question, or changes in the wishes of an important official in the user organization. Sometimes changes are necessary and/or desirable; sometimes they are merely arbitrary. Regardless of the reason for userdictated changes, they serve to invalidate previously developed statements of user needs, which can have a major impact on the design and cost of a project. Consequently, agencies try to limit nonessential user-requested changes once an agreement has been reached.

Effective Management of Design

As noted previously, when the low bid for a project exceeds the amount of funding available, those responsible for the project tend to attribute it to an inadequate budget. However, the problem may be the result of an overly elaborate or unduly conservative design. That this is often the case is demonstrated by the fact that in high-bid situations, budget problems frequently are resolved by redesigning the project to cut costs and/or by making certain features optional bid items, as discussed in Appendix A.

Such steps usually result in lower bids, and a contract award; however, when a project is readvertised, users often complain that the actions taken to reduce costs were ill-considered and that the quality or usefulness of the facility has been sacrificed excessively. Unfortunately, such complaints are often valid. The problem is that when bids are too high, design firms usually are required to do redesign work at no additional cost to the client. Naturally, design firms want to minimize the amount of work performed in such circumstances; consequently, they tend to deal with high-bid situations by expedient means.

It is generally agreed that it is much better to design a project to stay within funding limits from the start than to cut costs in a completed design.

The concept of controlling costs during design is often referred to as "designing to budget" In essence, with the designing-to-budget concept, budget estimates are treated as design criteria or design parameters rather than mere predictions of what the low bid will be when the design is completed.

The designing-to-budget concept can work because there are an infinite number of ways of combining building materials, products, and systems to create a building or facility to satisfy a particular need. Even with constraints imposed by the size and shape of the building site and other factors, the needs of the owner may be satisfied by a variety of different designs whose costs cover a broad range. When designing to budget, the designer uses the budget not merely as a constraint but also as an indicator of the level of quality, permanence, and sophistication desired.

However, designing-to-budget is not easy to apply. Users always want the largest, most elegant facility possible for the available funding, and designers are naturally inclined to try to comply with a clients wishes whenever possible. This inclination is reinforced by the widespread but erroneous belief that expensive buildings are well-designed buildings. Consequently, an upward pressure on cost is inherent in the design process and designers can resist it only if they have a very good knowledge of construction costs and exercise great restraint and discipline. Therefore, federal agencies need to consider cost control and management capabilities when selecting A-E design firms. However, it is probably unrealistic and unfair to expect a private design firm to assume the full burden of controlling costs. Federal construction agencies also need to play an active role in managing the design process if the designing-to-budget concept is to succeed.

Well-prepared Construction Documents

A satisfactory project also depends on having a well-prepared and coordinated set of construction documents (drawings, specifications, and general contract provisions). Clear and accurate construction documents are essential for controlling construction costs because construction contractors invariably react to contract ambiguity either by increasing their bids to cover their uncertainty about the precise nature of products or services desired or by submitting numerous requests for contract changes and extra money after the contract is awarded.

Effective Construction Execution

Most federal construction is performed by private construction firms under fixed-price contracts, which include detailed drawings and specifications describing the work to be done. It is often assumed that once a contract has been awarded, an agency can stop worrying about budget overruns and design problems and instead concentrate on checking to ensure that the contractor satisfies the terms of the contract. This is an erroneous and dangerous assumption. In fact, the construction phase is simply the last and by far the most costly step in a long process aimed at acquiring a facility to meet the needs of the expected occupants within a budget established by Congress. Even with excellent planning, programming, designing, estimating, and contracting, situations can occur during the construction phase that in the absence of good management by an agency can result in cost overruns and/ or construction of an unsatisfactory facility. Among the developments that can cause problems unless handled properly are requests for change orders by the contractor or the user, poor supervision and management by the contractor, unexpected conditions at the construction site, and value engineering proposals from the contractors.

The committee is convinced that agencies must pay careful and continuing attention during the entire construction phase to bring a project to satisfactory completion within the budget.

COMMITTEE SUGGESTIONS FOR IMPROVING THE PROCESS

The central message of this section is that the design and construction process is complex and involves many individuals and organizations, all of whom play an important part in the success of a project. The committee believes that a successful construction project depends on good construction documents, which are the end product of the design process. The success of the design process in turn depends on having an accurate statement of user needs, an accurate budget estimate, and good project management. Finally, the process must be supported by the policies, procedures, and personnel of the owner (the responsible construction agency in the case of federal projects).

In federal agencies, the most important considerations are policies, procedures, and personnel because, in a sense, they form the foundation of the entire process. In addition, in most federal agen

cies they are the only factors under the direct control of agency managers since detailed aspects of the process usually must be delegated to lower echelons in the organizations or to outside firms.

The various federal agencies operate so differently and have such different missions that the committee cannot comment on their policies and procedures in detail. However, the committee can offer the following general comments on the subject.

Involvement of Federal Personnel

In recent years federal agencies have come to rely heavily on the private sector to perform most of the work associated with the design and construction of federal facilities, and in general private firms have done a satisfactory job for the agencies. However, the committee believes there is a limit to how far the policy of relying on the private sector can or should be carried.

The committee believes, for example, that federal agency personnel must be directly involved from the beginning in translating user needs into facility requirements and in developing program estimates. The committee notes that most large private owners rely on their own personnel for programming work. These owners apparently have concluded that their own personnel know more about their operations and related facilities needs than do professionals from the outside.

Similarly, the committee believes that government personnel must be directly involved in over-seeing the design and construction of federal facilities. Many questions arise during both the design and construction phases that can only be answered by responsible government officials who are thoroughly familiar with the particular project.

To the committee's knowledge, most federal agencies recognize the importance of involving their employees in the planning and management of construction projects. However, the committee also is aware that agencies are under continuous pressure to reduce staff levels and to rely on the private sector as much as possible, and the committee believes that some federal agencies might in the future be tempted to reduce federal employee involvement in their design and construction programs below the minimum levels needed for effective control. To help preclude this, agencies must establish a policy that recognizes the need for some minimum level of federal employee participation in the process.

Procedures to Ensure Accurate Statements of User Needs

As discussed previously, there are two procedural matters that seem to be causing budget-related problems for federal agencies: (1) failure to provide sufficient time in the planning and budgeting process for proper analysis of user needs, and (2) failure to obtain the agreement of the user organization on statements of user requirements that are used as the basis for design.

The importance of proper analysis of user needs and avoidance of last minute changes in user requirements are generally recognized by federal agencies, as discussed previously. Therefore, the fact that federal agencies still sometimes fail to provide sufficient time for analysis of user needs or to get the formal concurrence of users on statements of need suggests that there are limitations in the facilities planning process of federal agencies that sometimes preclude them from carrying out the steps in the process as thoroughly as they would like. In all likelihood, such limitations are inherent in the facilities planning processes of most large organizations and the problems they cause cannot be avoided entirely. The committee can only suggest that federal agencies emphasize to all personnel involved with the design and construction process the paramount importance of developing accurate statements of user needs.

The planning and management of a construction program require considerable time and talent. They cannot be performed by inexperienced personnel and they cannot be performed without careful thought. In order to maintain an adequate staff of experienced professionals to plan and manage their construction programs, agencies must continually recruit, train, and reward personnel, just as most large private corporations do. Skimping on the number and/or grade levels of construction program planners, estimators, and managers inevitably shows up in budget-related problems. Agencies need good personnel of all types, but they have a special need for estimators with good conceptual skills to review estimates prepared by others. Good conceptual estimators are of great value because they can determine cost impacts and pinpoint cost problems much more quickly than other estimators. However, individuals with such talents are rare and in great demand, and agencies need to make special efforts to attract, train, and keep them.

3

Procedures Currently Used by Federal Agencies to Prepare Early Estimates

As part of this study, the committee reviewed the procedures currently used by seven federal agencies to prepare early estimates, which in most agencies are roughly equivalent to the pre-programming, program, concept/schematic, and design development estimates discussed in Chapter 1. The seven agencies were: the Department of Energy (Real Property and Facilities Management Division), the U.S. Air Force (Directorate of Engineering and Services), the U.S. Army (Corps of Engineers), the U.S. Navy (Naval Facilities Engineering Command), the U.S. General Services Administration (Public Buildings Service), the U.S. Public Health Service (Indian Health Service), and the Veterans Administration (Office of Facilities).

The information presented is based in part on a recent Federal Construction Council report (Consulting Committee on Cost Engineering, 1987) and in part on input from the agency liaison members of the committee.

The general observations and conclusions of the committee are presented at the end of this chapter.

In accordance with its charge, the committee's review of current procedures has concentrated on the policies and practices of federal agencies. However, as noted previously, many early estimates for federal projects are prepared by private A-E firms, and a significant percentage of agency budget-related problems undoubtedly are caused by A-E estimating errors (see Figure A-4, Appendix A). Recommended actions to reduce such errors are discussed in Chapter 4.

PRE-PROGRAMMING ESTIMATES

In almost all agencies, pre-programming estimates are used for preliminary screening purposes. Such estimates are ordinarily prepared by the engineering office in a user installation and generally are of the single unit cost type. The most commonly used unit for buildings is dollars per square foot; however, pre-programming estimates in the Veterans Administration are sometimes expressed in terms of dollars per hospital bed. The cost of elements other than buildings are usually shown as a lump sum or in terms of some other unit, such as dollars per linear foot for piping. In the Department of Energy (DoE), parametric estimating systems are sometimes used to check the accuracy of pre-programming estimates; however, the actual estimates that are submitted to DoE headquarters are always traditional order-of-magnitude estimates based on dollars per square foot or some similar unit.

In the Department of Defense (DoD), pre-programming estimates for commonly constructed military facilities are based on average unit prices published by DoD (see Tri-Service Committee on Cost Engineering, 1988). The DoD pricing guide* covers twenty-seven broad categories of facilities (there are several subcategories under some of the

*Each of the three military services actually publishes its own version of the DoD pricing guide; however, all of the versions are essentially identical.

broad categories). The pricing guide shows the average size of each type of facility for two different fiscal years. The unit costs shown include the cost of built-in equipment, but not the cost of furnishings and loose or portable equipment. The cost of site improvements beyond the five foot line also are not included, nor are allowances included for contingencies or administration of the project by the responsible agency. The pricing guide also includes a chart for adjusting the unit cost of a facility if it is larger or smaller than the average. Finally, the pricing guide gives area cost factors for over 600 locations in the United States and abroad, to permit the average unit cost values to be localized. When estimating the cost of facilities not listed in the DoD pricing guide, military users are expected to use whatever cost information is available, such as commercially published pricing guides and local historical cost data.

The Corps of Engineers has developed a computer system to help their local engineering offices prepare and submit requests for facilities and level one estimates. The system, called the 1391 processor,* is available on a time-sharing basis through an Army-wide network. The DoD pricing guide is stored in the 1391 processor system and the system automatically calculates building costs adjusted for year of construction and location. Other military agencies have similar but less sophisticated programs.

In the General Services Administration (GSA), pre-programming estimates are prepared in accordance with the *General Construction Cost Review Guide for Federal Office Buildings,* which shows ranges of unit costs in dollars per gross square foot for seven types of facilities: three categories of office buildings plus general storage space, basement parking space, conference and training space, and open-deck parking structures (see Public Buildings Service, 1987). The unit costs include allowances for construction change orders, normal site work and landscaping, and art work. The unit costs do not include the cost of design or construction management services, site acquisition or demolition work, unusual site work, special functional spaces like laboratories, or special building features or systems. Indices are provided to permit unit costs to be adjusted to reflect differences in construction costs in different locations.

Pre-programming estimates in GSA are used to make an economic assessment of space procurement options (e.g., whether to build a new building, purchase a building, or lease space). Such assessments are made in accordance with Office of Management and Budget Circular A-104.

It is interesting to note that in the early 1980s, GSA instituted a sophisticated procedure for establishing construction budgets on the basis of the amount of "rent" that GSA could charge the occupants of the building. The procedure was called the "Capitalized Income Approach to Project Budgeting" (Public Buildings Service, 1981). While the project budget established through the procedure was more detailed than a typical pre-programming estimate, it was used for preliminary screening proposes as well as for requesting congressional funding and project control. The use of the procedure was discontinued because the required analyses were complex and highly sensitive to certain economic assumptions.

The Indian Health Service (IHS) also distributes an estimating manual to its centers which provides data and worksheets for estimating the cost of the two types of facilities commonly constructed by the IHS: health care facilities and staff quarters (see Hanscomb Associates Inc., 1986). The cost of health care facilities is estimated on the basis of dollars per gross square foot and the cost of staff quarters is estimated on the basis of dollars per dwelling unit. Data is provided on the basic cost of these facilities plus the cost of "special" items (such as playgrounds and garages) and average site work, for ten locations. Factors are provided to adjust estimates for escalation and for locations different from those given. The manual is used for preparing both pre-programming and concept estimates. For pre-programming estimates, which are used for preliminary screening purposes, average site conditions are ordinarily assumed.

The Department of Energy and the Veterans Administration do not distribute pricing guides. Local users in these agencies are expected to use whatever pricing information is available to them.

PROGRAM ESTIMATES

Program estimates for military construction projects are essentially refined versions of pre-programming estimates. The program estimates are mostly used to indicate to design organizations (usually private A-E firms) the approximate budget for a needed facility, and to negotiatie the A-E's design fee. Program estimates for Army projects are ordi

*The number 1391 refers to the DoD form that military agencies use to indicate a facilities need.

narily prepared by district offices of the Corps of Engineers. Program estimates for Navy projects are prepared by engineering field divisions of the Naval Facilities Engineering Command (NAVFAC). Most program estimates for Air Force projects also are prepared by the Corps of Engineers district offices and NAVFAC division offices, since those two services manage most Air Force construction work. However, a limited number of program estimates for Air Force projects are prepared by major Air Force commands or Air Force Headquarters. Recently, some of these estimates have been prepared using a parametric estimating system known as the Construction Cost Management Analysis System (COMAS).

The COMAS includes a data base with detailed cost breakdowns for several types of facilities commonly constructed by the Air Force, including: administrative buildings, medical buildings, runways and taxiways, and supporting facilities. The COMAS will automatically generate a detailed cost breakdown for a proposed facility by modifying the appropriate prototype breakdown in the data base on the basis of certain modifiers, for which the specifier provides values. The system modifiers permit the estimator to (a) alter the types of systems to be included in the proposed facility, (b) change the size of the facility, (c) reflect market and/or bidding conditions, (d) reflect uncertainties about the site, and (e) indicate the anticipated duration of the project. The COMAS evolved from a parametric estimating system developed for the Air Force by a private professional firm (see CRS Group, Inc., 1983).

The Air Force has expressed confidence in the accuracy of parametric estimates based on the COMAS and has requested congressional permission to use such estimates as the basis for funding requests when appropriate. Congress has authorized limited use of parametric estimates on a trial basis. If the trial is successful, Congress is expected to begin accepting funding requests based on parametric estimates. For the present, most program estimates prepared by the Air Force using the COMAS are used like the concept estimates of other agencies.

The Veterans Administration (VA) develops program estimates in approximately the same manner as the Army and Navy. Specifically, the program estimates in the VA are ordinarily developed by cost engineers at VA headquarters and are based to a large extent on VA historical data. In addition, like the military agencies, the VA uses these estimates as a basis for selecting and negotiating with private A-E firms for preliminary design work.

Conversely, program estimates in the Department of Energy and the Indian Health Service are used as the basis for requests to Congress for funding. These agencies are not required to have partially completed designs before preparing budget requests.

Program estimates in the Indian Health Service are essentially refined versions of pre-programming estimates. Such estimates are prepared by engineering offices at IHS centers using the IHS estimating manual (as discussed previously). The main differences between a program estimate and a preprogramming estimate lie in the extent to which user needs have been defined and in the amount of analysis included in the estimate's site-work portion.

In the Department of Energy, program estimates for large projects are ordinarily prepared by private A-E firms, while program estimates for small projects are ordinarily prepared by the staffs of the private firms that operate DoE facilities. The estimates are based on some conceptual design work and a limited amount of analysis of materials and equipment needs. DoE does not provide any cost data to the A-E firms or field offices that prepare these estimates.

CONCEPT/SCHEMATIC AND DESIGN DEVELOPMENT ESTIMATES

In the military agencies, the great majority of both concept/schematic and design-development estimates are prepared by private A-E firms. However, a small percentage of projects are designed and estimated by government personnel.

Both concept/schematic and design development estimates for military projects are presented as detailed breakdowns, frequently in both an elemental and trade format (see Appendix D for a more detailed discussion of estimating formats).

The Corps of Engineers and the Naval Facilities Engineering Command both provide historical cost information to estimators preparing design development estimates. In addition, the Corps of Engineers makes available to estimators the Computer Assisted Cost Estimating System (CACES), and the Navy provides a similar system called the Cost Estimating System (CES). Both systems include extensive unit-cost data bases; however, estimators preparing detailed estimates are expected to verify the accuracy of prices taken from the data bases.

As noted previously, design development estimates are frequently used as the basis for funding requests to Congress; however, if a design is more fully developed when a budget request is being prepared, a more detailed estimate may be used.

The Veterans Administration also usually bases its budget requests to Congress on a design development estimate. Such estimates usually are prepared by a private A-E firm, and they usually are presented on the basis of an elemental breakdown. A-E's are expected to use their own data in preparing such estimates, but A-E estimates are ordinarily checked against VA historical cost data.

The Department of Energy and the Indian Health Service both require A-E's to submit design development estimates, which are used primarily as a design check to ensure that the project is within budget. Both agencies generally require that design development estimates be broken down on the basis of the CSI (trade) format, and both expect A-E's to use their own cost data in preparing such estimates.

COMMITTEE OBSERVATIONS

The procedures used by most federal agencies to prepare early estimates for construction are fairly traditional. While the computer estimating systems developed by the Corps of Engineers and the Naval Facilities Engineering Command are useful, the techniques built into the programs are based on traditional estimating concepts. One innovative estimating concept being used is the parametric estimating system developed by the Air Force.

Most agencies keep historical cost data and use such information in the preparation of various early estimates. However, except for the three military services, federal agencies apparently do not routinely exchange cost data. The sharing of historical cost data might be inhibited by the fact that the agencies have not adopted common cost estimating terminology and formats, and because the cost data of one agency is not always relevant to another agency.

The procedures used by most of the federal agencies are not necessary poor or inadequate; in fact, similar procedures are used by many private organizations. The results achieved, in terms of the extent of disparity between early estimates and contract awards, also are in line with the experiences of private companies. However, in view of the importance attached to controlling federal expenditures and the amount of critical attention estimates receive when budgets are exceeded, the committee had expected to see more emphasis on innovative approaches as well as more interagency cooperation.

4

Suggestions for Improving the Early Estimating Procedures for Federal Agencies

As discussed in the preceding chapters, inaccurate estimates are not the only cause of budget-related problems on federal projects, and the procedures currently used by federal agencies to prepare early estimates are not inferior to the procedures used by most private owners. Nevertheless, the committee agreed that federal procedures for preparing early estimates could be and should be improved, and the committee has prepared a list of suggestions for the consideration of the agencies. These suggestions, which are discussed below, were distilled from a large number of ideas generated in the course of the committee's discussion. Some of the suggestions tend to complement one another, while others are unrelated.

INTERAGENCY COOPERATION

Estimating is a field in which a free and continuous flow of information is vital—as illustrated by the flow diagram in Figure 1, Chapter 2. Federal agencies are in a unique position to interchange information to their mutual benefit; however, indications are it is an underused opportunity. The committee believes that there are four areas in particular in which agencies could benefit from greater cooperative action: standardization of terminology, standardization of estimate formats, joint research efforts, and pooling of cost data.

Standardization of Terminology

As shown in Appendix E and as discussed in the preceding chapter, different federal agencies use different terminology for cost estimates. While the differences in terminology have not caused any serious problem to the committee's knowledge, they certainly have made the committee's task much more difficult and have probably created problems for others who work with budgets and estimates for a number of different agencies (e.g., members of Congress, congressional staff personnel, Office of Management and Budget personnel, and private A-E firms). The absence of consistent terminology probably has also contributed to the general lack of interagency cooperation that the committee observed, particularly with regard to the collection and use of cost data. The committee suggests that agencies agree on terminology for construction cost estimates and budgets. The agencies might consider, for example, adapting the terms that the committee has used, which are defined in Chapter 1. In any event, conflicting use of the same terminology should be eliminated where possible.

Standardization of Estimating Formats

There has been considerable discussion among estimators for a number of years about the relative merits of trade (CSI) and elemental (UNIFORMAT) methods of organizing construction estimates. Proponents of the elemental method believe it is the best method for organizing estimates because costs can be presented in terms of building systems, which is in accord with the way most engineers, architects, and owners think of a building. Propo

nents of the trade approach note that most contractors use the CSI format, and furthermore, construction specifications are assembled using a CSI sequence. The committee believes that both approaches have merit, but the committee suggests the use of the elemental method for early estimates and the trade method for the later and more detailed estimates. Automated estimating systems like CACES permit estimates prepared in one format to be translated into the other format.

Joint Research Efforts

The committee has seen relatively little evidence of interagency cooperation on research related to cost engineering or the sharing of the results of research carried out by individual agencies. Agencies discuss their research work in Federal Construction Council meetings, but they do not initiate any joint research activities through the council or make extensive use of information that is presented at council meetings. For example, the committee understands that no agency has adopted a computer estimating system developed by another agency (e.g., the 1391 Processor or CACES).

The committee saw a great deal of interest on the part of the agencies in cost engineering in general and a desire to improve the accuracy of their cost estimates. However, agencies seem to have differing views on how estimates should be prepared and the need for or value of research. Agencies also probably suffer from the "not invented here" syndrome.

The committee believes that agencies would benefit greatly if they could overcome impediments to cooperative research efforts and the sharing of research results. Joint sponsorship of research might help eliminate the "not invented here" problem by giving all the participating agencies a feeling of ownership of research results.

Pooling of Cost Data

The committee also has observed that although historical cost data are kept by most agencies, such information is seldom shared by the agencies except in the Department of Defense. Some agencies have expressed the view that the pooling of cost data would be of little value because different agencies construct very different facilities. There may be some truth in this argument. For example, the health care facilities constructed by the Indian Health Service are very different from the health care facilities constructed by the Veterans Administration and the Department of Defense. On the other hand, the large hospitals constructed by the Veterans Administration would appear to be generally comparable to the large hospitals constructed by the Department of Defense, and the cost data of one agency should be usable by the other agency. Similarly, although the industrial plants of the Department of Energy are unique to that agency, other facilities constructed by DoE (e.g., laboratories, office buildings, and warehouses) are not unique, and DoE data on the cost of such facilities might be of benefit to other agencies. Finally, at the elemental level the cost of an item is unrelated to the type of facility being constructed; thus, data on the cost of brick, for example, could easily be shared.

While it is possible that the idea of pooling cost data on facilities constructed by many different agencies might prove impractical for administrative or organizational reasons, the committee believes that the idea should at least be explored.

THE IMPORTANCE OF A-E ESTIMATORS

In recent years federal agencies have come to rely on the private sector for most activities related to design of federal facilities, including the preparation of estimates. Thus, a large percentage of the early estimates used by federal agencies to request funds from Congress are prepared by estimators employed by A-E firms or by independant consultants who are subcontractors to A-E firms with prime design contracts. These private estimators also develop most of the subsequent higher level estimates that are prepared to help ensure that a project stays within budget.

Since, as discussed previously, accurate estimates are one of the keys to a successful project, the qualifications of estimators employed by A-E firms is a legitimate concern of the agencies. However, to the committee's knowledge the qualifications of the estimators to be used by an A-E are seldom a major consideration in the selection of an A-E firm for a design contract. In fact, it is sometimes not even discussed. The committee feels that this is a serious shortcoming of the A-E selection process and that cost estimating capability should be more heavily weighed in A-E selection criteria.

Agencies should also take steps to ensure that design fees include adequate money for estimating and that money earmarked for estimating is actually used for that purpose.

USE OF PARAMETRIC ESTIMATES

As discussed in the preceding chapter and Appendix D, the Air Force and several private corporations have developed parametric estimating systems in which the estimated cost of constructing a proposed facility can be predicted by modifying the known cost of constructing a similar facility in the past on the basis of certain key parameters.

Some committee members feel that parametric estimating techniques have advantages over traditional estimating techniques, especially for early estimates. These members believe that traditional estimates are prone to error because they depend on the identification of every possible cost item in a project and the assignment of accurate cost values to those items. Since the likelihood of an item being missed or of a cost being incorrectly estimated is high, proponents of parametric estimating believe it is better to start with a complete and accurate estimate and merely adjust to reflect the situation with regard to the proposed facility.

Other committee members are skeptical of the claims made for parametric estimating. They feel that the validity of the formulae used to adjust costs on the basis of parameters has not yet been sufficiently validated to justify the widespread use of the techniques. These members tend to support the decision of Congress not to accept parametric estimates as a basis for requests for funding. (However, Congress has authorized further investigation of the technique.)

On the other hand, Air Force personnel have investigated the accuracy of their parametric estimating system and they believe that the system produces estimates that are at least as accurate as estimates prepared using more traditional methods (see Bridges and Gregory, 1988).

The consensus of the committee is that parametric estimating is most appropriate when the facility being estimated is similar to a building for which cost data is available. The committee believes that parametric estimating is sufficiently promising that all agencies should consider using the technique more extensively.

USE OF PROBABILISTIC ESTIMATING

Periodically over the past 15 years it has been suggested that agencies could benefit from greater use of probabilistic estimating techniques such as range estimating (see Consulting Committee on Cost Engineering, 1983). Range estimating, as discussed in Appendix D, is a technique that permits an estimator to quantify his confidence/uncertainty about an estimate. There is of course a degree of uncertainty about all estimates, but the uncertainty is highest early in the design process, particularly in unusual projects and projects with many unknowns.

With probabilistic estimates, a number of possible construction costs for a project are determined, and the probability of each value being the low bid is calculated. If an estimator's confidence in his data is high, the range or spread of possible costs will be narrow and the probabilities attached to the values near the mean will be high. Conversely, if an estimator's confidence in his data is low, the range of possible costs will be wide and the probabilities attached to values near the mean will be low.

As in the case of parametric estimating, the committee members were split on the value of probabilistic estimates. Some members felt that probabilistic estimates more accurately reflect the real world, and thus are inherently better than single-value estimates. However, other members note that probabilistic estimates are more time-consuming to prepare than traditional estimates and that they can also be more difficult to interpret.

The majority of committee members agreed that there is a benefit to viewing project budgets in terms of probability and risk. It is the committee's recommendation, therefore, that agencies consider preparing early estimates as probabilistic estimates—especially for unusual and high-risk projects.

Appendix A

The Views of Agency Representatives on the Nature and Causes of Budget-Related Problems in Federal Construction Programs

In order to get a clear picture of the problems of federal agencies with early estimates, the committee asked the agency liaison members to provide data and expressions of views on the subject. Because agencies are especially attuned to and constrained by congressional appropriations, the liaison members were asked to focus on the budget estimates used to seek appropriations.

The desired information was obtained at a special meeting of the liaison members. The agencies represented were the Army, Navy, Air Force, Veterans Administration, Indian Health Service, and National Institutes of Health. The participants provided information primarily on the basis of their personal experience and knowledge.

In order to help the participants approach a consensus on the issues, a modified version of the "Delphi" technique* was employed. Specifically, the participants were asked first to answer various questions—all of which were framed to elicit responses in the form of percentages—separately in writing. Next the responses of all participants were revealed, averages were calculated, and the participants were asked to justify estimates that were far from the mean. Finally, after the responses to each question were discussed, the participants were given an opportunity to change their answers (which they often did), and new averages were calculated.

The participants were asked to provide information on five issues:

1. the percentage of major construction projects on which problems are encountered with budget estimates,
2. the effects of budget estimating problems,
3. how budget estimating problems are solved,
4. the causes of budget estimating problems, and
5. the percentage of initial low bids within various percentages of budget estimates.

The results of the exercise are summarized in Figure A-1, Figure A-2, Figure A-3, Figure A-4 through Figure A-5, which correspond to the five issues mentioned above. In each figure the judgments of the participants are shown both as overall average estimates and as ranges of estimates.

With regard Figure A-1, the participants were instructed to consider the entire spectrum of serious difficulties that could occur on a federal construction project as a result of a budget-related problem. Consequently, the percentages shown are higher than they would have been if the participants had been asked to estimate, for example, the percentage of contracts that cannot be awarded the first time they are advertised due to excessive bids.

*The Delphi technique is a systematic procedure for generating a reasoned consensus from the individual judgments of a group of experts. The technique was first used for long-range forecasting by the RAND Corporation. As described by Helmer (1968), the Delphi technique is an interactive process in which a group of experts first make independent estimates of a numerical value (e.g., a year) and then narrow the spread in their estimates through a series of reviews and revisions of their individual estimates.

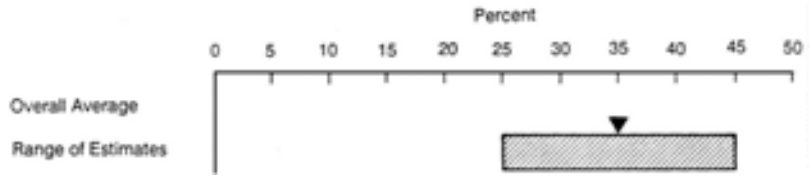

Figure A-1 Agency estimates of the percentage of construction projects on which budget-related problems are encountered.

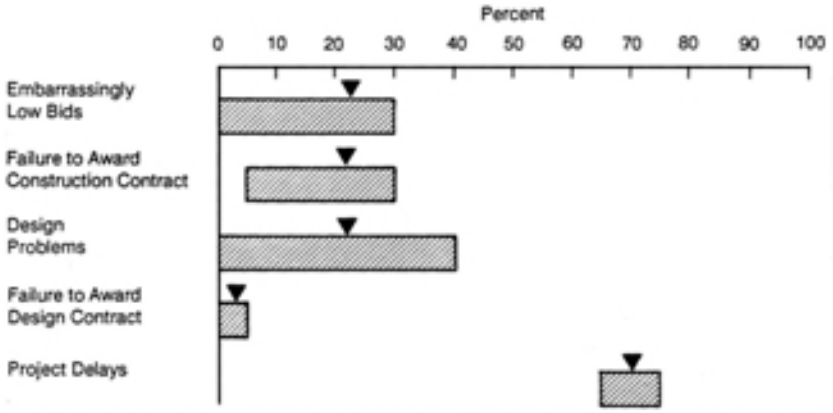

Figure A-2 Agency estimates of percentages (shown as ranges and overall averages) of budget-related problems that manifest themselves in various ways.

When providing input on the effects of budget-related problems (Figure A-2), survey participants were asked to estimate the percentage of problems that result in or manifest themselves as:

1. Embarrassingly low bids. Agency officials are embarrassed, and subject to criticism, when the low bid on a project is far below the budgeted amount. There are many competitors for federal funds, and when funds allocated to one project are not used, managers and sponsors of other programs are annoyed because they view the unspent funds as wasted.
2. Inability to award a construction contract because no responsive bids are low enough to permit an award. Eventually, almost all projects are constructed, but some percentage of projects cannot be awarded the first time they are advertised.
3. Design problems; for example, the design organization reports in the course of the design phase that it cannot design a facility that meets the criteria for the amount of funds available. Other less serious design problems are of course dealt with routinely during every design effort.
4. Inability to award a design contract because the selected design firms all indicate that the type of facility desired cannot be built without additional funding.
5. Project delays. These may be due, for example, to design problems and/or to the need to readvertise.

The sum of the estimated percentages shown in Figure 2 exceed 100 percent because budget-related problems can manifest themselves in several ways. For example, delays are a coincident effect of a large percentage of budget-related problems.

When providing input for Figure A-3, the agency participants were asked to estimate the percentage of budget-related problems that are solved by:

- redesigning the project, with or without a change in scope or criteria;
- a formal value engineering (or similar) analy

sis by a team that is not a part of the design organization;
- developing alternate bid items;
- obtaining an increase in the budget for the project through "reprogramming" (i.e., using money appropriated for other projects, with congressional approval);
- obtaining an increase in the budget for the project through a change in the appropriated amount; and
- dropping the project from the current program and adding it (with an increased budget) to the program for a subsequent year, or dropping the project entirely.

It will be noted that no percentages are given for the last option mentioned above (dropping a project) because the representatives all reported that their agencies almost never solve a budget problem by either dropping a project entirely or deferring it until a later year.

When discussing the causes of budget estimating problems (Figure A-4) the participants were asked to estimate the percentage of problems that are caused by:

- inexperienced or inadequately trained agency estimators,
- inexperienced or inadequately trained estimators employed by private A-E firms (which actually prepare a large percentage of government budget estimates),
- inadequate budget estimating procedures and methods,
- arbitrary reduction in budget estimates in order to conform to general cost limits or guidelines (such as the Cost Estimating Guidance for Military Construction),
- arbitrary reductions in budget estimates by agency managers or budget officers,
- arbitrary reductions in budget estimates by Congress,
- insufficient or inaccurate cost data,
- insufficient time in the budgeting process to prepare accurate estimates,
- the need to prepare budget estimates before designs have been completed,
- poor definition of needs by user organizations,
- poor design work by private A-E firms, and
- poor management of the design process by construction agencies.

It will be noted that, as in Figure A-2, the sum of the percentages for the various causes exceeds 100 percent. The reason, of course, is that there are sometimes multiple reasons for budget estimating problems.

With regard to Figure A-5, the participants were asked to indicate the percentage of initial low bids (i.e., low bids received the first time a project is advertised) that are within a certain range of the original budget estimate: from 20 percent under to 20 percent over, in increments of 5 percentage points. It should be noted that different agencies have different policies regarding how much a low bid may exceed the appropriated amount without necessitating re-advertising.

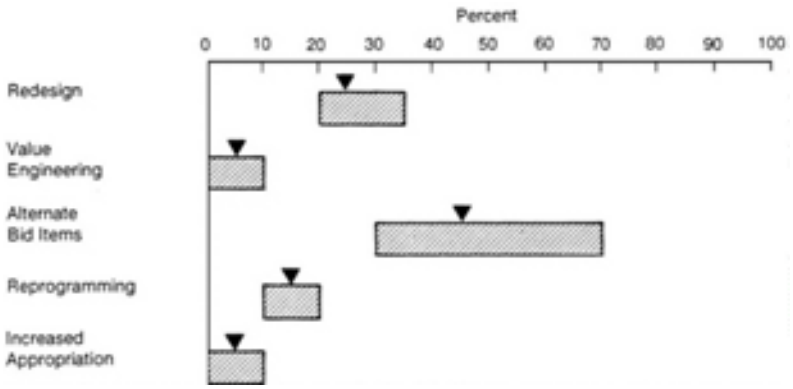

Figure A-3 Agency estimates of percentages (shown as ranges and overall averages) of budget-related problems that are solved by various means.

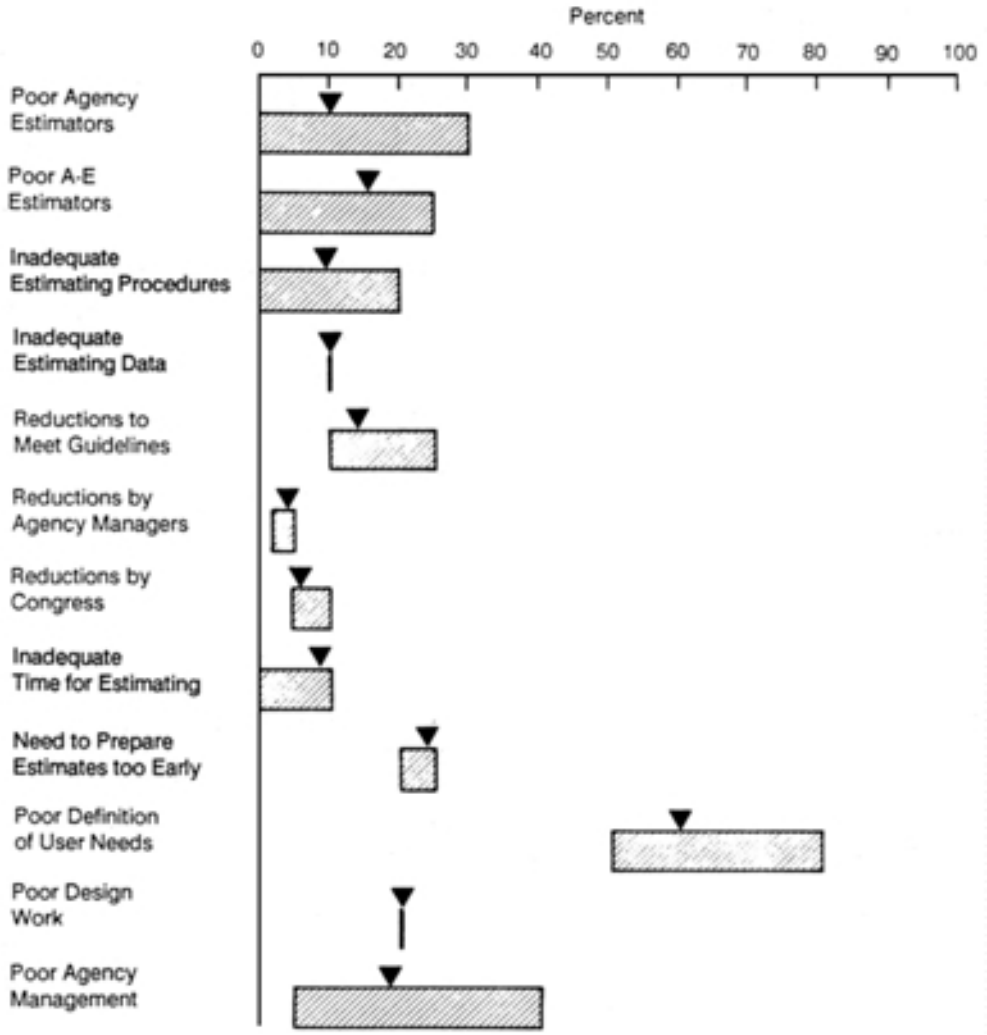

Figure A-4 Agency estimates of percentages (shown as ranges and overall averages) of budget-related problems that are caused by various factors.

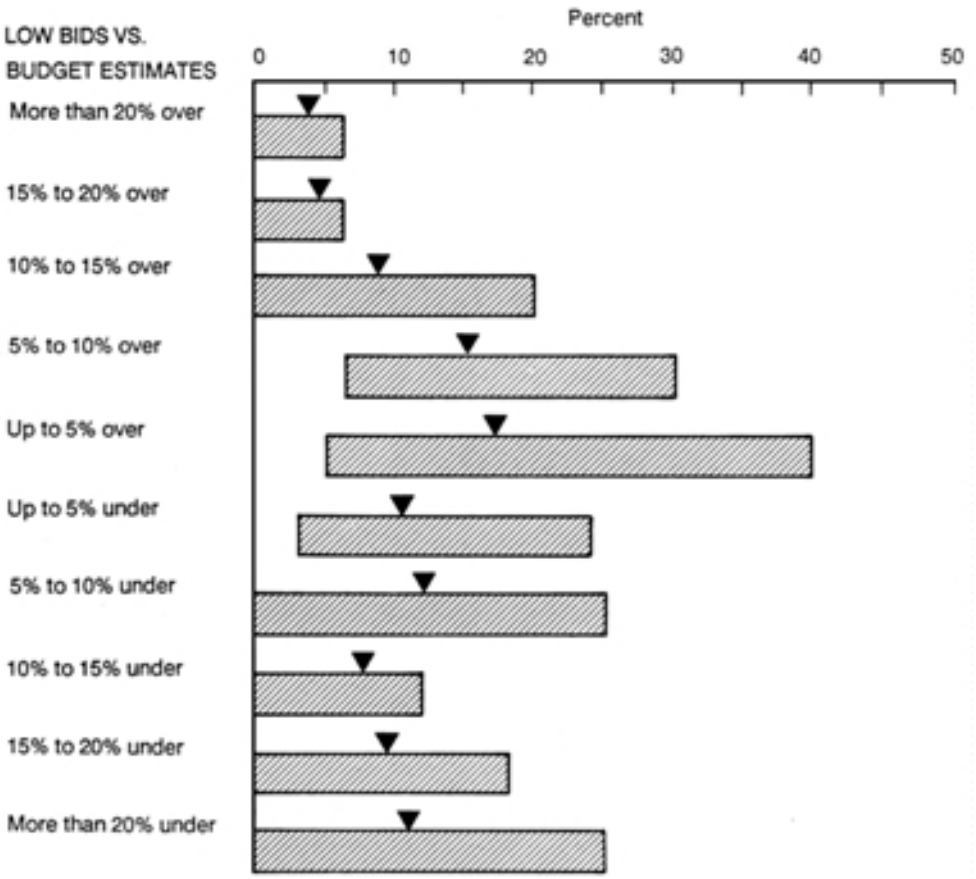

Figure A-5 Agency estimates of percentages (shown as ranges and overall averages) of low bids that are within various percentages of budget estimates for projects.

Appendix B

The Construction Budget Preparation Process at the Naval Facilities Engineering Command

Prepared by Donald Iselin*

The Navy, like most federal agencies, has total facilities requirements that dramatically exceed the amount of funding that is likely to be available in any given year, and specifically in the budget year. Thus, some system of prioritizing and screening is needed. The Navy has a standing instruction that requires each of its field units to identify on a continuing basis all of its current and foreseen *facility needs* by developing a Basic Facilities Requirements List (BFRL) to support the mission, task, and functions that have been assigned to that base by its next senior command. The Navy issues rules and guidance for the preparation of the BFRL, to achieve some degree of realism across its many BFRL submittals. Each BFRL must be reviewed, modified if necessary, and approved by a very senior command. This process provides a certain amount of leavening to all the lists. Each facility on the list will show the square footage required, construction class, and a quick parametric or preprogramming cost estimate.

After determining the basic facilities requirements, each naval base commander then evaluates rather rigorously all his existing facilities to see how well they are being used or can be used to satisfy the basic facilities on the list that has been approved for his base. From that review, a list of deficiencies is produced, and then, through some form of master planning effort, a series of discreet projects is generated, prioritized at the base, and arranged into program years (up to 5 years), or shown as "unprogrammed" if the local priority is not high enough to fit the project within the total dollar availability for facilities in any of the ensuing 5 years.

The dollar amount of projects that are permitted to be carried in each of the 5 program years results from negotiations up the chain, and the amount itself is frequently 50 percent to 100 percent more than can be realistically expected in the final budget results. However, that procedure enables senior reviewers to balance area-wide and Navy-wide priorities in putting both the budget year and the 5-year defense program together.

As one might expect, all of the foregoing actions occur in a continuum, rather than as one-time or annual events. BFRLs are updated at 3-5 year intervals or whenever a major change in the base's mission takes place. The base Master Plan, which looks ahead as far as 20 years, provides basic characteristics of all the discreet facilities that exist or should be planned and eventually programmed. The Master Plan is updated perhaps every five years or whenever major changes in mission are projected. But it is the updated Master Plan that usually gives credibility to the programming for the new projects.

Most of the preceding activities take place without too much argument or challenge, because they are basically preliminary, are related to a single

*Donald Iselin, Rear Admiral, Civil Engineer Corps, USN retired, was Commander of the Naval Facilities Engineering Command from 1977 to 1981.

base, and do not really have much direct impact on the one key issue—the "budget year" projects that will go to Congress.

As for the "budget year" process, a rather thorough screening of all the projects permitted to be "programmed" for that year is done at the agency top management level. (Recall that in total they were 150-200 percent of the anticipated facility budget request). The timing of this initial budget year review is ideally about 15 months before the President submits his budget to Congress. The review results in a specific list of projects (perhaps 110 percent of real expectation) authorized to have preliminary engineering and design done and hard budget estimates prepared. This is the "35 percent design" effort. This is the first expenditure of a significant amount of money on each project, and may be the first time that the user and the designer come to a meeting of the minds as to just what is being designed. This key step has a success ratio that goes from 0 to 100, depending on the user, the designer, and the agency's sophistication in promoting a true meeting of the minds that is still consistent with the programmed intent of the project. If the user overreaches to get more than the basic documents justified and described, he may lose the whole project because the *engineered estimate* could well be dramatically higher than the "programmed amount," and there isn't time to recycle the preliminary design. Result: the project goes on the shelf for at least a year.

Those projects whose preliminary engineering and related estimates are in the programming ballpark will stand at least two more rounds of scrutiny. One review results from competition with late-breaking requirements, such as a new overseas base or special facilities to support a research and development breakthrough. At this stage, very informed decisions are made at the top management level of the agency, after considerable input from knowledgeable in-house proponents, usually in Washington. A second challenge may occur when the Office of Management and Budget (OMB) convinces the President that gross cuts or deferrals should be made at the appropriation level. Here the time frame is frequently from several days to a week maximum. Again, just about the same players engage as in the preceding round, but a cut must be taken quickly, projects must be selected out, and usually there is only limited guidance other than gross dollar amounts. (In the military, there is a Secretary of Defense review intertwined before and among the two reviews just discussed).

The impact of the "estimate" can be seen from the foregoing. If the "program estimate" is unrealistically low, the project stands a good chance of dropping out just before it comes to bat, because the late-breaking realistic cost estimate is a shock to the system. If the estimate based on preliminary design (30-35 percent) is high, the project could drop in review because of a decrease in cost effectiveness. If it is intentionally and inaccurately low, the project may have to be bob-tailed during execution, or the agency will have to use some of its limited goodwill to gain special congressional approval to spend funds beyond those authorized. Regardless of the specific agency procedures involved, and the temptation toward gamesmanship, experience shows that those projects with realistic *programmed* amounts and accurate (within 5-10 percent) *engineered* or *budget* estimates will fare the best in the long run, consistent with their priorities.

Obviously, other factors are important in preparing individual projects and in preparing the agency's budget request for facilities, such as carrying out the remainder of the final design for each project, and effectively and satisfactorily constructing the project once it is authorized and funds are appropriated.

Appendix C

The Construction Budget Preparation Process at IBM Corporation

Prepared by Edward Marsch*

Based on business needs, operating units within the corporation working with the Real Estate and Construction Division (RECD) prepare a Statement of Requirements (S/R) to establish the need to house people and/or equipment in new facilities. The S/R includes absolute requirements for these facilities and also, in some cases," wish lists" of additional elements which the Operating units would like to incorporate, if feasible.

The Statement of Requirements is quantitative and covers approximate size, intended population, location, and inter-relationships. It also lists the need for such special spaces as cafeterias, auditoriums, computer spaces, classrooms, etc.

Once the requirements have been determined, the Consulting Services Group, comprising architects and engineers, takes the S/R and develops a Design Criteria (D/C) or building program which is qualitative in nature. Depending on the type of proposed building, certain Corporate Facilities Practices (CFPs) are observed. These documents define the minimum standards which must be maintained in the design of the facility.

Next, the D/C is translated by Consulting Services into a set of Estimating Assumptions (E/A) for all trades. The assumptions form the basis from which the Statement of Requirements could be built, to IBM's standards. At this time the building is purely hypothetical in nature, as all this preparatory work takes place before retaining an Architect. IBM has developed a standardized computerized format for these Assumptions which allows the group to work logically through the proposed project. It includes the elements and systems most commonly found in typical IBM facilities.

RECD has developed a standard Construction Library. This document is a detailed listing of all construction elements found on IBM projects. The library is coded specifically for IBM's use and it bridges the Masterformat/CSI trade numbering standard format to IBM's Construction numbering format. It is designed to be adapted for use on each IBM project, and ties in with the Standard Estimating Assumptions. RECD's estimating department prepares a budget estimate from the S/R, D/C, and E/A. As nearly as possible many of the elements of the proposed building are incorporated into the estimate, and the pricing reflects RECD's experience of constructing buildings in many parts of the country. In the civil, structural, and architectural trades, Unit Pricing is usually performed. For the mechanical and electrical trades, the estimator generally breaks down his estimate into labor, material, and equipment costs.

To the construction cost, the estimator adds line items including architects' fees, IBM costs, and any other special considerations to reach between the budget and a recently completed project. This provides a sanity check to his estimate.

The budget estimate, the bridge and a preliminary schedule are then presented to IBM's senior management for funding approval.

*Edward Marsch is the Director of Planning/Analysis of IBM's Real Estate and Construction Staff.

Assuming approval of the project, an architect is retained to begin design. RECD provides him with copies of the S/R, D/C, CFPs, and Construction Library. He is also given a construction budget within which he must design the facility. IBM specifically avoids giving him copies of the Estimating Assumptions and the Budget Estimate since these could well limit his creativity in reaching a successful design solution.

The architect prepares a design solution for IBM's review, together with his own budget estimate which is presented in the Construction library format to enable IBM to compare the costs against the original budget. After the scheme has been approved, the A-E prepares preliminary drawings which are submitted to RECD for review and comment. IBM examines the plans and specifications and verifies that the estimate is reasonable for the scope described. At this early stage the estimator ensures that the project remains within budget while the Consulting Services Group monitors overall design. As a team, the two groups manage the development of the project.

If, at any time, the cost for the proposed project exceeds the budget, RECD initiates a series of meetings with the A-E and the design team, to review the design with the intention of reducing the overall cost without sacrificing the quality of the job. Such “Value Engineering” could affect any part of the job, from substituting a structural system (steel vs. concrete frame), a mechanical system (ducted return vs. plenum), or an electrical system (conduit and wire vs. BX cable).

As the project becomes better defined, each level of detail is checked from preliminary and intermediate stages through final drawings. Each stage is accompanied by estimates reflecting the increased level of detail and are matched against the original estimate.

The Construction Library, as mentioned above, is used throughout the planning and budget stages of the project and into the bidding cycle.

Contractors are required to submit their proposals when bidding the work, using the IBM/CSI format in order to provide estimate comparison. Payment requisitions are submitted using the same format, and IBM's accountants use the same document to capitalize the project. The Library is a major resource in the creation of an Historical Data Base from which much valuable information can be obtained for use in the preparation of budgets for future projects.

Throughout the course of the project, IBM uses the budget estimate as a basis for comparison between the original concept and the finished product. During the buy out phase of the project and in the negotiation of change order work the IBM/CSI format provides ready access to cost data, which eliminates much of the guesswork otherwise encountered, primarily because the format allows the cost of the work to be broken down into fairly concise construction elements.

As can be seen from the above narrative, IBM places great importance in developing detailed, realistic budgets, and then manages the project to it.

Appendix D

Current Procedures for Preparing Early Estimates

Prepared by Michael Morris*

Many different methods and techniques are used to prepare early estimates for construction; that is the pre-programming, program, concept/schematic, and design development estimates. This appendix discribes the most commonly used methods. Some of the methods discussed are also used to prepare detailed owner (government) estimates and estimates to compare with contractor bids; such as, working drawing and contact document estimates. However, since the focus of the appendix is on early estimates, the methods are discussed only in that context.

Techniques for preparing early estimates can be categorized in various ways. In this appendix, the techniques are grouped and discussed under four broad headings: single unit estimates, multielement estimates, parametric estimates, and range estimates. Information for the discussion was obtained from many sources, but especially Adrian (1982) and Bower (1984).

SINGLE UNIT ESTIMATES

In single unit estimates, the cost of a facility is calculated on the basis of a unit of measurement, which may be expressed in terms of the functional use of the facility, areas and volume, or factoring.

Estimates Based on Function-of-Use Units

Among the function-of-use units sometimes used to prepare early estimates are the number of bedrooms in a hotel, the number of seats in a theatre, the number of beds in a hospital, and the number of parking spaces in a parking garage. Function-of-use estimates are prepared by multiplying the number of units to be included in a proposed facility by an average construction cost per unit (e.g., dollars per bed).

Such estimates can be prepared very easily and quickly if an estimator has the appropriate historical data—and when an owner constructs a particular type of facility on a regular basis, historical cost data related to a function-of-use unit for that facility can be accumulated easily. However, even with ample historical data, estimates based on functionof-use units frequently are unreliable since costs per unit are subject to wide variation.

It is generally agreed that estimates based on function-of-use units ought to be used only for very preliminary planning purposes (i.e., pre-programming estimates) and only by people who are thoroughly familiar with the type of facility in question and recognize the limitations of the data.

Estimates Based on Areas or Volume

Generally, one of the following three units are used to prepare area or volume budget estimates: floor area, building surface area, or building volume. Floor area is the most widely used unit for

*Michael Morris is President of Hanscomb Associates, Inc.

preparing early estimates in most parts of the world. Estimates based on floor area generally are prepared by measuring the gross floor area of the facility and multiplying the area by an average unit cost (e.g., dollars per gross square foot).

There is an abundance of data available on construction costs per square foot for many types of facility, and government agencies, developers, contractors, and cost consultants collect, store, and use such cost data routinely. In preparing areabased estimates, the estimator must be concerned with the accuracy of available unit cost data and have the necessary estimating skills to select the most appropriate rate for the building being estimated. Judgment is required because most cost data at this level includes little information on the characteristics of the buildings included in the historical data base.

Area-based cost data is published by several commercial houses and is widely used by owners and estimators who do not have data bases of their own. These data, which are typically generated annually, give median costs per square foot for various building types. The unit cost for each building type is related to a "typical" building of a particular size. If the size of the building being estimated is different from the size of the typical building, the unit costs may be adjusted using a nomograph called a "square foot project size modifier."

To improve the accuracy of floor-area based estimates, estimators sometimes use different unit costs per square foot for different functional areas of a building. This is known as the functional area method of estimating and the purpose is to account for the fact that in some types of buildings (such as hospitals) the cost per square foot to construct various departments may be significantly different. However, obtaining accurate cost data broken down by functional area can be difficult, and developing estimates using such data requires considerable skill.

One problem with all floor-area based estimates is that there are no universally accepted rules for measuring building areas. The American Institute of Architects has developed measuring rules, but many organizations—including most federal agencies—do not follow them. In fact federal agencies cannot agree among themselves on definitions of building areas; in a recent Federal Construction Council study (Consulting Committee on Planning and Design Terminology, 1988) it was found that various agencies use at least 13 different terms to define the areas of their buildings. Clearly, in the absence of standards on measuring and defining areas, area-based cost data must be used with caution.

The building surface area method of estimating is similar to the floor area method. However, whereas with the floor area method the estimate is based on the area of just the horizontal floor surface of the building, with the building surface method both vertical and horizontal surfaces are considered. To prepare an estimate based on a building surface areas, the surface areas of all floors, roofs, and external and internal walls are measured (but only one surface of an element is measured). An average unit cost rate for all surfaces is then selected and multiplied by the measured surface area to compute the total cost of the facility. There are also variations on this theme; for example, in some cases the areas of the various elements are multiplied by weighing factors to reflect the differences in their construction costs.

The building surface area method is not widely used because reliable cost data of the type needed is often not available. Furthermore, if drawings of the building are sufficiently well-developed to allow use of this method of estimating, most estimators tend to use a multi-element approach (see below) for which unit cost data are more readily available.

The building volume method of estimating also is similar to the floor area method. The main difference is that the height as well as the floor area of the building is considered. The building volume method is not nearly as popular as the floor area method, but is sometimes used where buildings of the same type can have significantly different floor to ceiling heights (e.g., hangars, hospitals, and warehouses). The building volume method—like the building surface area method—is used infrequently partly because of a lack of cost data; however, some published cost-per-cubic-foot data is available in the market place.

The Factoring Method of Preparing Budget Estimates

The factoring method of preparing early estimates is most often used for major manufacturing facilities where the cost of a single component, for example equipment, is the most significant cost item. Costs of the various components of the building required to house and support the equipment are assumed to be fixed percentages (factors) of the

cost of that equipment, as illustrated in the following example.

Cost of Equipment: $2,000,000

Cost of construction and support systems expressed as factors of the equipment costs:

Element/Component	Factor	Estimated Costs
Architectural/Structural	.30	$600,000
Mechanical	.25	450,000
Electrical	.10	200,000
Equipment Installations	.15	300,000
General Conditions	.10	200,000
Total Estimated Cost		$1,750,000

The type of cost data used with the factoring method is relatively inexpensive to collect and use, and the factoring method can produce reasonably accurate estimates provided a good data base is available. The factoring method does not, however, lend itself to the type of facilities ordinarily constructed by the federal agencies.

MULTI-ELEMENT ESTIMATES

The multi-element approach is a popular method of preparing cost estimates for construction: First, each of the various elements, systems, and components of the proposed facility are identified, sized, and priced separately in accordance with recognized procedures; next, the costs of the individual items are added to determine the total direct cost of the facility; finally, allowances are added for overhead, profit, and contingencies to determine the overall estimated cost of the project.

Most estimates of the multi-element type are based on one of two recognized formats: an elemental format in which most costs are related to the systems and physical elements that make up a building; and a trade format, in which costs are broken down by specification sections, most of which are related to construction trades or materials.

Elemental Format

Probably the most widely used elemental format is Uniformat (a contraction of “uniform” and “format”), originally developed by the American Institute of Architects (AIA). It was later modified and adopted by the General Services Administration (GSA). The GSA version is now a nationally recognized method for analyzing building construction costs on the basis of 12 standard building systems or elements: foundation, substructure, super-structure, exterior closure, roofing, interior construction, conveying systems, mechanical, electrical, general conditions and profit, equipment, and site work.

As developed by GSA, each of the 12 Uniformat elements can be further broken down into sub-elements, and each sub-element can be further subdivided into components to permit the preparation of highly detailed estimates. However, in practice, most estimators use the Uniformat breakdown for preparing early estimates and the CSI approach (see below) for preparing working drawing estimates. Some commercial houses and several federal agencies publish generalized cost data for early estimating purposes on the basis of the 12 Uniformat elements, but also have available detailed cost data for preparing more detailed estimates in accordance with the CSI format.

The Uniformat approach has been widely adopted for the preparation of early estimates because owners, architects, engineers, and others involved in making broad decisions about construction tend to relate more to the cost elements used in Uniformat than to the work items in the CSI format. The usefulness of the Uniformat approach has been enhanced by the development of computer programs that permit cost data in the CSI format to be sorted into Uniformat elements and vice versa.

CSI Format

The most widely used format for storing and presenting construction cost data is the 16-division specification format of the Construction Specifications Institute: general requirements, site works, concrete, masonry, metals, wood and plastics, thermal and moisture protection, doors and windows, finishes, specialties, equipment, furnishings, special construction, conveying systems, mechanical, and electrical.*

By design, the CSI format reflects the scheme used by most contractors to organize and manage construction projects, account for costs, and award subcontracts. Consequently, the CSI format is widely used by contractors to prepare bids and by

*The 16-division specification format of CSI is based on the 16-division “Uniform Construction Index” that was jointly developed in the late 1960s by a number of organizations including the American Institute of Architects, the Associated General Contractors, and CSI.

estimators to store cost data for working drawing estimates. However, while there is considerable historical cost data available in the CSI format on various building types, it is often of little value for early estimating purposes because it is usually in such detail that it cannot be used until the design of the facility has been developed to a significant degree. A detailed estimate using the CSI format is prepared by measurement of the quantities for all labor, materials, and equipment required for each item included in each of the 16 divisions. These quantities are then priced at appropriate rates, extended, and totaled. Allowances are then included for general conditions, overheads, profit, and contingencies to arrive at a total estimated cost. The preparation of such estimates, generally known as the quantity survey method, is labor-intensive and needs time to complete. It should be noted that detailed working drawing estimates can be prepared in CSI or elemental format or indeed in other formats to suit an owner's code of accounts.

As mentioned previously, the managers and professionals who make decisions in the early stages of a project do not think in terms of the work items in the CSI format. Rather, they tend to think in terms of systems, like those in the Uniformat. Thus, whereas detailed estimates are usually in the CSI Format, program and concept/schematic estimates tend to be in Uniformat.

PARAMETRIC ESTIMATES

To a certain extent all methods of estimating are parametric in that they are based on the use of cost parameters. However, the term “parametric estimating” is generally understood to mean the technique of developing estimates based on a limited number of important features that are the major cost drivers of an estimate. Parametric estimating is most applicable to relatively standard facilities since the starting point is a data base containing detailed estimates of various specific facilities. The premise underlying parametric estimating is that the cost of the facilities in the data base will vary as a function of certain values (parameters). Thus, by assigning new values to the parameters associated with the detailed estimate from a particular facility, a new detailed estimate for that facility can be generated. The concept is sound and produces reasonably accurate estimates provided the algorithms and statistical data used in connection with the parameters are accurate and extrapolations of the estimates in the data base are not excessive.

The major advantage of parametric estimating is that it provides detailed cost breakdowns—in either Uniformat or CSI format depending on how the prototype estimates in the data base are formatted—quickly and at relatively low cost with only limited analysis of the facility to be constructed. Thus, with parametric estimating, budget estimates can be prepared that include similar detail as working drawing estimates.

The disadvantages of parametric estimating are that it can be used only for facilities similar to the facilities for which there are estimates in the data base, and the computations are performed by computer, making it very difficult for estimators to verify the results. In addition, many parametric estimating systems are proprietary, and developers will not divulge the algorithms used; consequently, their validity must be taken on faith.

The U.S. Air Force has developed a parametric estimating system called the Construction Cost Management Analysis System (CCMAS) for estimating costs of various types of Air Force facilities that are constructed on a regular basis. The developers of the system, the Construction Cost Management group at Tyndall Air Force Base, report that the system has been tested and found accurate and reliable (Bridges and Gregory, 1987).

PROBABILISTIC ESTIMATING AND RANGE ESTIMATING

Construction cost estimating traditionally has been treated as a determinate problem; that is, a problem in which the answer can be expressed as a specific, definite value. However, since a cost estimate is really a prediction of what an item or group of items will cost in the future, many assumptions must be made in preparing an estimate, which introduces a degree of uncertainty into the process. In the case of early estimates, which usually are prepared before most design decisions have been made (and often many months before bids are received), the level of uncertainty may be high.

Traditionally, estimators and owners have dealt with uncertainty about the accuracy of estimates through the use of contingency factors, which in essence provide funds to cover cost overruns up to a certain amount. Although the contingency-factor approach has worked reasonably well, in recent years a number of estimators have developed alternative methods of quantifying the uncertainty that is inherent in almost all cost estimates. These methods are usually referred to as either range estimat

ing (Curran, 1988) or probabilistic estimating (Consulting Committee on Cost Engineering, 1983).

While there are significant differences in the various range estimating and probabilistic estimating techniques that have been developed, they tend to have several features in common; specifically: (1) they require that an estimate be made of the potential variability of each element in an estimate; (2) they employ the laws of probability to determine the impact of possible variations in the cost of individual elements on overall costs; (3) they require the use of a computer; and (4) they present the results in the form of a histogram or a cumulative distribution showing either the probability of various estimates proving to be the actual cost of the project, or the probability of cost overruns of various magnitudes.

Opinions vary on the value of range estimates for budgeting purposes. A number of users have enthusiastically endorsed the range estimating concept (see Curran 1988). However, several federal agencies that used range estimating on a trial basis encountered opposition from estimators on the grounds that the range estimating process as too time-consuming and from managers on the grounds that they did not want more complexity in the decision-making process (see consulting Committee on Cost Engineering, 1983).

Appendix E

Glossary of Estimating Terms Used by Federal Agencies

Federal agencies use many different terms when discussing cost estimates for construction. The following glossary of cost estimating terms was taken from a Federal Construction Council report prepared by the Consulting Committee on Planning and Design Terminology (1988). The initials in parentheses after each definition indicate the agencies that use that term essentially as defined. The initials shown refer to the following agencies: AF— Air Force Directorate of Engineering and Services; CE—Army Corps of Engineers; DoE—Department of Energy (Real Property and Facilities Management Division); NASA—National Aeronautics and Space Administration (Facilities Engineering Division); NAV—Naval Facilities Engineering Command; USPS—U.S. Postal Service (Facilities Department); and VA—Veterans Administration (Office of Facilities).

COST ESTIMATE—See ESTIMATE, COST

COST, ALLOWABLE CONSTRUCTION—The total estimated cost set forth in an authorization act for a construction project plus a stated percentage, as specified in the authorization act (historically 10 or 25 percent), is referred to as the "allowable cost" for that project.

(AF,CE, DoE)

See also ESTIMATE, BUDGET

COST, DIRECT—Any cost that can be specifically identified with a particular project or activity, including salaries, travel, equipment, and supplies directly benefiting the project or activity.

(AF, CE, DoE, NAV, USPS, VA)

COST, ESTIMATED TOTAL—The cost of the project, including the costs of land and land rights, engineering, design and inspection costs, direct and indirect construction costs, and initial equipment necessary to place the plant or installation in operation whether funded out of operating or plant and capital equipment appropriations.

(AF, CE, DoE, USPS)

COST, INDIRECT—A cost incurred by an organization for common or joint objectives and which cannot be identified specifically with a particular project or activity.

(AF, CE, DoE, NAV, USPS, VA)

COST, LIFE CYCLE—The sum total of the direct, indirect, recurring, nonrecurring, and other related costs incurred or estimated to be incurred in the design, development, production, operation, maintenance, support, and final disposition of a major system over its anticipated useful life span. Where system or project planning antici

pates use of existing sites or facilities, restoration and refurbishment costs should be included.

(AF, CE, DoE, NASA, NAV, USPS, VA)

COST, TOTAL PROJECT—All generic (research and development) operating costs associated with test and evaluation, and plant and capital equipment costs specifically associated with a project. It is the sum of the total estimated cost plus all other costs identifiable to the project.

(AF, CE, DoE, USPS, VA)

See also ESTIMATE, PROGRAM COST

ESTIMATE, BUDGET—An estimated fund requirement for any element included in the budget. Collectively all estimated fund requirements for a particular operating agency or component or consolidation thereof.

(NASA)

Or

The basis for project approval and initial funding request submitted to Congress for project authorization and appropriation actions. Usually based on 35 percent design submittal.

(NAV)

ESTIMATE, CHECK—Check estimate is a validating estimate. Its development and use is similar to an independent cost estimate except it is developed by program/project or operations office personnel or their supporting contractor. A check estimate should be developed by someone who had no involvement in the original estimate, but who may be an advocate of the project.

(DoE, NASA)

ESTIMATE, COST—A documented statement of costs estimated to be incurred to complete the project Cost estimates provide baselines against which cost comparisons are made during the (life of a) project.

(AF, DoE, NASA, USPS, VA)

Or

A general term referring to any officially prepared estimate whether in the planning, design, or construction stage. Although in wide use, this term requires further description to be meaningful.

(NAV)

ESTIMATE, CURRENT COST—A calculated anticipated amount which reflects the latest and best professional estimate for a given project at any given time during planning, design, or construction. It is the amount which is anticipated will be expended for labor, materials, and other items and contractor services required to execute fully the planned facility project. It includes all amounts anticipated to be expended for: land acquisition; site work; construction; the purchase and/or installation of building-type and built-in equipment or furnishings as well as large substantially affixed equipment. It must include a reasonable estimate for contingencies. If the project is to be carried out for NASA by a construction agent, the estimated cost also includes costs associated with the use of such an agent.

(NASA)

ESTIMATE, CURRENT WORKING—Current estimated cost of a project based on best available information including estimated or actual contract cost; contingencies; supervision and administration; inspection and overhead; engineering and design after contract award; other direct costs; pending costs; and government furnished materials and purchase orders.

(AF, CE)

Or

The sum of the construction cost estimate plus any other allowable contract project costs. Normally prepared at each stage of design accomplishment to monitor funding and to control design alternatives which will affect overall project costs.

(NAV)

ESTIMATE, ENGINEERING—Most projects require first (preliminary or 35 percent completion), second (90 percent completion) and final (100 percent completion) submittals. The engineering estimates for these submittals include all labor and material costs for each item, including built-in equipment which would usually be furnished by a contractor and permanently built in or attached to the structure and items with fixed utility connections. Overhead and profit are added separately. Such costs are based on current prices. A factor for cost growth projection (escalation) is added as a percentage cost, so that the cost can easily be updated if the contract award data is changed.

(AF, CE, NAV, NASA)

ESTIMATE, GOVERNMENT—A government estimate is used to determine the reasonableness of competitive bids received in connection with formally advertised construction contracts, and serve as a control in evaluating costs and pricing data in negotiated contracts. Normally, the (Title II) design estimate, after being reviewed and approved by the government, is the basis for the government estimate. However, the services of an operating contractor, architect-engineer, cost-plus-fixed-fee construction contractor (with respect to subcontractors), or construction manager may be used as appropriate to prepare, review, or revise the government estimate prior to government approval. The specifics of a government estimate vary with the size and type of contract.

(AF, CE, DoE, NASA, USPS, VA)

Or

A formal, approved construction cost estimate prepared for contract purposes. This estimate is required for all contracts of $25,000 or more (FAR 36.203). It is used to evaluate bids, to protect against erroneous or unbalanced prices, and to serve as a guide in establishing a schedule for partial payments. The government estimate is based on the final design. Contingencies and supervision, inspection and overhead are not included in a government estimate.

(NAV)

ESTIMATE, INDEPENDENT—A documented cost estimate that has the express purpose of serving as an analytical tool to validate, cross-check, or analyze estimates developed by proponents of a project. An independent cost estimate also serves as a basis for verifying risk assessments.

(DoE, NASA, VA)

ESTIMATE, MAGNITUDE (VA)-See ESTIMATE, PLANNING

ESTIMATE, MODIFICATION—A government estimate prepared for specific contract change order, incorporating a specific scope, methodology, and circumstances. In addition to cost of the changes work, the modification estimate must also include any cost the contractor incurs from impact on the unchanged work. The estimate is used to assist negotiations and to protect the government's interests toward a fair price settlement.

(NAV)

ESTIMATE, ORIGINAL—The first total estimated cost that is shown: (1) in a project data sheet submitted to the Congress for line item projects; or (2) in a project data sheet submitted to OMB for contingency type projects; or (3) in the initial authorization for general plant, operating-funded, equipment-funded, or other contingency-type projects.

(CE, DoE)

ESTIMATE, PLANNING—Planning estimates are developed for each project at the time of project identification. Since these are developed prior to conceptual design, they are order of magnitude only and have the least amount of accuracy and lowest confidence level. Care should be exercised in these estimates to assure that the order of magnitude is correct, since a tendency exists to avoid changing, particularly upward, this estimate once established.

(CE, DoE, NAV)

ESTIMATE, PROGRAM COST—Provides a current and accurate cost analysis which identifies the source and basis for each major cost ele

ment. It is provided in support of military construction program submittals, including DO form 1391.

(AF)

ESTIMATE, TITLE I DESIGN—Prepared upon completion of Title I design. Through use of plant engineering and design funds, Title I may be completed prior to inclusion of the project in the budget. If this should occur, the Title I design estimate becomes synonymous with the budget estimate.

(DoE)

YEAR, BUDGET—The fiscal year of the construction program under review by Congress.

(AF, CE, DoE, NASA, NAV)

YEAR, ESTIMATE—The fiscal year for which cost estimates are developed. Example: a cost estimate developed in February 1979 for Program Year 1980 would be identified as Estimate Year 1980.

(NAV)

References

Adrian, James. 1982. Construction Estimating. Englewood Clifts, NJ: Reston Publications.

American Association of Cost Engineers. 1986. Cost Engineering Notebook. Morgantown, WV: American Association of Cost Engineers.

American Society of Professional Estimators. 1987. Standard Estimating Practice. Alexandria, VA: American Society of Professional Estimators.

Bowen, Brian. 1984. Design and construction cost management. In Architects Handbook of Professional Practice. Washington, DC: American Institute of Architects.

Bridges, Larry, and Rita Gregory. 1988. Accuracy of Cost Estimating Techniques (staff summary sheet). Tyndall Air Force Base, FL: Air Force Engineering and Services Center.

Committee on Improving Preliminary Planning/Programming in the Building Delivery Cycle. 1986. Programming Practices the Building Process. Washington, DC: National Academy Press.

Consulting Committee on Cost Engineering. 1983. Probabilistic Estimating in the Building Process (Federal Construction Council Technical Report No. 72). Washington, DC: National Academy Press.

Consulting Committee on Cost Engineering. 1987. Procedures Used By Federal Agencies to Prepare Budget Estimates for Construction (Federal Construction Council Technical Report No. 85). Washington, DC: National Academy Press.

Consulting Committee on Planning and Design Terminology. 1988. Glossary of Special Terms Used in Planning, Designing and Constructing Federal Facilities (Federal Construction Council Technical Report No. 91). Washington, DC: National Academy Press.

Cost/Schedule Controls Task Force. 1986. Scope Definition and Control. Austin, TX: Construction Industry Institute.

Curran, Michael W. 1988. Range estimating: conquering the cost overrun. DE Technology, 49(3).

Hanscomb Associates, Inc. 1986. Indian Health Service Budget Cost Estimating System (Instruction Manual, Revision 3.0). Rockville, MD: Department of Health and Human Services.

Helmer, Olaf. 1968. Analysis of the future: the delphi method. In Technological Forecasting for Industry and Government, James Bright, ed. Englewood Cliffs, NJ: Prentis-Hall.

Jelen, Frederick C., and James H. Black. 1982. Cost and Optimization Engineering (2nd Edition). New York, NY: McGraw-Hill.

Parker, Donald E. 1984. Budgeting by Criteria Not Cost Per Square Foot (Conference Paper). Morgantown, WV: American Association of Cost Engineers.

Parker, Donald E. 1987. Defining Project Scope for Effective Cost Control (Cost Engineers'

Notebook). Morgantown, WV: American Association of Cost Engineers.

Public Buildings Service. 1981. Capitalized Income Approach to Project Budgeting. Washington, DC: U.S. General Services Administration.

Public Buildings Service. 1987. General Construction Cost Review Guide for Federal Office Buildings—Fiscal Year 1988. Washington, DC: U.S. General Services Administration.

RS Group, Inc. 1983. CCMAS Cost Guide (Cost Guide Primer and Cost Guide Direct Cost Modifiers). Washington, DC: United States Air Force/HQAFESC.

Standing Committee on Contract Management. 1982. Preliminary planning for construction projects. In Transactions of the Federal Construction Council for 1980-81. Washington, DC: National Academy Press.

Tri-Service Committee on Cost Estimating. 1988. Area Cost Factors and Unit Prices for FY 1990-1991 Department of Defense Facilities Construction (Memo dated 10 March 1988 from Douglas Forbrother). Washington, DC: Office of the Assistant Secretary of Defense.

True, Newton F., and Ronald A. Barry. 1985. Contemporary Estimating. American Power Conference Proceedings. Chicago, IL: Illinois Institute of Technology.