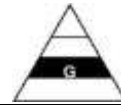


SUBJECT: ADMINISTRATIVE CHANGE TO DOE G 413.3-21, *COST ESTIMATING GUIDE*

1. EXPLANATION OF CHANGES. These Administrative Changes are limited to changing the Office of Primary Interest (OPI) to the Office of Project Management Oversight and Assessments.
2. LOCATIONS OF CHANGES:

Page	Paragraph	Changed	To
Title		INITIATED BY: Office of Management	INITIATED BY: Office of Project Management Oversight & Assessments



**NOT
MEASUREMENT
SENSITIVE**

**DOE G 413.3-21
Approved 5-9-2011
Chg 1 (Admin Chg) 10-22-2015**

Cost Estimating Guide

[This Guide describes suggested non-mandatory approaches for meeting requirements. Guides are not requirements documents and are not to be construed as requirements in any audit or appraisal for compliance with the parent Policy, Order, Notice, or Manual.]



**U.S. Department of Energy
Washington, D.C. 20585**

AVAILABLE ONLINE AT:
<https://www.directives.doe.gov>

INITIATED BY:
**Office of Project Management
Oversight & Assessments**

FOREWORD

This Department of Energy (DOE) Guide may be used by all DOE elements. This Guide provides uniform guidance and best practices that describe the methods and procedures that could be used in all programs and projects at DOE for preparing cost estimates. This guidance applies to all phases of the Department's acquisition of capital asset life-cycle management activities. Life-cycle costs (LCCs) are the sum total of the direct, indirect, recurring, nonrecurring, and other costs incurred or estimated to be incurred in the design, development, production, operation, maintenance, support, and final disposition of a system over its anticipated useful life span. This includes costs from pre-operations through operations to the end of the project/program life-cycle, or to the end of the alternative. DOE programs may use alternate methodologies or tailored approaches more suitable to their types of projects and technologies.

DOE Guides are not requirement documents and should not be construed as requirements. Guides are part of the DOE Directives Program and provide suggested ways of implementing Orders, Manuals, and other regulatory documents.

TABLE OF CONTENTS

1.0	PURPOSE.....	1
2.0	GUIDANCE OVERVIEW	1
2.1	<i>Purpose of the Cost Estimate</i>	<i>3</i>
2.2	<i>Overview of the Cost Estimating Process Model</i>	<i>4</i>
3.0	COST ESTIMATING INPUTS	4
3.1	<i>Project/Program Requirements.....</i>	<i>5</i>
3.2	<i>Documentation Requirements.....</i>	<i>7</i>
4.0	COST ESTIMATING CHARACTERISTICS AND CLASSIFICATIONS	12
4.1	<i>Planning the Cost Estimates</i>	<i>12</i>
4.2	<i>Cost Estimate Classifications.....</i>	<i>13</i>
4.3	<i>Cost Estimate Ranges.....</i>	<i>17</i>
5.0	COST ESTIMATING METHODS.....	18
5.1	<i>Detailed Estimating Method.....</i>	<i>18</i>
5.2	<i>Parametric Estimating Techniques</i>	<i>19</i>
5.3	<i>Other Estimating Methods</i>	<i>21</i>
5.4	<i>Methods of Estimating Other Life-Cycle Costs</i>	<i>25</i>
6.0	COST ESTIMATING DEVELOPMENT PROCESS	26
6.1	<i>Overview of the Cost Estimating Process.....</i>	<i>26</i>
6.2	<i>Estimate Planning</i>	<i>30</i>
6.3	<i>Cost Estimate Inputs.....</i>	<i>31</i>
6.4	<i>Cost Estimate Production.....</i>	<i>34</i>
6.5	<i>Cost Estimate Review.....</i>	<i>59</i>
6.6	<i>Estimate Reconciliation.....</i>	<i>60</i>
6.7	<i>Cost Estimate Documentation</i>	<i>60</i>
6.8	<i>Estimate Maintenance</i>	<i>66</i>
7.0	COST ESTIMATING OUTPUTS	67
7.1	<i>Cost Estimate Interfaces.....</i>	<i>67</i>
7.2	<i>Estimate Presentations to Management</i>	<i>68</i>
7.3	<i>Baselines and Change Control.....</i>	<i>68</i>
7.4	<i>Analysis</i>	<i>69</i>
8.0	COST ESTIMATING EXPECTATIONS.....	69

8.1	<i>Summary of Expectations</i>	69
8.2	<i>Lessons Learned</i>	70
8.3	<i>Independent Cost Reviews</i>	70
8.4	<i>Independent Government Cost Estimates</i>	73
9.0	APPENDICES	74
	Appendix A: Acronyms	A-1
	Appendix B: Definitions	B-1
	Appendix C: Summary of Federal Requirements	C-1
	Appendix D: Summary of DOE Requirements	D-1
	Appendix E: Generic Review Criteria	E-1
	Appendix F: Example of the Calculation and Use of Economic Escalation	F-1
	Appendix G: Example of Life-Cycle Cost Analysis	G-1
	Appendix H: Cost Estimate Classifications (AACEI)	H-1
	Appendix I: Bibliography	I-1
	Appendix J: Crosswalk to GAO-09-3SP	J-1
	Appendix K: ICR and ICE Guidance	K-1
	Appendix L: DOE Expectations for Quality Cost Estimates	L-1

1.0 PURPOSE

The purpose of the DOE *Cost Estimating Guide* is to provide uniform guidance and best practices that describe the methods and procedures recommended for use at DOE in preparing cost estimates that is specific to all work including but not limited to construction projects and/or programs. This guidance is applicable to all phases of the Department's acquisition of capital asset management activities. Practices relative to estimating life-cycle cost (LCC) are described. LCCs include all the anticipated costs associated with a project or program alternative throughout its life; i.e., from authorization through operations to the end of the facility/system life cycle (see Figure 3-3 in Section 3.2).

This Guide does not impose new requirements or constitute DOE policy, nor is this Guide intended to instruct Federal employees in *how* to prepare cost estimates (see Appendix C, Summary of Federal Requirements, and Appendix D, Summary of DOE Requirements). Rather, it may be used to provide information based on accepted standard industry estimating best practices and processes—including practices promulgated by the GAO Cost Estimating and Assessment Guide (GAO-09-3SP)—to meet Federal and DOE requirements and facilitate the development of local or site-specific cost estimating requirements. The GAO has specifically recommended that DOE cost estimating guidance be provided following the GAO Twelve Steps of a High-Quality Cost Estimating Process to improve the quality of its cost estimates (see GAO-10-199, Table 1, page 10).

2.0 GUIDANCE OVERVIEW

High quality cost estimates provide an essential element for *successful project and program management*. The main objective of the Guide is to provide guidance that should improve the quality of cost estimates supporting execution of projects and programs. The cost estimating principles and processes provided herein may be used to meet or adhere to Federal and DOE requirements while utilizing industry standards and best practices.

High-quality estimates should satisfy four characteristics as established by industry best practices—they should be credible, well-documented, accurate and comprehensive.¹ An estimate should be

- credible when the assumptions and estimates are realistic. It has been cross-checked and reconciled with independent cost estimates, the level of confidence associated with the point estimate has been identified,² and a sensitivity analysis (i.e., an examination of the

¹ GAO *Cost Estimating and Assessment Guide*, GAO-09-3SP (Washington, D.C., March 2009)

² A point estimate is the best guess or most likely value for the cost estimate, given the underlying data. The level of confidence for the point estimate is the probability that the point estimate will actually be met.

effect of changing one variable relative to the cost estimate while all other variables are held constant in order to identify which variable most affects the cost estimate) has been conducted;

- well-documented when supporting documentation includes a narrative explaining the process, sources, and methods used to create the estimate and identifies the underlying data and assumptions used to develop the estimate;
- accurate when actual costs deviate little from the assessment of costs likely to be incurred; and
- comprehensive when it accounts for all possible costs associated with a project, is structured in sufficient detail to insure that costs are neither omitted nor duplicated, and has been formulated by an estimating team with composition commensurate with the assignment.

From the GAO Cost Estimating and Assessment Guide, there are 12 key steps that are essential to producing high quality cost estimates.³

1. Define the estimate's purpose
2. Develop an estimating plan
3. Define the Project (or Program) characteristics
4. Determine the estimating structure [e.g., Work Breakdown Structure (WBS)]
5. Identify ground rules and assumptions
6. Obtain data
7. Develop a point estimate and compare to an independent cost estimate
8. Conduct sensitivity analysis
9. Conduct risk and uncertainty analysis
10. Document the estimate
11. Present the estimate for management approval
12. Update the estimate to reflect actual costs and changes

This guide contains industry best practices for carrying out these steps. Appendix L comprises a suggested crosswalk of the 12 key GAO estimating steps and their implementing tasks to the sections of this Guide wherein guidance for accomplishing those steps within the DOE project environment is addressed and discussed.

DOE O 413.3B, *Program and Project Management for the Acquisition of Capital Assets*, dated 11-29-10, promotes the development of a well-defined and managed project performance baseline (defined by scope, schedule, cost and key performance parameters). The guidance provided in this document highlights the importance of three closely interrelated processes to

³ GAO-09-3SP

help define the project baseline: development of a Work Breakdown Structure (WBS) for scope definition, cost estimating, and schedule development.

- **The Work Breakdown Structure process provides:**
 - A complete decomposition of the project into the discrete products and activities needed to accomplish the desired project scope (the WBS dictionary should contain in a narrative format what each activity includes);
 - Compatibility with how the work will be done and how costs and schedules will be managed;
 - The visibility to all important project elements, especially those areas of higher risk, or which warrant additional attention during execution;
 - The mapping of requirements, plans, testing, and deliverables;
 - A clear ownership by managers and task leaders;
 - Organization of data for performance measurement and historical databases; and
 - Information that is the basic building block for the planning of all authorized work.
- **The Cost Estimate process provides:**
 - Documented assumptions and basis of estimate that provide further project definition;
 - The activity quantities that make up the scope of work;
 - The cost element data (labor and non-labor) needed to complete the products/deliverables;
 - The estimated resource hours and non-labor values that make up the work;
 - The component elements (labor, materials, equipment, etc.) required to complete activities and work packages; and
 - Additional WBS elements mined during the detailed take-off.
- **The Schedule process provides:**
 - The activity durations based on the “crew” production rates per quantity and other work influences, i.e. hold points, space restrictions, cure time, etc.;
 - Logical relationships of all schedule activities;
 - Critical path that represents the longest duration for the project and the sequence of work with the least margin for deviation or flexibility;
 - The time phasing of activities that identify new activities or costs, i.e. winter work, escalation needs, etc.; and
 - The milestones and activity relationships that define possible impacts, i.e. overtime needed to complete activities.

2.1 Purpose of the Cost Estimate

The purpose of a cost estimate is determined by its intended use (e.g., studies, budgeting, proposals, etc.), and its intended use determines its scope and detail. Cost estimates should have general purposes such as:

- Help the DOE and its managers evaluate and select alternative solutions;

- Support the budget process by providing estimates of the annual funding and phased budget requirements required to efficiently execute work for a project or program;
- Establish cost and schedule ranges during the project development phases;
- Establish a Project Performance Baseline to obtain Critical Decision-2 (CD-2) approval and to measure progress following the CD-2 approval (see Figures 3-1 and 3-2 for a pictorial description of the DOE Critical Decision Process);
- Support Acquisition Executive approval for acquisition of supplies, services, and contracts; and
- Provide data for value engineering studies, independent reviews, and baseline changes.

2.2 Overview of the Cost Estimating Process Model

Traditionally, cost estimates are produced by gathering input, developing the cost estimate and its documentation, and generating necessary output. Figure 2-1 depicts the cost estimating process model, which should be similar for cost estimates at various points within the project life cycle. The scope of work, schedule, risk management plan, and peer review interact to influence the cost estimating process and techniques used to develop the output. These process interactions—inputs, processes (tools and techniques), and outputs—are used by the Project Management Institute and others to depict the transfer of information between steps in a knowledge area such as cost estimating.



Figure 2–1. The Cost Estimating Process Model

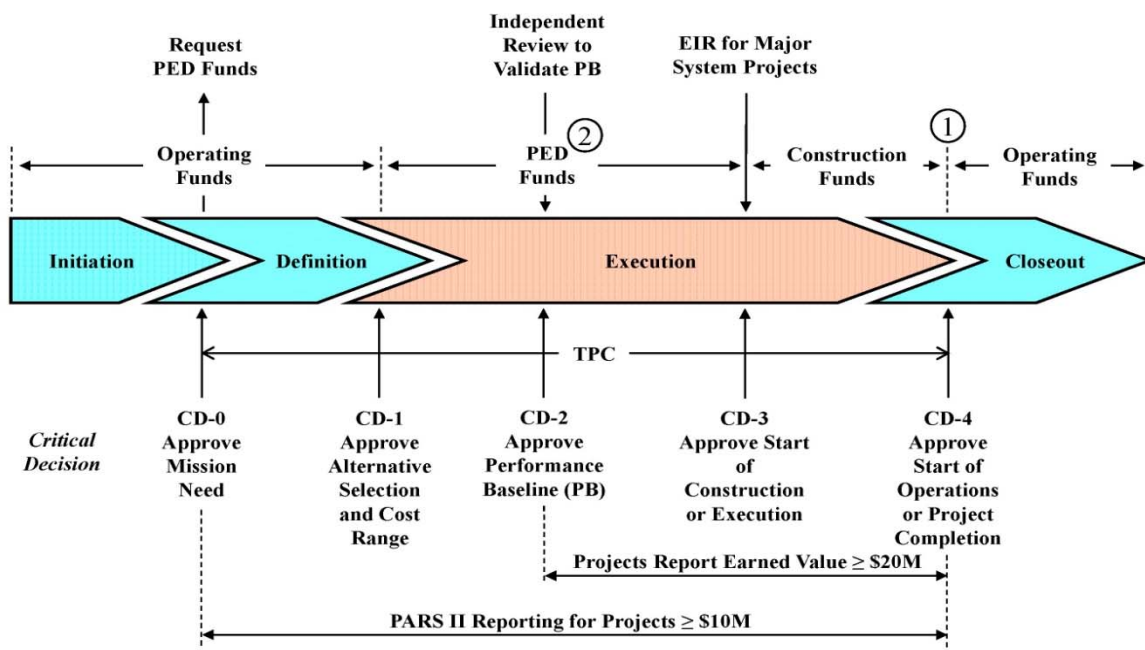
3.0 COST ESTIMATING INPUTS

Cost estimate development is initiated by *inputs* to the process. These inputs are process elements that can be either one-time or iterative in nature as illustrated in the above process model. One-time inputs may include project/program requirements, the mission need statement,

and the acquisition strategy or acquisition plan. Iterative inputs may include the technical/scope development, the schedule development, and the risk management plan with associated risk identification and mitigation strategies. The peer review results in the process may also identify the need to revisit various process elements to improve the quality of the cost estimate. Cost estimates that are developed early in a project's life may not be derived from detailed engineering designs and specifications (may not be a point estimate but a high/low range project estimate), but they should be sufficiently developed to support budget requests for the remainder of the project definition phase. Over the life of the project, cost estimates become increasingly more definitive, and reflect the scope and schedule of work packages and planning packages defined for the project.

3.1 Project/Program Requirements

Appendixes C and D provide summaries of the Federal and DOE requirements for cost estimates, respectively. Each DOE program or project may have more specific, detailed requirements. Examples include the National Environmental Policy Act (NEPA); safety and health; site security requirement; and local requirements that may be specified in contracts, labor agreements, etc. Many of these requirements are implemented through the DOE annual budget formulation and execution process, and may add cost to projects. The primary requirement for developing cost estimates for capital asset projects is DOE O 413.3B, *Program and Project Management for the Acquisition of Capital Assets*, dated 11-29-10. During the life cycle of a project (see Figures 3-1 and 3-2), various cost estimates and related documents are required to support the Critical Decision process, the project reviews process, and the annual budget formulation and execution process.

**NOTES:**

1. Operating Funds may be used prior to CD-4 for transition, startup, and training costs.
2. PED funds can be used after CD-3 for design.

Figure 3-1. Typical DOE Acquisition Management System for Line Item Capital Asset Projects⁴

CD = Critical Decision
 EIR = External Independent Review
 PARS = Project Assessment and Reporting System
 PB = Performance Baseline
 PED = Project Engineering and Design
 TPC = Total Project Cost

⁴ DOE O 413.3B

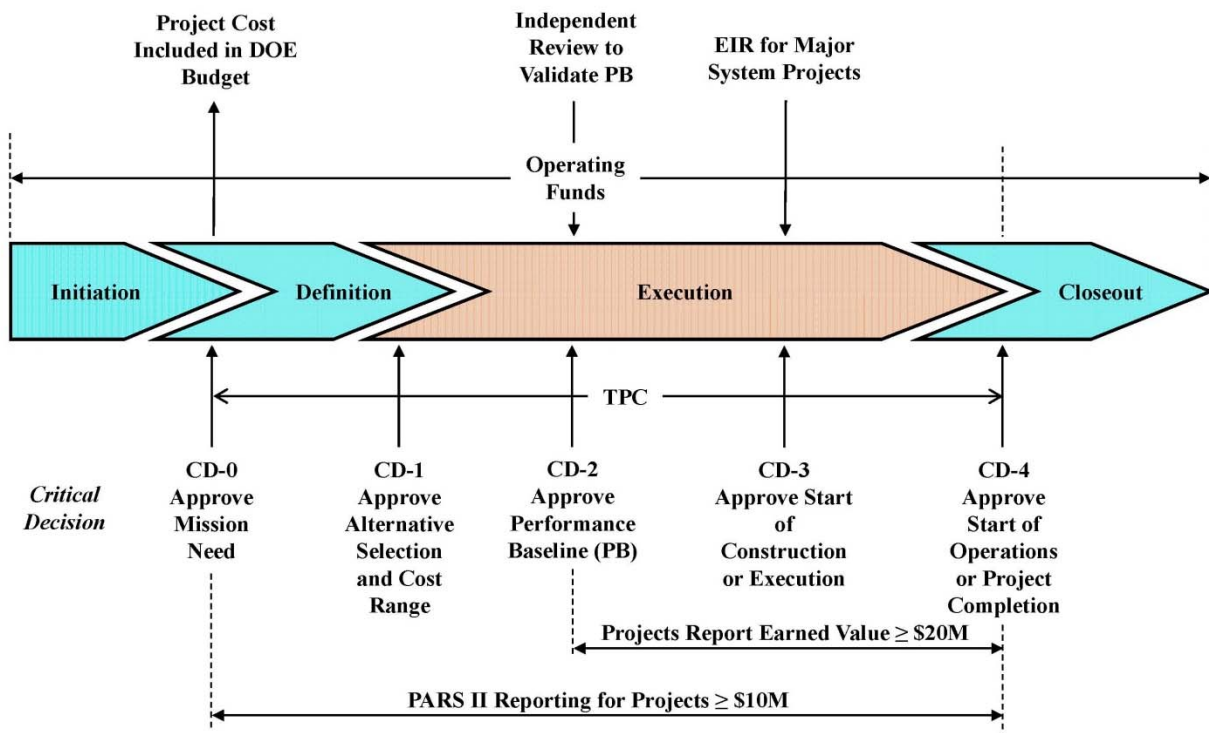


Figure 3-2. Typical DOE Acquisition Management System for Other Capital Asset Projects (i.e., Major Items of Equipment and Operating Expense Projects)⁵

3.2 Documentation Requirements

Common cost estimating outputs are shown in Figure 3-3. As this figure depicts, cost estimates must be developed, updated, and managed over the total life-cycle of any asset and are an important element for total life-cycle asset management within the DOE. Furthermore, project cost estimates are an integral element and key input into the management of programs over their life-cycle. Thus the concepts for cost estimate development described in this Guide should be applied to all instances when cost estimates are required to support both project and program management objectives.

As described by the DOE O 413.3B and other DOE directives, cost estimates and LCC analyses may be produced for a variety of purposes. As discussed below, these may include:

- The critical decision process within programs/projects (DOE O 430.1B Chg 1, *Real Property Asset Management*, and DOE O 413.3B).

⁵ DOE O 413.3B

- The DOE annual budget guidance document.
- Contract actions specifying requirements.
- Other project/program management purposes (various Federal regulations, DOE Orders, and industry practices).

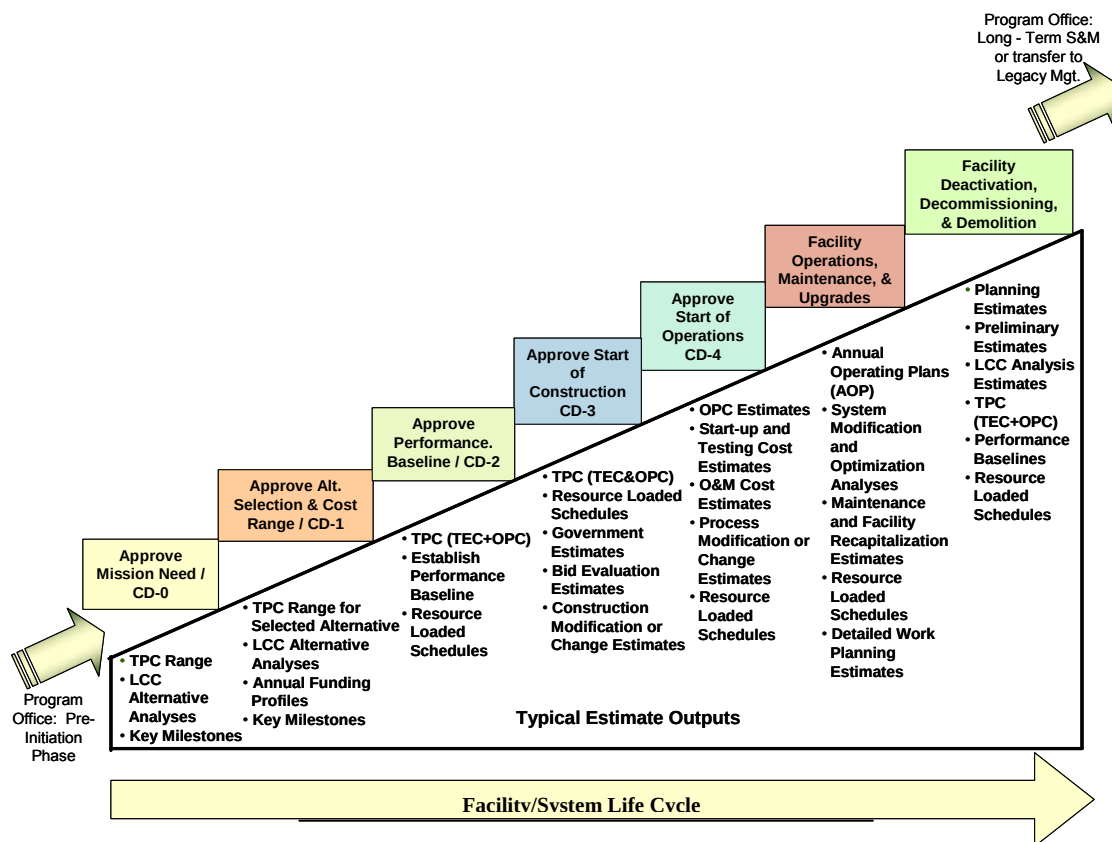


Figure 3-3. Facility/System Estimate Outputs as Compared to Life-Cycle Major Milestones

3.2.1 DOE Critical Decisions for Project Management and the Supporting Cost Estimates

- **Critical Decision (CD)-0, Approve Mission Need** — Generally, a cost estimate range is prepared to support CD-0. Assumptions developed by the project team generally will drive the project scope and bound both the project scope and costs. There will likely be very little detail to support these cost estimates, so it is important that scope assumptions be well-documented. A project cost magnitude range should be established based on potential project alternatives and major areas of risk, with appropriate consideration of the accuracy range of any supporting estimates or analyses. The proposed range should be sufficiently broad such that it fully bounds all possible project cost outcomes, understanding the very limited design basis that exists at the time and the more imprecise methodologies used at this stage of the project. This estimate assists in establishing the Acquisition Authority Level for CD-0. In addition, an estimate of the costs to be incurred prior to CD-1 which is for developing the Conceptual Design for the project, could also be required to support resource

planning and near-term schedules.

- **CD-1, Approve Alternative Selection and Cost Range**—There are three cost estimates needed for CD-1.
 1. Prior to the approval of CD-1, the project team should develop a definitive estimate of the near term preliminary design cost, which is needed for the project engineering and design (PED) funding request (if needed for project execution). An estimate may also be used to support PED funding for use in preliminary design, final design and baseline development.
 2. As part of the CD-1 requirement, the project team should perform analyses of the most likely project alternatives. Thus, the second cost estimate needed at CD-1 is the LCC of the likely alternatives that are being considered. A risk adjusted LCC estimate should be prepared for each alternative under consideration to ensure the alternative with the best cost/benefit ratio (and generally the lowest life-cycle cost) to the government is considered. Full LCCs, including all direct and indirect costs for planning, procurement, operations and maintenance (operational analysis should be used to evaluate condition and any negative trends on cost projections for assets in use), and disposal costs must be considered for each alternative being evaluated (OMB A-11).
 3. After selecting the alternative that best meets the mission, the project team develops the third estimate, the total project cost (TPC) range, a schedule range with key milestones and events, and annual funding profiles. The TPC range should consider identified project risks and estimate uncertainty and encompass the full range of potentially required resources necessary to successfully execute the planned work associated with the preferred/recommended alternative. The TPC range also assists in establishing the Critical Decision Authority Thresholds.
- **CD-2, Approve Performance Baseline**—Cost estimates supporting CD-2 should utilize more definitive cost estimating techniques (see Section 5.0). For CD-2, since available information will be more developed, the range should be collapsed to a point estimate. A single cost estimate will represent the entire project, utilizing the current scope and associated design parameters. The estimate will include appropriate allowances for risk and estimate uncertainty, i.e., Management Reserve and Contingency (see Section 6.4.5). This estimate is the basis for the cost estimate of the project's Performance Baseline and the Performance Measurement Baseline used for earned value reporting as required for projects with a TPC greater than \$20 million.⁶
- **CD-3, Approve Start of Construction**—Cost estimates based on the Final Design may incorporate some actual bids received from contractors used to establish the project's requirements for construction or execution. Cost estimates for Other Project Costs and Operational phases of the asset being acquired are finalized. These updated estimates

⁶ DOE O 413.3B

support authorization to commit resources necessary, within funds provided, to execute the project.

- **CD-4, Approve Start of Operations or Project Completion**—Establishes when the project is ready for turnover or transition to operations, if applicable. Determines the final Estimate at Completion (EAC) and provides final project cost and performance reports developed in accordance with the project's approved WBS. Cost and performance reports are necessary to document the TPC for the asset acquired, as well as assisting in the capture of historical cost information.

3.2.2 Annual Budget Process

Project or program budgets are sometimes adjusted to accommodate appropriations and allocations that are more or less than expected. Some situations may require development of alternative budget scenarios that can mitigate the risk of project funding uncertainty. When actual funding differs from planned budgets, baselines and estimates for current-period work (work packages) should be adjusted accordingly. Timing changes of actual funding versus planned budgets may not change the technical scope for which an estimate has been developed. However, those timing changes (extending work into the future from planned schedules) can cause changes to programmatic scope, project duration, and efficiencies, which affect overall project costs (such changes are subject to change control – scope, schedule and cost).

3.2.3 Contract Actions

During the normal course of project execution, contract actions occur. These commonly entail developing a government cost estimate, a proposed estimate, and a final estimate. Depending on contract types and other factors, varying levels of information will be available to facilitate the cost estimating process.

Before determining the content of an estimate, it is relevant to understand the contract types that will be used to execute the work. Types of contracts include firm-fixed price, fixed-price incentive, and cost reimbursable with a variety of fee structures, including fixed fee, award fee, and performance-incentive fee. Understanding the contract that will be used can influence the assumed government risks, contractor risks, productivity, and overhead and profit rates used in the estimate. The contract type should be defined in the Acquisition Strategy/Plan.

Independent Government Cost Estimates (IGCEs) are required before most acquisitions and may become either the basis for contract negotiations or settling claims. The purpose of the IGCE is to establish a basis for reserving funds for a contract during acquisition planning, comparing costs or prices subject proposed by offerors, and providing an objective basis for assisting in determining price reasonableness, and to assist in establishing the Government's negotiation position and strategy.

NOTE

Performance-based contracting could be a preferred contracting method that would require discrete, quantifiable, and measurable objectives tied to an incentive for which the development of discrete quantifiable estimates tied to the measurable objectives would be required. A project baseline (established at CD-2) and near-term contracts, or work packages, should also have characteristics that are discrete, quantifiable, and measurable.

Fee is normally associated with reimbursable cost contracts and is determined on the basis of pre-established performance objectives (e.g., meeting target dates, achieving target unit costs, etc.) Once the contract is in place, it will stipulate the fee structure and must be considered when developing or updating the cost estimate.

Profit is normally associated with a fixed-price contract and is unknown until all costs have been incurred. Cost estimates developed for this type of contract should assume a reasonable amount of profit based on market conditions and risks involved.

DEARS 915.404-4 provide guidance for estimating profit/fees for DOE contracts. Under DEARS 915.404-4-70 it is notable that construction and construction management contracts are subject to fee/profit limits which can only be exceeded after review and approval by the Senior Procurement Executive – important consideration when estimating the full contract price.

3.2.4 Other Project/Program Management Actions

Various other project or program management actions, such as development of LCC analyses, cost-benefit analyses, value engineering (VE) studies, earned value analyses, and change requests may require development of cost estimates.

LCC estimates may be required for many purposes. As a part of alternative selection, LCC analysis may point to the alternative with the lowest LCC but other analyses and considerations may need to be considered in the decision process. In cases where benefits can be quantified, LCC analyses can support more formal cost-benefit analysis for alternative evaluation and selection. Any time a change in the project is contemplated, or an alternative must be evaluated, LCC analysis should be considered. (Appendix G presents a simplified example of a LCC analysis)

Cost estimates are also required to support day-to-day project management decisions. In many cases, alternatives (e.g., changes in the work flow) are considered that do not affect the entire project, but do affect the day-to-day details of managing a project. A design detail change that does not exceed a cost or schedule threshold for management approval is an example.

Comparisons of government estimates to other results (e.g., bid opening prices) may require a reconciliation of the figures. Generally, the differences are due to the estimates not being based on consistent, current information, such as weather delay assumptions, productivity assumptions, market conditions for commodities, etc. The reconciliation should clearly state the differences and the rationale for the differences.

4.0 COST ESTIMATING CHARACTERISTICS AND CLASSIFICATIONS

4.1 Planning the Cost Estimates

Table 4-1 describes the elements of planning required to produce credible cost estimates.⁷ In a 2006 survey to identify the characteristics of a good estimate, participants from a wide variety of industries— including aerospace, automotive, energy, consulting firms, the Navy, and the Marine Corps—concurred that the characteristics listed in the table are valid (GAO-09-3SP, Chapter 1, page 7). The Government Accountability Office (GAO) also found that despite the fact that these characteristics have been published and known for decades, many agencies still lack the ability to develop cost estimates that can satisfy these basic characteristics.

Planning Step	Description
Clear Identification of Task	Estimator must be provided with the scope description, ground rules and assumptions, and technical and performance characteristics.
	The estimate's constraints and conditions must be clearly identified to ensure the preparation of a well-documented estimate.
Broad Participation in Preparing Estimates	The Integrated Project Team and the Integrated Acquisition Team should be involved in determining requirements based on the mission need and in defining parameters and other scope characteristics.
	Data should be independently verified for accuracy, completeness, and reliability.
Availability of Valid Data	Use numerous sources of suitable, relevant, and available data.
	Use relevant, historical data from similar work to project costs of the new work. The historical data should be directly related to the scope's performance characteristics.
Standardized Structure for the Estimate	Use of a standard WBS that is as detailed as possible, continually refining it as the maturity of the scope develops and the work becomes more defined. The WBS elements should ultimately drill down to the lowest level, the work package.
	The WBS ensures that no portions of the estimate (and schedule) are omitted or duplicated. This makes it easier to make comparisons to similar work.
Provision for	Identify the confidence level (e.g., 80 percent) needed to establish a successful planning process. Identify uncertainties and develop an allowance to mitigate cost

⁷ GAO-09-3SP

Planning Step	Description
Uncertainties and Risk	effects of the uncertainties.
	Include known costs and allow for historically likely but specifically unknown costs. (Reference: DOE G 413.3-7A, <i>Risk Management Guide</i>)
Recognition of Escalation	Ensure that economic escalation is properly and realistically reflected in the cost estimate. Escalation is schedule driven, and scheduling assumptions need to be clearly noted. NOTE: Project teams may use specific rates relative to the site when available. In any case, the source of escalation information used should be identified and the applicability of the rates should be explained/justified.
Recognition of Excluded Costs	Include all costs associated with the scope of work; if any cost has been excluded, disclose and include a rationale.
Independent Review of Estimates	Conducting an independent review of an estimate is crucial to establishing confidence in the estimate. The independent reviewer should verify, modify, and correct an estimate to ensure realism, completeness, and consistency.
Revision of Estimates for Significant Changes	Update estimates to reflect changes in the design requirements. Large changes that affect costs can significantly influence decisions.

Table 4-1. Basic Characteristics of Credible Cost Estimates

4.2 Cost Estimate Classifications

Most cost estimates have common characteristics, regardless of whether the technical scope is traditional (capital funded, construction, equipment purchases, etc.) or nontraditional (expense funded, research and development, operations, etc.). The most common characteristics are levels of definition, requirements (end usage/purpose), and techniques used. These characteristic levels are generally grouped into cost estimate classifications. Cost estimate classifications may be used with any type of traditional or nontraditional project or work and may include consideration of (1) where a project stands in its life cycle, (2) level of definition (amount of information available), (3) techniques to be used in estimation (e.g., parametric vs. definitive), and/or (4) time constraints and other estimating variables.

Typically, as a project evolves, it becomes more definitive. Cost estimates depicting evolving projects or work also become more definitive over time. Determination of cost estimate classifications helps ensure that the cost estimate quality is appropriately considered. Classifications may also help determine the appropriate application of contingency, escalation, use of direct/indirect costs (as determined by cost estimate techniques), etc.

Widely accepted cost estimate classifications are found in the Association for Advancement of Cost Engineering International (AACEI), Recommended Practice (RP) No. 17R-97 and RP No. 18R-97; see Appendix H). Appendix H includes a complete description of AACEI's classifications. The five suggested cost estimate classifications are listed in Table 4-2 along with their primary characteristics. Table 4-3 lists the secondary characteristic and the estimate

uncertainty range, as a function of the estimate class; that could be used for contingency evaluations (estimate uncertainty contributes to both cost and schedule contingency) as part of the risk analysis for the project.⁸ DOE's cost estimate classifications generally follow these recommended practices, although historically the more common cost estimate classifications are order of magnitude, preliminary, and definitive, which approximately equate to the ACEI's Classes 5, 3 and 1, respectively. Table 4.4 provides an example of the typical suggested types of cost estimates for each DOE Critical Decision as compared with the ACEI classification. Figure 4.1 provides an example of the variability in uncertainty ranges for a process industry estimate versus the level of project/scope definition. (Reference: ACEI RP No. 18R-97)

A project cost estimate may comprise separate estimates of differing classifications. Certain portions of the design or work scope may be well defined, and therefore warrant more detailed cost estimating techniques and approaches, while other areas are relatively immature and therefore appropriately estimated using parametric or other less definitive techniques.

Cost Estimate Classification	Primary Characteristics	
	Level of Definition (% of Complete Definition)	Cost Estimating Description (Techniques)
Class 5, Concept Screening	0% to 2%	Stochastic, most parametric, judgment (parametric, specific analogy, expert opinion, trend analysis)
Class 4, Study or Feasibility	1% to 15%	Various, more parametric (parametric, specific analogy, expert opinion, trend analysis)
Class 3, Preliminary, Budget Authorization	10% to 40%	Various, including combinations (detailed, unit-cost, or activity-based; parametric; specific analogy; expert opinion; trend analysis)
Class 2, Control or Bid/Tender	30% to 70%	Various, more definitive (detailed, unit-cost, or activity-based; expert opinion; learning curve)
Class 1, Check Estimate or Bid/Tender	50% to 100%	Deterministic, most definitive (detailed, unit-cost, or activity-based; expert opinion; learning curve)

Table 4-2. Generic Cost Estimate Classifications and Primary Characteristics

⁸ DOE G 413.3-7A, *Risk Management Guide*, dated January 2011.

ESTIMATE CLASS	Primary Characteristic	Secondary Characteristic		
	DEGREE OF PROJECT DEFINITION Expressed as % of complete definition	END USAGE Typical purpose of estimate	METHODOLOGY Typical estimating method	EXPECTED ACCURACY RANGE Typical variation in low and high ranges ^[a]
Class 5	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 70%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	70% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Notes: [a] The state of process technology and availability of applicable reference cost data affect the range markedly. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of contingency (typically at a 50% level of confidence) for given scope.

Table 4.3 – Cost Estimate Classification for Process Industries

Critical Decision	Suggested Estimate	AACEI Estimate Classification
CD-0	Cost estimate range	Class 5
	Estimate of costs to be incurred prior to CD-1	Class 3
CD-1	Estimate of near term preliminary design cost	Class 3
	LCC of likely alternatives that are being considered	Class 5
	TPC range	Class 4
CD-2	Single point estimate representing entire project:	
	Low risk projects	Class 3
	High risk projects	Class 2
CD-3	Cost estimate based on Final Design [or sufficiently mature to start construction]:	
	Low risk and final design complete	Class 1
	Low risk and final design not complete	Class 2
	High risk (final design or not)	Class 2
CD-4		N/A

Table 4.4 – Generic Suggested Types of Estimates for DOE Critical Decisions

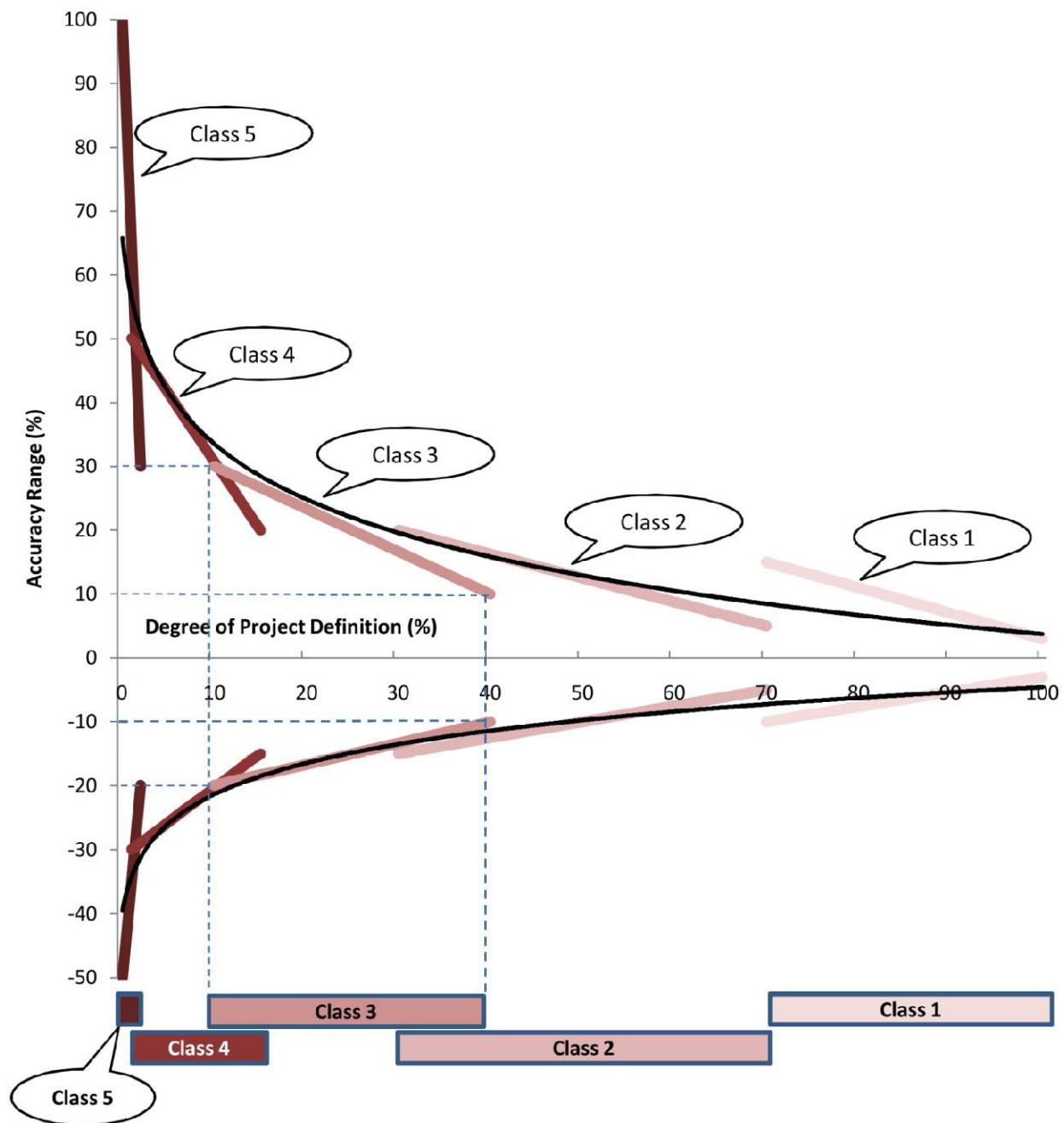


Figure 4.1 – Example of the Variability in Accuracy/Uncertainty Ranges for a Process Industry Estimate

As a general rule, particularly for projects that are in the early stages of development, a combination of estimate classifications must be used to develop the entire estimate. In these situations, estimators should use a combination of detailed unit cost estimating (Class 1) techniques for work that will be executed in the near future, preliminary estimating (Class 3) techniques for work that is currently in the planning stages but less defined, and order of magnitude estimating (Class 5) techniques for future work that has not been well defined. As a

project progresses through the Acquisition Management System (initiation, definition, execution, and transition/closeout phases) and the project development and planning matures, the life-cycle cost estimate becomes more definitive. This may be referred to as “**rolling-wave**” planning, where detailed planning of future work is done in increments, or waves as the project progresses through phases.

4.3 Cost Estimate Ranges

The Department’s Acquisition Management System includes Critical Decisions (CDs) that define exit points from one phase of project development and entry into the succeeding project phase. Prior to CD-2 approval, DOE O 413.3B requires the use of ranges to express project cost estimates. These ranges should depict TPCs in the early stage, even at CD-0. Ranges may be determined or based upon various project alternatives, project identified risks, and confidence levels.

LCC estimates that are developed early in a project’s life may not be derived from detailed engineering, but must be sufficiently developed to support budget requests for the remainder of the project definition phase. In addition, ranges should include all anticipated resources, using appropriate estimating techniques that are necessary to acquire or meet the identified capability.

During the project definition phase, at the conclusion of the concept exploration process, the alternative selected as the best solution to a mission need is presented for approval. The solution presented includes the TPC range, a schedule range with key milestones and events, and annual funding profiles that are risk-adjusted and define all required resources necessary to successfully execute the planned work.

The estimate range (lower and upper bounds) as defined in DOE G 413.3-13, *U.S. Department of Energy, Acquisition Strategy Guide for Capital Asset Projects*, dated 7-22-08, is determined by independently assessing the lower and upper cost estimate range for each of the major WBS elements. In some situations, the range may in part be a function of scope variability; e.g., if a decision to add five or 10 glove-boxes is pending. The range can also be established by the project team considering the cost and schedule estimate uncertainties as part of the risk analysis. A risk analysis is analytical in nature and, although simulation tools aid the analyst in assessing impact and consequences, no simulation tool can substitute for a thorough logical deterministic process. The risks are identified by the likelihood of occurrence and the probable impact.

The lower bound of the cost range may represent a scenario where the project team has determined a low likelihood of occurrence and low impact of the identified risks, and a higher likelihood of opportunities occurrence. The risks may be accepted; therefore it is not necessary to include resources to mitigate them.

The upper bound of the cost range may represent a scenario where the project team has determined a low likelihood of occurrence, but the impact is significant of the identified impact risks. The risks will be managed and appropriate resources identified to mitigate each risk.⁹

5.0 COST ESTIMATING METHODS

Many cost estimating methods/techniques are available to facilitate the cost estimating process. Depending on project scope, estimate purpose, project maturity, and availability of cost estimating resources, the estimator may use one, or a combination, of these techniques. As shown in Table 4.3, as the level of project definition increases, the estimating methodology tends to progress from conceptual (stochastic/parametric) techniques to deterministic/definitive techniques. The following sub-sections include techniques that may be employed in developing cost estimates.

5.1 Detailed Estimating Method

Activity-based, detailed or unit cost estimates are typically the most definitive of the estimating techniques and use information down to the lowest level of detail available. They are also the most commonly understood and utilized estimating techniques.

The accuracy of activity-based detailed or unit cost techniques depends on the accuracy of available information, resources spent to develop the cost estimate and the validity of the bases of the estimate. A work statement and set of drawings or specifications may be used to identify activities that make up the project. Nontraditional estimates may use the WBS, team input and the work statement to identify the activities that make up the work.

Each activity is further decomposed into detailed items so that labor hours, material costs, equipment costs, and subcontract costs are itemized and quantified. Good estimating practice is to use a verb as the first word in an activity description. Use of verbs provides a definitive description and clear communication of the work that is to be accomplished. Subtotaled, the detailed items comprise the direct costs. Indirect costs, overhead costs, contingencies and escalation are then added as necessary. The estimate may be revised as known details are refined. The activity-based detailed or unit cost estimating techniques are used mostly for Class 1 and Class 2 estimates, and they should always be used for proposal or execution estimates.

Activity-based detailed cost estimates imply that activities, tasks, work packages, or planning packages are well-defined, quantifiable, and are to be monitored, so that performance can be reported accurately. Quantities should be objective, discrete, and measurable. These quantities provide the basis for an earned value measurement of the work within the activities and the WBS.

⁹ A more thorough discussion on the risk management process can be found in **DOE G 413.3-7A**, *Risk Management Guide*, January 2011.

Advantages in using activity-based detailed or unit cost estimating methods include:

- a greater level of confidence
- more detail that can be used for better monitoring, change control, etc.
- enhanced scope and individual activity definition
- detailed quantities to establish more accurate metrics
- better resource basis for the schedule

Disadvantages include:

- more time needed to develop the estimate
- more costly to develop than relationship estimating

5.2 Parametric Estimating Techniques

A parametric model is a useful tool for preparing early conceptual estimates when there is little technical data or engineering deliverables to provide a basis for using more detailed estimating methods.¹⁰ A parametric estimate comprises cost estimating relationships and other cost estimating functions that provide logical and repeatable relationships between independent variables, such as design parameters or physical characteristics and cost, the dependent variable. Capacity factor and equipment factor are simple examples of parametric estimates; however, sophisticated parametric models typically involve several independent variables or cost drivers. Parametric estimating is reliant on the collection and analysis of previous project cost data in order to develop the cost estimating relationships.

5.2.1 Cost Estimating Relationships

Cost estimating relationships (CERs), also known as cost models, composites, or assemblies/subassemblies, are developed from historical data for similar systems or subsystems. A CER is used to estimate a particular cost or price by using an established relationship with an independent variable. For example, a CER of design hours per drawing may be applied to the estimated number of drawings to determine total design hours. Identifying an independent variable (driver) that demonstrates a measurable relationship with contract cost or price develops a CER. That CER may be mathematically simple in nature (e.g., a simple ratio), or it may involve a complex equation.

Parametric estimates are commonly used in conceptual and check estimates. A limitation to the use of CERs is that to be most effective, one must understand completely how the CER was developed and where and how indirect costs, overhead costs, contingency, and escalation are applicable. The parametric estimating technique is most appropriate for Class 5, 4, and 3 cost

¹⁰ It is recommended that when using these cost estimating models that they should be verified and validated by recognized standard industry practices such as the Tri Services Parametric Cost Model Standard .

estimates. The parametric technique is best used when the design basis has evolved little, but the overall parameters have been established.

There are several advantages to parametric cost estimating. Among them are:

- **Versatility**—If the data are available, parametric relationships can be derived at any level (system, subsystem component, etc.). As the design changes, CERs can be quickly modified and used to answer “what-if” questions about design alternatives.
- **Sensitivity**—Simply varying input parameters and recording the resulting changes in cost will produce a sensitivity analysis
- **Statistical output**—Parametric relationships derived through statistical analysis will generally have both objective measures of validity (statistical significance of each estimated coefficient and of the model as a whole) and a calculated standard error that can be used in risk analysis. This information can be used to provide a confidence level for the estimate based on the CERs predictive capability.

There are also disadvantages to parametric estimating techniques, including:

- **Database requirements**—The underlying data must be consistent and reliable. In addition, it may be time-consuming to normalize the data or to ensure that the data were normalized correctly. Without understanding how data were normalized, the estimator is accepting the database on faith, thereby increasing the estimate’s risk.
- **Currency**—CERs must represent the “state-of-the-art;” that is, they must be periodically updated to capture the most current cost, technical, and programmatic data.
- **Relevancy**—Using data outside the CER range may cause errors because the CER loses its predictive capability for data outside the development range.
- **Complexity**—Complicated CERs (e.g., non-linear CERs) may be difficult for others to readily understand the relationship between cost and its independent variables.

5.2.2 End Products Unit Method

The End Products Unit Method is used when enough historical data are available from similar work based on the capacity of that work. The method does not take into account any economies of scale, or location or timing of the work.

Consider an example of estimating the construction cost of a parking lot. From a previous project the total cost was found to be \$150,000 for 100 parking stalls, or \$1,500/stall. For a new parking lot of 225 parking stalls, the estimated cost would be \$1,500/parking stall x 225 parking stalls = \$337,500.

5.2.3 Physical Dimension Method

The Physical Dimension Method is used when enough historical data is available from similar work based on the area or volume of that work. This method uses the physical dimension relationship of existing work data to that of the physical dimensions of similar new work. The method does not take into account any economies of scale, or location or timing of the work

To consider the example in section 5.3, the total cost of the previous project was \$150,000 for a 3,000 square feet parking lot. The new parking lot is to be 7,000 square feet; therefore, $(\$150,000/3,000 \text{ square feet} = \$50/\text{square feet})$ for the previous project so the estimated cost of the new project is $\$50/\text{square feet} \times 7,000 \text{ square feet} = \$350,000$.

5.2.4 Capacity Factor Method

The Capacity Factor Method is used when enough historical data are available from similar work based on the capacity of that work. The method uses the capacity relationship of existing work data to that of the capacity of similar new work. It accounts for economies of scale, but not location or timing of the work.

For example, consider a known power plant that produces 250 MW(t)/hour and costs \$150,000,000 to construct. A new plant will produce 300 MW(t)/hour. From historical data, 0.75 is the appropriate capacity factor.

Using the equation $\text{Cost (new)} = \text{Cost (known)} (\text{Capacity (new)} / \text{Capacity (known)})^e$
Where: $e = \text{capacity factor derived from historical data}$
 $\text{Cost (new)} = \$150,000,000 (300/250)^{.75}$
 $\text{Cost (new)} = \$172,000,000 \text{ (rounded)}$

5.2.5 Ratio or Factor Method

The Ratio or Factor Method is used when historical building and component data are available from similar work. Scaling relationships of existing component costs are used to predict the cost of similar new work. This method is also known as “equipment factor” estimating. The method does not account for any economies of scale, or location or timing of the work.

To illustrate, if a plant that cost \$1,000,000 to construct has major equipment that costs \$300,000, then a factor of 3.33 represents the plant cost to equipment cost “factor.” If a proposed new plant will have \$600,000 of major equipment, then the factor method would predict that the new plant is estimated to cost $\$600,000 \times 3.33 = \$2,000,000$.

5.3 Other Estimating Methods

5.3.1 Level of Effort Method

A form of parametric estimating is based on level of effort (LOE). Historically, LOE is used to determine future repetitive costs based on past cost data, as in, “*we spent ~\$10M on operations last year, so we need ~\$10M next year.*” Often LOE estimates have few parameters or performance objectives from which to measure or estimate, but are carried for several time periods at a similar rate (e.g., the costs of operations, such as X number of operators for Y amount of time). LOE estimates are normally based on hours, full-time equivalents (FTEs), or “lot.” Since they are perceived to have little objective basis, LOE estimates are often subject to scrutiny. The keys to LOE estimates are that they should generally be based on known scope

(although quantities may be assumed) and have a basis, even if it is simply the opinion of an expert or a project team.

Variations on LOE techniques are numerous and should be considered carefully before deciding to employ a specific technique. For instance, using LOE for installing a piece of equipment may raise questions about why it does not include the circumstances surrounding the installation (contamination and security issues and related productivity adjustments). Also questionable in LOE estimates are indirect costs, overhead costs, profit/fee, and other assumptions.

5.3.2 Specific Analogy Method

Specific analogies use the known cost or schedule of an item as an estimate for a similar item in a new system. Adjustments are made to known costs to account for differences in relative complexities of performance, design, and operational characteristics.

A variation of this technique is the “review and update technique,” where an estimate is constructed by examining previous estimates of the same or similar projects for logic, scope completion, assumptions, and other estimating techniques, and then updated to reflect any pertinent differences. The specific analogy technique is most appropriate in the early stages of a project; that is, for Class 5 and 3 cost estimates.

There are several advantages to using the analogy method, including:

- It can be used before detailed program requirements are known;
- If the analogy is strong, the estimate will be defensible;
- An analogy can be developed quickly and at minimal cost; and
- The tie to historical data is simple enough to be readily understood.

There are, however, also some disadvantages in using analogies, such as:

- An analogy relies on a single data point;
- It is often difficult to find the detailed cost, technical, and programmatic data required for analogies; and
- There is a tendency to be too subjective about the technical parameter adjustment factors.

The last disadvantage can be better explained through an example. If a cost estimator assumes that a new component will be 20 percent more complex, but cannot explain why, this adjustment factor is unacceptable. The complexity must be related to the system’s parameters, such as the new system will have 20 percent more data processing capacity or will weigh 20 percent more. (GAO)

5.3.3 Expert Opinion Method

As stated in the GAO Cost Estimating and Assessment Guide, “expert opinion, also known as engineering judgment, is commonly applied to fill gaps in a relatively detailed WBS when one or more experts are the only qualified source of information, particularly in matters of specific

scientific technology.” Expert opinion is an estimating technique whereby specialists are consulted until a consensus can be established regarding the cost of a program, project, sub-project, task, or activity. The expert opinion technique is most appropriate in the early stages of a project, or for Class 5, 4, and 3, cost estimates. These cost estimates document a list of the experts consulted, their relevant experience, and the basis for their opinions.

A formalized procedure, the Oracle Method, has been used to forecast cost based on expert opinion. Six or more experts are given a specific, usually quantifiable, question. Each expert sees the estimates produced by the others and modifies his or her previous estimate until a consensus is reached. If after four rounds there is no consensus, the original question may be broken into smaller parts for further rounds of discussion or a moderator may attempt to produce a final estimate.

This technique may be used for either portions of or entire estimates and activities for which there is no other sound basis. A limitation arises when a cost estimator’s or project manager’s status as an expert is questioned.

The advantages of using an expert opinion are:

- It can be used in the case where there are no historical data available;
- The approach takes minimal time and is easy to implement once the experts are assembled;
- An expert may provide a different perspective or identify facets not previously considered leading to a better understanding of the program; and
- It can be useful as a cross-check for CERs that require data significantly beyond the data range.

The disadvantages associated with an expert opinion include:

- It should be used as a last resort due to its lack of objectivity;
- There is always a risk that one expert will try to dominate the discussion and sway the group toward his/her opinion; and
- This approach is not considered very accurate or valid as a primary estimating method.

The bottom line is that, because of its subjectivity and lack of supporting documentation, expert opinion should be used primarily for confirming that the estimate does not contain elementary mistakes or invalid assumptions.

5.3.4 Trend Analysis Method

Trend analysis method is an estimating technique for current, in-progress work, and is also used to explain quantitatively how a project is progressing. It is especially useful when large quantities of commodities are a significant part of a project, (e.g., mass excavations, mass concrete placement, structural steel fabrication/installation, etc.) A trend is established using an efficiency index derived by comparing originally planned costs (or schedules) against actual costs (or schedules) for work performed to date. For example, a project’s actual costs to date,

divided by the number of units produced provides a measure of current costs per unit. Variations in this measure from previous periodic trending information can be used to adjust the estimate for the remaining work, as well as to help project managers with decisions regarding resources (people, equipment, etc.) and make near term planning adjustments.

The trend analysis technique can be used at almost any stage of project development and can even be used to update cost estimates developed using other techniques. It should be remembered, however, that during a long project activity, productivity rates may vary, with less than optimal productivity occurring as project activity begins, improved productivity developing until an optimum sustained level can be achieved, and then less than optimal productivity encountered near the end of the project as problems are resolved and final activities are completed. Thus trend analysis estimates should consider the current stage and remaining stage of a project activity carefully before extrapolating current productivity or cost values.

5.3.5 Learning Curve Method

The learning curve is a way to understand the efficiency of producing or delivering large quantities. Studies have found that people engaged in repetitive tasks will improve their performance over time, i.e., for large quantities of time and units, labor costs will decrease, per unit.

The aircraft industry first recognized and named the learning curve and successfully used it in estimating. It can be used most effectively when new procedures are being fielded and where labor costs are a significant percentage of total unit cost. But it should always be understood that the learning curve applies only to direct labor input. Materials and overhead will not necessarily be affected by the learning curve. Figure 5-1 illustrates a hypothetical learning curve.

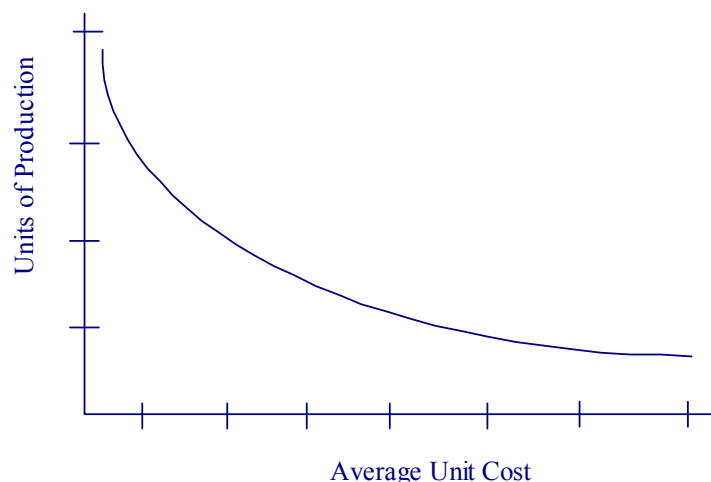


Figure 5-1. The Learning Curve Method

Typical learning curves start with high labor costs (hours) that decrease rapidly on early production units, and then flatten as production continues. This exponential relationship between

labor productivity and cumulative production is expressed in terms of labor reduction resulting from production increases. For example, a 90-percent learning curve function requires only 90 percent of the labor hours per unit each time production doubles. When a total of 200 units are produced, labor costs for the second 100 units will be only nine tenths the costs of the first 100.

Increased productivity allows for lower labor costs later in a project, and should result in a lower overall project cost. Subsequent similar projects should have fewer labor hours for each unit of production also, which could result in both more contractor profit and lower government contract costs.

No standard reduction rate applies to all programs, and learning curve benefits will vary. When labor hour reductions of the first units are known, an accurate percentage reduction can be calculated and extended to subsequent units. If no data exists, it may be risky to assume that learning curve savings will be experienced.

The learning curve estimating technique can be considered for all traditional and nontraditional projects. The learning curve is most effective when applied to repetitive activities, and can also be used to update labor hours calculated in earlier estimates.

5.4 Methods of Estimating Other Life-Cycle Costs

Different methods may be used to estimate other project/program support costs, including design, engineering, inspections, ES&H, etc. Some common methods are counting drawings and specifications, FTE, and percentage.

5.4.1 Count Drawings and Specifications Method

The estimator calculates the number of drawings and specifications representing a specific project. The more complex a project is, the more drawings and specifications it will require meaning that associated design costs will be higher.

5.4.2 Full-Time Equivalent Method

The number of individuals anticipated to perform specific functions of a project forms the basis. The man-hour quantity is calculated and multiplied by the cost per labor hour and the duration of the project function to arrive at the cost.

5.4.3 Percentage Method

The estimator calculates a certain percentage of the direct costs and assigns this amount to the other project functions (such as design, project management, etc.). Some possible benchmarks for DOE projects include:

- Total design percentages are usually 15-25 percent of estimated construction costs for DOE projects. Non-traditional, first of a kind projects may be higher, while simple construction such as buildings will be lower than this range (on the order of 6 percent);

the more safety and regulatory intervention is involved, the higher the percentage.

- Project management costs range from 5 to 15 percent of the other estimated project costs for most DOE projects, depending on the nature of the project and the scope of what is covered under project management. The work scope associated with this range should be defined very specifically and clearly.

6.0 COST ESTIMATING DEVELOPMENT PROCESS

6.1 Overview of the Cost Estimating Process

The overall Cost Estimating Process Model followed here was described graphically by Figure 2.1 in Section 2.2. The cost estimating development process discussed in this section follow the 12 steps model recommended by GAO¹¹ and are part of the circle of iterative activities in Figure 2.1 for developing the cost estimate. Figure 6-1 depicts the 12 step GAO model. Table 6-1 further identifies the implementing tasks related to the GAO-12 step cost estimating development process. Systematically conducting these tasks enhances the reliability and validity of cost estimates. The process is iterative.

¹¹ GAO-09-3SP

Initiation and Research
Your audience, what you are estimating, and why you are estimating it are of the utmost importance.

Assessment
Cost assessment steps are iterative and can be accomplished in varying order or concurrently.

Analysis
The confidence in the point or range of the estimate is crucial to the decision maker.

Presentation
Documentation and presentation make or break a cost estimating decision outcome.

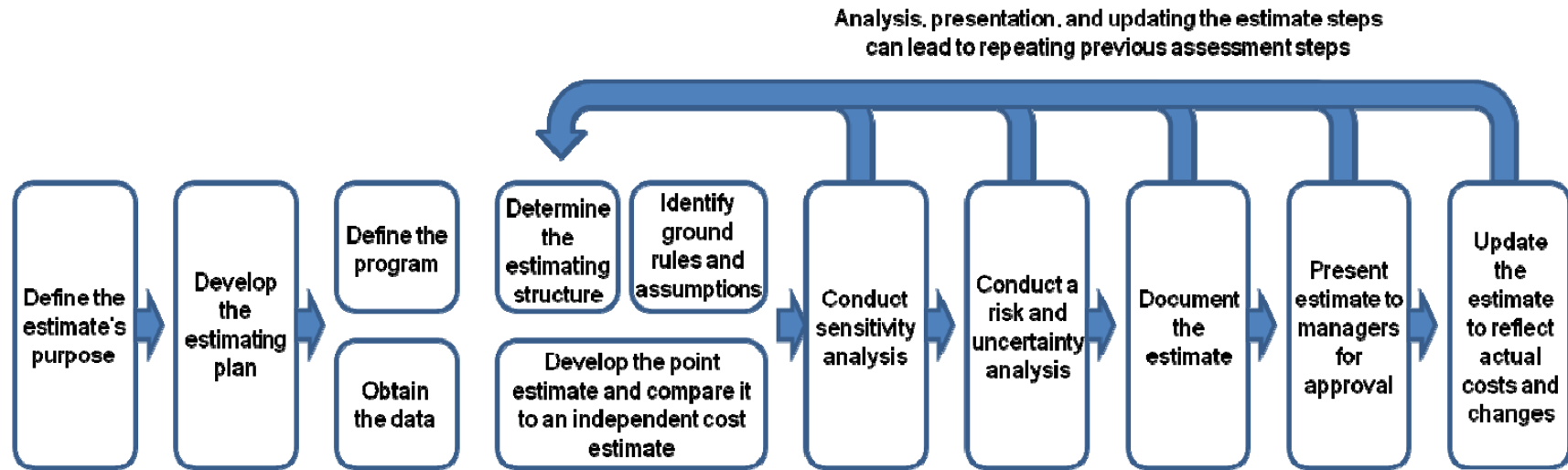


Figure 6.1. The GAO 12 Steps Cost Estimating Development Process Model

SOURCE: GAO-09-3SP

Note: A crosswalk between the GAO 12 Steps and the different sections in this Guide is shown in Appendix J.

Table 6-1. The GAO Cost Estimating Development Process

Step	Description	Associated Tasks
1	Define the Estimate's Purpose	- Determine the estimate's purpose. - The level of detail required. - Determine who will receive the estimate. - Identify the overall scope of the estimate.
2	Develop the Estimating Plan	- Determine the cost estimating team. - Outline the cost estimating approach. - Develop the estimate timeline. - Determine who will do the independent cost estimate. - Develop the team's master schedule.
3	Define the Program/Project Characteristics of the work	Identify the technical and program/project parameters that will bind the cost estimate based on the following information: - The purpose of the project. - Its system and performance characteristics. - Any technology implications. - All system configurations. - Project acquisition schedule. - Acquisition strategy. - Relationship to other existing systems. - Support (manpower, training, etc.) and security needs. - Identification of risk items. - System quantities for development, test and production. - Deployment and maintenance plans. - Predecessor or similar legacy systems.
4	Determine the Estimating Structure	- Define the work breakdown structure (WBS) and define each element in a WBS dictionary. - Choose estimating method best suited for each WBS element. - Identify potential cross-checks for likely cost and/or schedule drivers. - Develop a cost estimating checklist.
5	Identify Ground Rules and Assumptions	Clearly define what is included and excluded from the estimate. Identify global, program, and project specific assumptions such as: - The estimate's base year including its time-phasing and life cycle. - Project schedule information by phase. - Project acquisition strategy - Any schedule or budget constraints. - Inflation assumptions. - Travel costs. - Equipment to be furnished by the government. - Prime and major subcontractors involved. - Use of existing facilities or new modification / development. - Technology refresh cycles. - Technology assumptions and new technology to be developed. - Commonality with legacy systems and assumed heritage savings. - Effects of new ways of doing business.
6	Obtain the data	- Create a data collection plan with emphasis on collecting current and relevant technical, programmatic, project, and cost and risk data. - Investigate possible data sources. - Collect and normalize data for cost accounting, inflation, learning, location, quantity, and other adjustments. - Analyze the data to look for cost drivers, trends, and outliers. Compare

Step	Description	Associated Tasks
		results against rules of thumb and standard factors derived from historical data. - Interview data sources and document all pertinent information including an assessment of data reliability and accuracy. - Store the data for future estimates.
7	Develop the Point Estimate	- Develop the cost by estimating each WBS element using the best methodology from the data collected. - Include all estimating assumptions. - Express costs in constant year dollars. - Time-phase the results by spreading costs in the years they are expected to occur based on the project resources and schedule. - Sum each of the WBS elements to develop the overall point estimate - Validate the estimate by reviewing for errors such as double counting and omitting costs. - Compare estimate against the independent cost estimate and examine where and why there are differences. - Perform cross-checks on cost drivers to see if results are similar. - Update the estimate as more data becomes available or as changes occur. - Compare results against previous estimates.
8	Conduct Sensitivity Analysis	- Test the sensitivity of cost elements to changes in estimating input values and key assumptions. - Identify the effects of changing the project schedule, funding profile, or quantities on the overall estimate. - Based on this analysis determine which assumptions are key cost drivers and which cost elements are the most impacted by changes.
9	Conduct a Risk and Uncertainty Analysis	- Determine the level of cost, schedule, and technical risk associated with each WBS element and discuss with technical experts. - Analyze each risk for its probability of occurrence and impact. - Develop minimum, most likely, and maximum ranges for each element of risk. - Use an acceptable statistical analysis methodology (e.g., Monte Carlo simulation) to develop a confidence interval around the point estimate. - Determine type of probability distributions and reason for their use. - Identify the confidence level of the point estimate based on risks that have already been mitigated. - Identify the amount of contingency funding and add this to the point estimate to determine the risk adjusted cost estimate. - This analysis should be performed by the IPT and reflect the latest approved project Risk Management Plan.
10	Document the Estimate	- Document all steps used to develop the estimate so that it can be recreated quickly by a cost analyst unfamiliar with the program and produce the same result. - Document the purpose of the estimate, the team that prepared it, and who approved the estimate and on what date. - Provide a description of the project including the schedule and technical baseline used to create the estimate. - Present the time-phased life cycle cost of the program. - Discuss all ground rules and assumptions. - Include auditable and traceable data sources for each cost element. - Document for all data sources how the data was normalized. - Describe in detail the estimating methodology and rationale used to derive each WBS element's cost (more detail preferred over too little). - Describe the results of the risk, uncertainty and sensitivity analysis and

Step	Description	Associated Tasks
		whether any contingency funds were identified. - Describe if the contingency and risk analysis was based on mitigated or unmitigated risks. - Document how the estimate compares to the funding profile. - Track how this estimate compares to previous estimates if applicable.
11	Present Estimate to Management for Approval	- Develop a briefing that presents the documented life cycle cost estimate for management approval including an explanation of the technical and programmatic baseline and any uncertainties. - Briefing should be detailed enough so the presenter can easily defend the estimate by showing how it is accurate, complete, and of high quality. - Focus should be on the largest cost elements and drivers of cost presented in a logical manner. - Content should be clear and complete making it easy for those unfamiliar with the cost estimate to comprehend the competence that underlies the estimate results. - Backup slides should be available to answer more probing questions. - Comparisons to an independent cost estimate should also be made and any differences explained. - Feedback from management should be acted upon and documented. - Cost estimating team should request acceptance of the estimate. - Include a comparison of the estimates (LCCE and/or ICE) to the budget.
12	Update the Estimate to Reflect Actual Costs and Changes	- Update estimate to reflect any changes in technical, programmatic, or project assumptions or as the project passes through new phases / milestones so that it is always current - Replace estimates with EVM EAC and Independent EAC from the integrated EVM system - Report progress on meeting cost and schedule estimates - Perform a post-mortem and document lessons learned for elements whose actual costs or schedules are different from the estimate - Document all changes to the program and each affects the cost estimate.

Source: DOD, DOE, NASA, Society of Cost Estimating and Analysis (SCEA), Industry, DHS

6.2 Estimate Planning

Estimate planning (Input in Figure 2.1, Process Model) should include:

- Establishing when the estimate is required
- Determining who will prepare the estimate
- Producing a plan/schedule for estimate completion
- Selecting and notifying individuals whose input is required
- Collecting scoping documents
- Selecting estimating technique
- Conducting an estimate kickoff meeting
- Visiting the work site

Develop Estimate Purpose Statement—The purpose of the estimate should be stated in precise, unambiguous terms. The purpose statement should indicate why the estimate is being prepared and how the estimate is to be used. This should include a description of any relevant

regulatory or DOE drivers.

Prepare Technical Scope Summary—The technical scope summary should provide a detailed description of the work included in the estimate. Additionally, the technical scope should identify the activities included in the cost estimate as well as relevant activities excluded from the cost estimate and the rationale for their exclusion.

Determine Approaches to be used to develop the Estimate—Develop the estimate using techniques and methodologies such as the ones described in Section 5. For example, when developing a detailed estimate, the following approach could be followed (among others):

- **Activity-Based Estimates**—Section 5.1 describes detailed estimating methodologies used for preparing activity-based cost estimates. To be activity based, an estimate activity should have discrete quantifiable units of work associated with it. Examples of work items that are activity-based include:
 - Place 16 CY of concrete
 - Produce 12 monthly reports
 - Perform 100 surveillances
 - Prepare a lesson plan for a course in safe lifting
- **Level-of-Effort (LOE)**—Certain activities cannot be associated with quantifiable units of work. Instead, these activities should be expressed as a defined level of expenditure over time. Estimates that include LOE activities should be closely scrutinized, and the use of LOE estimates minimized. Examples of LOE activities include:
 - Secretarial support
 - Site safety program
 - Clerical support

6.3 Cost Estimate Inputs

6.3.1 Sources of Data Input

Since all cost estimating methods are data-driven, it is critical that the estimator know the best data sources (Input in Figure 2.1, Process Model). Whenever possible, estimators should use primary data sources. Primary data are obtained from the original source, are considered the best in quality, and are ultimately the most useful. They are usually traceable to an audited document. Secondary data are derived, rather than obtained directly from a primary data source. Since they were derived (and thus changed) from the original data, they may be of lower overall quality and usefulness. In many cases, data may have been “sanitized” for a variety of reasons that may further complicate its use as full details and explanations may not be available. Cost estimators must understand if and how data were changed before determining if they will be useful or how that data can be adjusted for use. Furthermore, it is always better to use actual costs, rather than estimates as data sources since actual costs represent the most accurate data available.

While secondary data are not the first choice, they may be all that are available. Therefore, the cost estimator must seek to understand how the data were normalized, what the data represent,

how old the data are, and whether the data are incomplete. If these questions can be answered, the secondary data should be useful for estimating and would certainly be helpful for cross-checking the estimate for reasonableness.

Some specific sources of data are the following:

Estimating Manuals—The construction industry produces numerous costing manuals to assist in the pricing of work. RS Means and Richardson are two readily available manuals.

Data Bases—Commercial and in-house data bases provide the estimator with the ability to retrieve data to be used for estimating. Commercial data bases are readily available. In-house data bases more accurately reflect the parameters that influence local costs.

Vendor Quotes—Vendor quotes provide for a greater confidence of real time accuracy. Use caution when using vendor quotes. Often the vendors provide quotes with either incomplete or preliminary information. Other times only one vendor is polled, possibly skewing the information. In other situations, market conditions may drastically change from the time vendor quotes were obtained.

Level of Effort Data—As discussed in Section 5.3.1, LOE activities are of a general or supportive nature usually without a deliverable end product. Such activities do not readily lend themselves to measurement of discrete accomplishment. LOE is generally characterized by a uniform rate of activity over a specific period of time. Value is earned at the rate that the effort is being expended. LOE activities should be kept at a minimum for Class 1 and 2 estimates.

Expert Opinions (Subject Matter Experts)—As described in Section 5.3.3, expert opinions can provide valuable cost information in the early stages of a project, for Class 5, 4, and 3 cost estimates. The data base should include a list of the experts consulted, their relevant experience, and the basis for their opinions. If a formalized procedure was used, such as the Oracle Method, it should be properly documented.

Benchmarking—Benchmarking is a way to establish heuristics, or rules-of-thumb. Benchmarks may be useful when other means of establishing reasonable estimates are unavailable. An example of a benchmark is the statistic indicating that design should be 6 percent of construction cost for non-complex facilities. If construction costs can be calculated (even approximately) using a parametric technique, design should be approximately 6 percent. Typical benchmarks include such rules as:

- Large equipment installation costs should be X percent of the cost of the equipment
- Process piping costs should be Y percent of the process equipment costs
- DOE facility work should cost approximately Z percent of current, local, commercial work

Team/Individual Judgment Data—Team/Individual judgment data are used when the maturity of the scope has not been fully developed and/or the ability to compare the work to historical or published data is difficult. This involves the reliance of information on individuals or team

members who have experience in the work that is to be estimated. This process may involve interviewing the person(s) and applying their judgment to assist in the development of the cost estimate. Because of its subjectivity and usually the lack of supporting documentation, team/individual judgment should be used sparingly.

Trend Analysis Data—As described in Section 5.3.4, trend analysis can provide data for comparing the original planned baseline costs (or schedules) and the per unit value against actual costs (or schedules) and the per unit value for work performed to date. Trend analysis data can be used at almost any stage of work and can even be used as a basis for cost estimates developed using other techniques.

The Learning Curve Data—As described in Section 5.3.5, learning curve data are useful for understanding the efficiency of producing or delivering large quantities. Numerous sources are available from trade associations and governmental organizations.

6.3.2 Considerations for Cost Estimate Development

When given the task of developing an estimate, an estimator must first gather general project information, including:

- project background,
- where the project stands in its life cycle,
- general description of the technical scope,
- pertinent contract or sub-contract information,
- estimate purpose, classification, how the estimate will be used, and techniques anticipated, and
- Approximate time frame for the work to be performed.

Some specific inputs to the cost estimating process include:

- Mission Need Statement
- Critical Decision approval documents
- Acquisition Strategy
- Project Execution Plan
- Work Breakdown Structure (WBS)
- Code of Accounts (COA; also known as account code)
- Key Milestone Activities and Proposed Dates
- Functional Design Criteria
- Functional Performance Requirements
- Conceptual Design Report
- Preliminary Design
- Definitive Design
- Risk Analysis and Register
- Historical Information and Other Sources of Information, including previous cost

estimates

- Results of Alternative and Requirements Analyses
- Applicable Resources and Labor Rates
- Applicable Indirect Rates
- Assumptions
 - Estimate ground rules and constraints; e.g., 4 day work-weeks, 10 days of weather shutdowns per year, site access limitations, acquisition strategies and associated contractor markups, and all other assumed conditions under which the estimator believes project work will be performed.
 - Assumptions made by the estimator to fill gaps and inconsistencies in the technical scope, sources of materials, etc.
- Estimate Allowances (see 6.4.2.3)
- Exclusions (a clearly stated list of excluded items such as furnishings, equipment, finishes, landscaping, etc.)
- Government supplied equipment
- Construction and Operations Input

From this information, whether provided by others or developed by the estimator as an assumption, appropriate estimating techniques may be determined.

6.4 Cost Estimate Production

The principle step in the estimating process is producing the cost estimate and its corresponding schedule and basis of estimate. It is important that scope development, documentation, and control be coordinated with the cost estimate production as key iterative processes. Cost estimate production includes several steps that should be based on requirements, purpose, use, classification, and technique, including:

- Identify the scope of work.
- Identify the project, subprojects, milestones, activities, and tasks.
- Document all bases of the estimate, assumptions, allowances, risks, etc. during the estimating process.
- Perform quantity takeoffs and field walk-downs.
- Develop the detail items or models that make up the activities.
- Assign measurable quantities to the detail items or models.
- Obtain budgetary or vendor information, conduct market research, or establish other pertinent sources of information.
- Establish productivity rates or perform task analyses.
- Calculate all applicable costs, including direct costs, indirect costs, contingency, and escalation (utilizing the schedule to calculate years for escalation).
- Produce all applicable detail and summary reports.
- Establish a funding profile utilizing the work breakdown structure and time phasing from the schedule.
- Determine what risks (and to what extent) should be mitigated with activities (or assumptions) in the cost estimate.

- Consider other inputs, including schedule information, risk management plan, and peer reviews, as appropriate.

6.4.1 Schedule Development

A project plan and schedule should be developed as a key basis for any cost estimate. By going through the process of schedule development, the activities needed to execute a project are clearly identified and appropriately sequenced. This then forms a basis for estimating the resources and costs needed to accomplish the project plan. That process in turn provides a basis for estimating activity durations used to construct the schedule. As this process indicates, the development of schedule and cost estimates is a highly iterative and inter-related process. However, it is difficult to generate a credible and realistic cost estimate without at least a basic understanding of the project plan and the activities that comprise the project schedule.

After both the schedule and cost estimates have been developed, the project schedule is also used to determine a cost estimate over time in order to calculate escalation, identify available resources, and establish budget requirements. This process can result in further iteration, both to refine the schedule (to accommodate resource and budget constraints) and to finalize the estimate (to adjust escalation allowances and other time-based costs, e.g., management staffing).

A project's schedule should not only reflect activities in a cost estimate, but it should also indicate project milestones, deliverables, and relationships between activities.

6.4.2 Direct Cost Development

Direct Costs include any costs that can be attributed solely to a particular project or activity, including labor, materials, subcontracts, equipment, salaries, and travel. Emphasis is placed on the term *activity*, which typically in standard practice equates to a lowest WBS element, account code, work package, or planning package.

Commonly recognized direct costs include:

- Common construction activities to include mobilization and de-mobilization, site work, concrete work, masonry work, etc.
- Operations labor, materials, equipment, subcontract costs, premium pay, and similar productivity adjustments, such as those for contamination or security restrictions.
- Maintenance labor, materials, equipment, subcontract costs, premium pay, and similar productivity adjustments, such as those for contamination or security restrictions.
- Common routine and preventive maintenance activities include minor facility repairs and/or upgrades, minor paving or landscaping, etc.
- Decontamination, decommissioning, dismantling, and demolition.
- Project management
- Construction management
- Design, development, and start-up
- Security escorts and restrictions
- Special (capital) and standard (capital or non-capital) equipment

- Freight, packaging, and transportation
- Health physics support, radiological controls support, protective clothing/PPE, and industrial safety/health
- Sales and use taxes

Some items that may be included within direct costs as a part of a loaded labor rate include:

- Holiday and vacation pay
- Payroll taxes and insurance
- Fringe benefits or labor burdens
- Contract fee/profit

6.4.2.1 Resources and Crews and Quantities

Cost estimators should be familiar with any site or project-specific labor agreements, and if applicable, reflect these labor agreements in the cost estimate.

Resources include the labor, material, equipment, services, and any other cost items required to perform a scope of work. One or more resource can be assigned to an activity. A list of the resources and their associated unit prices needs to be defined before applying resources to activities.

- Rates for labor should include wages, taxes, insurance, fringe benefits, overtime, and shift differential as applicable.
- Unit prices for material should include the material price, sales tax, and shipping costs as applicable.
- Equipment may be previously purchased by the Government; the hourly rate in these cases should only include operation and maintenance costs (not capital cost of ownership). The Site may have some pre-arranged pool and the equipment rate should correspond with current pool service rates.

Crews are groupings of the various labor classifications along with the tools and equipment (not installed equipment) required to accomplish activities. A production rate for each crew is identified. A crew used to place concrete slabs might include a foreman, laborers, cement finisher, concrete vibrators, forms, and air compressor. In addition, the crew's production rate should be established (e.g., 110 cubic yards per day).

- Estimators should examine the production rate for each crew and make adjustments for local conditions if necessary. Working with crews, rather than the individual cost elements, allows the estimator to estimate work activities more quickly.

Quantities are the units of measure and number of units associated with each activity. Each activity needs to have an identifiable unit of measure and a quantity associated with that

activity (e.g., 200 tons, 75 linear feet, etc.) For LOE activities, the quantity may be “one” and the unit of measure “lot.”

6.4.2.2 Assigning Resources to Activities

Detailed Work Scope. Once activities have been defined, units of measure identified, and quantities determined, resources are assigned to each activity. Unit rates are used to assign resources to estimate activities. The resources assigned should correspond with the resources that will be used to complete the work. Such distinctions are especially important when detailed schedules are required, but less important for Rough Order of Magnitude (ROM) or Conceptual Estimates. Unit rates can be expressed as dollars per unit, labor hours per unit, or a percentage of an associated cost.

Direct Labor. Unit rates expressed as labor hours per unit require that the type of labor (carpenter, engineer, secretary, etc.) be identified by associating a labor type or a crew with each unit rate. A crew is defined by the various labor types that make up the crew. Each labor type has a corresponding wage rate to allow calculation of cost in dollars. The wage rates for each labor type includes the base rate, taxes and insurance, fringe benefits, travel or subsistence, and adjustment for overtime, if required.

Percentages. Some activities may use percentages to assign resources. The appropriateness of using percentages for such items as project management and construction management will depend on the level of maturity in the work scope definition. Examples of cost items where percentages are often used include:

- Plan of the day (POD) meetings
- Small tools
- Consumable materials
- Labor insurance
- Project management
- Construction management

Regardless of the method used to assign resources to an activity, the following is true for each activity; all costs are identified, labor hours, when applicable, are identified, and labor type for all labor hours is identified.

Summary Work Scope. When details of the work scope are not known, the work scope may be estimated by using the analogy technique or the parametric technique. These techniques may use unit rates expressed as dollars per unit, labor hours per unit, or percentages.

Costs Included in Unit Rate. All costs should be “fully burdened.” A description of what is included in the burdened rate should be included because the definition of “fully burdened” frequently varies.

Unit Rate Adjustments. The development and/or use of estimating factors to adjust unit rates require the skills of an experienced cost estimator. Such adjustments allow use of a database

with known productivity or costs, which are then adjusted to reflect the project specific activities and the conditions under which the work is to be performed. Situations that might affect productivity include type of work, weather conditions, level of confinement, security posture, etc.

Examples of estimating factors (or unit rate adjustments):

- Add 25 percent to labor for work in radiation zones.
- Reduce labor for shop work by 20 percent.
- Add 20 percent to labor for work requiring use of a respirator.

Estimating factors are available from published sources or estimators can develop them. For example, the U. S. Army Corps of Engineers, “Productivity Study for Hazardous, Toxic and Radioactive Waste (HTRW) Remedial Action Projects,” dated October 1994, provides suggested labor productivity adjustment factors considering levels of worker protection and temperature.

6.4.2.3 Allowances

In planning projects, it is normal to include allowances for activities for which there is little or no design basis, especially in the earliest stages. These are *not* considered contingency costs. Allowances should be included at the discretion of the Federal Project Director, project manager, and IPT to cover anticipated costs associated with a known technical requirement or activity. Any allowances included in cost estimates should include a basis for these costs within the supporting Basis of Estimate (BOE) document.

For instance, in a Class 5 cost estimate (order of magnitude), it would be appropriate to see a line item (cost account or activity) such as “utility relocation, 1 lot, \$1M material and \$1M labor,” indicating that some utilities needed to be relocated as part of this project. Documentation supporting these costs should include approximate quantities, basis for those quantities, and source of the projected costs (e.g., consensus of the project team) proportional to the significance of the activity. Allowances also may be included in a project to cover costs associated with productivity adjustments, anticipated subcontract changes, anticipated design changes, and similar elements of known scope and costs.

6.4.2.3.1 Allowances for Special Conditions

Consideration must be given to all factors that affect a project or program. Some of these factors are:

- Availability of skilled and experienced manpower and its productivity
- The need for overtime work
- The anticipated weather conditions during the period of performance
- Work in congested areas
- Working under the authorization basis
- Work in radiation areas
- Security requirements imposed on the work area
- Use of respirators and special clothing

- Training
- Site access

Special conditions may be estimated by applying a factor. For example, 10 percent applied to labor hours for loss of productivity due to work in a congested area. Other items may be calculated by performing a detailed takeoff. An example would be an activity that could only be performed over a 2-days period. Overtime would be required to complete the activity and the number of hours and rates could be calculated.

An estimator should be vigilant that there is no duplication of costs—for example, if the control account manager who provided the cost data to the estimator already included unit rate adjustments such as productivity factors, additional allowances for productivity should not be included or the cost estimate may be inflated. All allowances applied or used to develop the cost estimate should be documented in the Basis of Estimate (BOE).

6.4.2.4 Design Costs

To estimate design costs, the estimator should understand what activities are included. Table 6-2 lists typical design-related activities.

Design-Related Activities		
Preliminary and final design calculations and analyses	Surveys (surveying), topographic services, core borings, soil analyses, etc., to support design	Design studies required to support safety analysis if not included in the Conceptual Design Report
Preparation of as-built drawings	Travel to support design	Acceptance procedures
Outline specifications	Reproduction during design	Design Reviews (not third party)
Construction cost estimates	Design kickoff meeting	Certified engineering reports
Computer-Aided Drafting and computer services	Constructability reviews	Bid package preparation
A/E internal design coordination	Safety reviews by A/E	Bid evaluation/opening/ award
Design cost and schedule analyses and control	Value engineering	Inspection planning
Design progress reporting	Identification of long lead procurements	Inspection services
Regulatory/code overview by A/E	Design change control	Review shop drawings
Procurement and construction specifications	Modification of existing safety analysis report	Preliminary and final plans and drawings

Table 6-2 Typical Design-Related Activities

Design costs are normally directly related to the magnitude and complexity of a project. Table 6-3 lists factors that should be considered when assessing design costs for the design-related activities due to the magnitude and complexity of a particular project.

Factors Impacting Design Costs	
Comprehensive functional requirements	Off-site architecture/engineering
Quality level	Overtime
Design planning	Adequacy of plans and specifications
Design layout	Off-site fabrications
Drafting and CADD methodologies	Travel and per diem
Project reviews	Guidelines
Design reviews	Performance specification
Safety analysis requirements	Cost estimating Activities
Reporting requirements	Inspection Requirements
Government furnished equipment	Schedule Analysis
Complexity	Labor density

Table 6-3 Factors Impacting Design Costs

All factors in Table 6-3 bear upon the cost *of a project* design phase.

For EM projects, the regulatory process requires rigorous examination of design alternatives before the start of cleanup design, especially for remedial investigation/feasibility studies under CERCLA to support a record of decision (ROD) or for corrective measure studies under RCRA to support issuance of a permit. Cleanup design executes a design based on the method identified in the ROD or permit, which often narrows the scope of preliminary design and reduces the cost and schedule requirements.

On EM projects, the estimator should assess the extent to which design development is required or allowed in cleanup design. In some cases, the ROD or permit will be specific, such as for a disposal facility where all features such as liner systems and configuration, are fixed. When treatment options such as incineration are recommended, considerable design effort may be required.

Requirements for construction engineering, including observation, design of temporary facilities, quality control, testing, and documentation, will often be higher than for conventional construction because of requirements to comply with rigid regulations governing health and safety, quality assurance and other project requirements.

6.4.2.5 Construction Management Costs

A construction management (CM) firm, whether in the form of a subcontractor or as a function of an M&O contractor, is responsible for construction activities, including coordination between prime contractors and subcontractors. This responsibility includes subcontracting, purchasing, scheduling, and often a limited amount of actual construction. The cost estimate for this function must include all CM costs for site management and force account labor wages, payroll taxes, overheads, and procurements for which the CM is

responsible.

6.4.2.6 Project Management Costs

The estimates for project and program management must consider project duration from start of preliminary design through completion of the construction for the project. Other factors to consider are the complexity of the project, the specific design group, the organization for which the project is to be performed, and the extent of procured items. The encompassed functions include:

- management and integration
- program/project management
- administrative services
- peer review
- records management
- training
- information resources management
- project controls
- quality assurance
- licensing
- communications
- travel by management staff

Management functions associated with environmental restoration projects parallel construction project management.

6.4.2.7 Construction Coordination Costs

Construction coordination comprises field engineering services, sometimes called “Title III Engineering” services or “Engineering Support during Construction”. Field engineers should be involved in the review of the design documents, as well as in the coordination of field construction and resolution of design conflicts encountered during the construction phase. Other responsibilities may include furnishing and maintaining governing lines and benchmarks to provide horizontal and vertical controls to which construction may be referred; checking and approving or requiring revision to all vendor shop drawings to assure conformity with the approved design, working drawings and specifications; inspecting the execution of construction to assure conformance with approved drawings and specifications, and with established requirements for workmanship, materials and equipment; and providing field or laboratory tests of construction workmanship, materials and equipment as may be required.

6.4.2.8 Research and Development (R&D) Costs

Traditionally, cost estimating involves the use of historical cost data to correlate and validate existing estimating methodologies. Historical cost data lend some accuracy and credibility to a

cost estimate. When a cost estimate is required for new, innovative, state-of-the-art, first-, or one-of-a-kind projects, historical data are not always available.

For these projects, knowledge of the processes involved should help the cost estimator to prepare an accurate and credible cost estimate. In the absence of accurate cost information, process knowledge can focus the estimator toward parts of the project that are significant contributors to overall project cost.

Personnel Costs—Personnel costs are usually the largest R&D expense. R&D personnel are often well-educated and may have a correspondingly higher pay scale than personnel for conventional projects. Personnel resources include those needed to construct R&D facilities; purchase supplies, materials, and equipment; operate equipment, prototypes, pilot plants or laboratories; develop software; information technology operations; and other labor functions needed to complete R&D efforts.

Equipment Costs—Equipment costs for R&D projects can be divided into hardware (for prototypes and pilot plants as well as other activities) and software costs (including computer models discussed below). Hardware includes machinery, computers, and other technical equipment. Equipment costs increase with increasing project complexity and a lengthy testing and verification phase may be required. Vendor quotes can sometimes be obtained to support early-stage cost estimates, but expert opinion is often the only recourse to obtain Class 5 cost estimates for equipment with no precedent.

Prototypes and Pilot Plants—In some instances, it will be cost effective to develop a prototype or a pilot plant for an R&D project. A cost estimate for a prototype or a pilot plant will have to account for the following major items:

- Procurement and/or construction of the equipment or plant
- Operation of the equipment, including necessary utilities
- Development of test criteria for plant studies
- Analysis of test results
- Computer simulation of plant processes
- Supplies and materials used for testing

The cost estimate may also need to include costs for project management and other personnel during the pilot plant study or prototype testing.

Scaled and Computer Models—Scaled or computer-generated 3D models may need to be created for some projects. For example, if the project goal is to construct a new incinerator for mixed waste, site-specific air-dispersion modeling may be required to demonstrate that emissions from the incinerator will not have an adverse impact on public health or the environment.

Groundwater modeling may be required for some remediation sites (e.g., groundwater contamination has been found at a site, and several technologies are being proposed). Modeling can be used to select the best technology or determine the optimum locations for equipment. Some models can be quite complex and require specialized technical expertise.

R&D Disposition – Finally, it is important to consider the cost of disposing of all equipment, chemicals, products, materials, facilities, etc., used during the R&D phase. The assumption that another project will pay for the “cleanup” of an experiment, bench-scale demonstration or even a pilot scale facility has often resulted in low initial government life-cycle estimates. The initial government life-cycle estimate should consider the R&D disposition estimate attributable to the project or share of the R&D disposition estimate when attributable to multiple projects.

6.4.2.9 Regulatory Costs

Environmental, safety and health (ES&H) regulatory compliance is required for all projects thus, an estimate should contain sufficient provisions for ES&H compliance costs. Regulatory costs should include the cost of coordination and negotiation with regulators, documentation costs, site characterization analysis, stakeholder meetings and other related activities.

For Government projects, the facility must satisfy all Federal, state, and local requirements (i.e., building permits, energy conservation and the Leadership in Energy and Environmental Design (LEED) requirements, waste disposal, wastewater effluent disposal, and air emission limitations) imposed by the other agencies. Regulations are even more stringent for facilities that process or store radioactive materials. Construction sites must follow Occupational Safety and Health Administration (OSHA) rules.

Familiarity with applicable regulations is required so that a plan may be developed for the project to comply with those regulations.

Environmental Compliance Costs

The number and requirements of environmental regulations have increased dramatically in the past 30 years. When preparing cost estimates for environmental compliance activities, the following should be considered.

- type of project
- project location
- waste generation
- effluent characteristics
- air emissions
- noise requirements
- project start-up or completion date

Location is significant to project cost when a wetlands area will be disturbed, or the project is located in an area with extensive environmental regulations (e.g., California). Increased environmental compliance costs should be factored into projects in such locations.

Knowledgeable design staff and personnel familiar with environmental regulations that will affect the project should be consulted when composing an estimate. Knowledge of wastes or air emissions generated during the project will facilitate the identification of environmental compliance design requirements and subsequent costs. For example, wastewater treatment

may be required prior to effluent discharge into a stream or publicly owned treatment works. Air pollution control devices may be required for process equipment. Permitting costs could include

- labor for data gathering
- equipment for testing
- analytical tests
- data analysis and writing or completing documents
- time for interface with project personnel and outside consultants
- time for interaction and negotiation with regulator and stakeholders
- application and/or permit fees
- annual permitting costs
- upgrades to existing equipment
- new pollution control equipment

Once a plan for regulatory compliance has been established, the regulatory costs can be estimated. This will establish a baseline for the regulatory costs such that changes that affect the baseline can be tracked and estimated throughout the project's life.

For some projects, a permit is required before work can commence. For example, construction projects that will disturb more than 5 acres are required to obtain a storm water permit before commencing construction. Project scheduling can be affected if operating permits are not received in a timely manner. Facilities may be shut down for violations of operating permits or failure to comply with existing regulations. The time required for regulatory review of the permit application also must be factored into the cost estimate.

Health and Safety Compliance Costs

Employee health and safety regulations have also increased. As allowable limits for worker exposure decrease, design cost estimates must account for specific engineering controls to minimize employee exposures to toxic or hazardous substances in the workplace, especially for facilities with radioactive materials. Planning for environmental controls is essential because retrofit costs can exceed original installment costs. State-of-the-art, high-technology facilities may require initial employee exposure monitoring if unknown factors are encountered. Protective equipment must also be supplied and maintained for the employee.

Past experience with increased regulatory rigor within DOE has shown that the costs associated with employee workspace controls, including industrial hygiene monitoring, is the most significant cost factor in a rigorous health and safety program. The trend will probably continue. Health and safety compliance issues may involve strict health and safety requirements, including routine medical surveillance, preparation of health and safety plans, and employee training. Employees may not be able to work 8 hours per day if daily personnel and equipment decontamination is mandatory.

Other Regulatory Costs

In addition to the costs described above, there are QA, security, and other ES&H requirements that the project must consider.

6.4.3 Indirect Costs

Indirect costs are incurred by an organization for common or joint objectives that cannot be specifically identified with a particular activity or project. Indirect costs are those resources that need to be expended to support the activity or asset but that are also associated with other activities and assets. In other words, indirect costs are “Any costs not directly identified with a single final cost objective but identified with two or final cost objectives.” Consequently, allocate indirect costs to an activity or asset based upon some direct cost element, such as labor hours, material cost or both (see Section 6.4.3.1)

Some typical indirect costs are:

- facilities, operating equipment, small tools, and general maintenance;
- temporary facilities (e.g., water, compressed air, and power);
- motor pool, camp, and aircraft operations;
- warehousing, transfer, and relocation;
- safety, medical, fire protection, and first aid;
- security;
- administration, accounting, procurement, and legal;
- personnel expenses, office supplies, and time reporting
- site-wide permits and licenses;
- contributions to welfare plans and signup/termination pay; and
- contract fee/profit, bond costs (performance and material payment).

NOTE: Do not double count costs. For example, if acquisitions personnel are costed with the pilot plant activity ensure that this person is not also included as part of Indirect Costs.

6.4.3.1 Indirect Rates

The development of indirect rates is usually the responsibility of both the financial accounting organization and the cost estimator. Indirect rates should be developed in accordance with Cost Accounting Standards. The financial accounting organization determines rates for organizational overheads and general and administrative (G&A) cost, while the cost estimator usually estimates rates for project management, construction management, and subcontract costs. The estimator, however, should clearly understand how to allocate all indirect rates in the estimate to avoid duplication or omission, as well as document what is included in the indirect rates.

Indirect rates for work to be performed by contractors should be developed by the contractor for review and approval by DOE. Backup information that clearly describes how the indirect rates

were developed should be provided to DOE and maintained by the contractor. Indirect rates should be evaluated and revised on a periodic basis as necessary.

Indirect rates estimated for subcontract work such as Architect/Engineer services, construction, and remedial actions should be estimated and documented at a level of detail appropriate to the type of cost estimate being prepared. There is no uniform standard for establishing indirect rates; a typical method for applying indirect rates calculates indirect costs as a percentage of a category of work. For example, quality control inspection could be estimated as 6 per cent of direct craft labor, consumable materials at 6 per cent of direct craft labor, and administrative support for engineering at 38 per cent of direct engineering, etc.

The basis for applying individual indirect rates will vary greatly depending on the specific costs included in the rate. Allowances for small tools or consumable materials would typically use the direct labor cost of the appropriate construction craft, operations or maintenance activities as its base. General and administrative cost is usually estimated using the sum of all direct and indirect costs for the specific items of work as its base. Indirect rates should be documented in detail so that what is included (and excluded) in each rate is clear. A separate line item in the estimate should exist for each rate used.

6.4.4 Escalation

Escalation costs change continuously following changes in: such as technology, availability of resources, and value of money (e.g., inflation).

Historical cost indices and forecast escalation indices have been developed to document and forecast changing costs. The use of an established escalation index is required to consistently forecast future project costs. To ensure proper use of an index, estimators must understand its bases and method of development.

Escalation is the provision in a cost estimate for increases in the cost of equipment, material, labor affected by continuing price changes over time. Escalation may be: forecasted, to estimate the future cost of a project based on current year costs; or historical, to convert a known historical cost to the present.

Although the forecasted and historical escalation rates may be used in succession, most cost estimating is done in current dollars and then escalated to the time when the project will be executed. This section discusses the use and calculation of escalation and historical cost indices. An example of the calculation and use of escalation can be found in Appendix F.

6.4.4.1 Forecasted Escalation Rates

Forecasted escalation rates may be obtained from commercial forecasting services, such as Global Insight, which supplies its most current predictions using an econometric model of the United States economy. The forecast escalation index is the ratio of the future value to the current value expressed as a decimal.

Forecasted escalation rates are simply the percentage change from one year to the next, typically prepared for various groups, utilizing different sources of data. Because larger projects extend over several years, it is necessary to have a method for predicting budgets that must be made available in the future. This is where forecasted escalation rates are used. The current year cost estimate is divided into components and then multiplied by the appropriate escalation rate to produce an estimate of the future cost of the component. The future costs of these components are then summed to give the total cost of the project.

To properly apply escalation, the following data are required:

- reference date the estimate was prepared and base date of costs:
- escalation index, or cumulative rates, to be used (including issue date and index); and
- schedule, with start and completion dates of scheduled activities

Escalation could be applied for the period from the date the estimate was prepared to the midpoint of the performance schedule or the activity being escalated. There are many other more detailed methods of calculating escalation, but care should be taken not to make this calculation too complex. Remember, someone external to the project may need to review this calculation. Regardless of the method used, the process should be well-documented.

“Which comes first, contingency or escalation?” If a project includes a contingency that is based on risks, and those risks have associated costs, this may imply use of the same base-year dollars. And generally, performance periods can be associated with those risks within components, so, escalation may be applied to contingency. However, if contingency is not easily discernable by WBS element (or cost elements) or cannot be associated with a time period, it may not be appropriate to escalate contingency. Also, the accuracy of an escalation forecast can also be considered a risk, with appropriate cost impacts that are then included in contingency allowances. *The cost estimate should ultimately represent total escalated costs, or “then-year dollars.”*

6.4.4.2 Historical Escalation

Generally, historical escalation is generally easily evaluated. For example, the cost of concrete increased between 1981 and 2002. The ratio of the two costs expressed as a percentage is the historical escalation rate, or expressed as a decimal number is the historical cost index. Several commercial historical cost indices are available.

To properly apply a historical cost index to make price more current, the following data are required

- The prior cost or price, with a reference date, such as an actual price for a known project or a component. This cost or price may include direct material and/or labor cost, and it should be known to what extent indirect costs (sales taxes, freight, labor burden, etc.), overheads, and profit were included.
- An applicable historical cost index.

6.4.4.3 Escalation Calculations

Most costs are estimated in “current dollars” and then escalated to the time when the work is expected to be performed. The escalation rates are used for developing project performance baselines. Rates should be evaluated for global, regional, and local conditions; should have a maximum period of 1 year; and should be clearly documented including the basis.

The following are some suggested sources of major indices and escalation (recognized by industry best practices).

- U.S. Department of Labor, Bureau of Labor Statistics, Inflation & Prices, <http://www.bls.gov/bls/inflation.htm>
- U.S. Department of Labor, Bureau of Labor Statistics, Contract Escalation, <http://www.bls.gov/bls/escalation.htm>
- Engineering News Record, Economics, <http://enr.construction.com/economics/>
- RSMeans, Cost Books, <http://rsmeans.reedconstructiondata.com/CostBooks.aspx>
- RSMeans, Market Analytics, <http://rsmeans.reedconstructiondata.com/MarketAnalytics.aspx>
- The Richardson Construction Estimating Standards, <http://www.costdataonline.com/>
- IHS Global Insight, <http://www.ihsglobalinsight.com>

6.4.5 Contingency

This section is compatible with the guidance provided in DOE G 413.3-7A, *Risk Management Guide*, dated January 2011, for the consistent use and development of Contingency and Management Reserve (MR) in capital asset projects cost estimates. Contingency and MR are project cost elements directly related to project risks and are an integral part of project cost estimates. For further detailed guidance and examples of calculations refer to DOE G 413.3-7A.

The specific confidence level (CL) used to develop a project performance baseline estimate is determined by the project’s FPD/IPT and approved by the Acquisition Executive. The project confidence level should be based on but not limited to the project risk assumptions, project complexity, project size, and project criticality. At a minimum, it is recommended that project performance baselines should be estimated, budgeted, and funded to provide a CL range of 70 - 90 percent for DOE capital asset projects. FPDs should confirm with their program sponsor whether additional guidance is to be provided. The CL for Major Items of Equipment may be significantly different from the construction of conventional facilities that will house the equipment. If a project has an approved performance baseline change, the FPD should consider reanalyzing the risks at a higher CL for budgetary requests and funding profiles to ensure project completion.

The DOE G 413.3-7A defines four categories of contingency, each of which is briefly described below:

- DOE contingency budget is identified as funded contingency for use by the FPD. Contingency is the risk based, quantitatively derived portion of the project budget that is available for managing risks within the DOE performance baseline. At a minimum, it is

recommended that DOE capital asset project costs should be estimated to provide a CL range of 70 - 90 percent.

- DOE schedule contingency is the risk-based, quantitatively derived portion of the overall project schedule duration that is estimated to allow for the time-related risk impacts and other time-related project uncertainties. It is recommended that project schedule contingency should be estimated to provide a CL range of 70 - 90 percent.
- Contractor MR budget is the risk-based quantitatively derived portion of the contract budget base (CBB) that is set aside for management purposes to handle risks that are within the contractor's contractual obligations. Once the CBB has been established, it is allocated to MR and the Performance Measurement Baseline (PMB). The MR is not intended to justify a post contract increase to the CBB. MR is maintained separately from the PMB and is utilized through the contractor's change control process. MR is not used to resolve past variances (positive or negative) resulting from poor contractor performance or to address issues that are beyond the scope of the contract requirements. Use of MR should follow EVMS rules as per ANSI/EIA-748A.
- Contractor schedule reserve is the risk-based quantitatively derived portion of the overall contract schedule duration estimated to allow the contractor time to manage the time-related impacts of contractor execution risks and other contractor duration uncertainties within the contract period. Contractor schedule reserve does not add time or schedule duration to the contracted end date.

The quantitative method used to analyze project contingency and MR should consist of objective analysis of cost and schedule estimate uncertainties and discrete project risks. The analysis should aggregate the probability and consequences of individual risks, and cost and schedule uncertainties to provide an estimate of the potential project costs.

The quantitative risk analysis determines a risk-based project budget and completion date using statistical modeling techniques such as Monte Carlo, Quasi-Monte Carlo, sensitivity simulations, and other stochastic methodologies depending upon the project data.

While the Monte Carlo simulation is one standard used by DOE, alternate forms of quantitative analysis may be used. Other recognized forms of quantitative analysis include: decision trees, influence diagrams, system dynamics models, and neural networks. Figures 6-4 and 6-5 show the typical components of the DOE project performance baseline.

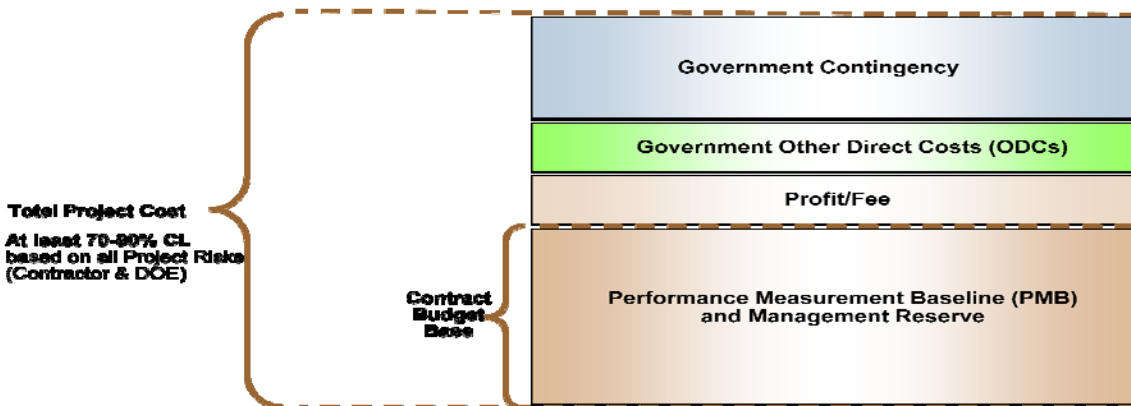


Figure 6-4. Total Project Cost Composition. *Note: CL = Recommended Confidence Level*

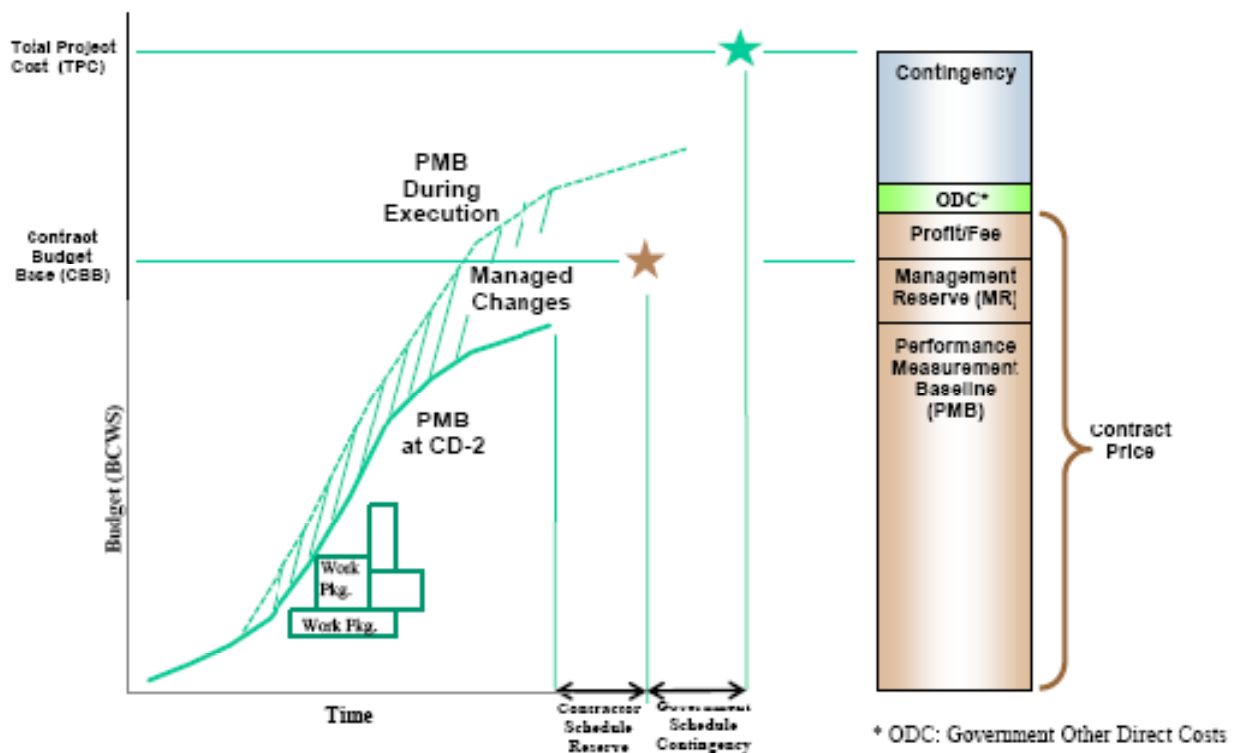


Figure 6-5. DOE and Contractor Budget Baseline

6.4.5.1 Quantitative Contingency Analysis

DOE O 413.3B requires that DOE project estimates be developed based on qualitative and quantitative analysis of project risks and other uncertainties. The DOE qualitative and quantitative analysis process begins in the project's planning stage with the identification of project risks during the initial project planning phase prior to the first CD point (approval of mission need). After CD-0, project development and planning documentation are prepared that

includes the initial Risk Management Plan (RMP). During this phase of the project, development of the project risk register is initiated with the identification of potential project risks and enabling assumptions.

At CD-1, the baseline scope is refined enough to develop a preliminary baseline cost range and schedule. The RMP continues to evolve as the project scope is refined, new risks are added to the risk register and existing risks are re-examined and the project knowledge base increases. In preparation for the CD-2, the performance baseline estimate is refined to include costs to be incurred in executing the risk handling strategies. The baseline estimate is also evaluated, and adequate contingency allowance incorporated, to determine the project budget needed to provide an appropriate CL so that the project execution will be successful as defined in DOE O 413.3B.

This document assumes Monte Carlo methodologies will be used to develop the cost and schedule baselines. The diverse and unique nature of DOE projects characterized by an assortment of distinct technologies, physical locations, project duration, and project size has a significant impact on the risk profile that makes it impossible to establish a prescriptive procedure or single quantitative risk model for determining a project's contingency needs. Consequently, only a basic framework is used to outline considerations essential in the development of DOE contingencies.

6.4.5.2 Cost and Schedule Risk Models

Contingency risk models are used to evaluate the probability and effects of risk impacts, and estimate uncertainties on project cost and schedule performance baselines. The results of the risk analysis are used to establish the cost and schedule contingency needed to provide a suitable confidence level for DOE project success. The analyses may use one or more risk models to evaluate the cost impacts and the associated schedule impacts.

For each risk, a percent or percentage distribution is assigned to the probability (the likelihood of the risk occurring), a dollar value or dollar value distribution is assigned to the cost impact, and a schedule duration impact or schedule duration distribution is assigned to the affected activity in the schedule.

In general the concept is implemented as:

$$EV = \sum P_{Ri} \times CI_{Ri} \text{ (or } SI_{Ri})$$

Where: EV = Expected Value of cost impact (or duration impact) of all risks

P_{Ri} = Probability distribution function of a risk occurring

CI_{Ri} = Cost Impact distribution function of a risk occurrence

SI_{Ri} = Schedule Impact distribution function of a risk occurrence.

[**Note:** $\sum$ is not the summation of individual expected values for each risk, but represents a stochastic process (e.g., Monte Carlo simulation) using the collective probabilities and cost/schedule impacts for all identified risk events.]

Figure 6-6 is a sample from a DOE construction project risk register showing the residual risk

data elements used for modeling the probability of occurrence (probability percentage) and the triangular distribution representing a three-point estimate of the anticipated range of cost and schedule impacts (the assumption in this example is of a triangular distribution of cost and schedule impacts; other distributions can be used, such as step, rectangular, etc.).

Risk #	Owner	Risk Description	Residual Risk									
			Likelihood	Consequence	Risk Score/Rank	Probability (%)	Cost Impacts (\$)			Schedule Impacts (Days)		
							Best Case	Most Likely	Worst Case	Best Case	Most Likely	Worst Case
T47	Federal	Nonperformance of contract to provide shielded overpack containers leads to project delays and cost.	Unlikely	Significant	Moderate	40	850,000	3,000,000	6,000,000	0	0	0
T52	Federal	Overnight organizations interpret requirements different than implementation, leading to cost and schedule impacts.	Likely	Significant	Moderate	60	--	3,000,000	6,000,000	0	30	90
T12	Contractor	Failure of crane results in delayed removal of canisters, impacting schedule.	Unlikely	Marginal	Low	40	100,000	200,000	1,400,000	1	2	14
T61	Contractor	Calibration services are unavailable causing shut down of operations.	Very Unlikely	Marginal	Low	10	100,000	410,000	715,000	1	4	7
T266	Contractor	Hot cell cannot be designed to meet active ventilation strategy increasing design and construction costs.	Very Unlikely	Critical	Moderate	10	3,200,000	7,000,000	20,000,000	30	60	150

Figure 6.6. Sample Risk Register

The results of Monte Carlo analyses are generally summarized by a probability distribution function (PDF) and a cumulative distribution function (CDF), as shown in Figure 6-7. The PDF represents the distribution of the analytical model outcomes. As an example, the Monte Carlo analysis may be designed to estimate the cost or duration of a project. The PDF represents the number of times a certain cost or duration is achieved. The CDF is a statistical function based on the accumulation of the probabilistic likelihoods of the analytical analysis. In the case of the DOE risk analysis, it represents the likelihood that at a given probability the project cost or duration will be at or below a given value. As an example, the x-axis might represent the range of potential project cost values evaluated by the Monte Carlo simulation, and the y-axis represents the project's probability of success.

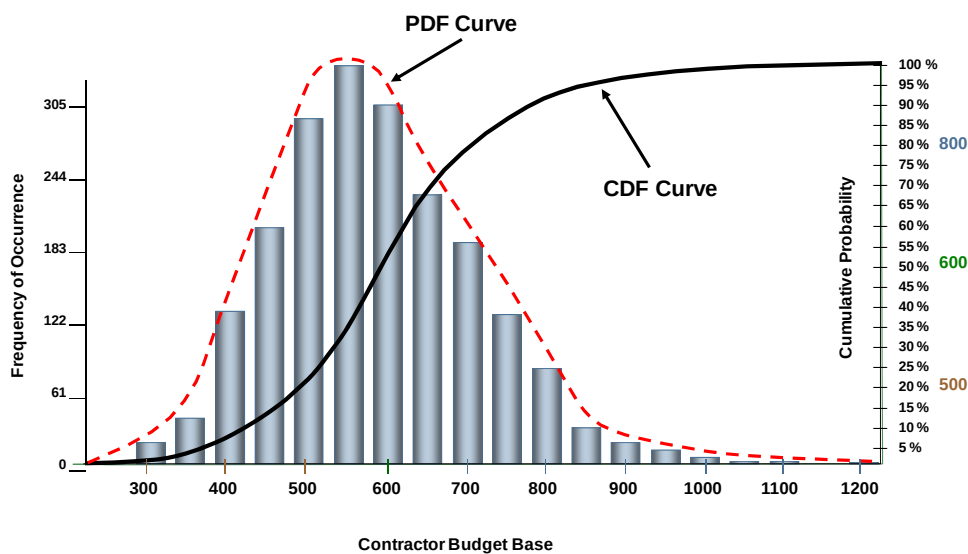


Figure 6-7. Sample PDF and CDF Curves

An advantage of an integrated cost and schedule risk model is the ability to capture schedule-related costs impacts, such as LOE support activities that increase project costs as schedule-related risk impacts delay or extend work efforts. Ideally, the integrated risk model is based on a life-cycle resource-loaded critical path schedule to which cost and schedule risks and cost and schedule uncertainties are applied. Integrated risk models increase the flexibility of the risk analysis and reduce the amount of manual coordination needed to model cost and schedule risk impacts.

Project risks and the associated cost and schedule impacts are the primary inputs to the risk model and are maintained within the project's risk register. Figure 6-8 depicts a conceptual risk model showing typical inputs and outputs.

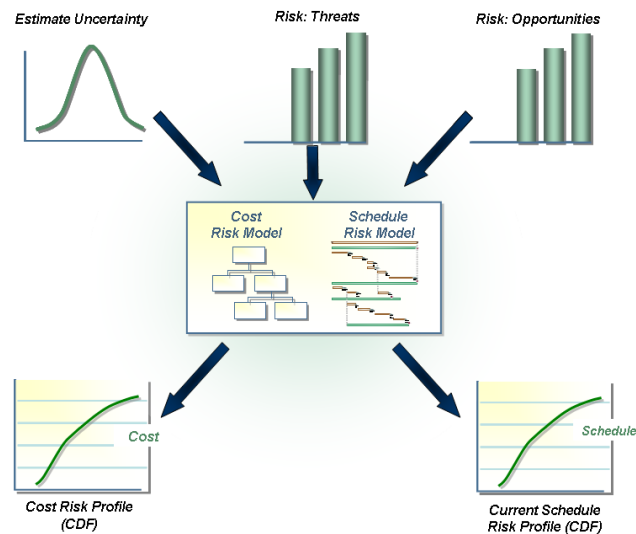


Figure 6-8. Conceptual Risk Analysis Process

An important consideration when identifying project risks is the careful analysis of the assumptions upon which the cost estimate and schedule are predicated. Each assumption made by the estimator, scheduler, or the project team should be analyzed by the IPT to determine if there is a risk (threat or opportunity) that the assumption may not be valid or representative of the actual conditions realized during project execution. In such cases, the probability of alternative situations should be assessed and the impacts of those situations occurring should be quantified and analyzed. These impacts can be an important element in both the cost and schedule risk models and the determination of cost and schedule contingency allowances appropriate for the project.

For example, if the estimate is based upon an assumption of full and open competition for the construction contract, with a suitably large number of bidders, and with incentive clauses built into the contract for schedule completion, it is likely that there will be fairly low contractor markups included in that estimate for the contractor's overhead and profit adders. If the actual bidding documents then require a small business award, and even include a liquidated damages clause for missing schedule milestones (rather than incentives), the actual contractor markups will most likely be significantly higher than had been estimated. In such a case, the baseline will not be adequate unless appropriate cost and schedule contingency allowances had been included because the threat of this alternative approach had been identified and modeled.

It should also be noted that Monte Carlo simulations are based on estimates of probability of occurrence and estimated impacts when risk events do occur. As such, the quality of the output is dependent on the quality and accuracy of these inputs. Inaccurate estimates of either probability or impact will lead to erroneous project probability outputs and misstatement of needed contingency allowances and/or CL.

Another issue that can lead to poor Monte Carlo analysis results is a failure to identify significant project risks. Only if all significant risks are identified and properly evaluated can the Monte Carlo model be expected to provide realistic forecasts of project outcomes and the contingency allowances needed to achieve the desired CL.

6.4.5.3 Cost Risk Model

DOE capital asset projects should be estimated to provide a CL which is adequate to support project success and reflects evaluation of all project risks, with reasonable estimates of cost and schedule impacts. Risk models should include all risks (DOE, contractor and subcontractor assumed risks). The risk cost model should provide an estimate of the performance baseline with a CL range of 70 - 90 percent for success (recommended), which includes the contractor's CBB, profit/fee, and government contingency and other direct costs. The contractor MR is determined by the contractor and represents the amount of the CBB that will be used for project management purposes for accomplishing the work scope within the contractor's PMB.

When developing risk models, care should be exercised to assure the risk models are developed using appropriate performance baseline information and project risk assumptions.

The recommended cost risk model should:

- Include all risks, especially significant risks;
- Use reasonable estimates of cost impacts;
- Include estimate uncertainties (cost and schedule) that are within the project baseline;
- Contain enough detail to allow identification of risk owners;
- Contain enough detail to allow project risks to be associated with the WBS they affect;
- Include a provision for uncertainty ranges in cost escalation rates for the project;
- Allow correlated risks that affect multiple cost elements, e.g., escalation rates, to be modeled at a high level to preserve the dependent relationship among correlated risks;
- Include sufficient information to estimate costs associated with uncertainties in task durations consistent with the schedule risk model;
- Allow for inclusion of threats and opportunities; and
- Allow risk impacts to be placed in the appropriate fiscal year to support the identification of annual contingency budgeting and reporting requirements.

6.4.5.4 Schedule Risk Model

Schedule risk models should be based on the project performance baseline schedule. If practical, the schedule risk model should be developed to include the schedule impacts of all risks that impact the project, as well as any schedule duration uncertainties.

The recommended schedule risk model should:

- Include all significant risks;
- Use reasonable estimates of schedule impacts;
- Contain enough detail to allow identification of risk owners;
- Contain enough detail to distinguish among schedule activities that have different degrees of schedule uncertainty and should include estimate uncertainties;
- Contain enough detail to allow specific risk events to be associated with the schedule activity that they affect;
- Estimate the schedule impact on LOE activities so cost increases associated with

- schedule slippages can be calculated and incorporated into the contingency estimates; and
- Allow for alterations in activity duration that result from implementation of risk handling strategies or opportunities.

6.4.5.5 Estimate Uncertainty

Estimate uncertainty is part of the risk analysis process for the development of contingency estimates as was illustrated in Figure 6-8. Estimate uncertainties are fundamental contributors to cost growth and are expected to decrease over time as the project definition improves and the project matures. Estimate uncertainty is a function of, but not limited to, the quality of the project scope definition, the current project life-cycle status, and the degree to which the project team uses new or unique technologies. Estimate uncertainties occur throughout the DOE baseline. One approach to account for estimate uncertainty is to use uncertainty ranges established by the professional societies such as the Association for the Advancement of Cost Engineering International (AACEI), Table 6-2, or other estimating guidance. Estimate uncertainty contributes to both cost and schedule contingency. Table 6-2 could be used for both cost and schedule estimate uncertainty and should be done separately for evaluating quantitative impacts on project contingency.

Class of Cost Estimate	Estimate Uncertainty (Low Range)	Estimate Uncertainty (High Range)
Class 5 – Concept Screening	-20% to -50%	+30% to +100%
Class 4 – Study or Feasibility	-15% to -30%	+20% to +50%
Class 3 – Budget Authorization	-10% to -20%	+10% to +30%
Class 2 – Control or Bid	-5% to -15%	+5% to +20%
Class 1 – Check Estimate	-3% to -10%	+3% to +15%

Table 6-2. Estimate Uncertainty Range as a Function of Estimate Class

6.4.5.6 Determining Cost Contingency Amounts

A common method to evaluate risk model results is the use of CDF curves, also referred to as S-curves. For a cost risk model, the S-curve represents the probability of completing the project at or below a given project cost baseline. In this example the x-axis represents the range of potential project cost values estimated by the Monte Carlo simulation and the y-axis represents the probability of project success. Figure 6-9 illustrates two S-curves for a hypothetical project. The S-curve on the left is based on the CBB and the S-curve on the right is for the DOE capital asset project performance baseline and includes both the contractor and DOE risks.

Probabilistic Projection of Cost using Monte Carlo Analyses

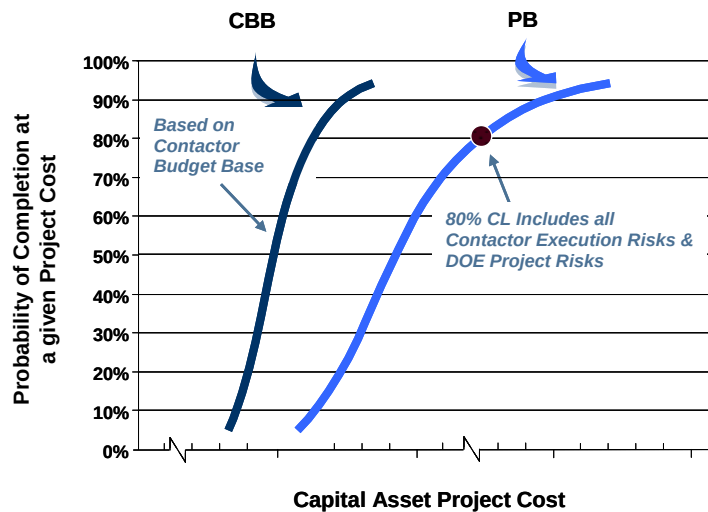


Figure 6-9. S-Curves of Contractor CBB and DOE Performance Baseline

6.4.5.7 Determining Schedule Contingency

The DOE schedule contingency is based on the same risks used in the development of the DOE cost contingency. The DOE schedule contingency requirements should be analyzed using a resource-loaded and logically tied schedule, so that impacts to overall schedule duration along the critical path can be fully assessed. As risks and uncertainties are realized, the critical path for the project may possibly change; the model needs to accommodate such situations.

Schedule activities that are affected by an identified risk or duration uncertainty are modeled in the schedule risk analysis with an appropriate probability distribution. The calculation of schedule contingency is an iterative process requiring an initial analysis of the schedule to determine the base schedule contingency values followed by a revision of the schedule to adjust work scope to meet the existing selected key milestones and deliverable dates.

DOE schedule contingency needs to be added to the overall critical path of the project. This can be completed by applying the DOE schedule contingency incrementally before key milestones or in total before the project completion date. In this way, forecasted completion dates (individual milestones and/or overall project) can be established based on a probabilistic determination of the expected completion date should project risks be realized. This differs from contractor schedule reserve, which cannot add time or schedule duration to the contracted end date.

6.4.5.8 Risk Model Outputs

To support the required budgeting, management, and reporting requirements of the project, the contingency analysis should provide the following:

- The contingency analysis models should be able to produce a PDF and a CDF for the project.
- The contingency analysis models should be able to produce a PDF and a CDF for each

selected milestone.

- The models should be capable of performing a sensitivity analysis for project cost and schedule elements. Risk analysis sensitivity results are typically presented as tornado diagrams that provide an analytical and visual representation of risk event impacts.
- Ideally, the model should place resulting contingencies in a time frame to allow for fiscal year budgeting of DOE contingency. Figure 6-10 illustrates how contingency budget projections can be depicted.

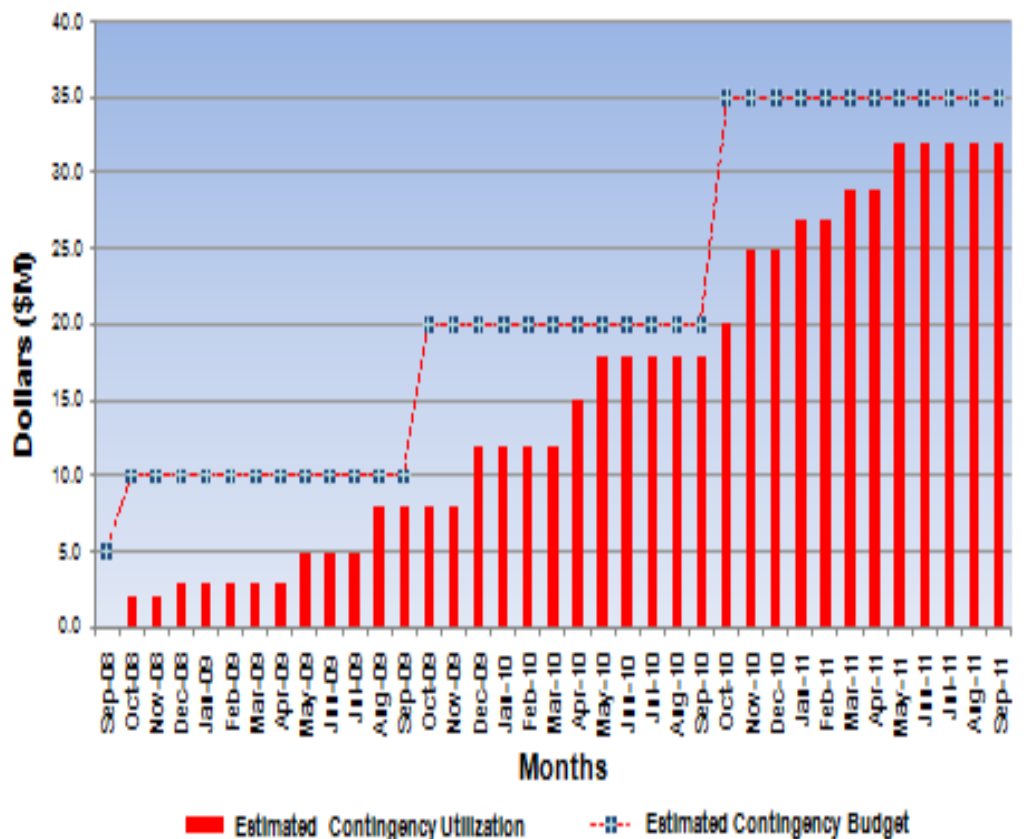


Figure 6-10. Contingency Budget Projection

6.4.5.9 Unknown-Unknowns

Because there may not be viable means to quantify certain “unknown-unknowns”, IPTs may not be expected to set aside contingency for them. Unknown-unknowns could be major schedule

changes or unknown design factors, unanticipated regulatory standards or changes, additions to project scope definition (changes outside a project's intended scope), *force majeure* situations, or program budget reductions. These may be considered *programmatic risks*, which could be applicable to all projects within a respective specific Program.

However, there should be clear communication between the project team and their sponsoring Program to communicate and agree to the bounding assumptions for the project. Furthermore, Programs are advised to include appropriate allowances for programmatic contingencies (for risks and events that occur outside project space but that may in fact impact on project execution) in their overall portfolio budgets.

6.4.5.10 Contingency Adequacy Evaluation

Numerous tools exist to analyze the adequacy of the contingency valuation that has resulted from the qualitative and/or quantitative analysis of the risks. Various costs estimating guidance documents have been compiled by industry and are available in texts and journals (e.g., AACEI), and are updated on a regular basis. These references provide percent ranges of the base that a contingency should represent in order to be considered adequate. Further, the contingency value should be commensurate with the maturity and type of the project, project size, and risks, including technical and technology uncertainties. It should be cautioned that the recommended contingency levels in these documents do not provide a basis for the recommended confidence levels (70 – 90 percent) in this Guide for the derivation of contingency and management reserve by quantitative risk analysis.

If a quantitative risk analysis will not be conducted, estimates for cost and schedule contingency should be provided. As a general rule, the IPT should use various inputs to determine those values. Those inputs may be, but should not be limited to:

- Historical records (considering actual costs and time impacts for certain events)
- Subject matter experts
- Employing Delphi techniques.
- Interviewing staff, crafts, retirees, and others familiar with similar work activities at the site or similar sites.
- Technical records such as safety analysis documents including the risk and opportunity assessment, quality assessments, and environmental assessments.

As the information is gathered and finalized, the data should be analyzed for bias and perception errors. While the data will not be systematically used for a quantitative analysis, it should still be analyzed and perceptions scrutinized.

6.5 Cost Estimate Review

Cost estimates should be reviewed for quality and reasonableness before release. Reviews can be either objective, subjective, or a combination of both. As a minimum, *all* estimates should address the review criteria listed in Appendix E.

DOE cost estimates, and the Basis of Estimate (BOE) that supports them should include an assessment of cost realism and reasonableness. In an effort to test the reasonableness and realism of a cost baseline, there needs to be an assessment of the overall cost baseline from the perspective of the primary cost elements that comprise the baseline. Such an assessment evaluates the relative percentages of the total proposed cost baseline and the underlying BOE for each of the significant cost elements. Additionally, primary cost drivers within the estimate consistent with a product oriented WBS, should be identified and compared to established benchmarks for similar items or activities.

Such efforts will facilitate independent reviews of cost estimate reasonableness by competent qualified personnel who have not been involved in preparing the estimate. This review should provide an unbiased check of the assumptions, productivity factors, and cost data used to develop the estimate. An independent cost review is a vital step in providing consistent, professionally prepared cost estimates (Step 7, GAO 12 Key Steps Development Process, GAO-09-SP). The review should be documented to indicate:

- The name of the reviewer(s) – Office/Agency/Contractor it belongs
- The date of the review
- Review comments and comment disposition

6.6 Estimate Reconciliation

Reconciliation may be necessary to account for changes made between CDs or other life-cycle project milestones. Reconciliations should be organized by WBS and cover all aspects of project documentation (cost estimate, basis of estimate, schedule, and risks). In general, reconciliation should recognize or focus on specific changes in scope, basis of estimate, schedule, and risks. There should be an understanding that, as time progresses, more and better information is expected to be available and used as project or cost estimate documentation. Reconciliations are necessary to mitigate budget shortfalls and may be used to correct deficiencies identified during internal or external reviews.

6.7 Cost Estimate Documentation

Well-documented cost estimates are considered a best practice for high-quality cost estimates for several reasons.¹²

- First, complete and detailed documentation is essential for validating and defending a cost estimate.
- Second, documenting the estimate in detail, step by step, provides enough documentation so that someone unfamiliar with the program/project could easily recreate or update it.

¹² GAO-09-3SP

- Third, good documentation helps with analyzing changes in program costs and contributes to the collection of cost and technical data that can be used to support future cost estimates.
- Finally, a well-documented cost estimate is essential if an effective independent review is to ensure that it is valid and credible. It also supports reconciling differences with an independent cost estimate, improving understanding of the cost elements and their differences so that decision makers can be better informed.
- Whenever possible, documentation should be organized into an indexed repository, either physical or digital, with a document control plan and, preferably, a documentation engineer/administrator. To the extent practical, the documentation index should be consistent with the WBS for the project for ease of reference.

6.7.1 Cost Estimate Package

A cost estimate package or report should be prepared for all cost estimates. Each estimate package should contain the same categories of information and the same types of documentation; only the level of detail in the estimate package varies. The contractor in coordination with the IPT determines the format used to present this information. A cost estimate package or report supporting baselines, management decisions, and budgetary documents should include the following information. A graded approach to cost estimate packaging and reporting should be used when documenting cost estimates for other purposes.

- **Estimate Purpose Statement**—the reason the estimate was prepared including
 - Determine the estimate's purpose
 - The level of detail required
 - Determine who will receive the estimate
 - Identify the overall scope of the estimate
- **Technical Scope Summary**—summary of the technical scope of the project including what is included in the project as well as what is not included.
- **Qualifications and Assumptions**—the key project qualifications and cost assumptions that provide a “bounding” of the estimate and scope. Specifically, the assumed condition under which the estimator believes the project work scope will be performed should be defined. The qualifications and assumptions may describe the types of work expected, the amount of work expected, the source of various materials, conditions in which the work is to be performed (winter, contaminated building, etc.), and any other information that significantly influences the estimate but is not clearly identified in the technical scope description. Major assumptions and exclusions that affect the project or the accuracy of the estimate are also described.

In completing this activity, the estimator should identify areas where work scope descriptions have deficiencies, or where key information is missing and has to be

assumed. Vital information concerning the project is also identified for those reviewing or using the estimate.

Qualifications and assumptions should be described and documented at the most detailed level practical, and they should be clearly described so an individual not intimately involved with the project can understand the estimate's basis.

- **Overall Basis of Estimate (BOE)**— The dollar amount indicated in a cost estimate is meaningless without understanding the quality of information that led to developing the estimate. With all estimates, the basis is communicated at a higher level in a summary document and at a more specific level within the estimate.

Include in the estimate package a high level summary explaining the genesis for the source information for the estimated resources and a breakdown of cost estimate basis. For example, 30% is vendor quote, 20% engineering judgment, 30% historical data, and 20% cost database/cost books.

The basis should also describe the design basis, the planning basis (significant features and components, proposed methods of accomplishment, and proposed project schedule), the risk basis, supporting research and development requirements (important when new technologies are contemplated for certain components, equipment or processes), special construction or operating procedures, site conditions, the cost basis, and any other pertinent factors or assumptions that may affect costs.

If the estimate is prepared in support of another formal document that addresses these issues (i.e., a Conceptual Design Report or definitive design document), separate documentation is not required. If the estimate is a standalone document, or deviates substantially from a previous estimate scope, the above issues should be addressed and included in the estimate basis.

- **Estimate Summary and Detail Reports**—a presentation of the estimate details in a variety of ways (e.g., sorted by labor type, by WBS etc.)
- **Technical Scope Detail**—a statement of the details of the technical scope necessary for a thorough understanding of the work. This may **be by reference to** specific technical documents.
- **Estimate Specific WBS and WBS Dictionary**—a decomposition of the organization and related cost estimates.

The initial basis for any cost estimate should be documented at the time the estimate is prepared. The basis should describe or reference the purpose of the project element, the design basis, the planning basis (significant features and components, proposed methods of accomplishment, and proposed project schedule), the risk basis, supporting research and development requirements (important when new technologies are contemplated for certain components, equipment or processes),

special construction or operating procedures, site conditions, the cost basis, and any other pertinent factors or assumptions that may affect costs.

If the estimate is prepared in support of another formal document that addresses these issues (i.e., a Conceptual Design Report or definitive design document), separate documentation is not required. If the estimate is a standalone document, or deviates substantially from a previous estimate scope, the above issues should be addressed and included in the estimate basis.

At the WBS level, include quantities, applicable rates and costs. Also, include sources of information, such as historical costs, industry standards, published price lists; cost databases, informal budgetary information, cost estimating relationships, etc. for the WBS.

At the WBS level, include the resource and Crew Listing—a listing of the type of resources used in the estimate.

- **Method and Justification for Use of Indirect Rates**—an explanation of how indirect rates were selected and applied.
- **Method and Justification for use of Allowances**—an explanation of how allowances were determined and applied.
- **Method and Justification for use of Escalation**—an explanation of the escalation rates used, how they were obtained, why they were selected and how they were applied.
- **Schedule**—a time-frame for the work to assist in understanding how escalation was applied. The schedule should reflect the same technical scope and cost as the estimate.
- **Risks**—discuss sources of risk and uncertainty, including critical assumptions, associated with the estimate. Identify major risks within the scope of work and how those risks are mitigated. The basis for contingency reserves and how they were calculated is fully documented.
- **Sensitivity Analysis**—describes the effect of changing key cost drivers and assumptions independently. Identifies the major cost drivers that should be closely monitored.
- **List of Participants**—a list of contacts for questions about the estimate. Estimate preparers and reviewers should be identified in the cost estimate documentation.
- **Documentation of Review and Approval**—evidence that the estimate was reviewed and approved.

- **Location of Estimate Files and Reference Information**—a location to obtain copies of the estimate, review the original, and review information that was not included in the estimate package. The cost estimate package should include documentation providing the location of the estimate, historical data, technical scope, worksheets and any other pertinent information used to prepare the estimate.
- **Documentation of Changes to the Estimate**—clarification of how and where the estimate was changed, eliminating the need to review the entire estimate. Cost estimates should be updated or modified as necessary. Updates should be promptly documented when significant changes occur.

6.7.2 Cost Classification

A specific definition of items to be included as direct costs and indirect costs should be included at the discretion of the DOE program offices and field offices and/or determined by their contractor's financial system. This would also apply to activities under either Other Project Costs (OPC) or Total Estimated Cost (TEC) (refer to DOE O 413.3B for definitions and requirements for these terms as they apply to projects).

It is important to assure that there is no double counting of costs estimated as direct, indirect, or overhead. Generally, all cost estimates include

- direct costs,
- indirect costs,
- contingency, and
- escalation.

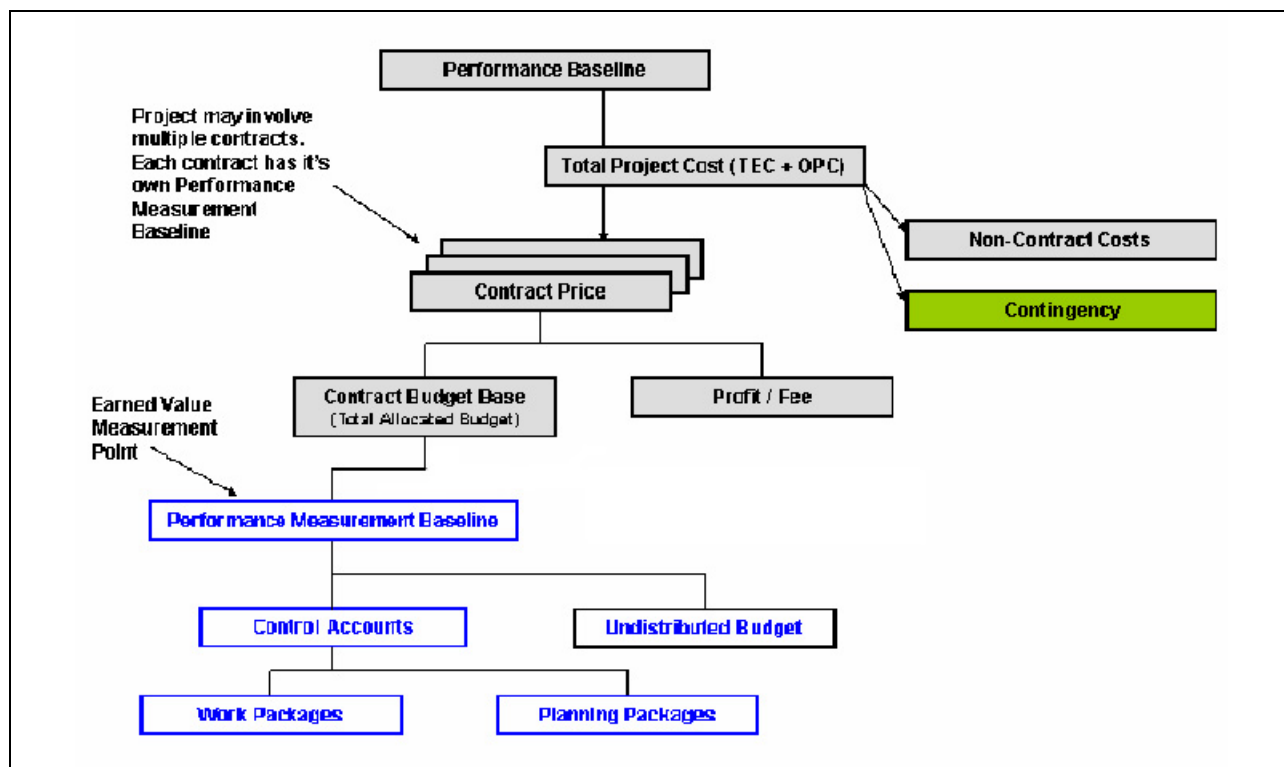


Figure 6–11. Contents of a Project Performance Baseline (Project Budget Allocations)

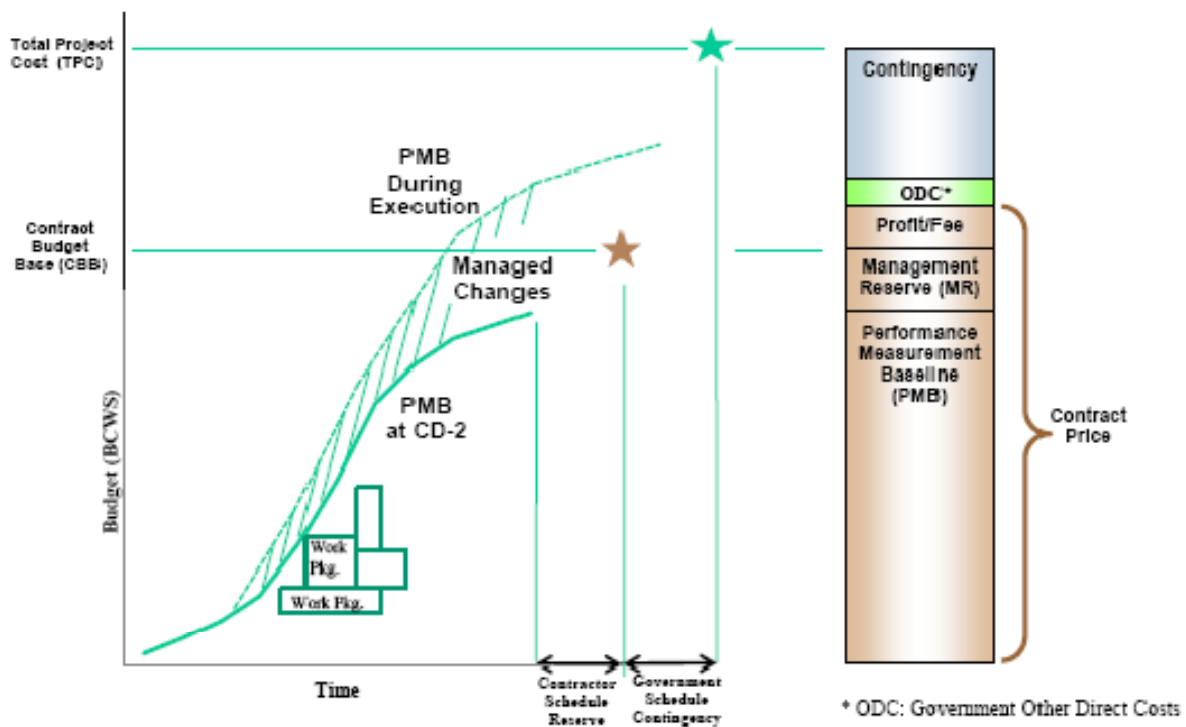


Figure 6-12. Typical Project Performance Baseline Including Cost and Schedule

6.8 Estimate Maintenance

It is important to maintain estimates over the life cycle of the project or program. For projects, the cost estimate is a key element in establishing the Performance Baseline, as depicted in Figures 6-11 and 6-12. The project cost performance baseline consists of a project's TPC, which includes various contract prices, non-contract costs, profit/fee, and contingency.

Project baselines in turn are key elements of overall program planning and budgeting, including portfolio management. As projects are identified and defined, and the cost estimates and baselines evolve, they become key inputs into the management of the program's life cycle. This may involve multiple projects and/or operational activities (e.g., construction of facilities to treat waste, decommissioning of treatment facilities, waste management, surveillance and maintenance). As such, active maintenance of all estimates is essential – they need to reflect the latest and most realistic projections of cost and resource requirements to facilitate effective program planning.

The need to make changes to a cost estimate generally results from determining that the estimate no longer accurately portrays the expected cost for the work. The means to formally control changes to a cost estimate are dependent on the purpose of the estimate. Estimates supporting project baselines must be changed and approved through a formal baseline change process (refer to DOE O 41.3.3B, Appendix A, Section 6, Baseline Management).

Changes require documentation, and as each estimate is updated, modified, or revised, an audit trail must be maintained to show the relationship between the new estimate and the previous estimate. The reason(s) for each change should be identified and may include such things as modification of scope, unexpected increases in labor rates, schedule extensions, variance in escalation rates, project reprioritization, etc. All such changes should be identified in a manner that will permit verification of the specific quantitative change(s) in the cost estimate. Changes may be documented by the use of addenda, officially approved change request documents, or by completion of a new estimate. The method used depends upon the magnitude of the estimated change and the underlying causes. All estimate changes should include the appropriate level of indirect costs, escalation, and allowances, as dictated by the phase of the project when the change was identified.

The process of officially revising and updating cost estimates supporting project baselines frequently involves the use of change requests. Change requests are the official means by which all changes to the cost baseline should be documented. Change requests are prepared using standard contractor procedures and forms, which describe proposed changes to approved technical, cost and/or schedule baselines.

As work is authorized to proceed, cost estimates become budgets. There is a distinction between budget allocations and cost estimates. The budget forms the basis for work execution.

7.0 COST ESTIMATING OUTPUTS

This Guide defines traditional output coming out of the Cost Estimating Process as shown in Figure 7.1. Outputs include, the traditional change control process, economic and cost-benefit analysis, value engineering, earned-value, and final project cost reports.

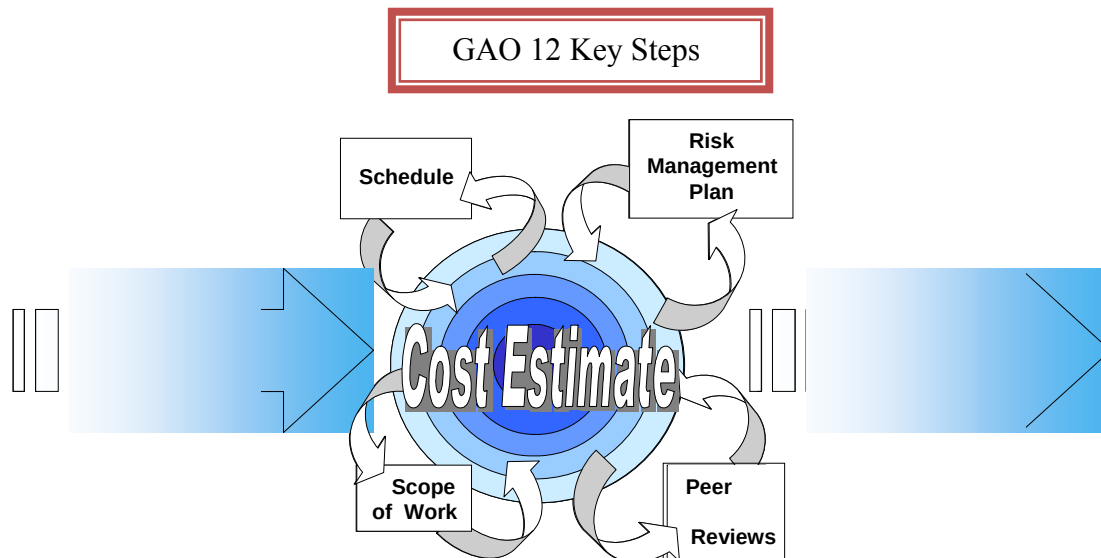


Figure 7-1. Cost Estimating Process Model

7.1 Cost Estimate Interfaces

Cost estimate development is initiated into a process through one-time or iterative inputs. Potential one-time inputs may include (but are not limited to) the project charter, project execution plan, acquisition strategy, and acquisition plan. All of these are inputs to the cost estimating process.

Other inputs may evolve through the cost estimating process and use the outputs from the cost estimating process, such as the risk assessment (primarily risk identification and impact assessment), schedule, and scope development. Input from cost estimating peers may improve the quality of a cost estimate, and peer reviews should be required before external reviews are conducted.

The cost estimate output provides a key interface to other project processes, including the planning/scheduling, project control, risk management, and project approval processes.

7.2 Estimate Presentations to Management

As discussed in Section 3, cost estimates are a primary input into the DOE decision-making and project approval CD process. As a result, a cost estimate is documented and presented to management with an understanding that the quality of the cost estimate adheres to such decisions and approvals. A graded approach to cost estimate packaging and reporting should be used when documenting cost estimates for other purposes. The following is recommended to be included in most presentations of cost estimates to management, whenever such presentations are necessary and warranted:

- Develop a briefing that presents the documented life-cycle cost (LCC) estimate;
- Include an explanation of the technical and programmatic baseline and any uncertainties;
- Compare the estimate to an independent cost estimate (ICE) and explain any differences;
- Compare the estimate LCC estimate or ICE to the budget with enough detail to easily defend it by showing how it is accurate, complete, and high quality;
- Focus in a logical manner on the largest cost elements and cost drivers;
- Make the content clear and complete so that those who are unfamiliar with it can easily appreciate the competence that underlies the estimate results;
- Make backup slides available for more probing questions;
- Act on and document feedback from management; and
- Request acceptance of the estimate.

In many instances, the results of sensitivity analyses should be presented to further management understanding of the reliability and accuracy of the presented cost estimate. Such analyses should focus on key cost drivers and critical assumptions and inform management of the resulting estimate result if those drivers or assumptions were changed. Usually ranges that can bracket potential estimate results are a useful management presentation approach; however, such bracketing must be clearly explained and the potential risks and uncertainties associated fully described for management's understanding.

7.3 Baselines and Change Control

Cost estimates are normally organized by a WBS, account code, and/or some other standardized definition. Standard definitions of direct and indirect costs provide consistency in estimating costs and project reporting. This also benefits program/project management, independent estimates (Government estimates), reviews, and contract/project validations and cost/price analysis. The cost portion of the performance baseline consists of a project's TPC, including various contract prices, non-contract costs, and contingency.

As projects evolve, baselines are established and changes are managed against those baselines. Cost estimates supporting proposed or directed changes should contain the same level of quality as the primary baseline cost estimate.

Baselines are expected to remain intact throughout the project execution from approval at CD-2 to completion at CD-4. Changes are expected to remain within the performance baseline as per

the definition of a successful project at CD-4 in DOE O 413.3B. Cost estimates for the baseline project are modified (updated) when changes are approved.

7.4 Analysis

Analysis includes decomposition and examination. In many cases, analysis will provide insight to a decision maker. Such is the case of cost benefit analysis. Cost-benefit analysis is a required element in capital planning within the Federal government. In the contracting community, cost analysis or price analysis is a comparison of either costs or price, respectively (e.g., comparing a proposal to a government estimate). If a contract is competitively bid, cost analysis (which is more detailed and complex than price analysis) may not be required.

Analysis could be performed in the life of a project, including cost benefit analysis, cost-effective analysis, economic analysis, LCC analysis, sensitivity analysis and uncertainty analysis. Analyses supporting CDs should be structured and formal; i.e., well documented. Other analyses may be loosely structured and informal.

Normally, analyses require using similar cost estimate structures (i.e., separate cost estimates for each alternative considered); having all costs for all alternatives depicted; and comparing alternatives using net present value or annuities. Normally a written summary of the findings is also prepared to explain the analysis.

More information on parametric cost estimates, including the Parametric Estimating Initiative (PEI) Parametric Estimating Handbook, can be found through the International Society of Parametric Analysts (ISPA), at <http://www.ispa-cost.org/>

More information on cost estimating and analysis can be found through the Society for Cost Estimating and Analysis (SCEA), at <http://www.sceaonline.net/>

More information on cost engineering can be found through the Association for the Advancement of Cost Engineering International (AACEI), at <http://www.aacei.org/>

8.0 COST ESTIMATING EXPECTATIONS

This Section summarizes what could be expected from the use of DOE cost estimates for capital asset projects.

8.1 Summary of Expectations

A DOE cost estimate, regardless of purpose, classification, or technique employed, should demonstrate sufficient quality to infer that it is appropriate for its intended use, is complete, and has been subjected to *internal* checks and reviews. It should also be clear, concise, reliable, fair, reasonable, and accurate, within some probability or confidence levels. **In addition, it is expected to have followed accepted standards such as the GAO 12 steps of a high quality cost estimating process (GAO-09-3SP).** There could be more expectations, depending on the

program, project, contract type, specific budget requirements, or other situations.

Common elements of good cost estimates are expected to be constant. Suggested review criteria are summarized in Appendix E. DOE expectations for quality cost estimates are summarized in Appendix L.

Other expectations are associated with organization of the estimate. Types of cost elements included; resources, material, other direct costs, and sub-contract costs, structure the type of work embodied in the cost estimate. These coded costs facilitate development of management information and earned value assessments, and can provide extremely useful information as projects are completed. Industry standard codes are exemplified by the Construction Specifications Institute's Uniformalt II and Masterformat, for construction projects. The environmental cost element structure (ECES), an ASTM standard for environmental projects, is another common coding structure. Some of these industry standard codes are listed in the appendices.

Other formats, such as project data sheets (PDSs) for budget formulation, should be produced, as necessary.

More information on the Uniformalt II can be found at <http://www.uniformalt.com/index.html>

More information on the Masterformat can be found at <http://www.masterformat.com/>

More information on the ECES can be found at
http://www.emcbc.doe.gov/dept/ce&a/aceteam_eces.php

More information on DOE Budget Guidance with PDS sample and template, can be found at
<http://www.cfo.doe.gov/crorg/cf30.htm>

More information on OMB's Exhibit 300 forms can be found in OMB A-11, Part 7 at
http://www.whitehouse.gov/omb/circulars_all_current_year_all_toc

8.2 Lessons Learned

Lessons learned from experience are essential to structuring increasingly more accurate cost estimates. A reasonable expectation of a cost estimating process is that it systematically collects historical project information in real time, rather than being done at the last minute or by trying to recollect long after the fact.

Historical cost information can be collected as lump sum (representing some specific scope of work), unit cost, or productivity (hours per unit, or units per hour) information. Historical costs should be collected for analysis, normalization, and use in future project cost estimates. Lessons learned that can help cost estimators with future cost estimates may be generic in nature or specific to a site, location, contract type, etc. They may apply to a particular scope of work or a cost estimating technique. There are many ways to communicate lessons learned. The point is to document what has been learned from the experience and share it with others, as appropriate (DOE G 413.3-11, *Project Management Lessons Learned*, dated 8-5-08).

8.3 Independent Cost Estimates and Cost Reviews

The following requirements are described in DOE O 413.3B:

Prior to CD-0, for Major System Projects, or for projects as designated by the SAE, OECM will conduct an Independent Cost Review (ICR).

Prior to CD-1, for projects with a TPC $\geq$ \$100M, OECM will develop an Independent Cost Estimate (ICE) and/or conduct an ICR, as they deem appropriate.

Prior to CD-2, for projects with a TPC $\geq$ \$100M, OECM will develop an ICE. The ICE will support validation of the Performance Baseline (PB).

Prior to CD-3, for projects with a TPC $\geq$ \$100M, OECM will develop an ICE, if warranted by risk and performance indicators or as designated by the SAE.

The definitions of ICR and ICE, as provided in DOE O 413.3B, are as follows:

Independent Cost Review. An independent evaluation of a project's cost estimate that examines its quality and accuracy, with emphasis on specific cost and technical risks. It involves the analysis of the existing estimate's approach and assumptions.

Independent Cost Estimate. A cost estimate, prepared by an organization independent of the project sponsor, using the same detailed technical and procurement information to make the project estimate. It is used to validate the project estimate to determine whether it is accurate and reasonable.

In addition to the specific requirements placed on OECM in DOE O 413.3B, a project may be well-served by having its own ICR or ICE completed at various points in the development and execution of the project, no matter the size of the project (for projects less than \$100M). Comparison to an ICE is a key element in Step 7 of the GAO Best Practices.

Appendix K provides some specific guidance relative to ICRs and ICEs. All ICRs and ICEs should be developed by individuals or organizations that are truly independent of the project. This may be accomplished by issuance of contracts or task orders by OECM, through another DOE direct contract vehicle, or directly by other DOE organizations. However, it may not be generally appropriate for the project proponents (i.e., a DOE site office, a DOE program office, or a DOE contractor) to conduct, or to contract for, and direct an ICE or ICR development.

In general, the types of reviews that DOE normally recognizes (the types of reviews may be modified/combined by the size, technology and complexity of the project) are the following:

Documentation Review (Type I)—this type of review is not normally accomplished as an ICR/ICE, nor does it fulfill the requirements as specified in DOE O 413.3B, since it only consists of an assessment of the documentation available to support the estimate. It is merely an inventory of existing documents to determine that the required support documentation exists and to identify any missing data. This type of review can be beneficial for a project team facing an upcoming EIR or ICE, to ensure readiness to proceed with those activities.

Reasonableness Review (Type II)—this equates to the DOE O 413.3B ICR

For this review the ICR team reviews all available project documentation, receives briefings from the project team, holds discussions with the project team, completes sufficient analysis to assess the reasonableness of the project assumptions supporting the cost and schedule estimates, ascertains the validity of those assumptions, assesses the rationale for the methodology used, and checks the completeness of the estimate, including appropriate allowances for risks and uncertainties. The result is a report that details the findings and recommendations.

Parametric Estimating Approach (Type III)—this approach, in addition to incorporating all of the activities needed for a Reasonableness Review, uses parametric techniques, factors, etc., to analyze project costs and schedules, and is usually accomplished at a summary WBS level. The parametric techniques (including CERs and factors) should be based on accepted historical cost/schedule analyses. At a minimum, these tools should be based on historic estimates from which models have been derived, and, where possible, from actual completed projects. An estimate with a minimum of 75 percent of the TPC based on parametric techniques is classified as a parametric estimate.

Sampling Approach (Type IV)—this review also begins with the activities needed for a Reasonableness Review, but it also requires the ICE team to identify the key cost drivers. A “cost driver” is a major estimate element whose sensitivity significantly impacts TPC. Detailed, independent estimates should be developed for these cost drivers. Such estimates should include vendor quotes for major equipment, and detailed estimates of other materials, labor, and subcontracts. For the balance of the project costs, the project team’s estimate may be used (if deemed reasonable), or, if appropriate, parametric techniques may be used for certain portions of the project costs. An estimate which provides a detailed cost for all cost drivers is classified as a Sampling Estimate.

Bottom-up Estimating Approach (Type V)—this is the most detailed and extensive ICE effort. It begins with the activities needed for a Reasonableness Review. In addition, this approach requires a detailed bottom-up independent estimate for both cost and schedule. This will require quantity take-offs/development, vendor quotations, productivity analysis, use of historical information, and any other means available to do a thorough and complete estimate of at least 75 percent of the project’s cost. It may not be possible to do a completely independent estimate on some portions of the project estimate, and for those portions – which should not exceed 25 percent of the total estimate – the project estimate may be used if it has passed the test of reasonableness. In all cases, the total cost (TEC and TPC) should be developed.

ICEs will often involve a combination of the approaches and techniques described above, due to the varying levels and quality of information available. The accuracy of the ICE will be subjectively determined based on the weighted evaluation of the information available.

A key element of any ICE is a comprehensive reconciliation between the ICE and the project team estimate. Such reconciliation identifies areas of significant difference between the estimates and attempts to explain those differences. This information provides a useful basis for subsequent estimate (cost range or baseline) approval or identification of necessary estimate revision and refinement.

8.4 Independent Government Cost Estimates

As described in DOE O 413.3B, an Independent Government Cost Estimate (IGCE) is the government's estimate of the resources and projected costs that a contractor will incur in the performance of a contract. These costs include direct costs such as labor, supplies, equipment, or transportation and indirect costs such as labor overhead, material overhead, as well as general and administrative expenses, profit or fee. (Refer to FAR 36.203 and FAR 15.406-1)

An IGCE should be based on the exact same bidding documents (describing scope, terms and conditions, contract clauses, etc.) as will be used by the contractor. Not only do IGCEs play an important role in the contractor bid evaluation and selection/award processes, but the actual IGCE development can also be a great value in making the actual bid documents and contract language more effective by clearing up ambiguous elements and identifying more cost/schedule efficient contract approaches.

The IGCE can play a vital role in helping identify what is "reasonable" because the IGCE is the Government's best independent estimation of the potential cost of a contract. A detailed and well-documented IGCE is a valuable tool for supporting cost or cost realism analysis. The IGCE also supports a Price Analysis, which is an estimate of the "should pay" price that the Government should reasonably expect to pay based on current competitive market conditions. Additionally, the IGCE is an aid in deciding whether to go ahead with the acquisition as well as provide supportive documentation for the Purchase Request.

It should also be understood that IGCEs, by themselves, do not fulfill the requirements for an ICR or ICE. That is because the scope of the estimate needs to be restricted to the contract scope and conditions. As such, an IGCE does not usually represent the full project scope nor does it appropriately incorporate government furnished items or reflect DOE risks and uncertainties.

9.0 APPENDICES

The objective of this Guide is to provide uniform guidance and best practices for developing high quality cost estimates for capital assets projects while meeting the requirements of DOE O 413.3B, *Program and Project Management for the Acquisition of Capital Assets*. The project cost estimate is an essential element of a credible project baseline. This Guide provides cost estimating and processes that meet Federal and DOE requirements and are consistent with industry standards and practices, and facilitate local requirements. The Appendices that follow supplement the material presented in the core sections of this Guide.

Appendices A and B – Provide the list of the most common acronyms used in this document plus the definition of common terms used with cost estimating.

Appendices C and D – Provide a summary of the most important Federal and DOE requirements for cost estimating.

Appendix E – Provide a suggested criteria for reviewing a cost estimate for quality and credibility.

Appendix F – Provides a generic example for the calculation and use of economic escalation for a project.

Appendix G – Provides a generic simple example for a life-cycle cost analysis for two alternatives in a project.

Appendix H – Provides as a reference the AACEI Cost Estimate Classification.

Appendix I – Provides a bibliography of references in cost estimating.

Appendix J – Provides a crosswalk of the 12 key GAO estimating steps to sections of this Guide wherein each step is described in detail.

Appendix K – Provides additional ICE and ICR guidance regarding the timeframe for completion, as well as documentation needs.

Appendix L – Provides DOE expectations for checking the quality of cost estimates to meet the four characteristics of quality estimates and the reasonableness of the cost estimating techniques employed.

Appendix A: Acronyms

AE	Acquisition Executive
A/E	architect/engineer
AACEI	Association for the Advancement of Cost Engineering, International
ABC	activity-based costing
ANSI	American National Standards Institute
AS	acquisition strategy
ASTM	American Society for Testing Materials
BOE	basis of estimate
CD	critical decision
CDR	conceptual design report
CER	cost estimating relationship
CFO	Chief Financial Officer
CFR	Code of Federal Regulations
CM	construction management
CO	contracting officer
COA	code of accounts
CPM	Contractor Project Manager, otherwise Critical Path Method
CSI	Construction Specifications Institute
DoD	Department of Defense
DOE	Department of Energy
EIR	external independent review
ESAAB	Energy System Acquisition Advisory Board
ES&H	Office of Environment, Safety, and Health
EVMS	Earned Value Management System
FPD	Federal Project Director
FTE	full-time equivalents
GFE	Government-Furnished Equipment
ICE	independent cost estimate
ICR	independent cost review
IGCE	independent government cost estimate
IPT	integrated project team
IT	information technology
LEED	Leadership in Energy and Environmental Design
LCC	life-cycle cost
LOE	level of effort
NPV	net present value
NNSA	National Nuclear Security Administration
OMB	Office of Management and Budget
OPC	other project costs
PARS	Project Assessment and Reporting System
PBC	performance based contracts
PDS	project data sheet
PED	project engineering design
PHA	preliminary hazard analysis

PM	project management or contractor project manager
PMB	performance measurement baseline
PPBES	Planning, Programming, Budgeting and Execution System
QA	quality assurance
QC	quality control
R&D	research and development
SME	subject matter expert
TEC	total estimated cost
TPC	total project cost
VE	value engineering
WBS	work breakdown structure

Appendix B: Definitions

These definitions of terms are derived within the context of how terms are used in this Guide.

Acquisition plan (AP) – is the document that facilitates attainment of the acquisition objectives. The plan must identify: those milestones of which decisions should be made; all the technical, business, management; and other significant considerations that will control the acquisition including, but not limited to, market research, competition, contract type, source selection procedures and socio-economic considerations.

Acquisition strategy (AS) - a business and technical management approach designed to achieve acquisition objectives within the resource constraints; the framework for planning, directing, contracting, and managing a system, program, or project; a master schedule for research, development, test, production, construction, modification, postproduction management, and other activities essential for success; the basis for formulating functional plans and strategies (e.g., acquisition strategy, competition, systems engineering). Once approved, the AS should reflect the approving authority's decisions on all major aspects of the contemplated acquisition.

Activity-based costing (ABC) -

- Costing using a method to ensure that the budgeted amounts in an account truly represent all the resources consumed by the activity or item represented in the account.
- Cost estimating in which the project is divided into activities and an estimate is prepared for each activity. Also used with detailed, unit cost, or activity-based cost estimating.

Actual Cost - the costs actually incurred and recorded in accomplishing work performed.

Allowance - an amount included in a base cost estimate to cover known but undefined requirements for a control account, work package, or planning package.

Analysis - the separation of a whole (project) into parts; examination of a complex entity, its elements, and their relationships; a statement of such analysis.

Assumptions - factors used for planning purposes that are considered true, real or certain. Assumptions affect all aspects of the planning process and of the progression of the project activities. (Generally, the assumptions will contain an element of risk.)

Baseline - a quantitative definition of cost, schedule, and technical performance that serves as a standard for measurement and control during the performance of an activity; the established plan against which the status of resources and the effort of the overall program, field programs, projects, tasks, or subtasks are measured, assessed, and controlled. Once established, baselines are subject to change control discipline.

Basis (basis of estimate, or BOE) - documentation that describes how an estimate, schedule, or other plan component was developed, and defines the information used in support of development. A basis document commonly includes a description of the scope, methodologies, references and defining deliverables, assumptions and exclusions, clarifications, adjustments, and level of uncertainty.

Benchmark - a standard by which performance may be measured.

Bias - a repeated or systematic distortion of a statistic or value, imbalanced about its mean.

Bounding assumption - identified risks that are totally outside the control of the project team and therefore cannot be managed (i.e., transferred, avoided, mitigated, or accepted). Bounding assumptions are also referred to as “enabling assumptions”.

Brainstorming - interactive technique designed for developing new ideas with a group of people.

Budgeting - a process for allocating estimated of resource costs into accounts (i.e., the cost budget) against which cost performance will be measured and assessed. Budgeting often considers time-phasing in relation to a schedule or time-based financial requirements and constraints.

Buried contingency - costs that may have been hidden in the details of an estimate to protect a project from the removal of explicit contingency and to ensure that the final project does not go over budget. To reviewers, buried contingency often implies inappropriately inflated quantities, lowered productivity, or other means to increase project costs. Buried contingency should not be used.

Capital assets -

- Land, structures, equipment, systems, and information technology (e.g., hardware, software, and applications) used by the Federal government and having an estimated useful life of 2 years or more. Capital assets include environmental restoration (decontamination and decommissioning) of land to make useful leasehold improvements and land rights, and assets whose ownership is shared by the Federal government with other entities (does not apply to capital assets acquired by state and local governments or other entities through DOE grants).
- Strategic assets; unique physical or intellectual property that is of long-term or ongoing value to an enterprise; in total cost management, a strategic asset may also include fixed or intangible assets; assets created by the investment of resources through projects (excludes cash and financial assets).

Change control - a process that ensures changes to the approved baseline are properly identified, reviewed, approved, implemented and tested, and documented.

Change order - a unilateral requirement signed by the Government contracting officer directing the contractor to make a change that the *changes clause* authorizes without the contractor’s consent.

Code of accounts (COA) - a systematic coding structure for organizing and managing asset, cost, resource, and schedule information; an index to facilitate finding, sorting, compiling, summarizing, and otherwise managing information to which the code is tied. A complete COA includes definitions of the content of each account.

Conceptual design - the concept that meets a mission need; requires a mission need as an input. Concepts for meeting a mission need are explored and alternatives considered before arriving at the set of alternatives that are technically viable, affordable, and sustainable.

Conceptual design report (CDR) - documentation of conceptual design phase outcome; forms the basis for a preliminary baseline.

Co-dependent risk - co-dependent project risks are generated when intermediate deliverables or outcomes (two or more projects or sub-projects at the same site) interlock in such a way that if both projects are not successfully completed, neither can be successfully completed.

Confidence (confidence level) - the probability that a cost estimate or schedule can be achieved or bettered. This is typically determined from a cumulative probability profile (see Cumulative Distribution Function”) that is the output from a Monte Carlo simulation.

Construction - a combination of engineering, procurement, erection, installation, assembly, demolition, or fabrication to create a new facility or to alter, add to, rehabilitate, dismantle or remove an existing facility; includes alteration and repair (dredging, excavating, and painting) of buildings, structures, or other real property and construction, demolition, and excavation conducted as part of environmental restoration or remediation. Construction normally occurs between Critical Decisions 3 and 4 (does not involve the manufacture, production, finishing, construction, alteration, repair, processing, or assembling of items categorized as personal property).

Consequence – is the outcome of an event. (Normally includes scope, schedule, and cost.)

Construction management - a wide range of professional services relating to the management of a project during the pre-design, design, and construction phases; includes development of project strategy, design review of cost and time consequences, value management, budgeting, cost estimating, scheduling, monitoring of cost and schedule trends, procurement, observation to ensure that workmanship and materials comply with plans and specifications, contract administration, labor relations, construction methodology and coordination, and other management of construction acquisition.

Contingency -

- The portion of a project budget that is available for uncertainty *within the project scope* but outside the scope of the contract. That is, contingency is budget that is not placed on contract.
- An amount derived from a structured evaluation of identified risks, to cover a likely future event or condition, arising from presently known or unknown causes, within a defined project scope. Contingency is controlled by the government.

Contract - a mutually binding agreement that obligates the seller to provide a specified product and obligates the buyer to pay for it.

Contract fee - fee earned by the contractor based on dollar value or another unit of measure, such as man hours; an indirect cost.

Contractor - a person, organization, department, division, or company having a contract, agreement, or memorandum of understanding with DOE or another Federal agency.

Control account (or cost account) - the point at which budgets (resource plans) and actual costs are accumulated and compared to earned value for management control purposes; a natural management point for planning and control that represents work assigned to one responsible organizational on one work breakdown structure element.

Correlation - relationship between variables such that changes in one (or more) variable(s) is generally associated with changes in another. Correlation is caused by one or more dependency relationships. Measure of a statistical or dependence relationship existing between two items estimated for accurate quantitative risk analysis.

Cost accounting - historical reporting of actual and/or committed disbursements (costs and expenditures) on a project. Costs are denoted and segregated within cost codes that are defined in a chart of accounts. In project control practice, cost accounting provides measure of cost commitment and expenditure that can be compared to the measure of physical completion (earned value) of an account.

Cost budgeting – is allocating the estimated costs to project components.

Cost control - controlling changes to a project budget and forecast to completion.

Cost-Benefit Analysis - is the systematic, quantitative method of assessing the desirability of government projects or policies when it is important to take a long view of future effects and a broad view of possible side-effects.

Cost-effective analysis - appropriate when it is unnecessary or impractical to consider the dollar value of the benefits provided by the alternatives under consideration when

- each alternative has the same annual benefits expressed in monetary terms or
- each alternative has the same annual effects, but dollar values cannot be assigned to their benefits.

Analysis of alternative defense systems often falls into this category. Cost-effective analysis can also be used to compare projects with identical costs but differing benefits. In this case, the decision criterion is the discounted present value of benefits. The alternative program with the largest benefits would normally be favored.

Cost estimate -

- A documented statement of costs to be incurred to complete a project or a defined portion of a project.
- Input to budget, contract, or project management planning for baselines and changes against which performance may be measured.

Cost estimating - a process used to quantify, cost, and price the resources required by the scope of an asset investment option, activity, or project. As a predictive process, estimating must address risks and uncertainties. The output of estimating is used primarily as input for budgeting, cost or value analysis, decision making in business, asset and project planning, or project cost and schedule control.

Critical decision (CD) - a formal determination made by an acquisition executive or designated official at a specific point in a project life cycle that allows the project to proceed. Critical decisions occur at any point in the course of a project (before commencement of conceptual design, at commencement of execution, and at turnover).

Critical decisions (CDs) -

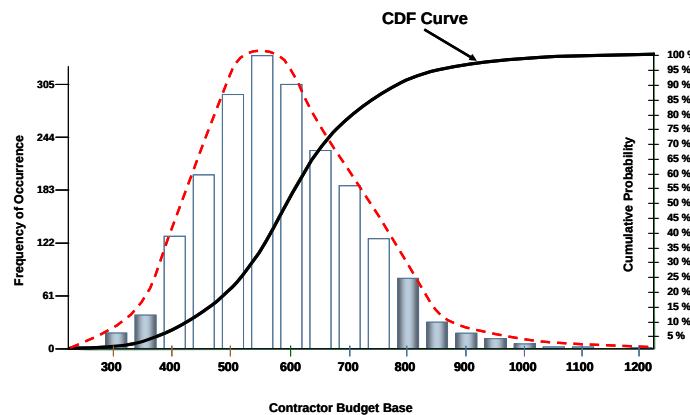
CD-0, Approve Mission Need

CD-1, Approve Alternative Selection and Cost Range

CD-2, Approve Performance Baseline
CD-3, Approve Construction Start
CD-4, Approve Start of Operations or Project Closeout

Critical path – is a logically related sequence of activities in a critical path schedule having the longest duration. The total float is zero. A delay in any activity will have a corresponding impact on the completion date of the project.

Cumulative Distribution Function (CDF) - a statistical function based on the accumulation of the probabilistic likelihood of occurrences. In the case of the DOE risk analysis, it represents the likelihood that at a given percentage the project cost or duration will be at or below a given value. As an example, the x-axis might represent the range of potential project cost values evaluated by the Monte Carlo simulation and the y-axis represents the project's probability of completion. (See the figure below.)



Decision analysis – is the process for assisting decision makers in capturing judgments about risks as probability distributions, having single value measure, and putting these together with expected value calculations.

Delphi technique - technique used to gather information used to reach consensus within a group of subject matter experts on a particular item. Generally a questionnaire is used on an agreed set of items regarding the matter to be decided. Responses are summarized, further comments elicited. The process is often repeated several times. Technique is used to reduce bias in the data and to reduce the bias of one person, one voice.

Decision trees: A diagram that shows key interactions among decisions and associated chain events as they are understood by the decision maker. Branches of the tree represent either decisions or change events. The diagram provides for the consideration of the probability of each outcome.

Deviation - when the current estimate of a performance, technical, scope, schedule, or cost parameter is not within the threshold value of the performance baseline for that parameter; handled as a deviation, not as part of the normal change control system.

Direct cost - costs identified with a particular project or activity; includes salaries, travel, equipment, and supplies directly benefiting the project or activity.

Discount rate - the interest rate used in calculating the present value of expected yearly benefits and costs (see definitions for *nominal interest rate* and *real interest rate*).

DOE acquisition management system - a systematic method to acquire and deliver a product or capability in response to a program mission or business need; includes facility construction, infrastructure repairs or modifications, systems, production capability, remediate land, closed site, disposal effort, software development, information technology, a space system, research capability, and other assets.

DOE contingency - cost contingency for risks that are within the project's baseline but outside the contractor's management control. DOE contingency is held by DOE.

DOE schedule contingency - duration allowance used to adjust schedule for realized risks that are within the project baseline, and outside the contractor's control.

Enabling assumption- identified risks that are totally outside the control of the project team and therefore cannot be managed (i.e., transferred, avoided, mitigated, or accepted).

Earned Value Management System (EVMS) - is the integrated set of processes used to implement the standard and its criteria. In its simplest form, EVMS can be implemented without any software. Software simply enhances productivity, allows the implementation of EVMS more economically and facilitates managing complex projects. EVMS is not software.

Economic analysis - considers all costs and benefits (expenses and revenues) of a project, considering various economic assumptions made, such as inflation and discount rates.

Escalation – the provision in actual or estimated costs for an increase in the cost of equipment, material, labor, etc, due to continuing price level changes over time. Inflation may be a component of escalation, but non-monetary policy influences, such as supply-and-demand, are often components.

Estimate – is the assessment of the most likely quantitative result. (Generally, it is applied to costs and durations with a confidence percentage indication of likelihood of its accuracy.)

Estimate-at-completion - the current estimated total cost for project authorized work. EAC equals the actual cost to a point in time plus the estimated costs to completion.

Estimate to complete (ETC) - the current estimated cost for remaining authorized work to complete the project.

Estimate uncertainty - the inherent accuracy of a cost or schedule estimate. Represents a function of the level of project definition that is available, the resources used (skill set and knowledge) and time spent to develop the cost estimate and schedule, and the data (e.g., vendor quotes, catalogue pricing, historical databases, etc.) and methodologies used to develop the cost estimate and schedule.

External independent review (EIR) - an assessment mandated by Congress for projects of significant size and complexity; may warrant management attention.

Expert interviews - process of seeking opinions or assistance on the project from subject matter experts (SMEs).

External risks - risks outside the project control or global risks inherent in any project such as global economic downturns, trade difficulties affecting deliverables such as construction materials or political actions that are beyond the direct control of the project.

Facilities - buildings and other structures; their functional systems and equipment; site development features such as landscaping, roads, walks, and parking areas; outside lighting and communications systems; central utility plants; utility supply and distribution systems; and other physical plant features.

Feedback - system concept where a portion of the output is fed back to the input.

Fishbone diagram - technique often referred to as cause and effect diagramming. Technique often used during brainstorming and other similar sessions to help identify root causes of an issue or risk. Structure used to diagram resembles that of a fish bone.

Government other direct costs - Government costs that are needed for the project such as government furnished services, items and equipment, government supplied utilities (if directly metered), and applicable waste disposal fees.

Historical cost information - a database of information from completed projects normalized to some standard (geographical, national average, etc.) and time-based (e.g., brought to current year data) using historical cost indices.

Holding Time – Time that an item is not operational so that it may be serviced.

Hotel loads - a term used to identify the cost associated with level of effort activities and fixed costs that will be incurred until a given piece of work is complete. These costs can include the costs for project management and administration and other direct costs associated with generic facilities, rentals, money or opportunity lost from the facility not being complete, and other indirect costs that are not part of the direct production activities.

Impact scores - convergence of the probability and consequence scores.

Improvements to land - site clearing, grading, drainage, and facilities common to a project as a whole (such as roads, walks, paved areas, fences, guard towers, railroads, port facilities, etc.) but excluding buildings, structures, utilities, special equipment/process systems, and demolition, tunneling, and drilling that are a significant intermediate or end products of the project.

Independent cost estimate (ICE) – a cost estimate, prepared by an organization independent of the project proponent, using the same detailed technical and procurement information to make the project estimate. It can be used to validate the project estimate to determine whether it is accurate and reasonable.

Independent cost review – an independent evaluation of a project's cost estimate that examines its quality and accuracy, with emphasis on specific cost and technical risks. It involves the analysis of the existing estimate's approach and assumptions.

Independent government cost estimate – the government’s estimate of the resources and their projected costs that a contractor would incur in the performance of a contract. These costs include direct costs such as labor, supplies, equipment, or transportation and indirect costs such as labor overhead, material overhead, as well as general and administrative expenses, profit or fee. (Refer to FAR 36.203 and FAR 15.406-1)

Indirect cost - costs incurred for common or joint objectives which cannot be identified with a particular activity or project.

Inflation - the proportionate rate of change in general price, as opposed to the proportionate increase in a specific price.

Influence diagram - a graphical aid to decision making under uncertainty, it depicts what is known or unknown at the time of making a choice, and the degree of dependence or independence (influence) of each variable on other variables and choices.

Information technology (IT) project – is one that establishes a system (hardware and/or software) capability to manage information.

Initiation - authorization of the project or phase of the project.

Integrated project team (IPT) - a cross-functional group organized to deliver a project to a customer (external or internal).

Integrated safety management system (ISMS) - a management system designed to ensure that environmental protection and worker and public safety are appropriately addressed in the planning, design, and performance of any task.

Internal risks - risks that the project has direct control over, such as organizational behavior and dynamics, organizational structure, resources, performance, financing, and management support.

Key risk - key risks are a set of risks considered to be of particular interest to the project team. These key risks are those estimated to have the most impact on cost and schedule and could include project, technical, internal, external, and other sub-categories of risk. For example on a nuclear design project, the risks identified using the “Risk and Opportunity Assessment” process may be considered a set of key risks on the project. Key risks should be interpreted to have the same meaning as “Critical Risks” as referred in DOE O 413.3B.

Lessons learned - formal or informal set of “learning” collected from project or program experience that can be applied to future projects or programs after a risk evaluation. They can be gathered at any point during the life of the project or program.

Level-of-effort – is baseline scope of a general or supportive nature for which performance cannot be measured or is impracticable to measure using activity-based methods. Resource requirements are represented by a time-phased budget scheduled in accordance with the time the support will likely be needed. The value is earned by the passage of time and is equal to the budget scheduled in each time period.

Life cycle – are the stages of an object’s or endeavor’s life. A life cycle presumes a series of beginnings and endings, with each end implying a new beginning. In life-cycle cost or

investment analyses, the life cycle is the length of time over which an investment is analyzed.

Life-cycle cost -

- The overall estimated cost for a particular program alternative over the time period corresponding to the life of the program, including direct and indirect initial costs plus any periodic or continuing cost of operation and maintenance. (OMB)
- The sum total of the direct, indirect, recurring, nonrecurring, and other 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 anticipates the use of existing sites or facilities, restoration, and refurbishment, costs should be included.

Life-cycle cost analysis (LCCA) - assessment 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. LCCA considers all costs (capital, operating, and decommissioning expenses for the duration of a project) for various alternative approaches, including inflation and discount rates.

Line-item project – are the ones that are specifically reviewed and approved by Congress; a project with total cost greater than \$10 million.

Major system (MS) – is a project or system of projects having a total project cost of \$750 million or greater or designated by the Deputy Secretary as a major system.

Management reserve (MR) - determined by the contractor and represents the amount of the contractor budget that will be used for cost contingency arising from estimate uncertainties and realized risk events that are within the contractor's contractual obligations. Developed by the contractor after contract award, MR is maintained separately from the performance measurement baseline and is utilized by means of the contractor's change control process.

Milestone - a schedule event marking the due date for accomplishment of a specified effort (baseline activity) or objective. A milestone may mark the start, an interim step, or the completion of one or more activities.

Mitigate - to eliminate or lessen the likelihood and/or consequence of a risk.

Mitigation strategy - the risk handling strategy used to eliminate or lessen the likelihood and/or consequence of a risk.

Mission need - a required capability within DOE's overall purpose, scope, cost, and schedule considerations. Mission analysis or studies directed by an executive or legislative authority that identifies a deficiency or an opportunity will be set forth as justification for system acquisition approvals, planning, programming, and budget formulation.

Monte Carlo Analysis - a method of calculation that approximates solutions to a variety of mathematical problems by performing statistical sampling experiments on a computer; applies to problems with no probabilistic content as well as to those with inherent probabilistic structure.

Net present value (NPV) – is the difference between the discounted present values of benefits and costs.

Network logic – is the collection of activity dependencies that makes up a project network diagram.

Nominal interest rate - a rate that is not adjusted to remove the effects of actual or expected inflation. Market interest rates are generally nominal interest rates.

Objective reviews - a very structured approach using checklists and grading systems, which address consistency of projects estimated or procedures followed. Objective reviews may also indicate a minimum acceptable level of quality.

Operation - an ongoing endeavor or activity that uses strategic assets for a defined function or purpose.

Opportunity – is a risk with positive benefits.

Optimization - a technique that analyzes a system to find the best possible result. Finding an optimum result usually requires evaluating design elements, execution strategies and methods, and other system inputs for effect on cost, schedule, safety, or some other set of outcomes or objectives; employs computer simulation and mathematical modeling.

Other project costs - all other costs related to projects that are not included in the TEC. OPCs will include, but are not limited to: research and development; pre-authorization costs prior to start of conceptual design; plant support costs during construction; activation and startup; NEPA documentation; PDS; CDR; surveying for siting; and evaluation of RCRA/EPA/State permit requirements.

Performance-based management, contracting, and budgeting - cost and performance tied to quantities, establishing a baseline, and regularly reported to assess performance.

Performance baseline -

- A quantitative expression reflecting the total scope of a project with integrated technical, schedule, and cost elements; the established risk-adjusted, time-phased plan against which the status of resources and the progress of a projects are measured, assessed, and controlled; a Federal commitment to OMB and Congress. Once established, performance baselines are subject to change control.
- The cost portion of a performance baseline represents a project's total project cost after CD 2.

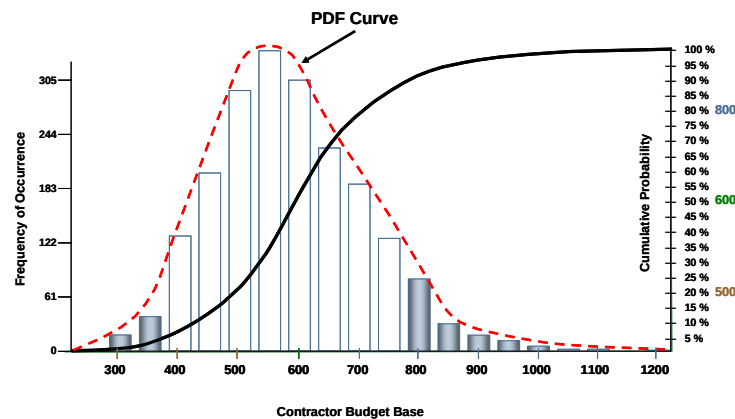
Preliminary design - continues the design effort using conceptual and project design criteria as bases for project development; develops topographical and subsurface data and determines the requirements and criteria that will govern the definitive design; includes preparation of preliminary planning and engineering studies, preliminary drawings and outline specifications, life-cycle cost analyses, preliminary cost estimates, and scheduling for project completion. Preliminary design provides identification of long-lead procurement items and analysis of risks associated with continued project development and occurs between CD-1 and CD-2.

Primary risk - initial risk entry in the risk register. A residual or secondary risk can become a primary risk if in the case of a residual risk the primary risk is closed and the Federal Project

Director and/or Contractor Project Manager determines the residual risk should be made the primary risk or the risk entry in the risk register. The secondary risk can become the primary risk in the risk register if the Federal Project Director and/or Contractor Project Manager determine that it should become the risk entry based upon the realization of the trigger metric or other determining factor.

Probability - likelihood of an event occurring, expressed as a qualitative and/or quantitative metric.

Probability Distribution Function (PDF) - a probability distribution, also described as a probability density function, represents the distribution of the probability of an outcome. As an example, the Monte Carlo analysis may be designed to estimate the cost or duration of a project. The PDF represents the number of times a certain cost or duration is achieved. (See the figure below.)



Productivity - consideration for factors that affect the efficiency of construction labor (e.g., location, weather, work space, coordination, schedule); a direct cost.

Program - an organized set of activities directed toward a common purpose or goal undertaken or proposed in support of an assigned mission area and characterized by a strategy for accomplishing a definite objectives, which identifies the means of accomplishment, particularly in quantitative terms, with respect to manpower, materials, and facilities requirements. Programs usually include an element of ongoing activity and are typically made up of technology, projects, and supporting operations.

Program risks - events identified as potential threats or opportunities that are within the program baseline cost or schedule.

Project - a unique effort that supports a program mission, having defined start and end points, undertaken to create a product, facility, or system, and containing interdependent activities planned to meet a common objective or mission. A project is a basic building block in relation to a program that is individually planned, approved, and managed. A project is not constrained to any specific element of the budget structure (e.g., operating expense or plant and capital equipment). Construction, if required, is part of the total project. Authorized, and at least partially appropriated, projects will be divided into two categories: major system projects and other projects. Projects include planning and execution of construction, renovation,

modification, environmental restoration, decontamination and decommissioning efforts, and large capital equipment or technology development activities. Tasks that do not include the above elements, such as basic research, grants, ordinary repairs, maintenance of facilities, and operations are not considered projects.

Project data sheet (PDS) - a document that summarizes project data and justifies a project as a part of the Departmental budget. PDSs are submitted to request project engineering design and construction funds. Specific instructions on the format and content of PDSs are contained in the annual budget call [DOE O 130.1, *Budget Formulation*, dated 9-29-95].

Project engineering and design (PED) funds - design funds established for use on preliminary design, which are operating expense funds.

Project execution plan (PEP) - the plan which establishes roles and responsibilities and defines how a project will be executed.

Project life cycle -

- A collection of generally sequential project phases with names and numbers determined by the control needs of the organization or organizations involved in the project.
- The stages or phases of project progress during the life of a project. Project life-cycle stages typically include ideation, planning, execution, and closure.

Project management - a structure in which authority and responsibility for executing a project are vested in a single individual to provide focus on the planning, organizing, directing, controlling, and closing of all activities within a project.

Project risk - risks that are captured within the scope, cost, or schedule of the project.

Project support - activities performed by the operating contractor for internal management and technical support of the project manager.

Qualitative risk analysis - involves assessing the probability and impact of project risks using a variety of subjective and judgmental techniques to rank or prioritize the risks.

Quantitative risk analysis - involves assessing the probability and impact of project risks and using more numerically based techniques, such as simulation and decision tree analysis for determining risk implications.

Range (cost estimate range) – is an expected range of costs for a project or its components. Ranges may be established based on a range of alternatives, confidence levels, or expected accuracy, and are dependent on a project's stage of development, size, complexity, and other factors.

Real property – is land and/or improvements or interests in them except for land in the public domain.

Reconciliation - comparison of a current estimate to a previous estimate to ensure that differences between them is appropriate and reasonably expected. A formal reconciliation may include an account of those differences.

Residual Risk – risk that remains after risk strategies have been implemented.

Resource - a consumable (other than time) required to accomplish an activity; include real or potential investment in strategic assets including time, money, human, and physical resources. A resource becomes a cost when it is invested or consumed in an activity or project.

Review - determination of project or system acquisition conditions based evaluation of project scope, cost, schedule, technical status, and performance in relation to program objectives, approved requirements, and baseline project plans. Reviews provide critical insight into the plans, design, cost, schedule, organization, and other aspects of a project (see definitions for *objective review* and *subject review*).

Objective review - one based on set criteria; a checklist approach to reviewing.

Review criteria - components of a review used to reflect the general nature of project (or project element) content.

Risk - factor, element, constraint, or course of action that introduces an uncertainty of outcome, either positively or negatively that could impact project objectives. This definition for risk is strictly limited for risk as it pertains to project management applications in the development of the overall risk management plan and its related documentation and reports.

Risk acceptance - an informed and deliberate decision to accept consequences and the likelihood of a particular risk.

Risk analysis - process by which risks are examined in further detail to determine the extent of the risks, how they relate to each other, and which ones are the highest risks.

Risk analysis method - the technique used to analyze the risks associated with a project. Specific categories of risk analysis methods are:

1. Qualitative - based on project characteristics and historical data (check lists, scenarios, etc.)
2. Risk models - combination of risks assigned to parts of the estimate or project to define the risk of the total project.
3. Probabilistic models - combining risks from various sources and events (e.g., Monte Carlo, Latin hypercube, decision tree, influence diagrams, etc.)

Risk assessment - identification and analysis of project and program risks ensuring an understanding of each risk in terms of probability and consequences.

Risk assumption – is any assumptions pertaining to the risk itself.

Risk category - a method of categorizing the various risks on the project to allow grouping for various analysis techniques such as Risk Breakdown Structure or Network Diagram.

Risk documentation – includes the recording, maintaining and reporting assessments, handling analysis and plans, and monitoring results.

Risk Event – is a potential (identified or unidentified) condition (threat or opportunity) that may or may not occur during the execution of a project.

Risk handling - strategies developed with the purpose of eliminating, or at least reducing, the higher risk levels identified during the risk analysis. The strategies may include risk reduction or mitigation, risk transfer/share, risk avoidance, and risk acceptance.

Risk handling strategy - process that identifies, evaluates, selects, and implements options in order to set risk at acceptable levels given project constraints and objectives. Includes specific actions, when they should be accomplished, who is the owner, and what is the cost and schedule.

Risk identification - process to find, list and characterize elements of risk.

Risk management - the handling of risks through specific methods and techniques.

Risk Management Plan - Documents how the risk processes will be carried out during the project.

Risk mitigation - process to reduce the consequence and/or probability of a risk.

Risk modeling - creation of a physical representation or mathematical description of an object, system or problem that reflects the functions or characteristics of the item involved. Model building may be viewed as both a science and an art. Cost estimate and critical path schedule development should be considered modeling practices and not exact representations of future costs, progress and outcomes.

Risk monitoring and tracking - process of systematically watching over time the evolution of the project risks and evaluating the effectiveness of risk strategies against established metrics.

Risk owner - the individual responsible for managing a specified risk and ensuring effective treatment plans are developed and implemented.

Risk planning - process of developing and documenting an organized, comprehensive, and interactive strategy and methods for identifying and tracking risk, performing continuous risk assessments to determine how risks have changed, developing risk handling plans, monitoring the performance of risk handling actions, and assigning adequate resources.

Risk register - database for risks associated with the project. (Also known as risk database or risk log.)

Risk transfer – is the movement of the risk ownership to another organizational element. (However, to be successfully and fully transferred, the risk should be accepted by the organization to which the risk is being transferred.)

S-curve (spending curve; funding profile) -

- Graphic display of cumulative costs, labor hours, or other quantities plotted against time. The name is derived from the S-shaped curve (flatter at the beginning and end, steeper in

the middle) produced on a project that starts slowly, accelerates, and then slows again.

- A representation of costs over the life of a project.

Schedule baseline - time phased project activity durations and milestone commitment dates by which projects are accomplished. The approved project schedule is a component of the overall project plan. The schedule baseline provides the basis for measuring and reporting schedule performance.

Schedule contingency - time allowance used to adjust schedule for realized DOE risks; based on the schedule risk analysis.

Schedule reserve - time allowance used to adjust schedule for realized risks within the contractor's baseline.

Secondary risk - risk arising as a direct result of implementing a risk handling strategy.

Scope - the sum of all that is to be or has been invested in and delivered by an activity or project. In project planning, the scope is usually documented (i.e., the scope document), but it may be verbally or otherwise communicated and relied upon. Generally limited to that which is agreed to by the stakeholders in an activity or project (i.e., if not agreed to, it is out of scope.). In contracting and procurement, scope includes all that an enterprise is contractually committed to perform or deliver.

Sensitivity analysis - considers all activities associated with one cost estimate. If a cost estimate can be sorted by total activity cost, unit cost, or quantity, sensitivity analyses can determine which activities are "cost drivers" to answer the question: "If something varies, what most affects the total cost of the project?"

Simulation, (Monte Carlo) - process for modeling the behavior of a stochastic (probabilistic) system. A sampling technique is used to obtain trial values for key uncertain model input variables. By repeating the process for many trials, a frequency distribution is built up, which approximates the true probability distribution for the system's output. This random sampling process, averaged over many trials, is effectively the same as integrating what is usually a very difficult or impossible equation.

Special equipment - large items of special equipment and process systems, such as vessels, (e.g., towers, reactors, storage tanks), heat transfer systems (e.g., heat exchangers, stacks, cooling towers, de-super-heaters), package units (e.g., waste treatment packages, clarifier packages, demineralization), and process piping systems.

Standard equipment - items which require only a minimum of design; off-the-shelf items (office furniture, laboratory equipment, heavy mobile equipment, and spare parts that are made part of the capital cost); a direct cost.

Start-up - one-time costs incurred during the transition from construction completion to facility operation.

Statement of work (SOW) – is a narrative description of contracted products or services.

String diagram - technique used to analyze the physical or proximity connections within a process. Technique is often used to find latent risks.

Subjective reviews - are less structured and may address areas differently, depending on various levels of emphasis. Internal reviews may combine objective and subjective criteria but should be performed consistently between projects within a program to the most practical extent.

Successful project - one that is completed or expected to be completed within the technical and schedule estimates of the performance baseline. Cost not to exceed by more than 10% of the original cost baseline approved at CD-2.

Technical risk - risks that include disciplines such as mechanical, electrical, chemical engineering, safety, safeguards and security, chemistry, biology, etc.

Threat - risk with negative consequences.

Total cost management - effective application of professional and technical expertise to plan and control resources, costs, profitability, and risks; a systematic approach to managing cost throughout the life cycle of any enterprise, program, facility, project, product, or service through the application of cost engineering and cost management principles, proven methodologies, and the latest technology in support of the management process. It can also be considered the sum of the practices and processes that an enterprise uses to manage the total life-cycle cost investment in its portfolio of strategic assets.

Total estimated cost (TEC) - all engineering design costs (after conceptual design), facility construction costs and other costs specifically related to those construction efforts. These are typically capitalized. TEC will include, but is not limited to: project, design and construction management during conceptual, preliminary and final design; contract modifications (to include equitable adjustments) resulting in changes to these costs; design and construction management reporting; contingency and economic escalation for TEC-applied elements; contractor support directly related to design and construction; and equipment rental and refurbishment.

Total project cost (TPC) - all costs between CD-0 and CD-4 specific to a project incurred through startup of a facility, but prior to the operation of the facility. Thus, TPC includes TEC and OPC.

Trending analysis - systematic tracking of performance against established or planned objectives.

Triangle distribution - subjective distribution of a population for which there is limited sample data. It is based on knowledge of the minimum and maximum and an inspired guess as to what the modal value might be. It is also used as an alternative to the Beta distribution in PERT, CPM, and similar forms of project management tools.

Uncertainty analysis - considers all activities associated with one cost estimate and their associated risks. An uncertainty analysis may also be considered part of a risk analysis or risk assessment.

Undistributed budget (UB) - funding associated with specific work scope or contract changes that have not been assigned to a control account or summary level planning package.

Unidentified Risks - risks that were not anticipated or foreseen by the IPT or by DOE-HQ staff members. Unidentified risks might originally be unanticipated because the probability of the event is so small that its occurrence is virtually unimaginable. Alternatively, an unidentified risk might be one that falls into an unanticipated or uncontrolled risk event category. (These risks are also categorized as “unknown-unknown” risks)

Validation - the process of evaluating project planning, development, baselines, and proposed funding before including a new project or system acquisition in the DOE program budget.

Value management - an organized effort to analyze the functions of systems, equipment, facilities, services, and supplies for the purpose of achieving essential functions at the lowest life-cycle cost that is consistent with required performance, quality, reliability, and safety.

Work breakdown structure (WBS) - product-oriented grouping of project elements that organizes and defines the total scope of the project; a multi-level framework that organizes and graphically displays elements representing work to be accomplished in logical relationships. Each descending level represents an increasingly detailed definition of a project component. Components may be products or services. The structure and code that integrate and relate all project work (technical, schedule, and cost) and are used throughout the life cycle of a project to identify and track specific work scope. Note: WBS should not be developed or organized along financial or organizational lines. It should be broken into organized blocks of work scope, and scope related activities. Financial and/or organizational identification needs should be attached as separate codes that relate to the WBS element.

Work package - a task or set of tasks performed within a control account.

Appendix C: Summary of Federal Requirements

Summary of Requirements

Generally, Federal requirements are promulgated by:

- Office of Management and Budget (OMB), which provides specifics for budgeting, discount rates, and management of projects (acquisitions) in their circulars.
- The Federal Acquisition Regulation (FAR), which provides Federal contract requirements for government estimates, cost and price analyses, and contract changes.
- The Code of Federal Regulations (CFR), which provides requirements for alternative considerations and life-cycle cost analyses.
- Various other Federal laws, such as the Government Performance and Results Act (GPRA), the Government Management Reform Act, the Federal Acquisition Reform Act, the Federal Acquisition Streamlining Act, the Information Technology Management Reform Act, the Chief Financial Officers Act (CFO Act), and others.

These Federal laws and policies drive the way DOE conducts business. DOE's Directives Management System is the means by which departmental policies, requirements, and responsibilities are developed and communicated. Directives are used to inform, direct, and Guide employees in the performance of their jobs and enable employees to work effectively within the Department and with Agencies, contractors, and the public.

The most significant, relevant DOE Orders include:

- DOE O 130.1, *Budget Formulation*, dated 9-29-95.
- DOE O 413.3B, *Program and Project Management for the Acquisition of Capital Assets*, dated 11-29-10.
- DOE O 430.1B Chg 1, *Real Property Asset Management*, dated 9-24-03.
- DOE O 520.1A Chg 1, *Chief Financial Officer Responsibilities*, dated 11-21-06.
- DOE O 534.1B, *Accounting*, dated 1-6-03.

This section includes a summary of Federal requirements stemming from Office of Management and Budget (OMB), the Code of Federal Regulations (CFR), Federal Acquisition Regulation (FAR), and Public Laws (P.L.) that drive DOE requirements for cost estimating relative to capital asset acquisitions and real property.

OMB Circular No. A-11, *Preparation, Submission, and Execution of the Budget* (7-21-10), Part 7, Planning, Budgeting, Acquisition, and Management of Capital Assets, provides the framework to guide Federal agencies through the process of formulating a cost-benefit analysis and ultimately the budget submission for Federal agency projects and programs. Major capital investments proposed for funding must:

- support Agency missions;
- support work redesign to cut costs and improve efficiency and use of off-the-shelf technology;
- be supported by a cost-benefit analysis based on both qualitative and quantitative measures;
- integrate work processes and information flows with technology to achieve the strategic

- goals;
- incorporate clear measures to determine not only a project's success, but also its compliance with a security plan;
- be acquired through a strategy that allocates the risk between the Government and the contractor and provides for the effective use of contracting; and
- ensure that the capital plan is operational and supports the Information resource management (IRM) strategic plan.

OMB Circular No. A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs* (October 29, 1992), provides an analytical framework for capital planning and investment control for information technology investments. The circular provides the information necessary to complete a thorough review of an IT investment's financial performance. Requirements include:

- evidence of a projected return on investment in the form of reduced cost; increased quality, speed, or flexibility; and improved customer and employee satisfaction; and
- a cost-benefit analysis for each information system throughout the life cycle that describes
 - level of investment,
 - performance measures , and
 - consistent methodology with regard to discount rates for cost benefit analyses of Federal programs.

10 CFR 436, Subpart A, *Methodology and Procedures for Life-Cycle Cost Analyses*, establishes methodology and procedures for estimating and comparing the life-cycle costs of Federal buildings, determining the life-cycle cost effectiveness of energy and water conservation measures, and rank-ordering life-cycle cost effectiveness measures in order to design a new Federal building or to retrofit an existing Federal building. It also establishes the method by which efficiency shall be considered when entering into or renewing leases of Federal building space.

In accordance with GAO-09-3SP, Chapter 5, *"A life-cycle cost estimate is a best practice because it provides an exhaustive and structured accounting of all resources and associated cost elements required to develop, produce, deploy, and sustain a program. As such, a life-cycle cost estimate should encompass all past (or sunk), present, and future costs for every aspect of the program, regardless of funding source. Life-cycle costing enhances decision making, especially in early planning and concept formulation of acquisition. Design trade-off studies conducted during this period can be evaluated on a total cost basis, as well as on a performance and technical basis. A life-cycle cost estimate can support budgetary decision, key decision points, milestone reviews, and investment decisions. Because they encompass all possible costs, life-cycle cost estimates provide a wealth of information about how much programs are expected to cost over time."*

Chief Financial Officers (CFO) Act of 1990 (P.L. 101-576)

Section 902(a) lists the CFO's regular duties. Among other things, these include:

- Develop and maintain an integrated Agency-accounting and financial management system, including financial reporting and internal controls, which:
 - Complies with applicable accounting principles, standards, and requirements and

internal control standards.

- Complies with such policies and requirements as may be prescribed by the Director of OMB.
- Complies with any other requirements applicable to such systems.

Provides for:

- Complete, reliable, consistent, and timely information, which is prepared on a uniform basis and which is responsive to the financial information needs of Agency management.
 - The development and reporting of cost information.
 - The integration of accounting and budgeting information.
 - The systematic measurement of performance.
- Direct, manage, and provide policy guidance and oversight of Agency financial management personnel, activities, and operations, including:
 - The preparation and annual revision of an Agency plan to (i) implement the 5-year financial management plan prepared by the Director of OMB under section 3512(a)(3) of this title and (ii) comply with the requirements established under sections 3515 and subsections (e) and (f) of section 3521 of this title.
 - The development of Agency financial management budgets.
 - The recruitment, selection, and training of personnel to carry out Agency financial management functions.
 - The approval and management of Agency financial management systems design or enhancement projects.
 - The implementation of Agency asset management systems, including systems for cash management, credit management, debt collection, and property and inventory management and control.

The CFO Act also set requirements for submission of annual financial statements and annual external audits.

Government Performance and Results Act (GPRA) of 1993, P.L. 103-62, establishes the foundation for budget decision making to achieve strategic goals in order to meet Agency mission objectives. GPRA provides for the establishment of strategic planning and performance measurement in the Federal government.

GPRA changes the way the Federal government does business, changes the accountability of Federal managers, shifts organizational focus to service quality and customer satisfaction, and improves how information is made available to the public. GPRA states that an organization's mission should drive its activities. Furthermore, GPRA states that the final measure of Federal program effectiveness and efficiency is results, and it requires organizations to measure their results through stated goals. It requires the development of annual performance plans and Agency strategic plans. It requires a return on investment that equals or exceeds those of alternatives.

Federal Managers Financial Integrity Act (FMFIA) of 1982 (P.L. 97-255), as codified in 31 U.S.C. 3512, requires accountability of financial and program managers for financial results of actions taken, control over the Federal government's financial resources, and protection of

Federal assets.

Paperwork Reduction Act of 1995 (P.L. 104-13) requires that Agencies perform their information resource management activities in an efficient, effective, and economical manner.

Federal Acquisition Streamlining Act of 1994 (P.L. 103-355) requires Agencies to establish cost, schedule, and measurable performance goals for all major acquisition programs and achieve, on average, 90% of those goals. OMB policy for performance-based management is also provided in this section.

Clinger-Cohen Act of 1996 (P.L. 104-106) requires Agencies to use a disciplined capital planning and investment control process to acquire, use, maintain, and dispose of IT. P.L. 104-208 directs the OMB to establish clear and concise direction regarding investments in major information systems and to enforce that direction through the budget process. The spirit and intent of ITMRA directs Agencies to ensure that IT investments are improving mission performance by:

- establishing goals to improve the efficiency and effectiveness of Agency operations and, as appropriate, the delivery of services to the public through the effective use of information technology;
- ensuring that performance measurements assess how effectively the information technology supports programs of the executive agency;
- quantitatively benchmarking processes in terms of cost, speed, productivity, and quality of outputs and outcomes where comparable processes and organizations in the public or private sectors exist;
- analyzing the missions of each executive agency and, based on the analysis, revising the executive agency's processes as appropriate before making significant investments in information technology; and
- ensuring that the information security policies, procedures, and practices of the executive agency are adequate.

Table C-1: Relevant Cost Estimating and EVM Legislation and Regulation

Applicable Agency	Name of Legislation or Regulation
All federal agencies	Government Performance and Results Act (GPRA) of 1993 (Among other things, GPRA requires agencies to prepare multiyear strategic plans that describe mission goals and methods for reaching them. The act also requires agencies to prepare annual program performance reports to review progress toward annual performance goals.)
All federal agencies	Clinger-Cohen Act of 1996 (Among other provisions, this law requires agencies to base decisions about Information Technology (IT) investments on quantitative and qualitative factors associated with the costs, benefits, and risks of those investments and to use performance data to demonstrate how well the IT expenditures support improvements to agency programs.)
All federal agencies	Federal Acquisition Regulation (FAR) Case 2004-019, Earned Value Management System (EVMS) Applicable Changes to Section 7.105 and Subpart 34.2

Source: GAO and DOD

Table C-2. Relevant Cost Estimating and EVM Policy

Applicable Agency	Name of Policy
All federal agencies	Office of Management and Budget (OMB) Circular No. A-11, <i>Preparation, Submission, and Execution of the Budget</i> , Part 7, 07-21-10
All federal agencies	Office of Management and Budget (OMB) Circular No. A-94, <i>Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs</i> , 10-29-92
All federal agencies	Office of Management and Budget (OMB) Circular No. A-109, <i>Major Systems Acquisitions</i> , April 5, 1976
All federal agencies	Office of Management and Budget (OMB) Memorandum for Chief Information Officers, No. M-05-23, <i>Improving Information Technology (IT) Project Planning and Execution</i> , August 4, 2005

Source: GAO, OMB, and DOD

Table C-3: Relevant Cost Estimating and EVM Guidance

Applicable Agency	Name of Guidance
All federal agencies	NDIA, PMSC, ¹³ <i>ANSI/EIA-748-A Standard for Earned Value Management System (EVMS) Intent Guide</i> , January 2006
All federal agencies	NDIA, PMSC, <i>Surveillance Guide</i> , October 2004
All federal agencies	NDIA, PMSC, <i>Integrating Risk Management with Earned Value Management</i>
All federal agencies	NDIA, PMSC, <i>Earned Value Management System Acceptance Guide</i> , November 2006

Source: DOD

¹³ National Defense Industrial Association (NDIA), Program Management Systems Committee (PMSC).

Federal Acquisition Regulation (FAR)

The FAR has many references to cost estimates and cost estimating. Some topics covered by the FAR that should be considered, especially in relation to the procurement or acquisition process, include:

- Acquisition
- Acquisition planning
- Alternate
- Architect-engineering services
- Best value
- Bundling
- Change order
- Claim
- Commercial item
- Component
- Computer software
- Construction
- Contract
- Cost or pricing data
- General and administrative (G&A) expense
- Indirect cost
- Indirect cost rate
- Information technology
- Inherently Government function
- Inspection
- Insurance
- Major system
- Make-or-buy program
- Market research
- Option
- Overtime
- Overtime premium
- Performance-based contracting
- Pricing
- Forward-pricing rate agreement
- Freight
- Warranty
- Waste reduction
- FOB-origin
- Value engineering
- FOB-destination
- Final indirect cost rate
- Task order
- Design-to-cost
- Residual value
- Cost sharing
- Cost realism
- Value engineering change proposal

Cost estimating and related topics can be found in the following sections of the FAR:

- Part 7, Acquisition Planning
- Part 10, Market Research
- Part 14, Sealed Bidding
- Part 15, Contracting by Negotiations
 - 15.4, Contract Pricing - Contains information on proposal analysis, cost and price analysis, technical analysis, and cost realism
 - 15.402, Pricing policy - Says “Contracting officers must (a) purchase supplies and services from responsible sources at fair and reasonable prices.”
 - 15.407-5, Estimating systems
- Part 16 - Contract Types
 - 16.4 - Incentive Contracts - Discusses establishing reasonable and attainable

- targets that are clearly communicated to the contractor and including appropriate incentive arrangements in contracts
- 16.402-2(f) - Says “Because performance incentives present complex problems in contract administration, the contracting officer should negotiate them in full coordination with Government engineering and pricing specialists”
- Part 34 - Major System Acquisitions
- Part 35 - Research and Development Contracting
- Part 36 - Construction and Architect-Engineering Contracts
- Part 37 - Service Contracting
- Part 42 - Contract Administration and Audit Services
- Part 43 - Contract Modifications
- Part 48 - Value Engineering

Appendix D: Summary of DOE Requirements

There are several DOE Orders that reference *cost estimating*. Among them, the primary DOE Orders are:

- DOE O 130.1, *Budget Formulation*, dated 9-29-95, establishes the processes for developing, reviewing, and exchanging budget data. DOE O 130.1 requires that budget formulation be performance based, supportive of the DOE strategic plans, measurable, verifiable, and based on cost estimates deemed reasonable by the program and field offices.
- DOE O 413.3B, *Program and Project Management for the Acquisition of Capital Assets*, dated 11-29-10, promotes the systematic acquisition of projects and emphasizes the necessity for managing successful projects. *DOE O 413.3B* defines particulars of the Critical Decision process: establishing protocol, authorities, and consistency between the DOE programs.
- DOE O 430.1B Chg 1, *Real Property Asset Management (RPAM)*, dated 9-24-03, establishes a corporate, holistic, and performance-based approach to real property life-cycle asset management that links real property asset planning, programming, budgeting, and evaluation to program mission projections and performance outcomes. The implementation of RPAM maintains requirements for cost estimates and Life Cycle Cost Analysis (LCCA). RPAM also includes DOE's requirements of the Facilities Information Management System (FIMS) and the Condition Assessment and Information System (CAIS). These systems require cost estimate information concerning replacement plant values (RPVs) and facility maintenance costs.
- DOE O 520.1A, *Chief Financial Officer Responsibilities*, dated 11-21-06, promotes the achievement of the objectives of the *CFO Act* (sound financial management policies and practices, effective internal controls, accurate and timely financial information, and well-qualified financial managers) by setting forth the functions, organizational roles, and specific financial management responsibilities of the CFO, the field CFOs, and other appropriate DOE officials.
- DOE O 534.1B, *Accounting*, dated 1-6-03, designates the requirements and responsibilities for the accounting and financial management of the DOE. Requirements include, but are not limited to establishing a single, integrated financial management system that serves program management, budgetary, and accounting needs so that DOE and integrated contract records contain sufficient details in accounting for all DOE funds, assets, liabilities, and costs.

Appendix E: Generic Review Criteria

When reviewing DOE cost estimates, this generic criterion is suggested as a minimum. All criteria should be addressed to be complete, and if all criteria are reasonably addressed, then the estimates represented may be considered of quality, reasonable and as accurate as possible. **The estimates should also have been prepared by following the GAO 12 steps for a High Quality Estimating Process (GAO-09-3SP) as recommended in this Guide.**¹⁴

Work Breakdown Structure (WBS) - A WBS should be consistent between the technical definition, cost estimate, and schedule. The use of a common WBS should be considered for consistency between projects within a program WBS. Use of a standardized code of accounts is also recommended.

Scope of Work - A scope of work should be commensurate with the planning phase size and complexity of the project and should be activity based to the most practical extent.

Direct and Indirect Costs - All direct costs should be included appropriately, *and* rates applied as percentages—including contract indirect and overhead rates or site indirect rates—should be documented and referenced in the basis of estimate. Indirect rates should be defined for consistent application and appropriate for a given project.

Escalation - Escalation should be included appropriately. The rates applied should be based upon those provided by DOE, or they should have some other documented basis. Escalation is the provision in a cost estimate for increases in the cost of equipment, material, labor, etc., due to continuing price changes over time. Escalation is used to estimate the future cost of a project or to bring historical costs to the present.

Contingency - Contingency should be included appropriately, based on apparent project risks or project risk analysis to the most possible extent. In any event, contingency should have a documented basis. Contingency may be calculated using a deterministic or probabilistic approach, but the method employed should be appropriate and documented.

Contingency is an amount included in an estimate to cover costs that may result from incomplete design, unforeseen and unpredictable conditions, or uncertainties. Contingency should also be commensurate with risk—a factor, element, constraint, or course of action in a project that introduces the uncertainty of outcomes and the possibilities of technical deficiencies, inadequate performances, schedule delays, or cost overruns that could impact a Departmental mission. In the evaluation of project risk, the potential impact and the probability of occurrence should be considered.

Contingency is most significant and appropriate for long-term projects and most order of magnitude and preliminary estimate classes with significant size and complexity. Contingency may be less significant for nearer term projects with less significant size and complexity.

¹⁴ GAO-09-3SP, Chapter 15, Validating the Estimate

Techniques - Cost estimating techniques employed should be appropriately based on estimate class and purpose, available technical information, time constraints, and compliance with planning and project size and complexity. The chosen techniques should facilitate systematic cost estimate duplication or verification.

Basis of Estimate Documentation - Documentation that should describe how an estimate, schedule, or other plan component was developed, and defines the information used in support of development. It should explain the origins and logic of all WBS elements. A basis document should commonly include a description of the scope, methodologies, references and defining deliverables, assumptions and exclusions, clarifications, adjustments, and level of uncertainty.

Cost Estimate Documentation - Cost estimate documentation should be easily discernable, traceable, and consistent. As a matter of great relative importance, cost estimate documentation should be very thorough (provided to the most possible extent). In most cases, documentation should be specific for a given project (or sub-project) and should be centrally maintained to assure technical/cost/schedule consistency, management focus, and ease of reference.

Cost Estimate Updates - Cost estimate updates should be considered and included, as appropriate, to reflect new information, given a project planning phase and/or execution. Previous versions of cost estimates should be appropriately considered, whether considering information contained in a previous estimate supporting a critical decision, a potential change to a project/contract/budget, or a value engineering study.

Life-Cycle Costs - Life-cycle costs should be appropriately included in estimates. Life-cycle cost estimates are most pertinent during the decision-making phases of a project's life, or when LCC analyses (comparison of life-cycle cost estimates or VE Studies) are performed, but should also be considered throughout a project's life.

Life-cycle costs should include: start-up costs, operating costs, manufacturing costs, machining costs, research and development costs, engineering costs, design costs, equipment costs, construction costs, inspection costs, and decommissioning costs, as well as direct costs, indirect costs, overhead costs, fees, contingency, and escalation costs.

Qualified Cost and Schedule Estimators - Normally, cost and schedule estimators/cost engineers and risk managers are an important part of an integrated project team. Cost estimates should be performed and documented by those qualified to do so. Professional cost and schedule estimators, and cost engineers are trained in the use of cost estimating tools, techniques, and all aspects of estimating, project control, and project management.

Appendix F: Example of the Calculation and Use of Economic Escalation

Economic cost escalation should be included in all estimates where TPC may be affected by inflation or increases in unit costs. Following are the steps in calculating escalation amounts.

Step 1 – Finalize the estimate cost in “current dollars” and develop a corresponding schedule estimate. Ensure that the cost and schedule estimates are organized by a common WBS.

Step 2 - Determine the midpoint of primary scheduled activity groups (e.g., design, construction, construction management, start-up, etc.)

Step 3 - Select appropriate escalation rates by using the estimate preparation date (“today”) as the index date for determining the rates. The rates are ideally based on documented information for the worksite location, but alternative rates provided by DOE/HQ may be used in the absence of appropriate local information.

Step 4 – Calculate the estimate of escalation for each scheduled activity grouping by applying the rates selected in Step 3 to the midpoint dates determined in Step 2. A straight-line spending curve application may be assumed, although other spending curves may be used, as appropriate.

To illustrate the application of escalation calculations, following is an example of a five-year project. The Tables F-1 through F-4 presents the stages necessary for calculating cost escalation. Note that major activity groupings defined as “scheduled activity.”

**Table F-1. Escalation Example - Step 1, Sample Project Cost Estimate Summary
Represents the Estimate Summary Prior to Adding Cost Escalation**

WBS	Scheduled Activity	Total Base Cost (000\$)	Start	Duration (Months)	Complete	Midpoint
A1A	Preliminary Design (Title I Design)	100	10/1/02	6	3/30/03	1/1/03
A1B	Definitive Design (Title II Design)	200	4/1/03	6	9/30/03	7/1/03
A1C	Design During Construction (Title III Design)	100	10/1/03	36	9/30/06	7/1/05
B2A	Equipment Procurement (General Services)	200	10/1/04	24	9/30/06	10/1/05
B2B	Equipment Procurement (Long-Lead, GFE)	2,500	3/30/03	18	9/30/04	1/1/04
B2C	Facility Construction	6,000	10/1/04	37	9/30/06	10/1/05
C1A	Project Management	500	10/1/02	48	9/30/06	10/1/04
C1B	Construction Management	250	10/1/02	48	9/30/06	10/1/04

WBS	Scheduled Activity	Total Base Cost (000\$)	Start	Duration (Months)	Complete	Midpoint
C1C	Project Support	250	10/1/02	48	9/30/06	10/1/04
	Totals	10,100				

Table F-2 provides illustrative DOE escalation rates taken from the DOE Budget Formulation Handbook. Site specific rates based on documented information for the worksite location are best, but alternative rates provided by DOE/HQ (when available) are used in the absence of appropriate local information. Regardless of the source, the rates used, and the reason for using them should be clearly explained in the cost estimate documentation. In the table, “index” represents the compounded escalation rate as a factor for multiplying costs in a given year. The “%” term is the expected percentage of cost increase in each stated year. Thus, the 1.076 construction index in 2005 is determined from the 2003, 2004 and 2005 escalation percentages as follows: 1.021 (2003 percentage)x 1.025 (2004 percentage)x 1.029 (2005 percentage)= 1.076. Thus, 1.076 would be the factor to multiply costs estimated in 2002 and expected to occur in 2005.

Table F-2. DOE Escalation Rates (as of January 2002)

Project Categories *										
FY	Construction		EM		IT		O&M		R&D	
2002	Index	%	Index	%	Index	%	Index	%	Index	%
2003	1.021	2.1	1.02	2	1.008	0.8	1.018	1.8	1.023	2.3
2004	1.046	2.5	1.047	2.7	1.017	0.9	1.045	2.6	1.051	2.8
2005	1.076	2.9	1.075	2.7	1.022	0.5	1.073	2.7	1.08	2.7
2006	1.106	2.8	1.103	2.6	1.032	1	1.101	2.6	1.108	2.6
2007	1.135	2.6	1.13	2.4	1.041	0.8	1.127	2.4	1.136	2.5

Table F-3 provides a table of monthly escalation rates through the corresponding fiscal years. This example assumes a straight-line escalation for each FY, although other applications may be appropriate (e.g., weighted at the beginning or end of a FY). Use of the escalation “curve” (i.e., straight-line or other) and the reason it was selected should be well-documented. From the table, the escalation rate to apply to costs estimated “today” and expected to occur in July 2005 would be 9.17%.

Table F-3. Illustrative Monthly Escalation Rates

Months of Escalation		0	1	2	3	4	5	6	7	8	9	10	11	12
Month of the Year (Mid-Point)		10	11	12	1	2	3	4	5	6	7	8	9	10
FY	Rate													
2002	2.10%	0.00%	0.17%	0.35%	0.52%	0.70%	0.87%	1.05%	1.22%	1.40%	1.57%	1.75%	1.92%	2.10%
2003	2.10%	2.10%	2.28%	2.46%	2.64%	2.81%	2.99%	3.17%	3.35%	3.53%	3.71%	3.89%	4.07%	4.24%
2004	2.50%	4.24%	4.46%	4.68%	4.90%	5.11%	5.33%	5.55%	5.76%	5.98%	6.20%	6.42%	6.63%	6.85%
2005	2.90%	6.85%	7.11%	7.37%	7.62%	7.88%	8.14%	8.40%	8.66%	8.92%	9.17%	9.43%	9.69%	9.95%
2006	2.80%	9.95%	10.21%	10.46%	10.72%	10.98%	11.23%	11.49%	11.74%	12.00%	12.26%	12.51%	12.77%	13.03%
2007	2.60%	13.03%	13.27%	13.52%	13.76%	14.01%	14.25%	14.50%	14.74%	14.99%	15.23%	15.48%	15.72%	15.97%
2008	2.60%	15.97%	16.22%	16.47%	16.72%	16.97%	17.22%	17.47%	17.72%	17.98%	18.23%	18.48%	18.73%	18.98%

Table F-4 provides an example of the project cost estimate summary with columns added to illustrate compound escalation rates and escalation amounts by summary WBS element.

In calculating applicable escalation percentages, repetitive calculations are normal, so use of a computerized escalation forecast algorithm is recommended. The specific conditions that prevail must also be taken into account. For example, a construction subcontract awarded to span multiple fiscal years at a firm fixed-price would not need to have escalation applied to the cost of that contract.

Table F-4. Sample Project Cost Estimate Summary (Including Escalation)

WBS	Scheduled Activity	Total Base Cost (000\$)	Start	Duration (Months)	Complete	Midpoint	Compounded Escalation Rate	Total Escalation Cost (000\$)
A1A	Preliminary Design (Title I Design)	100	10/1/02	6	3/30/03	1/1/03	2.64%	103
A1B	Definitive Design (Title II Design)	200	4/1/03	6	9/30/03	7/1/03	3.71%	207

WBS	Scheduled Activity	Total Base Cost (000\$)	Start	Duration (Months)	Complete	Midpoint	Compounded Escalation Rate	Total Escalation Cost (000\$)
A1C	Design during Construction (Title III Design)	100	10/1/03	36	9/30/06	7/1/05	9.17%	109
B2A	Equipment Procurement (General Services)	200	10/1/04	24	9/30/06	10/1/05	9.95%	220
B2B	Equipment Procurement (Long-Lead, GFE)	2,500	3/30/03	18	9/30/04	1/1/04	4.90%	2,623
B2C	Facility Construction	6,000	10/1/04	37	9/30/06	10/1/05	9.95%	6,597
C1A	Project Management	500	10/1/02	48	9/30/06	10/1/04	6.85%	534
C1B	Construction Management	250	10/1/02	48	9/30/06	10/1/04	6.85%	267
C1C	Project Support	250	10/1/02	48	9/30/06	10/1/04	6.85%	267
	Totals	10,100						10,927

NOTE

Cost vs. Obligations - Funding Profile

A funding profile is a normal part of budget submissions. There is a difference between the timing of project costs and obligations and funding requirements. As a project evolves, it should be very clear that funds are required prior to spending them. This lead time should be carefully evaluated and established by the project team. Care should be taken to establish the most appropriate funding profile to provide for efficient use of funds and to minimize carry-over (where funds are not obligated within the FY for which they are authorized).

Appendix G: Example of Life-Cycle Cost Analysis

OMB A-94 - Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs provides guidance in performing cost-benefit analyses, or life-cycle cost analyses (LCCA). Per OMB, LCCAs should always consider all pertinent costs and benefits. Due to the nature of projects considered in fulfilling missions of the DOE, LCCAs may include a component of benefits which may be depicted as costs to be avoided or saved as a result of a particular alternative. DOE has very few income or revenue streams. However, as a part of life-cycle analyses, all benefits and costs should be recognized, including those that are difficult to quantify (such as benefits to the public or the general economy).

Generally, the steps in performing LCCA are as follows:

- Step 1** – Determine cost estimate summary funding profile for base case and for each alternative case, including all costs and benefits.
- Step 2** - Determine appropriate discount rates to be used. Note discussion on real and nominal discount rates. If escalation is included in the cost estimate summary, use nominal discount rates established by OMB.
- Step 3** - Calculate appropriate discount factors, using the rates determined in Step 2.
- Step 4** - Calculate present-worth (PW) of base case and each alternative case.
- Step 5** - Compare all alternatives and determine the most cost-effective alternative. The lowest PW is the preferred alternative from an economic perspective.

Following is an example that generally shows the steps to be used in performing LCCA.

Step 1 - Determine the cost estimate summary funding profile for the base case and each alternative case being considered, including all costs and benefits. It is important to ensure that similar functions and activities are considered together (e.g., consistent use of a work breakdown structure or account code) to make the scenario as comparable as possible. Table G-2 and Table G-3 are examples of these summary tables.

Step 2 - Determine appropriate discount rates to be used. If escalation is included in the cost estimate summary, as in this example, use nominal discount rates established by OMB. The following information may also be found in OMB A-94. It is updated biannually.

Nominal Discount Rates - A forecast of nominal or market interest rates for 2003 based on the economic assumptions from the 2004 Budget are presented below. These nominal rates are to be used for discounting nominal flows, which are often encountered in lease-purchase analysis.

Table G-1. Nominal Interest Rates on Treasury Notes and Bonds of Specified Maturities (in Percent)

3-Year	5-Year	7-Year	10-Year	30-Year
3.1	3.6	3.9	4.2	5.1

Real Discount Rates - A forecast of real interest rates from which the inflation premium has been removed and based on the economic assumptions from the 2004 Budget are presented below in Table G-4. These real rates are to be used for discounting real (constant-dollar) flows, as is often required in cost-effective analysis.

**Table G-2. Example LCCA – Step 1
Life-Cycle Cost Estimate Summary, Base Case**

WBS	Activity	TPC	03	04	05	06	07	08	09	10	11	12	13	14	15
A1A	Preliminary Design	103	103												
A1B	Definitive Design	207	207												
A1C	Design During Construction	109		37	37	36									
B2A	Equipment Procurement (General Services)	220			110	110									
B2B	Equipment Procurement (Long- Lead, GFE)	2,623	2000	623											
B2C	Facility Construction	6,597		1500	3597	1500									
C1A	Project Management	534	75	175	175	109									
C1B	Construction Management	267	25	100	100	42									
C1C	Project Support	267	25	100	100	42									
E	Contingency (DOE-Held)	86	10	25	25	26									
	Total Project Costs (Escalated)	11,193	2,445	2,560	4,144	1,866	-	-	-	-	-	-	-	-	-
		Annual													
F	Operations (LOE)	250			269	277	284	291	299	307	315	323	331	340	349
G	Security (LOE)	100		105	108	111	114	117	120	123	126	129	132	136	139
H	Infrastructure (LOE)	50		52	54	55	57	58	60	61	63				
I	Maintenance (LOE)	100		105	108	111	114	117	120	123	126	129	132	136	139
J	Transition (LOE)	50										65	66	68	70
K	Decontamination (LOE)	50									63	65	66	68	70

WBS	Activity	TPC	03	04	05	06	07	08	09	10	11	12	13	14	15
L	Decommissioning (LOE)	50									63	65	66	68	70
M	Demolition (LOE)	500										646	662	680	697
	Total Operations (Escalated)	21,392	2,445	2,822	4,682	2,419	568	583	598	613	755	1,420	1,457	1,495	1,534
	Total Life-Cycle Costs (Escalated)	32,585	4,890	5,382	8,826	4,285	568	583	598	613	755	1,420	1,457	1,495	1,534

**Table G-3. Example LCCA – Step 1
Life-Cycle Cost Estimate Summary, Alternative Case**

	Activity	TPC	03	04	05	06	07	08	09	10	11	12	13	14	15
A	Design During Construction/Renovation	50	50												
B2A	Procurement/Lease Facility	1,560	102	105	108	111	114	117	120	123	126	129	132	136	139
B2C	Facility Construction/Renovation	6,597		1500	3597	1500									
C1A	Project Management	150	25	50	50	25									
C1B	Construction Management	100	25	50	25										
C1C	Project Support	60	10	40	10										
E	Contingency (DOE-Held)	78	5	5	5	6	6	6	6	6	6	6	7	7	7
	Total Project Costs (Escalated)	11,193	217	1,750	3,795	1,641	119	122	126	129	132	136	139	143	146
		Annual													
F	Operations (LOE)	250			269	277	284	291	299	307	315	323	331	340	349
G	Security (LOE)	100		105	108	111	114	117	120	123	126	129	132	136	139
H	Infrastructure (LOE)	50		52	54	55	57	58	60	61	63				
I	Maintenance (LOE)	100		105	108	111	114	117	120	123	126	129	132	136	139
J	Transition (LOE)	50										65	66	68	70
K	Decontamination (LOE)	50									63	65	66	68	70
L	Decommissioning (LOE)	50									63	65	66	68	70
M	Demolition (LOE)	500													

	Activity	TPC	03	04	05	06	07	08	09	10	11	12	13	14	15
	Total Operations (Escalated)	7,693	-	262	538	554	568	583	598	613	755	775	795	816	837
	Total Life-Cycle Costs (Escalated)	18,886	217	2,012	4,334	2,195	687	705	723	742	887	910	934	958	983

Table G-4. Real Interest Rates on Treasury Notes and Bonds of Specified Maturities (in Percent)

3-Year	5-Year	7-Year	10-Year	30-Year
1.6	1.9	2.2	2.5	3.2

Analyses of programs with terms different from those presented above may use a linear interpolation. For example, a four-year project can be evaluated with a rate equal to the average of the three-year and five-year rates. Programs with durations longer than 30 years may use the 30-year interest rate.

Step 3 - Calculate appropriate discount factors, using the appropriate discount rates. The discount factor is calculated as:

$$1/(1 + i)^t$$

where **i** is the discount rate and **t** is the year. For this example, a nominal discount rate is calculated for a ~15-year project, to be ~4.4%. Discount factors are calculated in Table G-5.

Step 4 - Calculate PW of base case and each alternative case using the discount factors calculated in Step 3. Table G-6 and G-7 show the results of this calculation.

**Table G-5. Example LCCA – Step 3, Discount Rate Application,
Discount Factor Calculation**

FY	Consecutive Year	Discount Rate	Discount Factor
2003	1	0.044	0.9579
2004	2	0.044	0.9175
2005	3	0.044	0.8788
2006	4	0.044	0.8418
2007	5	0.044	0.8063
2008	6	0.044	0.7723
2009	7	0.044	0.7398
2010	8	0.044	0.7086
2011	9	0.044	0.6787
2012	10	0.044	0.6501
2013	11	0.044	0.6227
2014	12	0.044	0.5965
2015	13	0.044	0.5713
2016	14	0.044	0.5473
2017	15	0.044	0.5242

Table G-6. Example LCCA – Step 4
Cost Estimate Summary, Including Present Worth, Base Case

	Activity	TPC	03	04	05	06	07	08	09	10	11	12	13	14	15
A1A	Preliminary Design	103	103												
A1B	Definitive Design	207	207												
A1C	Design During Construction	109			37	36									
B2A	Equipment Procurement (General Services)	220	37		110	110									
B2B	Equipment Procurement (Long-Lead, GFE)	2,623	2000	623											
B2C	Facility Construction	6,597			3597	1500									
C1A	Project Management	534	751	500 175	175	109									
C1B	Construction Management	267	25	100	100	42									
C1C	Project Support	267	25	100	100	42									
E	Contingency (DOE-Held)	86	10	25	25	26									
	Total Project Costs (Escalated)	11,193	2,445	2,560	4,144	1,866	-	-	-	-	-	-	-	-	-
		Annual													
F	Operations (LOE)	250				277	284	291	299	307	315	323	331	340	349
G	Security (LOE)	100			108	111	114	117	120	123	126	129	132	136	139
H	Infrastructure (LOE)	50			54	55	57	58	60	61	63				
I	Maintenance (LOE)	100			108	111	114	117	120	123	126	129	132	136	139
J	Transition (LOE)	50										65	66	68	70
K	Decontamination (LOE)	50									63	65	66	68	70

	Activity	TPC	03	04	05	06	07	08	09	10	11	12	13	14	15
L	Decommissioning (LOE)	50									63	65	66	68	70
M	Demolition (LOE)	500										646	662	680	697
	Total Operations (Escalated)	10,378	-	262	538	554	568	583	598	613	755	1,420	1,457	1,495	1,534
	Total Life-Cycle Costs (Escalated)	21,571	2,445	2,822	4,682	2,419	568	583	598	613	755	1,420	1,457	1,495	1,534
			0.9579	0.9175	0.8788	0.8418	0.8063	0.7723	0.7398	0.7086	0.6787	0.6501	0.6227	0.5965	0.5713
	Discounted Costs (PW)	16,979	2,342	2,589	4,115	2,036	458	450	442	435	513	923	908	892	877

Table G-7. Example LCCA – Step 4
Cost Estimate Summary, Including Present Worth, Alternative Case

	Activity	TPC	03	04	05	06	07	08	09	10	11	12	13	14	15
A	Design During Construction/Renovation	50	50												
B2A	Procurement/Lease Facility	1,560	102	105	108	111	114	117	120	123	126	129	132	136	139
B2C	Facility Construction/Renovation	6,597		1500	3597	1500									
C1A	Project Management	150	25	50	50	25									
C1B	Construction Management	100	25	50	25										
C1C	Project Support	60	10	40	10										
E	Contingency (DOE-Held)	78	5	5	5	6	6	6	6	6	6	6	7	7	7
	Total Project Costs (Escalated)	11,193	217	1,750	3,795	1,641	119	122	126	129	132	136	139	143	146
		Annual													
F	Operations (LOE)	250			269	277	284	291	299	307	315	323	331	340	349
G	Security (LOE)	100		105	108	111	114	117	120	123	126	129	132	136	139
H	Infrastructure (LOE)	50		52	54	55	57	58	60	61	63				
I	Maintenance (LOE)	100		105	108	111	114	117	120	123	126	129	132	136	139
J	Transition (LOE)	50										65	66	68	70
K	Decontamination (LOE)	50									63	65	66	68	70
L	Decommissioning (LOE)	50									63	65	66	68	70

	Activity	TPC	03	04	05	06	07	08	09	10	11	12	13	14	15
M	Demolition (LOE)	500													
	Total Operations (Escalated)	7,693	-	262	538	554	568	583	598	613	755	775	795	816	837
	Total Life-Cycle Costs (Escalated)	18,886	217	2,012	4,334	2,195	687	705	723	742	887	910	934	958	983
			0.9579	0.9175	0.8788	0.8418	0.8063	0.7723	0.7398	0.7086	0.6787	0.6501	0.6227	0.5965	0.5713
	Discounted Costs (PW)	12,778	208	1,846	3,808	1,847	554	545	535	526	602	592	582	572	562

Step 5 - Compare all alternatives and determine the most cost-effective one. The lowest PW is the preferred alternative, from an economic perspective. Table G-8 shows an example summary of this PW comparison and clearly shows the most cost-effective alternative.

Table G-8. Example LCCA – Step 5, Summary of Base Case and Alternative Discounted Costs, or PW

Activity FY	Base Case	Alt Case
03	2,342	208
04	2,589	1,846
05	4,115	3,808
06	2,036	1,847
07	458	554
08	450	545
09	442	535
10	435	526
11	513	602
12	923	592
13	908	582
14	892	572
15	877	562
PW	16,979	12,778

A standard for life-cycle cost analysis (LCCA) is currently being established by the National Institute for Science and Technology (NIST).

January 15, 2011

Appendix H: Cost Estimate Classifications (AACEI)

The following Association for the Advancement of Cost Engineering International (AACEI) Recommended Practices, No. 17R-97, *Cost Estimate Classification System*, and No. 18R-97, *Cost Estimate Classification System – As Applied in Engineering, Procurement and Construction for the Process Industries*, dated January 15, 2011; provide guidance for classifying project cost estimates.

Reprinted with the permission of AACE International
209 Prairie Ave., Suite 100, Morgantown, WV 25601 USA.
Phone 800-858-COST/304-296-8444
Fax: 304-291-5728
Internet: <http://www.aacei.org> E-mail: info@aacei.org
Copyright © by AACE International; all rights reserved.

Cost Estimate Classification System – As Applied in Engineering
Procurement, and Construction for the Process Industries

January 15, 2011

PURPOSE

As a recommended practice of AACE International, the Cost Estimate Classification System provides guidelines for applying the general principles of estimate classification to asset project cost estimates. Asset project cost estimates typically involve estimates for capital investment, and exclude operating and life-cycle evaluations. The Cost Estimate Classification System maps the phases and stages of asset cost estimating together with a generic maturity and quality matrix that can be applied across a wide variety of industries.

This guideline and its addenda have been developed in a way that:

- provides common understanding of the concepts involved with classifying project cost estimates, regardless of the type of enterprise or industry the estimates relate to;
- fully defines and correlates the major characteristics used in classifying cost estimates so that enterprises may unambiguously determine how their practices compare to the guidelines;
- uses degree of project definition as the primary characteristic to categorize estimate classes; and
- Reflects generally-accepted practices in the cost engineering profession.

An intent of the guidelines is to improve communication among all of the stakeholders involved with preparing, evaluating, and using project cost estimates. The various parties that use project cost estimates often misinterpret the quality and value of the information available to prepare cost estimates, the various methods employed during the estimating process, the accuracy level expected from estimates, and the level of risk associated with estimates.

This classification guideline is intended to help those involved with project estimates to avoid misinterpretation of the various classes of cost estimates and to avoid their misapplication and misrepresentation. Improving communications about estimate classifications reduces business costs and project cycle times by avoiding inappropriate business and financial decisions, actions, delays, or disputes caused by misunderstandings of cost estimates and what they are expected to represent.

This document is intended to provide a guideline, not a standard. It is understood that each enterprise may have its own project and estimating processes and terminology, and may classify estimates in particular ways. This guideline provides a generic and generally-acceptable classification system that can be used as a basis to compare against. If an enterprise or organization has not yet formally documented its own estimate classification scheme, then this guideline may provide an acceptable starting point.

INTRODUCTION

An AACE International guideline for cost estimate classification for the process industries was developed in the late 1960s or early 1970s, and a simplified version was adopted as an ANSI Standard Z94.0 in 1972. Those guidelines and standards enjoy reasonably broad acceptance within the engineering and

January 15, 2011

construction communities and within the process industries. This recommended practice guide and its addenda improves upon these standards by:

1. providing a classification method applicable across all industries; and
2. unambiguously identifying, cross-referencing, benchmarking, and empirically evaluating the multiple characteristics related to the class of cost estimate.

This guideline is intended to provide a generic methodology for the classification of project cost estimates in any industry, and will be supplemented with addenda that will provide extensions and additional detail for specific industries.

CLASSIFICATION METHODOLOGY

There are numerous characteristics that can be used to categorize cost estimate types. The most significant of these are degree of project definition, end usage of the estimate, estimating methodology, and the effort and time needed to prepare the estimate. The “primary” characteristic used in this guideline to define the classification category is the degree of project definition. The other characteristics are “secondary.”

Categorizing cost estimates by degree of project definition is in keeping with the AACE International philosophy of Total Cost Management, which is a quality-driven process applied during the entire project life cycle. The discrete levels of project definition used for classifying estimates correspond to the typical phases and gates of evaluation, authorization, and execution often used by project stakeholders during a project life cycle.

Five cost estimate classes have been established. While the level of project definition is a continuous spectrum, it was determined from benchmarking industry practices that three to five discrete categories are commonly used. Five categories are established in this guideline as it is easier to simplify by combining categories than it is to arbitrarily split a standard.

The estimate class designations are labeled Class 1, 2, 3, 4, and 5. A Class 5 estimate is based upon the lowest level of project definition, and a Class 1 estimate is closest to full project definition and maturity. This arbitrary “countdown” approach considers that estimating is a process whereby successive estimates are prepared until a final estimate closes the process.

Cost Estimate Classification System – As Applied in Engineering
Procurement, and Construction for the Process Industries

January 15, 2011

ESTIMATE CLASS	Primary Characteristic	Secondary Characteristic			
	LEVEL OF PROJECT DEFINITION Expressed as % of complete definition	END USAGE Typical purpose of estimate	METHODOLOGY Typical estimating method	EXPECTED ACCURACY RANGE Typical +/- range relative to best index of 1 [a]	PREPARATION EFFORT Typical degree of effort relative to least cost index of 1 [b]
Class 5	0% to 2%	Screening or Feasibility	Stochastic or Judgment	4 to 20	1
Class 4	1% to 15%	Concept Study or Feasibility	Primarily Stochastic	3 to 12	2 to 4
Class 3	10% to 40%	Budget, Authorization, or Control	Mixed, but Primarily Stochastic	2 to 6	3 to 10
Class 2	30% to 70%	Control or Bid/Tender	Primarily Deterministic	1 to 3	5 to 20
Class 1	50% to 100%	Check Estimate or Bid/Tender	Deterministic	1	10 to 100

Notes: [a] If the range index value of "1" represents +10/-5%, then an index value of 10 represents +100/-50%.

[b] If the cost index value of "1" represents 0.005% of project costs, then an index value of 100 represents 0.5%.

Figure 1 – Generic Cost Estimate Classification Matrix

DEFINITIONS OF COST ESTIMATE CHARACTERISTICS

The following are brief discussions of the various estimate characteristics used in the estimate classification matrix. For the secondary characteristics, the overall trend of how each characteristic varies with the degree of project definition (the primary characteristic) is provided.

Level of Project Definition (Primary Characteristic)

This characteristic is based upon percent complete of project definition (roughly corresponding to percent complete of engineering). The level of project definition defines maturity or the extent and types of input information available to the estimating process. Such inputs include project scope definition, requirements documents, specifications, project plans, drawings, calculations, learning from past projects, reconnaissance data, and other information that must be developed to define the project. Each industry will have a typical set of deliverables that are used to support the class of estimates used in that industry. The set of deliverables becomes more definitive and complete as the level of project definition (e.g., project engineering) progresses.

January 15, 2011**End Usage (Secondary Characteristic)**

The various classes (or phases) of cost estimates prepared for a project typically have different end uses or purposes. As the level of project definition increases, the end usage of an estimate

typically progresses from strategic evaluation and feasibility studies to funding authorization and budgets to project control purposes.

Estimating Methodology (Secondary Characteristic)

Estimating methodologies fall into two broad categories: stochastic and deterministic. In stochastic methods, the independent variable(s) used in the cost estimating algorithms are generally something other than a direct measure of the units of the item being estimated. The cost estimating relationships used in stochastic methods often are somewhat subject to conjecture. With deterministic methods, the independent variable(s) are more or less a definitive measure of the item being estimated. A deterministic methodology is not subject to significant conjecture. As the level of project definition increases, the estimating methodology tends to progress from stochastic to deterministic methods.

Expected Accuracy Range (Secondary Characteristic)

Estimate accuracy range is an indication of the degree to which the final cost outcome for a given project will vary from the estimated cost. Accuracy is traditionally expressed as a +/- percentage range around the point estimate after application of contingency, with a stated level of confidence that the actual cost outcome would fall within this range (+/- measures are a useful simplification, given that actual cost outcomes have different frequency distributions for different types of projects). As the level of project definition increases, the expected accuracy of the estimate tends to improve, as indicated by a tighter +/- range.

Note that in figure 1, the values in the accuracy range column do not represent + or - percentages, but instead represent an index value relative to a best range index value of 1. If, for a particular industry, a Class 1 estimate has an accuracy range of +10/-5 percent, then a Class 5 estimate in that same industry may have an accuracy range of +100/-50 percent.

Effort to Prepare Estimate (Secondary Characteristic)

The level of effort needed to prepare a given estimate is an indication of the cost, time, and resources required. The cost measure of that effort is typically expressed as a percentage of the total project costs for a given project size. As the level of project definition increases, the amount of effort to prepare an estimate increases, as does its cost relative to the total project cost. The effort to develop the project deliverables is not included in the effort metrics; they only cover the cost to prepare the cost estimate itself.

RELATIONSHIPS AND VARIATIONS OF CHARACTERISTICS

There are a myriad of complex relationships that may be exhibited among the estimate characteristics within the estimate classifications. The overall trend of how the secondary characteristics vary with the

Cost Estimate Classification System – As Applied in Engineering Procurement, and Construction for the Process Industries

January 15, 2011

level of project definition was provided above. This section explores those trends in more detail. Typically, there are commonalities in the secondary characteristics between one estimate and the next, but in any given situation there may be wide variations in usage, methodology, accuracy, and effort.

The level of project definition is the “driver” of the other characteristics. Typically, all of the secondary characteristics have the level of project definition as a primary determinant. While the other characteristics are important to categorization, they lack complete consensus. For example, one estimator’s “bid” might be another’s “budget.” Characteristics such as “accuracy” and “methodology” can vary markedly from one industry to another, and even from estimator to estimator within a given industry.

Level of Project Definition

Each project (or industry grouping) will have a typical set of deliverables that are used to support a given class of estimate. The availability of these deliverables is directly related to the level of project definition achieved. The variations in the deliverables required for an estimate are too broad to cover in detail here; however, it is important to understand what drives the variations. Each industry group tends to focus on a defining project element that “drives” the estimate maturity level. For instance, chemical industry projects are “process-equipment centric” (i.e., the level of project definition and subsequent estimate maturity level is significantly determined by how well the equipment is defined). Architectural projects tend to be “structure-centric,” software projects tend to be “function-centric,” and so on. Understanding these drivers puts the differences that may appear in the more detailed industry addenda into perspective.

End Usage

While there are common end usages of an estimate among different stakeholders, usage is often relative to the stakeholders’ identity. For instance, an owner company may use a given of estimate to support project funding, while a contractor may use the same class of estimate to support a contract bid or tender. It is not at all uncommon to find stakeholders categorizing their estimates by usage-related headings such as “budget,” “study,” or “bid.” Depending on the stakeholders’ perspective and needs, it is important to understand that these may actually be all the same class of estimate (based on the primary characteristic of level of project definition achieved).

Estimating Methodology

As stated previously, estimating methodologies fall into two broad categories: stochastic and deterministic. These broad categories encompass scores of individual methodologies. Stochastic

methods often involve simple or complex modeling based on inferred or statistical relationships between costs and programmatic and/or technical parameters. Deterministic methods tend to be straightforward counts or measures of units of items multiplied by known unit costs or factors. It is important to realize that any combination of methods may be found in any given class of estimate. For example, if a stochastic method is known to be suitably accurate, it may be used in place of a deterministic method even when there is sufficient input information based on the level of project definition to support a deterministic method. This may be due to the lower level of effort required to prepare an estimate using stochastic methods.

January 15, 2011

Expected Accuracy Range

The accuracy range of an estimate is dependent upon a number of characteristics of the estimate input information and the estimating process. The extent and the maturity of the input information as measured by percentage completion (and related to level of project definition) is a highly-important determinant of accuracy. However, there are factors besides the available input information that also greatly affect estimate accuracy measures. Primary among these are the state of technology in the project and the quality of reference cost estimating data.

State of technology - technology varies considerably between industries, and thus affects estimate accuracy. The state of technology used here refers primarily to the programmatic or technical uniqueness and complexity of the project. Procedurally, having “full extent and maturity” in the estimate basis deliverables is deceptive if the deliverables are based upon assumptions regarding uncertain technology. For a “first-of-a-kind” project there is a lower level of confidence that the execution of the project will be successful (all else being equal). There is generally a higher confidence for projects that repeat past practices. Projects for which research and development are still under way at the time that the estimate is prepared are particularly subject to low accuracy expectations. The state of technology may have an order of magnitude (10 to 1) effect on the accuracy range.

Quality of reference cost estimating data - accuracy is also dependent on the quality of reference cost data and history. It is possible to have a project with “common practice” in technology, but with little cost history available concerning projects using that technology. In addition, the estimating process typically employs a number of factors to adjust for market conditions, project location, environmental considerations, and other estimate-specific conditions that are often uncertain and difficult to assess. The accuracy of the estimate will be better when verified empirical data and statistics are employed as a basis for the estimating process, rather than assumptions.

In summary, estimate accuracy will generally be correlated with estimate classification (and therefore the level of project definition), all else being equal. However, specific accuracy ranges will typically vary by industry. Also, the accuracy of any given estimate is not fixed or determined by its classification category. Significant variations in accuracy from estimate to estimate are possible if any of the determinants of accuracy, such as technology, quality of reference cost data, quality of the estimating process, and skill and knowledge of the estimator vary. Accuracy is also not necessarily determined by the methodology used or the effort expended. Estimate accuracy must be evaluated on an estimate-by-estimate basis, usually in conjunction with some form of risk analysis process.

Effort to Prepare Estimate

The effort to prepare an estimate is usually determined by the extent of the input information available. The effort will normally increase as the number and complexity of the project definition deliverables that are produced and assessed increase. However, with an efficient estimating methodology on repetitive projects, this relationship may be less defined. For instance, there are combination design/estimating tools in the process industries that can often automate much of the design and estimating process. These tools can often generate Class 3 deliverables and estimates from the most basic input parameters for repetitive-type projects. There may be similar tools in other industry groupings.

It also should be noted that the estimate preparation costs as a percentage of total project costs will vary inversely with project size in a nonlinear fashion. For a given class of estimate, the preparation cost percentage will decrease as the total project costs increase. Also, at each class of estimate, the

Cost Estimate Classification System – As Applied in Engineering
Procurement, and Construction for the Process Industries

January 15, 2011

preparation costs in different industries will vary markedly. Metrics of estimate preparation costs normally exclude the effort to prepare the defining project deliverables.

ESTIMATE CLASSIFICATION MATRIX

The five estimate classes are presented in figure 1 in relationship to the identified characteristics. Only the level of project definition determines the estimate class. The other four characteristics are secondary characteristics that are generally correlated with the level of project definition, as discussed above.

This generic matrix and guideline provide a high-level estimate classification system that is non industry specific. Refer to subsequent addenda for further guidelines that will provide more detailed information for application in specific industries. These will provide additional information, such as input deliverable checklists, to allow meaningful categorization in that industry.

REFERENCES

ANSI Standard Z94.2-1989. **Industrial Engineering Terminology: Cost Engineering.**

ADDENDUM, RP No. 18-R-97 dated January 15, 2011

PURPOSE

As a recommended practice of AACE International, the Cost Estimate Classification System provides guidelines for applying the general principles of estimate classification to project cost estimates (i.e., cost estimates that are used to evaluate, approve, and/or fund projects). The Cost Estimate Classification System maps the phases and stages of project cost estimating together with a generic maturity and quality matrix, which can be applied across a wide variety of industries.

This addendum to the generic recommended practice provides guidelines for applying the principles of estimate classification specifically to project estimates for engineering, procurement, and construction (EPC) work for the process industries. This addendum supplements the generic recommended practice (17R-97) by providing:

- a section that further defines classification concepts as they apply to the process industries;
- a chart that maps the extent and maturity of estimate input information (project definition deliverables) against the class of estimate.

As with the generic standard, an intent of this addendum is to improve communications among all of the stakeholders involved with preparing, evaluating, and using project cost estimates specifically for the process industries.

The overall purpose of this recommended practice is to outline relationship of specific design input data and design deliverables, to the estimate accuracy and methodology used to produce the cost estimate. An implied confidence level can be inferred by the completeness of project data and design deliverables, coupled with the quality of the information shown. The estimate confidence level or estimate accuracy range is limited by the reliability of the scope information available at the time of the estimate, in addition to other variables.

January 15, 2011

It is understood that each enterprise may have its own project and estimating processes and terminology, and may classify estimates in particular ways. This guideline provides a generic and generally acceptable classification system for process industries that can be used as a basis to compare against. This addendum should allow each user to better assess, define, and communicate their own processes and standards in the light of generally-accepted cost engineering practice.

INTRODUCTION

For the purposes of this addendum, the term process industries is assumed to include firms involved with the manufacturing and production of chemicals, petrochemicals, and hydrocarbon processing. The common thread among these industries (for the purpose of estimate classification) is their reliance on process flow diagrams (PFDs) and piping and instrument diagrams (P&IDs) as primary scope defining documents. These documents are key deliverables in determining the degree of project definition, and thus the extent and maturity of estimate input information.

Estimates for process facilities center on mechanical and chemical process equipment, and they have significant amounts of piping, instrumentation, and process controls involved. As such, this addendum may apply to portions of other industries, such as pharmaceutical, utility, metallurgical, converting, and similar industries. Specific addendums addressing these industries may be developed over time.

This addendum specifically does not address cost estimate classification in non-process industries such as commercial building construction, environmental remediation, transportation infrastructure, “dry” processes such as assembly and manufacturing, “soft asset” production such as software development, and similar industries. It also does not specifically address estimates for the exploration, production, or transportation of mining or hydrocarbon materials, although it may apply to some of the intermediate processing steps in these systems.

The cost estimates covered by this addendum are for engineering, procurement, and construction (EPC) work only. It does not cover estimates for the products manufactured by the process facilities, or for research and development work in support of the process industries. This guideline does not cover the significant building construction that may be a part of process plants. Building construction will be covered in a separate addendum.

This guideline reflects generally-accepted cost engineering practices. This addendum was based upon the practices of a wide range of companies in the process industries from around the world, as well as published references and standards. Company and public standards were solicited and reviewed, and the practices were found to have significant commonalities.

COST ESTIMATE CLASSIFICATION MATRIX FOR THE PROCESS INDUSTRIES

The five estimate classes are presented in table 1 in relationship to the identified characteristics. Only the degree of project definition determines the estimate class. The other characteristics are secondary and are generally correlated with the degree of project definition, as discussed in the generic RP No. 17R-97. The characteristics are typical for the process industries but may vary from application to application.

Cost Estimate Classification System – As Applied in Engineering
Procurement, and Construction for the Process Industries

January 15, 2011

	Primary Characteristic	Secondary Characteristic		
ESTIMATE CLASS	DEGREE OF PROJECT DEFINITION Expressed as % of complete definition	END USAGE Typical purpose of estimate	METHODOLOGY Typical estimating method	EXPECTED ACCURACY RANGE Typical variation in low and high ranges ^[a]
Class 5	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 70%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	70% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Notes: [a] The state of process technology and availability of applicable reference cost data affect the range markedly. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of contingency (typically at a 50% level of confidence) for given scope.

Table 1 – Cost Estimate Classification Matrix for Process Industries

This matrix and guideline provide an estimate classification system that is specific to the process industries. Refer to the generic estimate classification RP No. 17-97 for a general matrix that is non-industry specific, or to other addendums for guidelines that will provide more detailed information for application in other specific industries. These will typically provide additional information, such as input deliverable checklists to allow meaningful categorization in those particular industries.

Table 1 illustrates typical accuracy ranges that are associated with the process industries. Depending on the technical and project deliverables (and other variables) associated with each estimate, the accuracy range for any particular estimate is expected to fall into the ranges identified.

In addition to the degree of project definition, estimate accuracy is also subject to:

- Level of non-familiar technology in the project.
- Complexity of the project.
- Quality of reference cost estimating data.
- Quality of assumptions used in preparing the estimate.
- Experience and skill level of the estimator.
- Estimating techniques employed.
- Time and level of effort budgeted to prepare the estimate.

January 15, 2011

Another way to look at the variability associated with estimate accuracy ranges is shown in Figure 1. Depending upon the technical complexity of the project, the availability of appropriate cost reference information, the degree of project definition, and the inclusion of appropriate contingency determination, a typical Class 5 estimate for a process industry project may have an accuracy range as broad as -50% to +100%, or as narrow as -20% to +30%.

Figure 1 also illustrates that the estimating accuracy ranges overlap the estimate classes. There are cases where a Class 5 estimate for a particular project may be as accurate as a Class 3 estimate for a different project. For example, this may occur if the Class 5 estimate is based on a repeat project with good cost history and data, whereas the Class 3 estimate is for a project involving new technology. There are also cases where a Class 3 estimate has no better accuracy than a Class 5 estimate. It is for this reason that Table 1 provides a range in accuracy values. This allows application of the specific circumstances inherent in a project, and an industry sector, to the indication of realistic estimate class accuracy range percentages.

Cost Estimate Classification System – As Applied in Engineering
Procurement, and Construction for the Process Industries

January 15, 2011

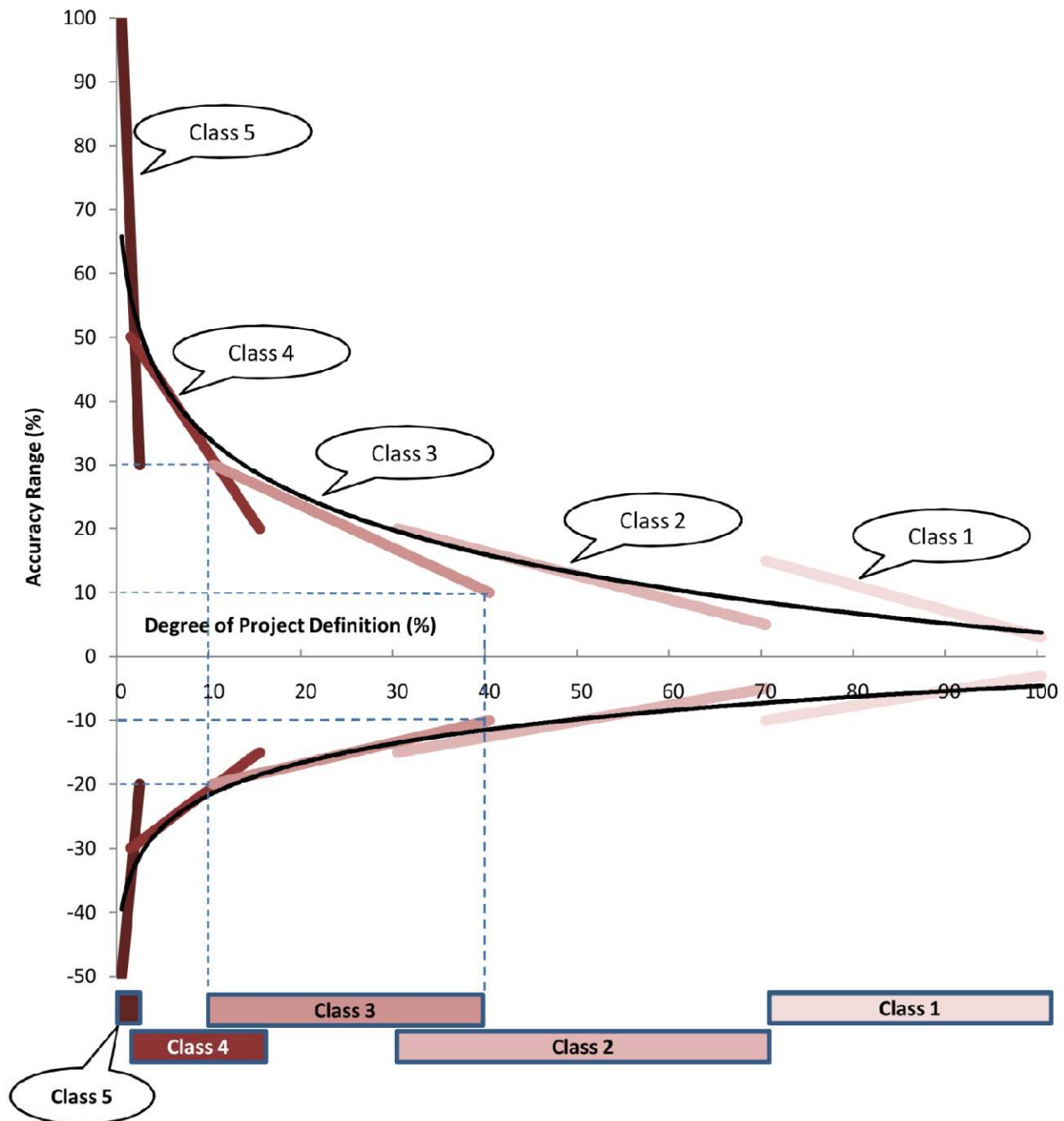


Figure 1 – Example of the Variability in Uncertainty Ranges for a Process Industry Estimate

January 15, 2011

DETERMINATION OF THE COST ESTIMATE CLASS

The cost estimator makes the determination of the estimate class based upon the degree of project definition (design % complete). While the determination of the estimate class is somewhat subjective, the design input data, completeness and quality of the design deliverables serve to make the determination more objective.

CHARACTERISTICS OF THE ESTIMATE CLASSES

The following tables (2a through 2e) provide detailed descriptions of the five estimate classifications as applied in the process industries. They are presented in the order of least-defined estimates to the most-defined estimates. These descriptions include brief discussions of each of the estimate characteristics that define an estimate class.

For each table, the following information is provided:

- **Description:** a short description of the class of estimate, including a brief listing of the expected estimate inputs based on the degree of project definition.
- **Degree of Project Definition Required:** expressed as a percent of full definition of project and technical deliverables. For the process industries, this correlates with the percent of engineering and design complete.
- **End Usage:** a short discussion of the possible end usage of this class of estimate.
- **Estimating Methods Used:** a listing of the possible estimating methods that may be employed to develop an estimate of this class.
- **Expected Accuracy Range:** typical variation in low and high ranges after the application of contingency (determined at a 50% level of confidence). Typically, this provides a 90% confidence level that the actual cost will fall within the bounds of the low and high ranges. The estimate confidence level and accuracy range is limited by the reliability of the scope information available at the time of the estimate in addition to the other variables identified above. Note: the cost estimate represents a point estimate based upon a prescriptive design, which may or may not change throughout the life cycle of the design phase. The expected accuracy range is influenced by the complexity and uncertainties of the project.
- **Alternate Estimate Names, Terms, Expressions, Synonyms:** this section provides other commonly used names that an estimate of this class might be known by. These alternate names are not endorsed by this Recommended Practice. The user is cautioned that an alternative name may not always be correlated with the class of estimate as identified in Tables 2a-2e.

Cost Estimate Classification System – As Applied in Engineering
Procurement, and Construction for the Process Industries

January 15, 2011

CLASS 5 ESTIMATE	
Description: Class 5 estimates are generally prepared based on very limited information, and subsequently have wide accuracy ranges. As such, some companies and organizations have elected to determine that due to the inherent inaccuracies, such estimates cannot be classified in a conventional and systemic manner. Class 5 estimates, due to the requirements of end use, may be prepared within a very limited amount of time and with little effort expended—sometimes requiring less than an hour to prepare. Often, little more than proposed plant type, location, and capacity are known at the time of estimate preparation. Degree of Project Definition Required: 0% to 2% of full project definition. End Usage: Class 5 estimates are prepared for any number of strategic business planning purposes, such as but not limited to market studies, assessment of initial viability, evaluation of alternate schemes, project screening, project location studies, evaluation of resource needs and budgeting, long-range capital planning, etc.	Estimating Methods Used: Class 5 estimates generally use stochastic estimating methods such as cost/capacity curves and factors, scale of operations factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, and other parametric and modeling techniques. Expected Accuracy Range: Typical accuracy ranges for Class 5 estimates are -20% to -50% on the low side, and +30% to +100% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. Alternate Estimate Names, Terms, Expressions, Synonyms: Ratio, ballpark, blue sky, seat-of-pants, ROM, idea study, prospect estimate, concession license estimate, guesstimate, rule-of-thumb.

Table 2a – Class 5 Estimate

CLASS 4 ESTIMATE	
Description: Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Typically, engineering is from 1% to 15% complete, and would comprise at a minimum the following: plant capacity, block schematics, indicated layout, process flow diagrams (PFDs) for main process systems, and preliminary engineered process and utility equipment lists. Degree of Project Definition Required: 1% to 15% of full project definition. End Usage: Class 4 estimates are prepared for a number of purposes, such as but not limited to, detailed strategic planning, business development, project screening at more developed stages, alternative scheme analysis, confirmation of economic and/or technical feasibility, and preliminary budget approval or approval to proceed to next stage.	Estimating Methods Used: Class 4 estimates generally use stochastic estimating methods such as equipment factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, the Miller method, gross unit costs/ratios, and other parametric and modeling techniques. Expected Accuracy Range: Typical accuracy ranges for Class 4 estimates are -15% to -30% on the low side, and +20% to +50% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. Alternate Estimate Names, Terms, Expressions, Synonyms: Screening, top-down, feasibility, authorization, factored, pre-design, pre-study.

Table 2b – Class 4 Estimate

January 15, 2011

CLASS 3 ESTIMATE	
Description: Class 3 estimates are generally prepared to form the basis for budget authorization, appropriation, and/or funding. As such, they typically form the initial control estimate against which all actual costs and resources will be monitored. Typically, engineering is from 10% to 40% complete, and would comprise at a minimum the following: process flow diagrams, utility flow diagrams, preliminary piping and instrument diagrams, plot plan, developed layout drawings, and essentially complete engineered process and utility equipment lists. Degree of Project Definition Required: 10% to 40% of full project definition. End Usage: Class 3 estimates are typically prepared to support full project funding requests, and become the first of the project phase control estimates against which all actual costs and resources will be monitored for variations to the budget. They are used as the project budget until replaced by more detailed estimates. In many owner organizations, a Class 3 estimate is often the last estimate required and could very well form the only basis for cost/schedule control.	Estimating Methods Used: Class 3 estimates generally involve more deterministic estimating methods than stochastic methods. They usually involve a high degree of unit cost line items, although these may be at an assembly level of detail rather than individual components. Factoring and other stochastic methods may be used to estimate less-significant areas of the project. Expected Accuracy Range: Typical accuracy ranges for Class 3 estimates are -10% to -20% on the low side, and +10% to +30% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. Alternate Estimate Names, Terms, Expressions, Synonyms: Budget, scope, sanction, semi-detailed, authorization, preliminary control, concept study, development, basic engineering phase estimate, target estimate.

Table 2c – Class 3 Estimate

Cost Estimate Classification System – As Applied in Engineering
Procurement, and Construction for the Process Industries

January 15, 2011

CLASS 2 ESTIMATE	
Description: Class 2 estimates are generally prepared to form a detailed contractor control baseline (and update the owner control baseline) against which all project work is monitored in terms of cost and progress control. For contractors, this class of estimate is often used as the bid estimate to establish contract value. Typically, engineering is from 30% to 70% complete, and would comprise at a minimum the following: process flow diagrams, utility flow diagrams, piping and instrument diagrams, heat and material balances, final plot plan, final layout drawings, complete engineered process and utility equipment lists, single line diagrams for electrical, electrical equipment and motor schedules, vendor quotations, detailed project execution plans, resourcing and work force plans, etc. Degree of Project Definition Required: 30% to 70% of full project definition. End Usage: Class 2 estimates are typically prepared as the detailed contractor control baseline (and update the owner control baseline) against which all actual costs and resources will now be monitored for variations to the budget, and form a part of the change management program.	Estimating Methods Used: Class 2 estimates generally involve a high degree of deterministic estimating methods. Class 2 estimates are prepared in great detail, and often involve tens of thousands of unit cost line items. For those areas of the project still undefined, an assumed level of detail takeoff (forced detail) may be developed to use as line items in the estimate instead of relying on factoring methods. Expected Accuracy Range: Typical accuracy ranges for Class 2 estimates are -5% to -15% on the low side, and +5% to +20% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. Alternate Estimate Names, Terms, Expressions, Synonyms: Detailed control, forced detail, execution phase, master control, engineering, bid, tender, change order estimate.

Table 2d – Class 2 Estimate

January 15, 2011

CLASS 1 ESTIMATE	
Description: Class 1 estimates are generally prepared for discrete parts or sections of the total project rather than generating this level of detail for the entire project. The parts of the project estimated at this level of detail will typically be used by subcontractors for bids, or by owners for check estimates. The updated estimate is often referred to as the current control estimate and becomes the new baseline for cost/schedule control of the project. Class 1 estimates may be prepared for parts of the project to comprise a fair price estimate or bid check estimate to compare against a contractor's bid estimate, or to evaluate/dispute claims. Typically, engineering is from 70% to 100% complete, and would comprise virtually all engineering and design documentation of the project, and complete project execution and commissioning plans. Degree of Project Definition Required: 70% to 100% of full project definition. End Usage: Generally, owners and EPC contractors use Class 1 estimates to support their change management process. They may be used to evaluate bid checking, to support vendor/contractor negotiations, or for claim evaluations and dispute resolution. Construction contractors may prepare Class 1 estimates to support their bidding and to act as their final control baseline against which all actual costs and resources will now be monitored for variations to their bid. During construction, Class 1 estimates may be prepared to support change management.	Estimating Methods Used: Class 1 estimates generally involve the highest degree of deterministic estimating methods, and require a great amount of effort. Class 1 estimates are prepared in great detail, and thus are usually performed on only the most important or critical areas of the project. All items in the estimate are usually unit cost line items based on actual design quantities. Expected Accuracy Range: Typical accuracy ranges for Class 1 estimates are -3% to -10% on the low side, and +3% to +15% on the high side, depending on the technological complexity of the project, appropriate reference information, and the inclusion of an appropriate contingency determination. Ranges could exceed those shown in unusual circumstances. Alternate Estimate Names, Terms, Expressions, Synonyms: Full detail, release, fall-out, tender, firm price, bottoms-up, final, detailed control, forced detail, execution phase, master control, fair price, definitive, change order estimate.

Table 2e – Class 1 Estimate

Cost Estimate Classification System – As Applied in Engineering
Procurement, and Construction for the Process Industries

January 15, 2011

ESTIMATE INPUT CHECKLIST AND MATURITY MATRIX

Table 3 maps the extent and maturity of estimate input information (deliverables) against the five estimate classification levels. This is a checklist of basic deliverables found in common practice in the process industries. The maturity level is an approximation of the degree of completion of the deliverable. The degree of completion is indicated by the following letters.

- None (blank): development of the deliverable has not begun.
- Started (S): work on the deliverable has begun. Development is typically limited to sketches, rough outlines, or similar levels of early completion.
- Preliminary (P): work on the deliverable is advanced. Interim, cross-functional reviews have usually been conducted. Development may be near completion except for final reviews and approvals.
- Complete (C): the deliverable has been reviewed and approved as appropriate.

Cost Estimate Classification System – As Applied in Engineering
Procurement, and Construction for the Process Industries

January 15, 2011

	ESTIMATE CLASSIFICATION				
	CLASS 5	CLASS 4	CLASS 3	CLASS 2	CLASS 1
DEGREE OF PROJECT DEFINITION	0% to 2%	1% to 15%	10% to 40%	30% to 70%	70% to 100%
General Project Data:					
Project Scope Description	General	Preliminary	Defined	Defined	Defined
Plant Production/Facility Capacity	Assumed	Preliminary	Defined	Defined	Defined
Plant Location	General	Approximate	Specific	Specific	Specific
Soils & Hydrology	None	Preliminary	Defined	Defined	Defined
Integrated Project Plan	None	Preliminary	Defined	Defined	Defined
Project Master Schedule	None	Preliminary	Defined	Defined	Defined
Escalation Strategy	None	Preliminary	Defined	Defined	Defined
Work Breakdown Structure	None	Preliminary	Defined	Defined	Defined
Project Code of Accounts	None	Preliminary	Defined	Defined	Defined
Contracting Strategy	Assumed	Assumed	Preliminary	Defined	Defined
Engineering Deliverables:					
Block Flow Diagrams	S/P	P/C	C	C	C
Plot Plans		S/P	C	C	C
Process Flow Diagrams (PFDs)		P	C	C	C
Utility Flow Diagrams (UFDs)		S/P	C	C	C
Piping & Instrument Diagrams (P&IDs)		S/P	C	C	C

January 15, 2011

	ESTIMATE CLASSIFICATION				
	CLASS 5	CLASS 4	CLASS 3	CLASS 2	CLASS 1
DEGREE OF PROJECT DEFINITION	0% to 2%	1% to 15%	10% to 40%	30% to 70%	70% to 100%
Heat & Material Balances		S/P	C	C	C
Process Equipment List		S/P	C	C	C
Utility Equipment List		S/P	C	C	C
Electrical One- Line Drawings		S/P	C	C	C
Specifications & Datasheets		S	P/C	C	C
General Equipment Arrangement Drawings		S	C	C	C
Spare Parts Listings			P	P	C
Mechanical Discipline Drawings			S/P		
Electrical Discipline Drawings			S/P	P/C	C
Instrumentatio n/Control System Discipline Drawings			S/P	P/C	C
Civil/Structural /Site Discipline Drawings			S/P	P/C	C

Table 3 – Estimate Input Checklist and Maturity Matrix

January 15, 2011

REFERENCES

1. AACE International Recommended Practice No.17R-97, *Cost Estimate Classification System*, AACE International, Morgantown, WV. (latest revision)
2. Hollmann, John K., PE CCE, Editor, *Total Cost Management Framework: An Integrated Approach to Portfolio, Program and Project Management*, AACE International, Morgantown, WV, 2006.
3. AACE International, Recommended Practice 10S-90, *Cost Engineering Terminology*, AACE International, Morgantown, WV. (latest revision).
4. John R. Heizelman, *Estimating Factors for Process Plants*, 1988 AACE Transactions, V.3, AACE International, Morgantown, WV, 1988.
5. K.T. Yeo, *The Cost Engineer Journal*, UK Vol. 27, No. 6, 1989.
6. Stevens, G. and T. Davis, *How Accurate are Capital Cost Estimates?*, 1988 AACE Transactions, B.4, AACE International. Morgantown, WV, 1988. (* Class III is inferred)
7. Behrenbruch, Peter, article in *Journal of Petroleum Technology*, Vol 45, No. 8, Society of Petroleum Engineers, August 1993.

Appendix I: Bibliography

General Cost Estimating/Cost Engineering References

“Cost Analysis of Prototyping Major Weapon Systems Scheduling Using Neural and Symbolic Processing,” *Cost Estimating and Analysis—Balancing Technology and Declining Budgets*, K.W. Tyson, J.R. Nelson, D.C. Gogerty, B.R. Harmon, and A. Salerno, 1992.

Applied General Statistics, Third Edition, F.E. Croxton, D.J. Cowden, and S. Klein, 1967.

Business and Economic Statistics, W.A. Spurr, L.S. Kellog, and J.H. Smith, 1961.

Construction Cost Estimates, Second Edition, Leo Diamant and C.R. Tumblin, 1990.

Contractors Business Handbook: Accounting, Finance, Tax Management, Cost Control, Michael S. Milliner, 1988.

Cost and Optimization Engineering, Second Edition, Frederic C. Jelen and James H. Black, 1983.

Cost Estimating, Second Edition, Rodney D. Stewart, 1990.

Cost Estimator’s Reference Manual, Rodney D. Steward and Richard M. Wyskida, editors, 1995.

Econometric Methods, Fourth Edition, John Johnston, Jack Johnston, John DiNardo, 1997.

Improving Early Cost Estimates, Construction Industry Institute, 1998.

Introduction to Life Cycle Costing, Brown, Robert J., Ph.D., and Rudolph R. Yanuck, P.E., 1985.

Introduction to the Theory of Statistics, Third Edition, A.M. Mood and F.A. Graybill, 1973.

Jelen’s Cost and Optimization Engineering, Third Edition, Kenneth K. Humphreys, 1991.

Life Cycle Costing: A Practical Guide for Energy Managers, Robert J. Brown, Ph.D., and Rudolph R. Yanuck, P.E., 1985.

Manual of Economic Analysis of Chemical Processes, Institut Francais Du Pétrole, 1981.

Means Estimating Handbook, R.S. Means, 1990.

Methods of Correlation and Regression Analysis, Third Edition, M.J.B. Ezekiel, and K.A. Fox, 1959.

Multivariate Logarithmic and Exponential Regression Models, C.A. Graver, and H.E. Boren, Jr., 1967.

Parameter Estimation in Engineering and Science, James V. Beck, and Kenneth J. Arnold, 1977.

Plant Design and Economics for Chemical Engineers, Fifth Edition, Max S. Peters, Ronald E. West and Klaus D. Timmerhaus, 2003.

Preliminary Chemical Engineering Plant Design, Second Edition, William D. Baasel.

Principles of Engineering Economy, Eighth Edition, Eugene L. Grant, W. Grant Ireson and Richard S. Leavenworth, 1990.

Project and Cost Engineers Handbook, Third Edition, Kenneth K. Humphreys and Lloyd M. English, 1993.

Project Estimating by Engineering Methods, Paul F. Gallagher, 1965.

Project Feasibility Analysis - A Guide to Profitable New Ventures, D.S. Clifton and D.E. Fyffe, 1977.

Project Management - A Systems Approach to Planning, Scheduling, and Controlling, Eighth Edition, Harold Kerzner, Ph.D. 2003.

Recommended Practices, AACEI.

Skills and Knowledge of Cost Engineering, Fourth Edition, AACEI, 1999.

Standard Handbook of Environmental Engineering, Robert A. Corbitt, editor, 1999.

Statistical Analysis for Business Decisions, W.A. Spurr and C.P. Bonini, 1973.

Statistics, a New Approach, W.A. Wallis and H.V. Roberts, 1956.

Transactions, AACEI.

Uranium Mill Tailings Remedial Action Surface Project, 1979-1999, End-of-Project Report, 1999 Cost Engineers' Notebook, AACEI, 1990.

U.S. Department of Energy (DOE) Related References

Cost and Scheduling Estimating Guide, DOE, Office of Waste Management, 1992.

Cost Estimating Guide, Civilian Radioactive Waste Management System, M&O Contractor, 1996.

Cost Estimating Handbook for Environmental Restoration, Environmental Restoration and Waste Management Cost Assessment Team, DOE, Office of Environmental Management, 1990.

Cost Estimating Manual, WVDP-033, West Valley Nuclear Services, c.1994.

Cost Estimating Standard Operating Manual, Martin Marietta, Central Engineering, 1987.

Cost Guide, Volume 6 Cost Estimating Guide, DOE, Office of Infrastructure Acquisition, 1994.

DOE Accounting Handbook, Chapter 10, Plant and Capital Equipment, DOE, 2009.

DOE G 413.3-7A, *Risk Management Guide*, January 2011.

DOE STD 1120-98, *Integration of Environment, Safety, and Health into Facility Disposition Activities*, 1980.

DOE STD-1073-93, *DOE Standard Guide for Operational Configuration Management Program*, 1992.

DOE-ALO PFMD Chapter 13.0 Estimating Guide, DOE, Albuquerque Operations Office, Los Alamos National Laboratory, 1997.

Estimating and Cost Control Manual for Construction Projects, DOE, Oak Ridge Operations Office, 1991.

Estimating Reference Manual, LMES Estimating Engineering Department, 1996.

Facility Disposition Cost Model, Summary of Model and Supporting Documentation, Revision 2, DOE, Rocky Flats Operations Office, Kaiser-Hill, LLC, 1999.

Improving Project Management in the Department of Energy, Letter Report, National Research Council, National Academy Press, 2001.

Improving Project Management in the Department of Energy, National Research Council, National Academy Press, 1999.

Privatization Cost Estimating Guide (A Supplement to the EM Privatization Guide), DOE, Office of Environmental Management, (Draft), 1998.

Program/Project Manager's Privatization Guide, DOE, Office of Environmental Management, (Draft), 1998.

Project Estimating and Scheduling (PES), Standard Operating Manual, Martin Marietta Energy Systems, Inc., 1991.

WSRC-MSI-94-01, *WSRC Site Cost Estimating Manual*, Westinghouse Savannah River Company (WSRC), 1994.

U.S Department of Defense (DOD) Related References

Cost Analysis Manual, Department of the Army, U.S. Army Cost and Economic Analysis Center, 2001.

DAU/DSMC Risk Management Guide for DOD Acquisition, Fifth Edition DOD, Defense Acquisition University, Defense Systems Management College, 2003.

DISA Acquisition Deskbook, "Independent Government Cost Estimates," Defense Information Systems Agency (DISA), 1998.

DOD 5000.4, *Cost Analysis Improvement Group (CAIG)*, , 1992.

DOD-5000.4-M-1, *Contractor Cost Data Reporting Manual*, DOD, Program Analysis and Evaluation, 1999.

Economic Analysis Manual, Department of the Army, U.S. Army Cost and Economic Analysis Center, 2001.

EI-01-D010, *Construction Cost Estimates*, Department of the Army, U.S. Army Corps of Engineers, 1997.

Environmental Cost Analysis Methodology, DOD, Deputy Undersecretary of Defense for Environmental Security, 1999.

ER-1110-1-1300, *Cost Engineering Policy and General Requirements*, Department of the Army, U.S. Army Corps of Engineers, 1993.

Information Assurance Information Technology Capabilities Contract (IA/ITCC), Defense Information Systems Agency (DISA), 2003.

Operating and Support Cost-Estimating Guide, Office of the Secretary of Defense, 1992.

Parametric Estimating Handbook, Second Edition, DOD, 1999.

Project Schedule, UFGS-01320A, Unified Facilities Guide Specifications, USACE/NAVFAC/AFCEA, 200.

Supervision, Inspection, and Overhead (SIOH), DOD, Naval Facilities Engineering Command (NAVFAC), 2000.

TRADOC Pamphlet 715-6, *Independent Government Estimate Preparation Guide*, DOD, 2000.

General and Other Federal References

A Guide to Developing and Documenting Cost Estimates During the Feasibility Study, EPA-540-R-00-002, U.S. Environmental Protection Agency, 2000.

Administration of Government Contracts, Third Edition, John Cibinic, Jr., Ralph C. Nash, Jr George Washington University, 1985.

Avoiding and Resolving Construction Claims, Barry B. Bramble, Esq., Michael F. D'Onofrio, PE, and John B Stetson, IV, 1990.

Bidding and Managing Government Construction, Theodore J. Trauner, Jr. and Michael H. Payne, 1988.

Characteristics of Successful Megaprojects, National Research Council, National Academy Press, 2000.

Construction Contracting, Richard J. Bednar, George Washington University, 1991.

Construction Litigation, Kenneth M. Cushman, editor, 1981.

Contract Pricing Reference Guide, Volumes 1-5 Federal Acquisition Institute, 1997.

Cost Engineering and Project Management, ANSI Z94.4-1998

Federal Management Regulation, 41 CFR 102)

Federal Property Management Regulations, 41CFR 101)

Form and Content of Agency Financial Statements, Technical Amendments to OMB Bulletin No. 97-01, M-00-05, Office of Management and Budget (OMB), 2000.

Formulation of Government Contracts, Second Edition, George Washington University, 1986.

Fundamentals of the Construction Process, Kweku K. Bentil, AIC, 1989.

Guidelines to Standardize Measures of Costs and Benefits and the Format of Accounting Statements, M-00-08, Office of Management and Budget (OMB), 2000.

Industrial R&D Management, A. J. Gambino and M. Gartenberg, 1979.

Methodology and Procedures for Life-Cycle Cost Analysis, 10 CFR 436.19, Part A

NASA Cost Estimating Handbook, National Aeronautics and Space Administration (NASA), 2002.

OMB Bulletin No. 98-08, *Audit Requirements for Federal Financial Statements*, 1998.

Perry's Chemical Engineers' Handbook, Seventh Edition, Robert H. Perry, and Don Green, editors, 1997.

Preliminary Chemical Engineering Plant Design, Second Edition, William D. Baasel, 1990.

Project Management Terms: A Working Glossary, Second Edition, J. LeRoy Ward, editor, 1999.

Proposal Preparation, Rodney D. Stewart and Ann L. Stewart, 1984.

Standard Classification for Allowance, Contingency and Reserve Sums in Building Construction Estimating, ASTM E2168-01, 2003.

Standard Classification for Building Construction Field Requirements, and Office Overhead & Profit, ASTM E2083-00, 2003.

Standard Classification for Life-Cycle Environmental Work Elements—Environmental Cost Element Structure, ASTM E2150-02, 2003.

Standard Guide for Estimating Monetary Costs and Liabilities for Environmental Matters, ASTM E2137-01, 2001.

The McGraw-Hill Handbook of Essential Engineering Information and Data, Ejup N. Ganić, Tyler G. Hicks, editors, McGraw-Hill, 1991.

The President's Management Agenda: Fiscal Year 2002, Office of Management and Budget, 2002.

UNIFORMAT II Elemental Classification for Building Specifications, Cost Estimating and Cost Analysis, National Institute of Standards and Technology Interagency Report 6389, Robert P. Charette and Harold E. Marshall, 1999.

Internet References

Association for the Advancement of Cost Engineering, International (AACEI)
<http://www.aacei.org/>

DOE Budget Guidance <http://www.cfo.doe.gov/crorg/cf30.htm>

DOE Directives System <http://www.directives.doe.gov/>

DOE Lessons Learned Program <http://www.hss.energy.gov/csa/analysis/DOE/index.asp>

DOE Office of Engineering and Construction Management (OECM)
<http://www.management.energy.gov/oecm.htm>

DOE's Energy Facility Contractors Group Best Practices
<http://efcog.org/Best%20Practices/Best%20Practices.htm>

DOE Project Management Policy and Guidance
http://www.management.energy.gov/policy_guidance/project_management.htm

GA-09-3SP GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs <http://www.gao.gov/products/GAO-09-3SP1>

Appendix J: Crosswalk to GAO-09-3SP

GAO Project Phase	GAO Best Practice	GAO Associated Tasks	Where Conformance to GAO Practice is Demonstrated in DOE G 413.3-21
INITIATION AND RESEARCH —Your audience, what you are estimating, and why you are estimating it are of the utmost importance.	Step 1: Define the Estimate's Purpose	Determine estimate's purpose, required level of detail, and overall scope.	Guidance related to the purpose of the estimate can be found in Sections 2.1, 3.2.1, and 6.7.1..
		Determine who will receive the estimate.	
	Step 2: Develop an Estimating Plan	Determine the cost estimating team and develop its master schedule.	Guidance related to planning the estimate development can be found in Section 4.1, Table 4-1, and Section 6.2.
		Determine who will do the independent cost estimate	
		Outline the cost estimating approach	
		Develop the estimating timeline.	
ASSESSMENT —Cost assessment steps are iterative and can be accomplished in varying order or concurrently.	Step 3: Define the Program Characteristics	In a technical baseline description document, identify the program's purpose and its system and performance characteristics and all system configurations.	Guidance related to DOE Program characteristics and requirements for cost estimates are discussed in Section 3 and also in Section 6.3.2.
		Describe technology implications.	
		Describe acquisition schedule and strategy.	
		Describe relationship to other existing systems, including predecessor or similar legacy systems.	
		Define support (manpower, training, etc.) and security needs and risk items.	
		Develop system quantities for development, test, and production.	
		Develop system quantities for development, test, and production.	
		Define deployment and maintenance plans.	
	Step 4: Determine the Estimating Structure	Define a work breakdown structure (WBS) and describe each element in a WBS dictionary (a major automated information system may have only a cost element structure).	Guidance relative to estimate structure is found in Table 4-1, and discussed extensively in Section 5
		Choose the best estimating method for each WBS element.	
		Identify potential cross-checks for likely cost and schedule drivers.	
		Develop a cost estimating checklist.	
	Step 5: Identify Ground Rules and Assumptions	Clearly define what the estimate includes and excludes.	The concepts related to ground rules and

GAO Project Phase	GAO Best Practice	GAO Associated Tasks	Where Conformance to GAO Practice is Demonstrated in DOE G 413.3-21
		Identify global and program-specific assumptions, such as the estimate's base year, including time-phasing and life cycle.	assumptions are discussed in Table 4-1, and again in Section 6, with specific guidance in Section 6.7.1.
		The estimate's base year, including time-phasing and life cycle.	
		Identify program schedule information by phase and program acquisition strategy.	
		Identify any schedule or budget constraints, inflation assumptions, and travel costs.	
		Specify equipment the government is to furnish as well as the use of existing facilities or new modification or development.	
		Identify prime contractor and major subcontractors.	
		Determine technology refresh cycles, technology assumptions, and new technology to be developed.	
		Define commonality with legacy systems and assumed heritage savings.	
		Describe effects of new ways of doing business.	
	Step 6: Obtain Data	Create a data collection plan with emphasis on collecting current and relevant technical, programmatic, cost, and risk data.	Estimate data sources and associated guidance can be found in Section 2.2, Section 3, and is the focus of Section 6.3
		Investigate possible data sources.	
		Collect data and normalize them for cost accounting, inflation, learning and quantity adjustments.	
		Analyze the data for cost drivers, trends, and outliers and compare results against rules of thumb and standard factors derived from historical data.	
		Interview data sources and document all pertinent information, including an assessment of data reliability and accuracy.	
		Store data for future estimates	
	Step 7: Develop a Point Estimate and Compare it to an Independent Cost Estimate	Develop the cost model, estimating each WBS element, using the best methodology from the data collected, and including all estimating assumptions.	The techniques available for estimate development are described in Section 5 and the estimate development process itself is discussed extensively in Section 6.4.
		Express costs in constant year dollars.	

GAO Project Phase	GAO Best Practice	GAO Associated Tasks	Where Conformance to GAO Practice is Demonstrated in DOE G 413.3-21
		Time-phase the results by spreading costs in the years they are expected to occur, based on the program schedule.	Other tasks identified here are discussed in Sections 6.5 and 6.6.
		Sum the WBS elements to develop the overall point estimate.	Independent Cost Estimates are discussed in Section 8.3 with guidance provided in Appendix K.
		Validate the estimate by looking for errors like double counting and omitted costs.	
		Compare estimate against the independent cost estimate and examine where and why there are differences.	
		Perform cross-checks on cost drivers to see if results are similar.	
		Update the model as more data become available or as changes occur and compare results against previous estimates.	
ANALYSIS —The confidence in the point or range of the estimate is crucial to the decision maker.	Step 8: Conduct Sensitivity Analysis	Test the sensitivity of cost elements to changes in estimating input values and key assumptions.	The concept of Sensitivity Analysis is discussed in Section 6.4.5 as a subset of contingency analysis. However the requirements for such analyses can also be found throughout the Guidance document, specifically, Section 6.1, Table 6-1 and Section 6.7.1.
		Identify effects on the overall estimate of changing the program schedule or quantities.	
		Determine which assumptions are key cost drivers and which cost elements are affected most by changes.	
	Step 9: Conduct Risk and Uncertainty Analysis	Determine and discuss with technical experts the level of cost, schedule, and technical risk associated with each WBS element.	A full explanation of DOE's guidance relative to risk and uncertainty analysis and contingency allowances can be found in Section 6.4.5 and more in-depth treatment can be found in DOE G 413.3-7A, Risk Management Guide.
		Analyze each risk for its severity and probability.	
		Develop minimum, most likely, and maximum ranges for each risk element.	
		Determine type of risk distributions and reason for their use.	
		Ensure that risks are correlated.	
		Use an acceptable statistical analysis method (e.g., Monte Carlo simulation) to develop a confidence interval around the point estimate.	
		Identify the confidence level of the point estimate.	

GAO Project Phase	GAO Best Practice	GAO Associated Tasks	Where Conformance to GAO Practice is Demonstrated in DOE G 413.3-21
		Identify the amount of contingency funding and add this to the point estimate to determine the risk-adjusted cost estimate.	
		Recommend that the project or program office develop a risk management plan to track and mitigate risks.	
	Step 10: Document the Estimate	Document all steps used to develop the estimate so that a cost analyst unfamiliar with the program can recreate it quickly and produce the same result.	Estimate documentation is discussed in Section 3.2, and extensively in Section 6.7.
		Document the purpose of the estimate, the team that prepared it, and who approved the estimate and on what date.	
		Describe the program, its schedule, and the technical baseline used to create the estimate.	
		Present the program's time-phased life-cycle cost.	
		Discuss all ground rules and assumptions.	
		Include auditable and traceable data sources for each cost element and document for all data sources how the data were normalized.	
		Describe in detail the estimating methodology and rationale used to derive each WBS element's cost (prefer more detail over less).	
		Describe the results of the risk, uncertainty, and sensitivity analyses and whether any contingency funds were identified.	
		Document how the estimate compares to the funding profile.	
		Track how this estimate compares to any previous estimates.	

GAO Project Phase	GAO Best Practice	GAO Associated Tasks	Where Conformance to GAO Practice is Demonstrated in DOE G 413.3-21
PRESENTATION— Documentation and presentation make or break a cost estimating decision outcome.	<i>Step 11: Present Estimate to Management for Approval</i>	Develop a briefing that presents the documented life-cycle cost estimate.	Guidance related to the presentation of estimate results can be found in Table 3-1, Section 3.2.4, Section 6.7.1, and specifically in Section 7.2.
		Include an explanation of the technical and programmatic baseline and any uncertainties.	
		Compare the estimate to an independent cost estimate (ICE) and explain any differences.	
		Compare the estimate (life-cycle cost estimate (LCCE)) or independent cost estimate to the budget with enough detail to easily defend it by showing how it is accurate, complete, and high in quality.	
		Focus in a logical manner on the largest cost elements and cost drivers.	
		Make the content clear and complete so that those who are unfamiliar with it can easily comprehend the competence that underlies the estimate results.	
		Make backup slides available for more probing questions.	
		Act on and document feedback from management.	
		Request acceptance of the estimate.	
	<i>Step 12: Update the Estimate to Reflect Actual Costs and Changes</i>	Update the estimate to reflect changes in technical or program assumptions or keep it current as the program passes through new phases or milestones.	Estimate maintenance is discussed in Sections 6.8 and 7.3, and more extensively in DOE O 413.3B (requirements) and other associated guidance documents.
		Replace estimates with EVM EAC and Independent estimate at completion (EAC) from the integrated EVM system.	
		Report progress on meeting cost and schedule estimates.	
		Perform a post mortem and document lessons learned for elements whose actual costs or schedules differ from the estimate.	
		Document all changes to the program and how they affect the cost estimate.	

Appendix K: ICR and ICE Guidance

General ICR/ICE Guidance

- In most cases it is best to allow the ICE team to have access to the project estimate. In this way, the approaches used to develop the ICE can be tailored to fit the available data and subsequent reconciliation between the estimates is facilitated if the ICE is structured in the same manner as the project estimate.
- ICR/ICE teams need to be comprised of individuals with appropriate industry and DOE experience and credentials. Ideally, teams will include individuals with appropriate industry certifications (PE, CCE, PMP, etc.) and subject matter experts knowledgeable in the areas addressed by the project (in particular any unique technical areas or project execution strategies).
- It is important to establish a charter that clearly defines the boundaries of ICR and ICE teams. For example, it should be clearly understood that the purpose of an ICR or ICE is to establish an independent cost for a project based on the same execution strategy, conditions, technical scope and schedule as used by the project team. It is not appropriate for an ICR or ICE team to question mission need, develop alternative execution strategies, etc. and then generate an estimate based on these “new” strategies, scope or alternatives. The ICR or ICE team may propose or recommend alternatives based on observation and expert opinion; however attempting to use those alternatives to compare to project estimates is generally inappropriate.

ICR/ICE Schedule (suggested and varies by project size and complexity)

Activity	Typical Duration (weeks)
Establish ICR/ICE requirements and approved budget	1 - 2
Develop task order and complete negotiations with ICE contractor	2-4
Hold kick-off meeting and initial site briefings	1-2
Development of ICR/ICE and draft report	2-10 (varies with project and ICE Type)
Reconciliation between ICE and project estimate	1-2
Complete and issue final report	1-4
Overall Duration	8-24 weeks

Typical Information Requirements for ICR/ICE

The following lists some typical data needs to support ICRs and ICEs. These needs should be addressed in light of the stage of project development (CD-0, CD-1, CD-2, etc.) and the nature of the project (environmental remediation, standard construction, new technology, etc.)

1. Project Status/Management/Technical Briefings should include, but not be limited to:
 - a. Project history and overview
 - b. Technical baseline
 - c. Current project status
 - d. Major issues and problems
 - e. Project organization
 - f. Acquisition Strategy
 - g. Project Execution Plan
 - h. Work Breakdown Structure (WBS)
 - i. Risk Management Plan and Risk Analysis
2. Project Schedule should include, but not be limited to:
 - a. NEPA activities
 - b. Milestones (including Critical Decisions)
 - c. Critical Path
 - d. Major contracts
 - e. Procurement Plan
3. Design and Estimate Documentation/Back-up should include, but not be limited to:
 - a. Project information such as
 - i. Facilities descriptions
 - ii. Plot plans and layout drawings
 - iii. P&IDs, Process Diagrams
 - iv. Electrical One-Line drawings
 - v. System Descriptions
 - b. Design basis documentation
 - c. Cost estimate summary
 - d. Cost estimate details
 - e. Cost estimate backup data, such as
 - i. Vendor quotes
 - ii. Labor rates
 - iii. Productivity factors
 - iv. Contracting basis/assumptions
 - v. Overhead/markup assumptions and calculations
 - vi. Engineering/CM/PM staffing plans and manpower estimates
4. Cost Briefing (analysis of the results of the estimate) should include, but not be limited to:
 - a. Current estimate
 - b. Estimate basis (all major components)
 - c. Contingency analysis (and supporting risk and uncertainty analysis)
 - d. Escalation
 - e. Cash flow
 - f. Funding plan

- g. TEC and OPC buildup and classification
- h. Major assumptions
- i. Value engineering results
- j. Project staffing plan and resource availability/leveling analysis

Reconciliation of ICR/ICE and Project Estimate

- A draft of the DOE ICE report is generated which represents the consensus of both the DOE lead (e.g., OECM) and the ICE contractor, and includes the ICE contractor's report as backup.
- The DOE ICE report includes the team leader's programmatic observations and comments.
- The draft DOE ICE report is transmitted to the project office for review and comments.
- The ICE team leader will review the comments with the support contractor to determine whether the major differences between the project estimate and the ICE can be resolved via a teleconference or if a face-to-face meeting is required for reconciliation.
- Reconciliations
 - o Concentrate on major cost differences or items of special interest.
 - o Reconciliation does not necessarily mean consensus.
 - o An attempt should be made to keep reconciliations non-adversarial.
 - o If data is presented at the reconciliation that proves the ICE is in error, the ICE should be changed. The project team should adhere to this rule as well.
- A final draft ICE report will be developed to reflect any changes resulting from the reconciliation meeting.

ICE Report Contents

- Executive Summary
- Background (including project cost/baseline history)
- Project Status
- Technical Baseline Description
- Information available to the ICE team
- Cost estimate methodology (s) used
- Comparison of Project Estimate and the ICE by WBS
- Variance Analysis
- Contingency Analysis
- Schedule Analysis/Variance
- Funding Profile Analysis/Variance

- Conclusions
- Recommendations

Appendix L: DOE Expectations for Quality Cost Estimates

It is important that cost estimators and the program office validate that all cost elements are credible and can be justified by acceptable estimating methods, adequate data, and detailed documentation. This crucial step ensures that a high-quality cost estimate is developed, presented, and defended to management. This process verifies that the cost estimate adequately reflects the program baseline and provides a reasonable estimate of how much it will cost to accomplish all tasks. It also confirms that the program cost estimate is traceable and accurate and reflects realistic assumptions.

Verifying the quality of the point estimate is considered a best practice. One reason for this is that independent cost estimators typically rely on historical data and therefore tend to estimate more realistic program schedules and costs for state-of-the-art technologies. Moreover, independent cost estimators are less likely to automatically accept unproven assumptions associated with anticipated savings. That is, they bring more objectivity to their analyses, resulting in estimates that are less optimistic and higher in cost. An independent view provides a reality check of the point estimate and helps reduce the odds that management will invest in an unrealistic program that is bound to fail.

Cost Estimating Best Practices

There are four characteristics of a high-quality, reliable cost estimate. It is well-documented, comprehensive, accurate, and credible.

An estimate must be thoroughly documented, including source data and significance, clearly detailed calculations and results, and explanations of why particular methods and references were chosen. Data must be traced to their source documents.

An estimate must have enough detail to ensure that cost elements are neither omitted nor double counted. All cost-influencing ground rules and assumptions are detailed in the estimate's documentation.

An estimate must be unbiased, not overly conservative or overly optimistic, and is based on an assessment of most likely costs. Few, if any, mathematical mistakes are present; those that are minor.

Any limitations of the analysis because of uncertainty or bias surrounding data or assumptions are discussed. Major assumptions are varied, and other outcomes are recomputed to determine how sensitive they are to changes in the assumptions. Risk and uncertainty analysis is performed to determine the level of risk associated with the estimate. The estimate's results are crosschecked, and an independent cost estimate (ICE) conducted by a group outside the acquiring organization is developed to determine whether other estimating methods produce similar results.

Table L-1 shows how the 12 steps of a high-quality cost estimating process can be mapped to these four characteristics of a high-quality, reliable cost estimate.

**Table L-1: The Twelve Steps of High-Quality Cost Estimating (GAO)
Mapped to the Characteristics of a High-Quality Cost Estimate**

Cost estimate characteristic:	Cost estimating step:
Well documented. The estimate is thoroughly documented, including source data and significance, clearly detailed calculations and results, and explanations for choosing a particular method or reference: • Data are traced back to the source documentation; • Includes a technical baseline description; • Documents all steps in developing the estimate so that a cost analyst unfamiliar with the program can recreate it quickly with the same result; • Documents all data sources for how the data were normalized; • Describes in detail the estimating methodology and rationale used to derive each WBS element's cost.	1. Define the estimate's purpose; 3. Define the program; 5. Identify ground rules and assumptions; 6. Obtain the data; 10. Document the estimate; 11. Present the estimate to management.
Comprehensive. The estimate's level of detail ensures that cost elements are neither omitted nor double counted: • Details all cost-influencing ground rules and assumptions; • Defines the WBS and describes each element in a WBS dictionary; • A major automated information system program may have only a cost element structure.	2. Develop the estimating plan; 4. Determine the estimating approach.
Accurate. The estimate is unbiased, not overly conservative or overly optimistic, and based on an assessment of most likely costs: • It has few, if any, mathematical mistakes; its mistakes are minor; • It has been validated for errors like double counting and omitted costs; • Cost drivers have been cross-checked to see if results are similar; • It is timely; • It is updated to reflect changes in technical or program assumptions and new phases or milestones; • Estimates are replaced with EVM EAC and the independent EAC from the integrated EVM system.	7. Develop the point estimate and compare it to an independent cost estimate; 12. Update the estimate to reflect actual costs and changes.

Cost estimate characteristic:	Cost estimating step:
Credible. Discusses any limitations of the analysis from uncertainty or biases surrounding data or assumptions: • Major assumptions are realistic, varied and other outcomes recomputed to determine their sensitivity to changes in assumptions; • Risk and uncertainty analysis is performed to determine the level of risk associated with the estimate; • An independent cost estimate is developed to determine if other estimating methods produce similar results	7. Develop the point estimate and compare it to an independent cost estimate; 8. Conduct sensitivity analysis; 9. Conduct risk and uncertainty analysis.

Validating Cost Estimates

Too often program assumptions are optimistic and thus cost estimates are unrealistic and as a result, cost more than originally estimated. One way to avoid this predicament is to ensure that program and project cost estimates are both internally and externally validated—that is, that they are comprehensive, well documented, accurate, and credible. This increases the confidence that an estimate is reasonable and as accurate as possible.

The following steps should be taken to validate a program or project cost estimate:

1. Determine That the Estimate Is Well Documented:

Cost estimates are considered valid if they are well documented to the point at which they can be easily repeated or updated and can be traced to original sources through auditing. Rigorous documentation also increases an estimate's credibility and helps support an organization's decision making. The documentation should explicitly identify the primary methods, calculations, results, rationales or assumptions, and sources of the data used to generate each cost element.

Cost estimate documentation should be detailed enough to provide an accurate assessment of the cost estimate's quality. For example, it should identify the data sources, justify all assumptions, and describe each estimating method (including any cost estimating relationships) for every WBS cost element. Further, schedule milestones and deliverables should be traceable and consistent with the cost estimate documentation. Finally, estimating methods used to develop each WBS cost element should be thoroughly documented so that their derivation can be traced to all sources, allowing for the estimate to be easily replicated and updated.

2. Determine That the Estimate Is Comprehensive:

Cost Estimators or Analysts should make sure that the cost estimate is complete and accounts for all costs that are likely to occur. They should confirm its completeness, its consistency, and the realism of its information to ensure that all pertinent costs are included. Comprehensive cost estimates completely define the program, reflect the current schedule, and are technically reasonable. In addition, cost estimates should be structured in sufficient detail to ensure that cost elements are neither omitted nor double-counted. For example, if it is assumed that software will be reused, the estimate should account for all associated costs, such as interface design, modification, integration, testing, and documentation.

To determine whether an estimate is comprehensive, an objective review must be performed to certify that the estimate's criteria and requirements have been met. This step also infuses quality assurance practices into the cost estimate. In this effort, the reviewer checks that the estimate captures the complete technical scope of the work to be performed, using a logical WBS that accounts for all performance criteria and requirements. In addition, the reviewer must determine that all assumptions and exclusions the estimate is based on are clearly identified, explained, and reasonable.

3. Determine That the Estimate Is Accurate:

Estimates are accurate when they are not overly conservative or too optimistic, based on an assessment of most likely costs, adjusted properly for inflation, and contain few, if any, minor mistakes. In addition, when schedules or other assumptions change, cost estimates should be revised to reflect their current status.

Validating that a cost estimate is accurate requires thoroughly understanding and investigating how the cost estimate was constructed. For example, all WBS cost estimate elements should be checked to verify that calculations are accurate and account for all costs, including indirect costs. Moreover, proper escalation factors should be used to inflate costs so that they are expressed consistently and accurately. Finally, rechecking spreadsheet formulas and data input is imperative to validate cost model accuracy.

Besides these basic checks for accuracy, the estimating technique used for each cost element should be reviewed, to make sure it is appropriate for the degree of design or requirements definition that is complete.

Depending on the analytical method chosen, several questions should be answered to ensure cost estimate accuracy. Table L-2 outlines typical questions that should be answered to assess accuracy associated with various estimating techniques.

Table L-2: Questions for Checking the Accuracy of Cost Estimating Techniques

Technique:	Question:
Analogy;	• What heritage programs and scaling factors were used to create the analogy? • Are the analogous data from reliable sources? • Did technical experts validate the scaling factor? • Can any unusual requirements invalidate the analogy? • Are the parameters used to develop an analogous factor similar to the program being estimated? • How were adjustments made to account for differences between existing and new systems? Were they logical, credible, and acceptable?
Data collection;	• How old are the data? Are they still relevant to the new program? • Is there enough knowledge about the data source to determine if it can be used to estimate accurate costs for the new program? • Has a data scatter plot been developed to determine whether any outliers, relationships, and trends exist? • Were descriptive statistics generated to describe the data, including the historical average, mean, standard deviation, and coefficient of variation? • If data outliers were removed, did the data fall outside three standard deviations? • Were comparisons made to historical data to show they were an anomaly? • Were the data properly normalized so that comparisons and projections are valid? • Were the cost data adjusted for inflation so that they could be described in like terms?
Engineering build-up;	• Was each WBS cost element defined in enough detail to use this method correctly? • Are data adequate to accurately estimate the cost of each WBS element? • Did experienced experts help determine a reasonable cost estimate? • Was the estimate based on specific quantities that would be ordered at one time, allowing for quantity discounts? • Did the estimate account for contractor material handling overhead? • Is there a definitive understanding of each WBS cost element's composition? • Were labor rates based on auditable sources? Did they include all applicable overhead, general and administrative costs, and fees? Were they consistent with industry standards? • Is a detailed and accurate materials and parts list available?

Technique:	Question:
Expert opinion	• Do quantitative historical data back up the expert opinion? • How did the estimate account for the possibility that bias influenced the results?
Extrapolate from actuals (averages, learning curves, estimates at completion)	• Were cost reports used for extrapolation validated as accurate? • Was the cost element at least 25% complete before using its data as an extrapolation? • Were functional experts consulted to validate the reported percentage as complete? • Were contractors interviewed to ensure the cost data's validity? • Were recurring and nonrecurring costs separated to avoid double counting? • How were first unit costs of the learning curve determined? What historical data were used to determine the learning curve slope? • Were recurring and nonrecurring costs separated when the learning curve was developed? • How were partial units treated in the learning curve equation? • Were production rate effects considered? How were production break effects determined?
Parametric;	• Was a valid statistical relationship, or CER, between historical costs and program, physical, and performance characteristics established? • How logical is the relationship between key cost drivers and cost? • Was the CER used to develop the estimate validated and accepted? • How old are the data in the CER database? Are they still relevant for the program being estimated? • Do the independent variables for the program fall within the CER data range? • What is the level of variation in the CER? How well does the CER explain the variation (R²) and how much of the variation does the model not explain? • Do any outliers affect the overall fit? • How significant is the relationship between cost and its independent variables? • How well does the CER predict costs?
Software estimating;	• Was the software estimate broken into unique categories: new development, reuse, commercial off-the-shelf, modified code, glue code, integration? • What input parameters—programmer skills, applications experience, development language, environment, process—were used for commercial software cost models, and how were they justified? • How was the software effort sized? Was the sizing method reasonable?

Technique:	Question:
	• How were productivity factors determined? • How was labor hours converted to cost? How many productive hours were assumed in each day? • How were savings from auto-generated code and commercial off-the-shelf software estimated? Are the savings reasonable? • What were the assumptions behind the amount of code reuse? Were they supported? • How were the integration between the software, commercial software, system, and hardware estimated, and what historical data supported the results? • Were software license costs based on actual or historical data? • Were software maintenance costs adequately identified and reasonable?

Validating Parametric Cost Estimates and Cost Models

Cost Estimating Relationships (CERs) and cost models also need to be validated to demonstrate that they can predict costs within an acceptable range of accuracy. To do this, data from historical programs similar to the new program should be collected to determine whether the CER selected is a reliable predictor of costs. In this review, technical parameters for the historical programs should be examined to determine whether they are similar to the program being estimated. For the CER to be accurate, the new and historical programs should have similar functions, objectives, and program factors, like acquisition strategy, or results could be misleading. Equally important, CERs should be developed with established and enforced policies and procedures that require staff to have proper experience and training to ensure the model's continued integrity.

Before a parametric model is used to develop an estimate, the model should be calibrated and validated to ensure that it is based on current, accurate, and complete data and is therefore a good predictor of cost. Like a CER, a parametric model is validated by determining that its users have enough experience and training and that formal estimating system policies and procedures have been established. The procedures focus on the model's background and history, identifying key cost drivers and recommending steps for calibrating and developing the estimate. To stay current, parametric models should be continually updated and calibrated.

Validation with calibration gives confidence that the model is a reliable estimating technique. To evaluate a model's ability to predict costs, a variety of assessment tests can be performed. One is to compare calibrated values with independent data that were not included in the model's calibration. Comparing the model's results to the independent test data's "known value" provides a useful benchmark for how accurately the model can predict costs. An alternative is to use the model to prepare an estimate and then compare

its result with an independent estimate cost or check estimate based on another estimating technique.

4. Determine That the Estimate Is Credible:

Credible cost estimates clearly identify limitations because of uncertainty or bias surrounding the data or assumptions. Major assumptions should be varied and other outcomes recomputed to determine how sensitive outcomes are to changes in the assumptions. In addition, a risk and uncertainty analysis should be performed to determine the level of risk (cost estimate uncertainty) associated with the estimate. Finally, the results of the estimate should be cross-checked and an ICE performed to determine whether alternative estimate views produce similar results.

To determine an estimate's credibility, key cost elements should be tested for sensitivity, and other cost estimating techniques should be used to cross-check the reasonableness of Ground Rules & Assumptions (GR&As). It is also important to determine how sensitive the final results are to changes in key assumptions and parameters. A sensitivity analysis identifies key elements that drive cost and permits what-if analysis, often used to develop cost ranges and risk reserves. This enables management to know the potential for cost growth and the reasons behind it.

Along with a sensitivity analysis, a risk and uncertainty analysis adds to the credibility of the cost estimate, because it identifies the level of confidence associated with achieving the cost estimate. Risk and uncertainty analysis produces more realistic results, because it assesses the variability in the cost estimate from such effects as schedules slipping, missions changing, and proposed solutions not meeting users' needs. An uncertainty analysis gives decision maker's perspective on the potential variability of the estimate should facts, circumstances, and assumptions change. By examining the effects of varying the estimate's elements, a degree of uncertainty about the estimate can be expressed with a range of potential costs that is qualified by a factor of confidence.

Another way to reinforce the credibility of the cost estimate is to see whether applying a different method produces similar results. In addition, industry rules of thumb can constitute a sanity check. The main purpose of cross-checking is to determine whether alternative methods produce similar results. If so, then confidence in the estimate increases, leading to greater credibility. If not, then the cost estimator should examine and explain the reason for the difference and determine whether it is acceptable.

An Independent Cost Estimate (ICE) is considered one of the best and most reliable validation methods. ICEs are typically performed by organizations higher in the decision-making process than the office performing the baseline estimate. They provide an independent view of expected program costs that tests the program office's estimate for reasonableness. Therefore, ICEs can provide decision makers with additional insight into a program's potential costs—in part, because they frequently use different methods and are less burdened with organizational bias. Moreover, ICEs tend to incorporate adequate risk and, therefore, tend to be more conservative by forecasting higher costs than the program office.

The ICE is usually developed from the same technical baseline description the program office used so that the estimates are comparable. An ICE's major benefit is that it provides an objective and unbiased assessment of whether the program estimate can be achieved, reducing the risk that the program will proceed underfunded. It also can be used as a benchmark to assess the reasonableness of a contractor's proposed costs, improving management's ability to make sound investment decisions, and accurately assess the contractor's performance.

In most cases, the ICE team does not have insight into daily program events, so it is usually forced to estimate at a higher level or use analogous estimating techniques. It is, in fact, expected that the ICE team will use different estimating techniques and, where possible, data sources from those used to develop the baseline estimate. It is important for the ICE team and the program's cost estimate team to reconcile the two estimates.

Two issues with ICEs are the degree of independence and the depth of the analysis. Degree of independence depends on how far removed the estimator is from the program office. The greater the independence, the more detached and disinterested the cost estimator is in the program's success. The basic test for independence, therefore, is whether the cost estimator can be influenced by the program office.

Thus, independence is determined by the position of the cost estimator in relation to the program office and whether there is a common superior between the two. For example, if an independent cost estimator is hired by the program office, the estimator may be susceptible to success-oriented bias. When this happens, the ICE can end up too optimistic.

History has shown a clear pattern of higher cost estimates the further away from the program office that the ICE is created. This is because the ICE team is more objective and less prone to accept optimistic assumptions. To be of value, however, an ICE must not only be performed by entities far removed from the acquiring program office but must also be accepted by management as a valuable risk reduction resource that can be used to minimize unrealistic expectations. The second issue with an ICE is the depth of the review.

Table L-3 lists eight types of independent cost estimate reviews and describes what they entail.

Table L-3: Eight Types of Independent Cost Estimate Reviews:

Review:	Description:
Document review;	It is an inventory of existing documentation to determine whether information is missing and an assessment of the available documentation to support the estimate.

Review:	Description:
Independent cost assessment;	An outside evaluation of a program's cost estimate that examines its quality and accuracy, with emphasis on specific cost and technical risks, it involves the same procedures as those of the program estimate but using different methods and techniques.
Independent cost estimate Description:	Conducted by an organization outside the acquisition chain, using the same detailed technical information as the program estimate, it is a comparison with the program estimate to determine whether it is accurate and realistic.
Independent government cost estimate;	Analyzing contractors' prices or cost proposals, it estimates the cost of activities outlined in the statement of work; does not include all costs associated with a program and can only reflect costs from a contractor's viewpoint. Assumes that all technical challenges can be met as outlined in the proposal, meaning that it cannot account for potential risks associated with design problems.
Non-advocate review Description:	Performed by experienced but independent internal non-advocate staff, it ascertains the adequacy and accuracy of a program's estimated budget; assesses the validity of program scope, requirements, capabilities, acquisition strategy, and estimated life-cycle costs.
Parametric estimating technique;	Usually performed at the summary WBS level, it includes all activities associated with a reasonableness review and incorporates cross-checks using parametric techniques and factors based on historical data to analyze the estimate's validity.
Reasonableness, or sufficiency, review;	It is a review of all documentation by an independent cost team, meeting with staff responsible for developing the program estimate, to analyze whether the estimate is sufficient with regard to the validity of cost and schedule assumptions and cost estimate methodology rationale and whether it is complete.

Sampling technique;	It is an independent estimate of key cost drivers of major WBS elements whose sensitivity affects the overall estimate; detailed independent government cost estimates developed for these key drivers include vendor quotes and material, labor, and subcontractor costs. Other program costs are estimated using the program estimate, as long as a reasonableness review has been conducted to ensure their validity.
---------------------	--

As the table shows, the most rigorous independent review is an ICE. Other independent cost reviews address only a program's high-value, high-risk, and high-interest elements and simply pass through program estimate values for the other costs. While they are useful to management, not all provide the objectivity necessary to ensure that the estimate going forward for a decision is valid.

After an ICE or independent review is completed, it should be reconciled to the project or baseline estimate to ensure that both estimates are based on the same GR&As. A synopsis or reconciliation of the cost estimates and their differences is then presented to management. Using this information, decision makers use the ICE or independent cost estimate review to validate whether the program estimate is reasonable.