NOT MEASUREMENT SENSITIVE

DOE G 413.3-21A
6-6-2018

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
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FOREWORD

A strong cost estimating foundation is essential to achieving program and project success. Every Federal cost estimating practitioner is challenged to strive for high quality cost estimates by using *the preferred* best practices, methods and procedures contained in this Department of Energy (DOE) Cost Estimating Guide. Content in this guide supersedes DOE Guide 413.3-21, Chg1, Cost Estimating Guide, 10-22-2015.

The Guide is applicable to all phases of the Department's acquisition of capital asset life-cycle management activities and may be used by all DOE elements, programs and projects. When considering unique attributes, technology, and complexity, DOE personnel are advised to carefully compare alternate methods or tailored approaches against this uniform, comprehensive cost estimating guidance. Programs may specify more specific processes and procedures that augment or replace those in this guide (e.g. NNSA Life Extension Programs (LEPs) fall under the process/timeline in the Phase 6.X process).

Guides provide non-mandatory supplemental information and additional guidance regarding executing the Department's Policies, Orders, Notices, and regulatory standards. Guides may also provide acceptable methods for implementing these requirements. Guides are not substitutes for requirements, nor do they replace technical standards that are used to describe established practices and procedures for implementing requirements. Send citations of errors, omissions, ambiguities, and contradictions found in this guide to PMpolicy@hq.doe.gov.

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1.0 PURPOSE

The primary purpose of the DOE Cost Estimating Guide is to supply DOE cost estimating practitioners with uniform guidance, methodologies, and best practices to ensure development of high quality cost estimates. Although applicable to all cost estimating, this guidance is tailored to be largely applicable to the cost estimation of construction projects and/or programs. These cost estimates usually result in project independent cost estimates (ICEs) to validate a project performance baseline. They are similar but different from an independent government cost estimate (IGCE) normally used to support a contract action. The guidance considers all phases of the Department's work in creating credible project cost estimates that can be used to predict, analyze, and evaluate a project and program's cost and schedule, and serve as a critical program control planning tool. Once credible cost estimates have been presented to and approved by management, they can be used as a basis for measuring performance against an approved baseline using an Earned Value Management (EVM) System.

While this guide is largely applicable to the cost estimation of construction projects and/or programs, the recommended practices and methodologies are also valid when applied to IGCEs. The IGCE can be used to support contract cost and price analysis, cost realism analysis for a negotiated contract action, or a contract source selection matter must be coordinated with the contracting officer and their supporting cost and price analyst to ensure that they are consistent with the prescribed methodologies, cost treatment, and guidance set forth in the Federal Acquisition Regulations, DOE Acquisition Regulations, and other agency policies and guidance. This guide references the GAO *Twelve Steps of a High-Quality Cost Estimating Process* (GAO-09-3SP) for techniques that have been proven to improve cost estimates. Formally documenting the cost estimate using the GAO 12-step process provides an additional measure of quality. GAO best practices alone are not sufficient to ensure a high quality cost estimate in all cases; thus this Guide outlines additional techniques and best practices that, when used in conjunction with the GAO 12-step process, should improve cost estimates.

The Guide conveys information that conforms to the accepted industry estimating standards and is intended to facilitate the development of local or site-specific cost estimating requirements.

2.0 KEY GUIDANCE CHARACTERISTICS

High quality cost estimates support the execution of projects and programs and help to ensure that management is given the information it needs to make informed decisions. 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.

2.1 High-Quality Cost Estimates

The GAO Cost Estimating Guide, through documentation of industry best practices, cites four characteristics of high quality cost estimates. They should be credible, well-documented, accurate and comprehensive.[1]

1. **Credible –** Estimates are considered credible if they 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. A risk and uncertainty analysis should be performed to determine the level of cost estimate uncertainty or risk. A full scale Monte Carlo analysis may not be necessary based on type of estimate. Results of the estimate should be cross-checked and an Independent Cost Estimate (ICE) performed when deemed necessary based on the CD requirement and/or the risk of the work to determine whether alternative estimate views produce similar results. Estimates should also be evaluated against historical ACWP values for similar work that may have been done at DOE sites. Cost estimating involves collecting and analyzing available historical data and applying quantitative models techniques, tools and databases to predict a program's future cost.

    a. Sensitivity analysis is used to identify key elements that drive cost by manipulating each potential driver in the cost estimate individually and analyzing the associated impact, to determine which activities have the potential for the greatest impact to the program amounting to a what-if analysis.

    b. 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 makers 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.

    c. 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.

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[1] *GAO Cost Estimating and Assessment Gui*de, GAO-09-3SP (Washington, D.C., March 2009), p.179.

2. **Well-documented –** Cost estimates need to be well documented, traceable to original sources, and easily repeatable or updated. Rigorous documentation also increases an estimate's credibility and helps support an organization's decision making.

    a. 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 Work Breakdown Structure (WBS) cost element. Further, schedule milestones and deliverables should be traceable and consistent with the cost estimate documentation.

    b. 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.

3. **Accurate –** Estimates should be based on an assessment of most likely costs, adjusted properly for inflation, and contain few, if any, minor mistakes. In addition, revise cost estimates to reflect schedule revisions initiated by contract modifications.

    a. 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. Rechecking spreadsheet formulas and data input is imperative to validate cost model accuracy.

    b. 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.

    c. Depending on the analytical method chosen, several questions should be answered to ensure cost estimate accuracy. The GAO Cost Estimating and Assessment Guide outlines typical questions that should be answered to assess accuracy associated with various estimating techniques.

4. **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.

    a. Comprehensive cost estimates completely define the program, reflect the project schedule, and are technically reasonable. The Cost Estimator should also identify the technical approach to complete the scope identified, considering that each approach may yield a different estimate covering the same scope. Estimates should be structured in sufficient detail to ensure that cost elements are neither omitted nor redundant. 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.

b. 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.

From GAO-09-3SP, there are 12 key steps that are recommended to DOE practitioners to produce high quality cost estimates:[2]

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., 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

2.2 Cost Estimate Structure

One of the GAO characteristics and best practice steps – determining the estimating structure – includes the need to develop a "product-oriented" WBS that reflects the requirements and basis for identifying resources and tasks necessary to accomplish the project's objectives.

DOE O 413.3B promotes the development of a well-defined and managed project performance baseline (defined by scope, schedule, cost, and key performance parameters).

This guidance highlights the importance of four closely interrelated processes to help define the project baseline: development of a WBS for scope definition, cost estimating, schedule development, and risk management.

- **The Work Breakdown Structure process provides:**

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[2] GAO-09-3SP

  - 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,
  - A living document 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.
  - Description of any applicable indirect costs (e.g. operation and maintenance, security, legacy pension requirements).

- **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;
  - 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;
  - The milestones and activity relationships that define possible impacts, i.e. overtime needed to complete activities.
  - The durations of Level of Effort (LOE) activities needed for the cost estimate to accurately develop costs.
  - The sequence of the procurement of long lead items needed for the cost estimate to accurately develop costs and expose any possible impacts to the overall project planning due to the procurements; and
  - Additional WBS elements exposed during the development of the planning sequence and logic.

- **The Risk Management process provides[3]:**
    - Identification of technical, schedule, and cost risks.
    - Selection of appropriate risk handling strategies to either reduce impact of threats (negative risks) and enhance impact of opportunities (positive risks)
    - Analysis of both threats and opportunities to determine fair and reasonable allowances for risk and estimate uncertainty to support the project/ program (Contingency & Management Reserve)

2.3 Purpose of the Cost Estimate

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

- Establish cost and schedule ranges throughout the project development phases;
- 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;
- Support long-term portfolio cost projections;
- Provide data for value engineering/value analysis studies, independent reviews, and baseline changes.

For projects governed by DOE 413.3B, the purposes of cost estimates include:

- Provide a rough order of magnitude cost range at Critical Decision (CD)-0 (see Figures 3-1 and 3-2 for a pictorial description of the DOE Critical Decision Process);
- Help the DOE and its managers evaluate and select alternative solutions at CD-1;
- Create a Project Performance Baseline to obtain CD-2 approval and to measure progress following the CD-2 approval; or,

2.4 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 in an iterative fashion. 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.

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

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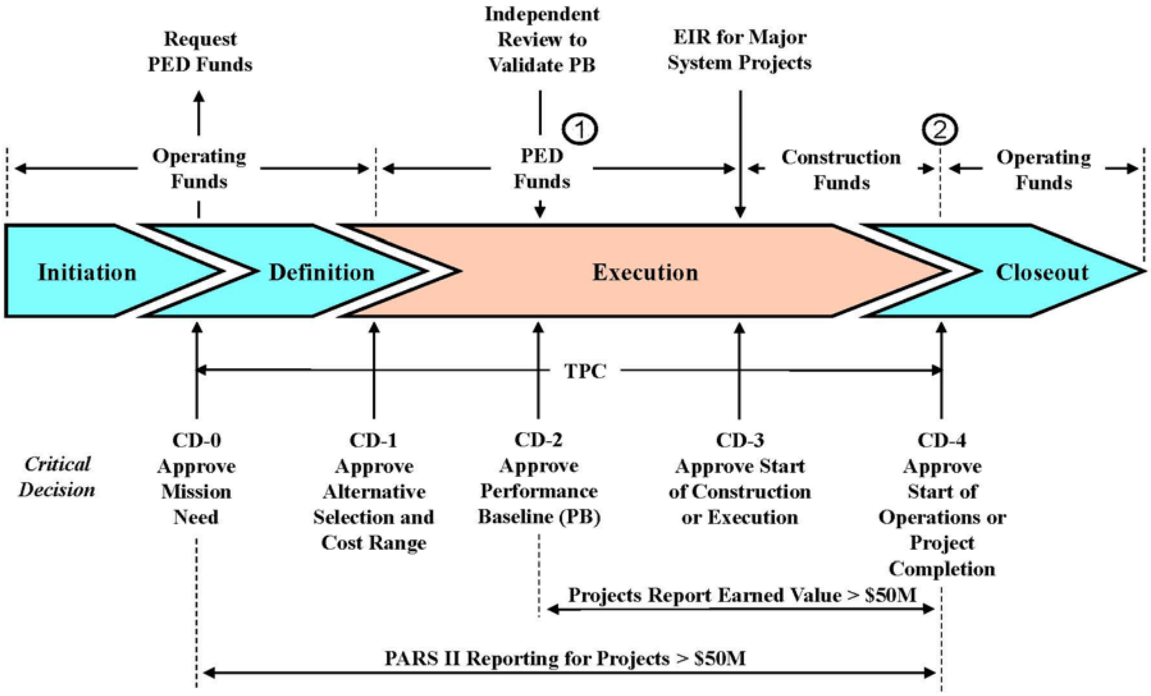
[3] See DOE G 413.3-7A, *Risk Management* for more information.

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 or program, the scope will become more definitive. As this level of definition increases cost estimates become more definitive with narrower cost ranges, and will eventually reflect the scope and schedule of work packages and planning packages defined for the project. Normally, this should reduce uncertainty, assumptions, and number of risks and/or their impact if realized.

3.1 Project/Program Requirements

Appendixes B and C 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 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), National Environmental Policy Act (NEPA); safety and health; site security requirements; 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. 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. **PED funds can be used after CD-3 for design.**
2. **Operating Funds may be used prior to CD-4 for transition, startup, and training costs.**

Figure 3-1. Typical DOE Acquisition Management System for Line Item Capital Asset Projects[4]

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

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[4] DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets* (October 2017).

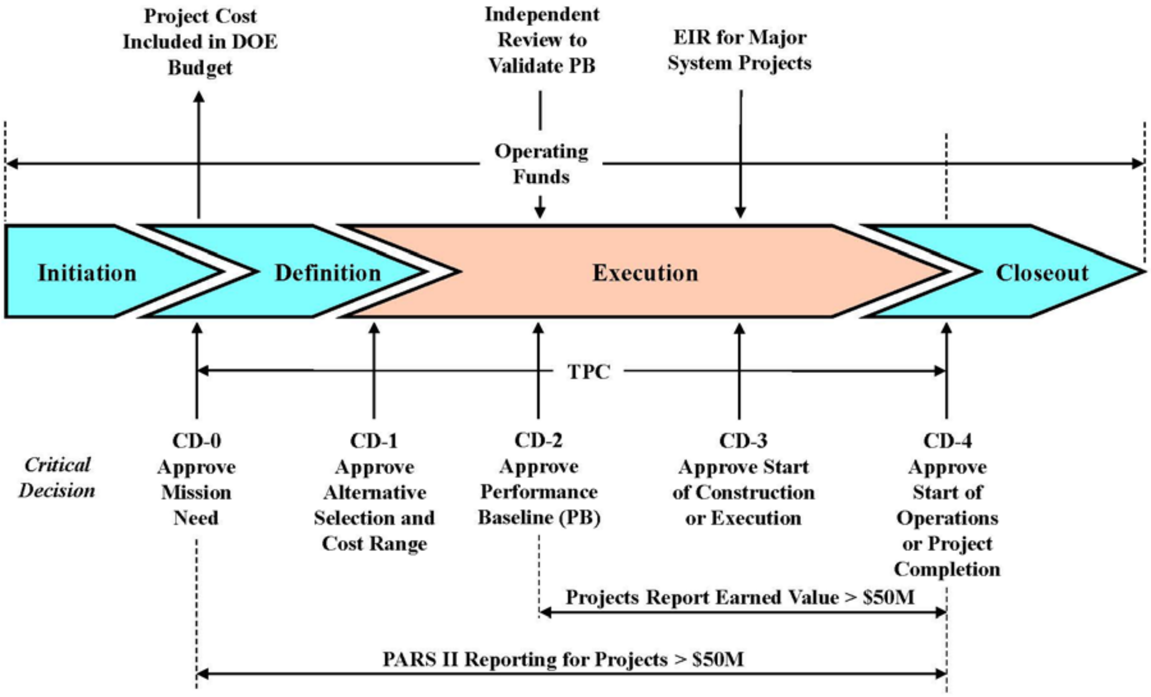

Figure 3-2. Typical DOE Acquisition Management System for Other Capital Asset Projects (i.e., Major Items of Equipment and Operating Expense Projects)[5]

3.2 Application of this Guide to DOE Estimating

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 can 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 430.1C and DOE O 413.3B);
- The DOE annual budget guidance document; and
- Other project/program management purposes (various Federal regulations, DOE Orders, and industry practices).

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[5] DOE Order 413.3B

Best practices for Life-Cycle Cost (LCC) include all 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. (Figure 3-3).[6]

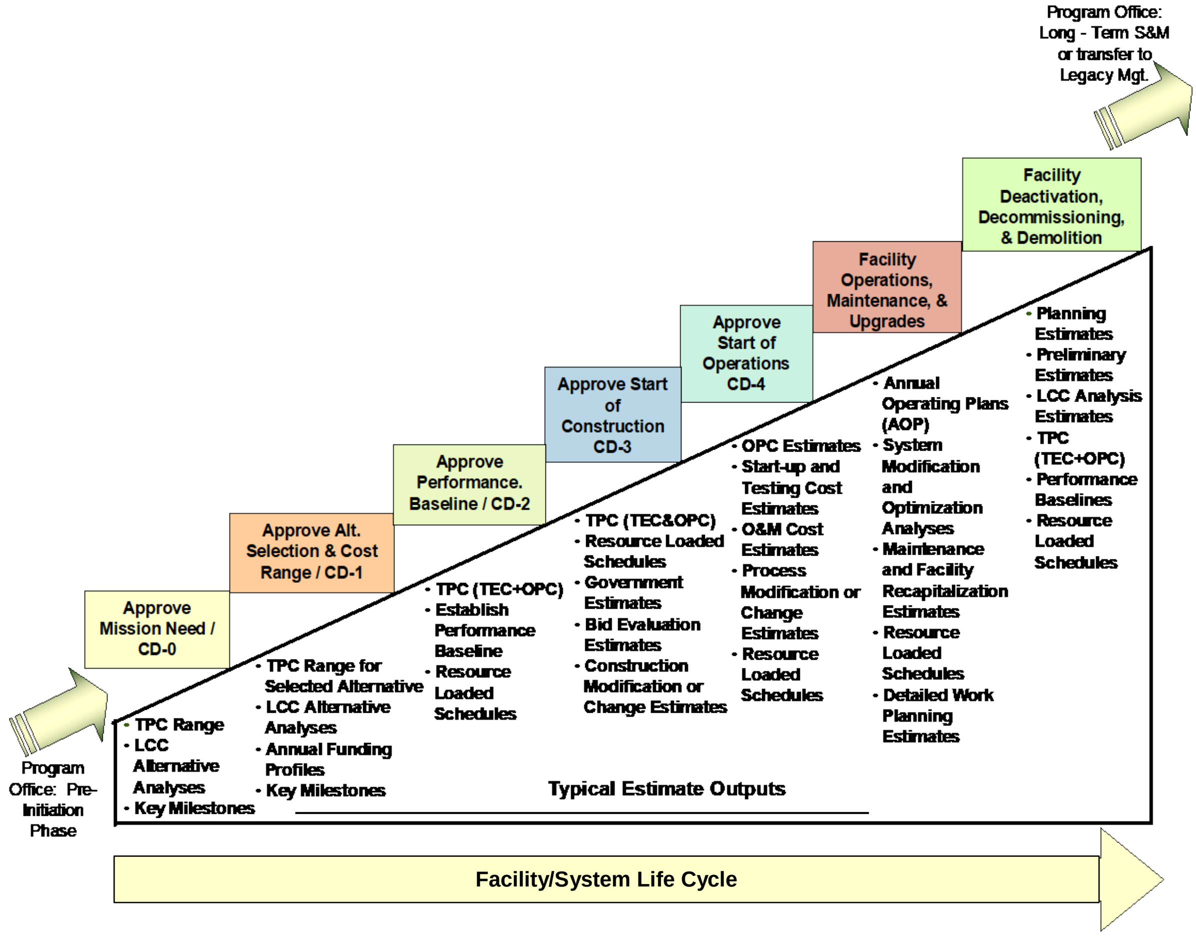

Figure 3-3. Facility/System Estimate Outputs as Compared to Life-Cycle Major Milestones

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

Critical Decision (CD)-0, *Approve Mission Need* — Generally, a Rough Order of Magnitude (ROM) 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

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[6] DOE *Life Cycle Cost Handbook, Guidance for Lifecycle Cost Estimation and Analysis* (September 2014), pages 30-40; see also Appendix F - Example of Life-Cycle Cost Analysis.

CD-0. In addition, an estimate of the costs to be incurred prior to CD-1, such as preparing an Analysis of Alternatives and 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* — 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. The quality of the cost estimate at this stage, as well as other stages, depends on the uncertainties and risk.

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[7] 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).

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 $50 million.[8]

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

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[7] DOE *Life Cycle Cost Handbook*.

[8] DOE Order 413.3B

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. The Contracting Officer may request an Independent Government Cost Estimate (IGCE) to support the action. The guidance, methodologies, and best practices reflected in this guide are largely applicable to the cost estimation of projects (i.e., ICEs). However, the development of an IGCE and other analyses that will be used to support contract cost and price analysis, cost realism analysis for a negotiated contract action, or a contract source selection matter must be coordinated with the contracting officer and their supporting cost and price analyst to ensure that they are consistent with the prescribed methodologies, cost treatment, and guidance set forth in the Federal Acquisition Regulation, DOE Acquisition Regulations, and other agency policies and guidance. As a best practice and to derive efficiencies, it is possible and advisable to use the same cost estimating team to estimate the direct costs (labor, material, and subcontracts) and additional project cost elements (contingency and government other direct costs (ODCs)) required to complete an ICE in support of a project performance baseline but advisable to firewall information on other costs such as contract cost elements (e.g., indirect, fee, etc.) and incentives that directly impact contract negotiating strategies.

The type of contract that will be used to execute the work impacts the basis of an estimate. Types of contracts range from firm-fixed price, where the contractor assumes the full cost and performance risk, to cost reimbursement, where the Government assumes the cost and performance risk and the available strategies for incentivizing successful performance include the potential for an award fee or a performance-based incentive fee. The contract type and incentive structure influences the balance of assumed government and contractor risks.

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 F 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 estimates from diverse sources may require reconciliation. Generally, the differences are due to the estimates not being based on consistent or current information. Some examples of sources for differences include assumptions concerning weather, productivity, and commodity markets. The reconciliation should clearly state the differences and the rationale for the differences. The Government may have access to more detail on cost estimates for cost reimbursement projects.

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. GAO conducted an industry-wide survey to address the characteristics of a good estimate; participants represented a wide variety of industries– including aerospace, automotive, energy, consulting firms, the Navy, and the Marine Corps. The survey verified that the characteristics listed in the table are valid and support estimate credibility. GAO also found that despite the fact that these characteristics have been published and known for decades, many Federal agencies still lack the ability to develop cost estimates that can satisfy these basic characteristics.

Table 4-1. Basic Characteristics of Credible Cost Estimates[9]

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, in development of the Project Execution Plan, and in defining parameters and other scope characteristics at each Critical Decision milestone. • 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 Uncertainties and Risk	• Identify the confidence level (e.g., 80 percent) needed to establish a successful planning process. Identify uncertainties and develop an allowance to mitigate cost effects of the uncertainties. • Include known costs and allow for historically likely but specifically unknown costs. (Reference: DOE G 413.3-7A, Risk Management Guide).
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

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[9] GAO 09-3SP, p.6.

Planning Step	Description
	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.

DOE project review and assessment teams examine how well project cost estimates align with the GAO 12 Step Best Practices. Most DOE contractors have already incorporated a best management practice depicting how their project planning and cost estimating structure development relates to the GAO 12 Steps. Appendix I presents more detail for applying GAO guidelines to develop quality DOE 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 AACE International Recommended Practice (RP) 17R-97 and RP 18R-97; see Appendix G). Appendix G includes a complete description of AACE International’s classifications. Table 4-2 provides example primary and secondary characteristics and expected estimate uncertainty ranges, as a function of the estimate class. These characteristics and ranges provide expected estimate accuracy ranges based on scope definition data from historical projects, however they should not be used to calculate contingency. Further information on risk analysis can be found in DOE G 413.3-7A, *Risk Management Guide*. 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 AACE International's Classes 5, 3 and 2, respectively. Table 4-3 provides an example of the typical suggested types of cost estimates for each DOE Critical Decision as compared with the AACE International classification.

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.

Table 4-2. Cost Estimate Classification for Process Industries[10]

	Primary Characteristic	***Secondary Characteristic***		
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** 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
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 75%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

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[10] AACE International Recommended Practice 18R-97, *Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries* (March 2016).

Table 4-3. Generic Anticipated Types of Estimates for DOE Critical Decisions

Critical Decision	Suggested Estimate	Recommended Minimum AACE International Estimate Classification
CD-0	Cost estimate range	Class 5
	Estimate of costs to be incurred prior to CD-1	Class 3
CD-1	TPC Range	Class 4
	Estimate of near term preliminary design cost	Class 3
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 projects	Class 2
	– High risk projects	Class 2
CD-4		N/A

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, unit costs, and detailed take-off (Class 1) techniques for work that will be executed in the near future and is well defined; semi-detailed unit costs with assembly level items (Class 3) techniques for for preliminary or budget authorization and control estimating work that is currently in the planning stages but less defined; and capacity factored parametric models, judgment, or analogy (Class 5) techniques for order of magnitude estimating of 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, *Acquisition Strategy Guide,* 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 be in part 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 for the realization of opportunities. 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 of the identified risks would be significant. The risks will be managed and appropriate resources identified to mitigate each risk.[11]

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.

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

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.

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; and,
- Better resource basis for the schedule.

Disadvantages include:

- More time needed to develop the estimate; More costly to develop than relationship estimating; and,
- Some elements can be omitted by accident.

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.[12] 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.

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[12] 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.

Parametric estimating is reliant on the collection and analysis of previous or historical 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.[13] 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 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.

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[13] FAI Glossary, FAR 15.404-1(c)(2)(i)(C); PM Glossary of Terms Handbook; and, AACE International Cost Engineering Terminology

- **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 square feet = $50/ square feet for the previous project so the estimated cost of the new project is $50/ square feet x 7,000 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 Cost (new) = Cost (known) (Capacity (new)/ Capacity (known)^{e}
Where: e = capacity factor derived from historical data
Cost (new) = $150,000,000 (300/250)$^{.75}$
Cost (new) = $172,000,000 (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 x 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.

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.

Due to 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.

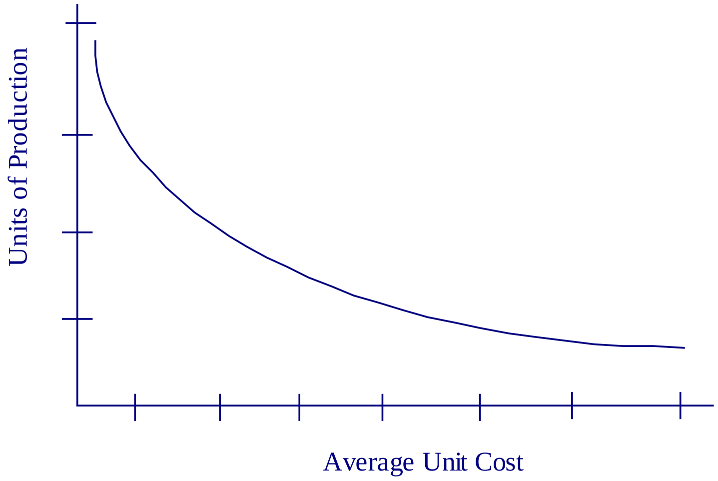

Figure 5-1. **The Learning Curve Method**

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, environmental, safety and health (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 to 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 (approximately 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 described here appeared earlier in Section 2.4, Figure 2-1. The cost estimating development process discussed in this section follows the 12 steps model recommended by GAO[14] and is part of the cycle of iterative activities for developing the cost estimate depicted in Figure 2-1. 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.

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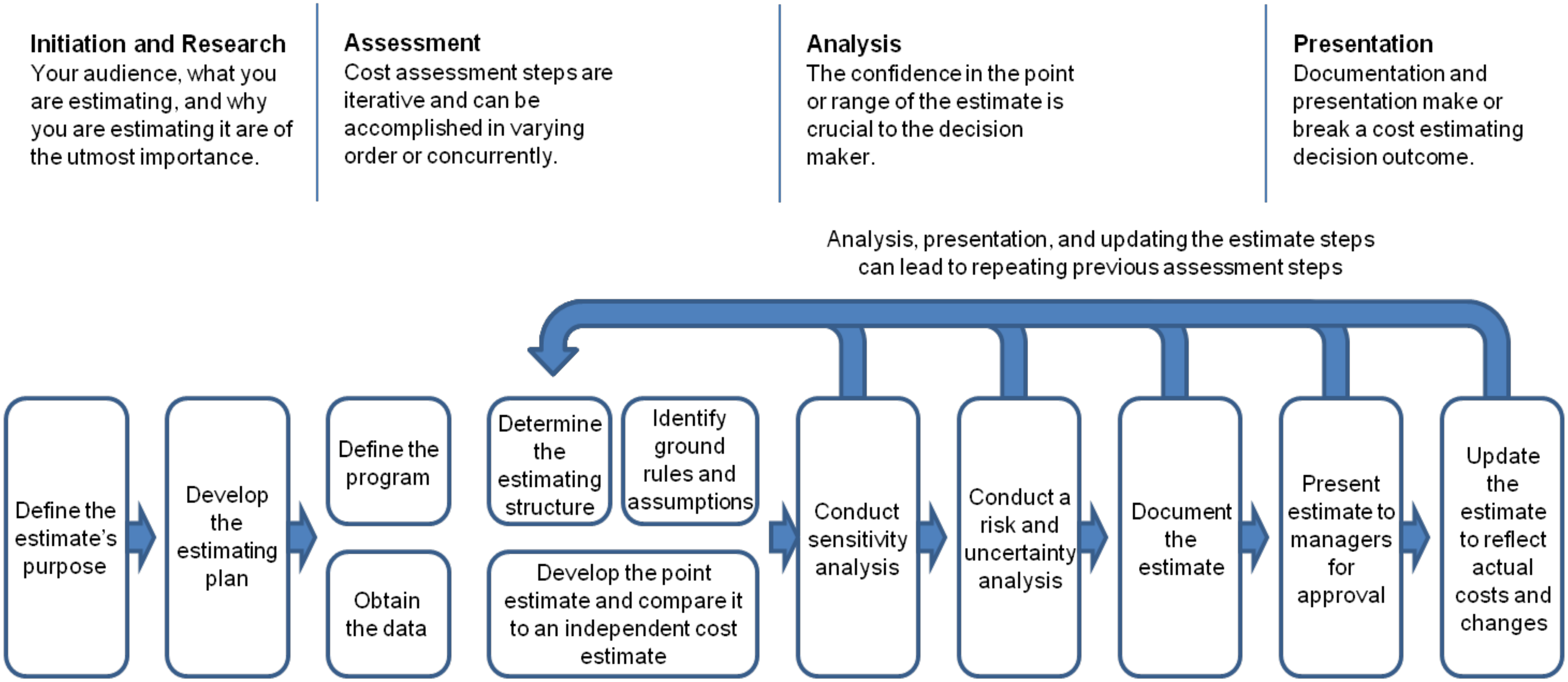
[14] GAO-09-3SP



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.

Analysis, presentation, and updating the estimate steps can lead to repeating previous assessment steps

Figure 6-1. The GAO 12 Steps Cost Estimating Development Process Model

SOURCE: GAO-09-3SP

Table 6-1. DOE Crosswalk Depicting DOE G 413.3-21 and GAO Twelve Steps of a High-Quality Cost Estimating Process by Project Phase, Best Practices

GAO Best Practice	GAO Cost Estimating Activities	Where Conformance to GAO Practice is Demonstrated in DOE G 413.3-21
Step 1: Define the Estimate's Purpose	1. Determine estimate’s purpose, required level of detail, and overall scope. 2. Determine who will receive the estimate.	Guidance related to the purpose of the estimate is found in Sections 2.3, 3.2, 6.2, & 6.7.1.
Step 2: Develop an Estimating Plan	1. Determine the cost estimating team and develop its master schedule. 2. Determine who will do the independent cost estimate 3. Outline the cost estimating approach 4. Develop the estimating timeline.	Guidance related to planning the estimate development can be found in Section 4.1, Table 4-1, & Section 6.2.
Step 3: Define the Program Characteristics	1. In a technical baseline description document, identify the program’s purpose and its system and performance characteristics and all system configurations. 2. Describe technology implications. 3. Describe acquisition schedule and strategy. 4. Describe relationship to other existing systems, including predecessor or similar legacy systems. 5. Define support (manpower, training, etc.) and security needs and risk items. 6. Develop system quantities for development, test, and production. 7. Define deployment and maintenance plans.	Guidance related to DOE Program characteristics and requirements for cost estimates are discussed in Section 3 & also in Section 6.3.2.
Step 4: Determine the Estimating Structure	1. Define a WBS and describe each element in a WBS dictionary (a major automated information system may have only a cost element structure). 2. Choose the best estimating method for each WBS element. 3. Identify potential cross-checks for likely cost and schedule drivers. 4. Develop a cost estimating checklist.	Guidance relative to estimate structure is found in Table 4-1, & discussed extensively in Section 5

GAO Best Practice	GAO Cost Estimating Activities	Where Conformance to GAO Practice is Demonstrated in DOE G 413.3-21
Step 5: Identify Ground Rules and Assumptions	1. Clearly define what the estimate includes and excludes. 2. Identify global and program-specific assumptions, such as the estimate's base year, including time-phasing and life cycle. 3. Identify program schedule information by phase and program acquisition strategy. 4. Identify any schedule or budget constraints, inflation assumptions, and travel costs. 5. Specify equipment the government is to furnish as well as the use of existing facilities or new modification or development. 6. Identify prime contractor and major subcontractors. 7. Determine technology refresh cycles, technology assumptions, and new technology to be developed. 8. Define commonality with legacy systems and assumed heritage savings. 9. Describe effects of new ways of doing business.	The concepts related to ground rules and assumptions are discussed in Table 4-1, and again in Section 6, with specific guidance in Section 6.7.1.
Step 6: Obtain Data	1. Create a data collection plan with emphasis on collecting current and relevant technical, programmatic, cost, and risk data. 2. Investigate possible data sources. 3. Collect data and normalize them for cost accounting, inflation, learning and quantity adjustments. 4. Analyze the data for cost drivers, trends, and outliers and compare results against rules of thumb and standard factors derived from historical data. 5. Interview data sources and document all pertinent information, including an assessment of data reliability and accuracy. 6. Store data for future estimates	Estimate data sources and associated guidance can be found in Section 2.2, Section 3,and is the focus of Section 6.3
Step 7: Develop a Point Estimate and Compare it to an Independent Cost Estimate	1. Develop the cost model, estimating each WBS element, using the best methodology from the data collected, and including all estimating assumptions. 2. Express costs in constant year dollars. 3. Time-phase the results by spreading costs in the years they are expected to occur, based on the program schedule. 4. Sum the WBS elements to develop the overall point estimate. Validate the estimate by looking for errors like double counting and omitted costs. 5. Compare estimate against the independent cost estimate and examine where and why there are differences. 6. Perform cross-checks on cost drivers to see if results are similar. 7. Update the model as more data become available or as changes occur and compare results against previous estimates.	The techniques available for estimate development are described in Section 5 and the estimate development process itself is discussed extensively in Section 6.4. Other tasks identified here are discussed in Sections 6.5 and 6.6. Independent Cost Estimates are discussed in Section 8.3 with guidance provided in Appendix I.

GAO Best Practice	GAO Cost Estimating Activities	Where Conformance to GAO Practice is Demonstrated in DOE G 413.3-21
Step 8: Conduct Sensitivity Analysis *(method and rigor of the analysis will vary depending on the estimate level)*	1. Test the sensitivity of cost elements to changes in estimating input values and key assumptions. 2. Identify effects on the overall estimate of changing the program schedule or quantities. 3. Determine which assumptions are key cost drivers and which cost elements are affected most by changes.	The concept of Sensitivity Analysis discussed in Section 6.4.5 is a subset of contingency analysis. Requirements for analyses can also be found in Guidance document Section 6.1, Table 6-1 and Section 6.7.1.
Step 9: Conduct Risk and Uncertainty Analysis *(method and rigor of the analysis will vary depending on the estimate level)*	1. Determine and discuss with technical experts the level of cost, schedule, and technical risk associated with each WBS element. 2. Analyze each risk for its severity and probability. 3. Develop minimum, most likely, and maximum ranges for each risk element. 4. Determine type of risk distributions and reason for their use. 5. Ensure that risks are correlated. 6. Use an acceptable statistical analysis method (e.g., Monte Carlo simulation) to develop a confidence interval around the point estimate. 7. Identify the confidence level of the point estimate. 8. Identify the amount of contingency funding and add this to the point estimate to determine the risk-adjusted cost estimate. 9. Recommend that the project or program office develop a risk management plan to track and mitigate risks.	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.

GAO Best Practice	GAO Cost Estimating Activities	Where Conformance to GAO Practice is Demonstrated in DOE G 413.3-21
Step 10: Document the Estimate *(method and rigor of the analysis will vary depending on the estimate level)*	1. 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. 2. Document the purpose of the estimate, the team that prepared it, and who approved the estimate and on what date. 3. Describe the program, its schedule, and the technical baseline used to create the estimate. 4. Present the program's time-phased life-cycle cost. 5. Discuss all ground rules and assumptions. 6. Include auditable and traceable data sources for each cost element and document for all data sources how the data were normalized. 7. Describe in detail the estimating methodology and rationale used to derive each WBS element's cost (prefer more detail over less). 8. Describe the results of the risk, uncertainty, and sensitivity analyses and whether any contingency funds were identified. 9. Document how the estimate compares to the funding profile. 10. Track how this estimate compares to any previous estimates.	Estimate documentation is discussed in Section 3.2, and extensively in Section 6.7.
Step 11: Present Estimate to Management for Approval	1. Develop a briefing that presents the documented life-cycle cost estimate. 2. Include an explanation of the technical and programmatic baseline and any uncertainties. 3. Compare the estimate to an independent cost estimate (ICE) and explain any differences. 4. 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. 5. Focus in a logical manner on the largest cost elements and cost drivers. 6. Make the content clear and complete so that those who are unfamiliar with it can easily comprehend the competence that underlies the estimate results. 7. Make backup slides available for more probing questions. 8. Act on and document feedback from management. 9. Request acceptance of the estimate.	Guidance related to the presentation of estimate results can be found in Section 3.2.4, Section 6.7.1, and specifically in Section 7.2.

GAO Best Practice	GAO Cost Estimating Activities	Where Conformance to GAO Practice is Demonstrated in DOE G 413.3-21
Step 12: Update the Estimate to Reflect Actual Costs and Changes *(Projects should update estimates once incurring actual costs.)*	1. Update the estimate to reflect changes in technical or program assumptions or keep it current as the program passes through new phases or milestones. 2. Replace estimates with EVM EAC and Independent estimate at completion (EAC) from the integrated EVM system. 3. Report progress on meeting cost and schedule estimates. 4. Perform a post mortem and document lessons learned for elements whose actual costs or schedules differ from the estimate. 5. Document all changes to the program and how they affect the cost estimate.	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.

Sources: GAO-09-3SP, 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; and,
- 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. RSMeans 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;
- 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;
- 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; and,
- 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 WBS and time phasing from the schedule;
- Determine what risks (and to what extent) should be mitigated with activities (or assumptions) in the cost estimate; and,
  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 the main 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:

- Design, planning, and development;
- Project management;
- Construction management;
- Construction activities to include mobilization and de-mobilization, site work, concrete work, masonry work;
- 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;
- Routine and preventive maintenance activities include minor facility repairs or upgrades, minor paving or landscaping;
- De-contamination, de-commissioning, dismantling, and demolition;
- 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; and,
- Sales and use taxes.

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; and,
- The hourly rate in cases involving equipment purchased by the Government should include only operation and maintenance costs but not the capital cost of ownership since 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/output 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/output should be established (e.g., 110 cubic yards per day).

- Estimators should examine the production rate/output 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 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. If there is a contract already in place, rates should be provided by the cognizant auditor. 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; or,
- 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.
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; and,
- 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 two-day 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 BOE.

6.4.2.4 Design Costs

To estimate design costs, the estimator should understand what activities are included. Typical design-related activities include:

- Surveys (surveying), topographic services, core borings, soil analyses, etc., to support design
- Preliminary and final design calculations and analyses

- Design studies required to support safety analysis if not included in the Conceptual Design Report
- Building Energy Modeling
- 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

Design costs are normally directly related to the magnitude and complexity of a project. The following factors should be considered when assessing design costs for the design-related activities due to the magnitude and complexity of a particular project.

- 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

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 or 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; and,
- 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. DOE regulations on energy efficiency performance standards require the use of whole building energy simulation models in accordance with 10 CFR 433.[15] Some models can be quite complex and require specialized technical expertise.

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[15] Energy Efficiency Standards for New Federal Commercial and Multi-Family High-Rise Residential Buildings. https://www.gpo.gov/fdsys/granule/CFR-2013-title10-vol3/CFR-2013-title10-vol3-part433/content-detail.html

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

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[16], 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; and,
- Project start-up or completion date.

Location significantly influences project costs when a wetlands area will be disturbed, or the project is located in an area with extensive environmental regulations. Increased environmental compliance costs should be factored into projects in such locations.

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[16] Energy conservation and LEED requirements in particular will require calculation of future building energy costs for new construction.

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; and,
- 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 five 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 quality assurance (QA) costs, security costs, other ES&H requirements, project controls compliance costs, building energy modeling costs to meet energy performance standards, and other standards or legal requirements that drives costs the project must consider.

6.4.3 Indirect Costs

Indirect costs support common or joint objectives that do not link to a particular activity or project. Indirect costs are "any costs not directly identified with a single final cost objective but identified with two or more final cost objectives." Consequently, IPTs should identify opportunities to allocate indirect costs to an activity or asset based on direct cost elements, such as labor hours, material cost, or both (see Section 6.4.3.1). No definitive criteria for determining the appropriate cost type, direct or indirect, exists.

Some examples of indirect costs include:

- 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; or,
- 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. If there is a contract in place, the indirect rates are provided by the Contracting Officer (CO), obtained from the cognizant audit entity). 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 each indirect rate includes.

Indirect rates estimated for subcontract work such as design 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 percent of direct craft labor, and administrative support for engineering at 38 percent 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 basis 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 E.

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:

1. Reference date the estimate was prepared and base date of costs;
2. Escalation index, or cumulative rates, to be used (including issue date and index); and,
3. 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:

- An applicable historical cost index; and,
- 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.

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, https://rsmeans.com/CostBooks.aspx;
- The Richardson Construction Estimating Standards, http://www.costdataonline.com/;
- IHS Global Insight, http://www.ihsglobalinsight.com; and
- Office of Management and Budget Circular A-94, Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs, https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/circulars/A94/a094.pdf

6.4.5 Contingency

This section is compatible with the guidance provided in DOE G 413.3-7A, *Risk Management Guide*, 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.

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 Project Management 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 95% CL or at a confidence level deemed appropriate for the project’s size and complexity 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%; the normal default is 80% at CD-2, to as high as 95% with a BCP.

- 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.

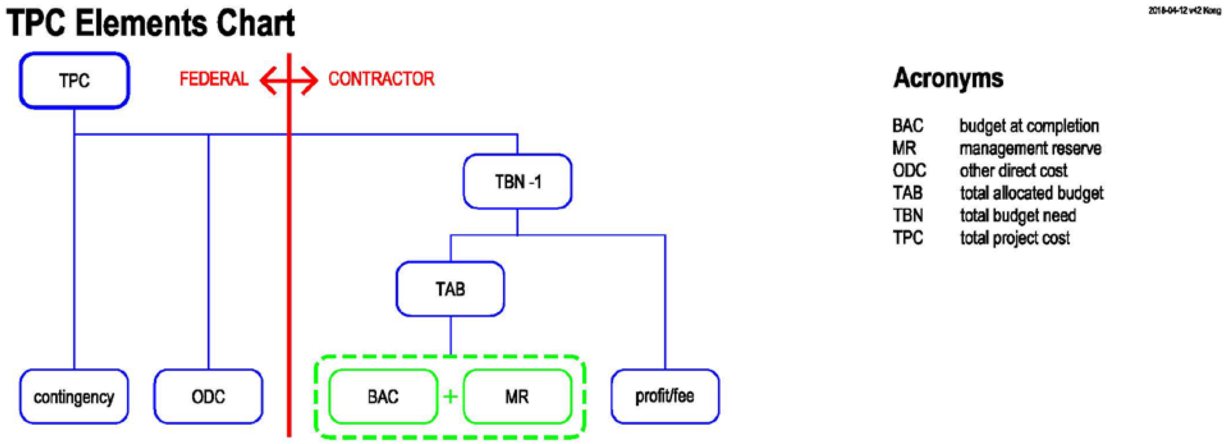
- Contractor MR Budget is the risk-based quantitatively derived portion of the contract budget base (CBB) that is set aside for management purposes to handle risks that are within the contractor's contractual obligations. Once the CBB has been established, it is allocated to MR and the Performance Measurement 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 EIA-748 (current).

- Contractor schedule margin 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 margin 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.

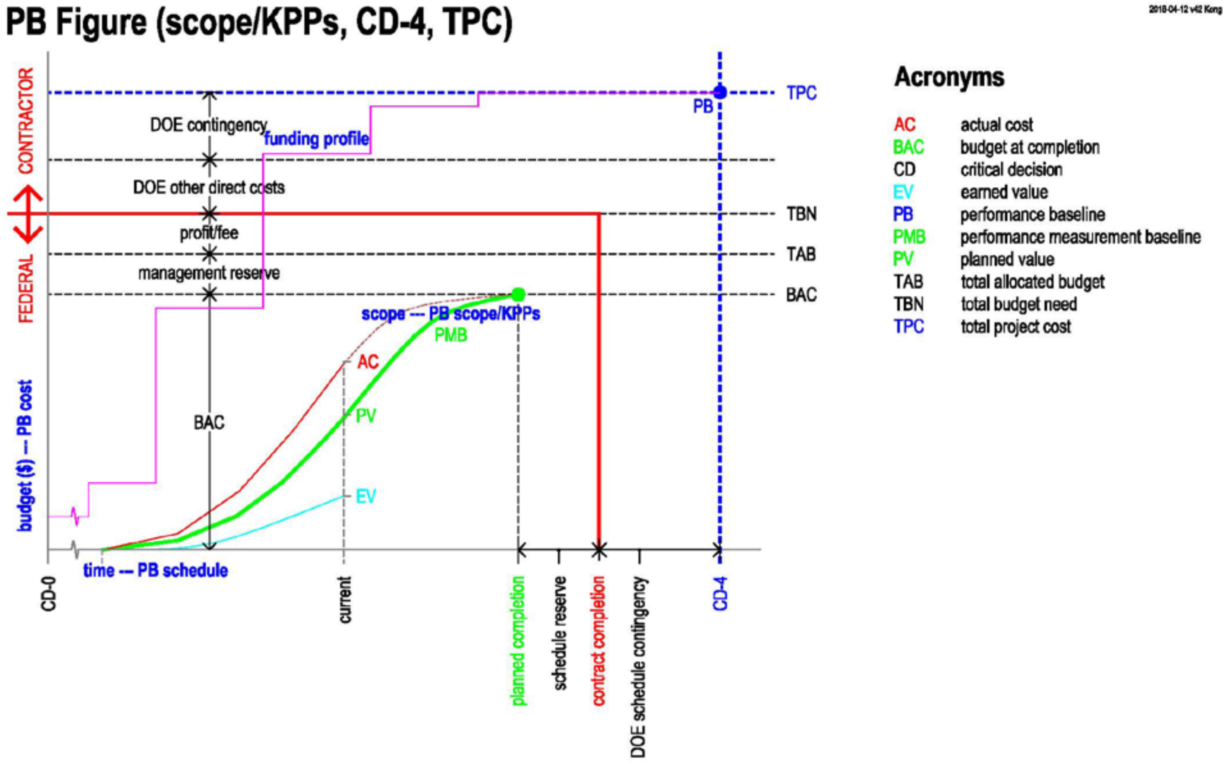
While the Monte Carlo simulation is one standard used by DOE, alternate forms of quantitative analysis may be used. Other recognized forms of quantitative analysis include: decision trees, influence diagrams, system dynamics models, and neural networks. Figures 6-2 and 6-3 show the typical components of the DOE project performance baseline.



Acronyms

BAC	budget at completion
MR	management reserve
ODC	other direct cost
TAB	total allocated budget
TBN	total budget need
TPC	total project cost

Figure 6-2. Total Project Cost Composition. ***Note: CL = Recommended Confidence Level***



Acronyms

AC	actual cost
BAC	budget at completion
CD	critical decision
EV	earned value
PB	performance baseline
PMB	performance measurement baseline
PV	planned value
TAB	total allocated budget
TBN	total budget need
TPC	total project cost

Figure 6-3. 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 CD-0, Approve 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:

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

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 6-4 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 unavilable 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 6-4. 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 6-5. 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.

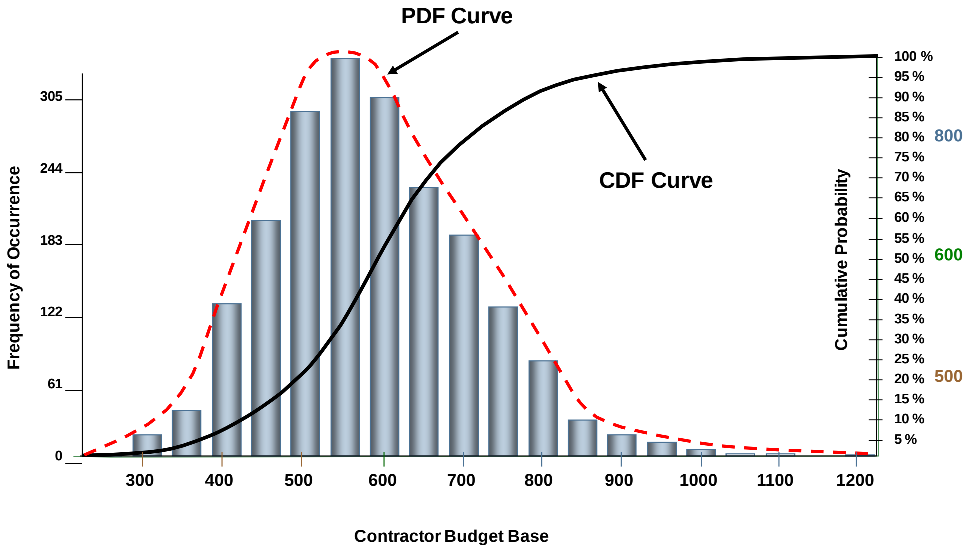


Figure 6-5. Sample PDF and CDF Curves

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 6-6 depicts a conceptual risk model showing typical inputs and outputs.

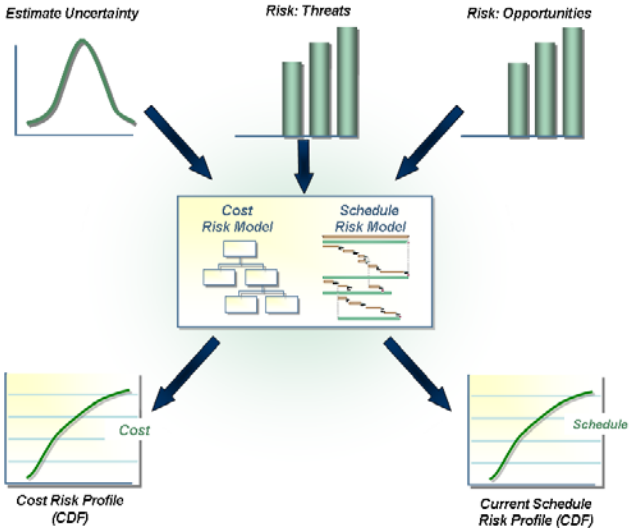


Figure 6-6. Conceptual Risk Analysis Process

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.

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 Sensitivity Analysis

The GAO-09-3SP, GAO Cost Estimating and Assessment Guide, states that, “As a best practice, sensitivity analysis should be included in all cost estimates because it examines the effects of changing assumptions and ground rules.” DOE endorses this best practice and believes it to be a vital element and consideration when developing a cost estimate. Since uncertainty cannot be avoided, it is necessary to identify what cost elements present the most risk and if, possible, cost estimators should quantify the risk. Only when decision makers fully understand the results of sensitivity analyses, combined with the results of the uncertainty and risk analyses, can they ensure they made the best choices at either a programmatic or project level.

A 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?’”[17] A tailored analysis may be needed to avoid overly burdensome or repetitive site wide impacts arising in lower level estimates down to the work package level.

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[17] Project Management Glossary of Terms, Office of Project Management Oversight and Assessments, September 2014.

Uncertainty about the values of technical parameters is common initially in design and development and can result in inaccurate assumptions. Some examples of cost drivers that GAO has identified[18] include:

- A shorter or longer economic life
- Volume, mix or pattern of workload
- Potential requirements changes
- Configuration changes
- Higher or lower learning curves
- Alternative assumptions
- Testing requirements
- Changes in performance characteristics
- Acquisition strategy
- Labor rates.
- Testing requirements
- Down-scoping a project

To determine what the key cost drivers are, a cost estimator needs to determine the percentage of total cost that each cost element represents. The major contributing variables within the highest percentage cost elements are the key cost drivers that should be varied in the sensitivity analysis.

The cost practitioner should always include the assumptions that are most likely to change, such as an assumption that was made for lack of knowledge or one that is outside the control of the program or project office. The sensitivity analysis addresses some of the estimating uncertainty by testing discrete cases of assumptions and other factors that could change. By examining each assumption or factor independently, while holding all others constant, the cost estimator can then evaluate the results to discover which assumptions or factors most influence the estimate.
It is important to understand and be able to communicate the potential impact from variations in key assumptions and estimate cost drivers.

GAO recommends incorporating a five-step process that will result in a *credible* sensitivity analysis:

Step 1. Identify key cost drivers, ground rules, and assumptions for sensitivity testing
Step 2. Re-estimate the total by choosing one of the identified cost drivers or assumptions and varying it between two set amounts. The amounts chosen may represent maximum and minimum, various performance thresholds, or alternative assumptions; ranges should be documented during data collection and cost estimating
Step 3. Document the results
Step 4. Repeat Steps 2 and 3 until all factors identified in Step 1 have been independently tested
Step 5. Evaluate results to determine which drivers affect the cost estimate the most

To identify the key cost drivers and critical assumptions, there are several recommended approaches:

- Research and appropriately reference historical data, industry benchmarks, and other relevant data sources to determine the ranges of values a sensitivity analysis should

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[18] GAO Cost Estimating and Assessment Guide, CAO-09-3SP, Chapter 13 pages 147-150.

consider. It is not a best practice to merely use arbitrary plus or minus values or other approaches that do not have a sound basis. However, in the absence of relevant data, use the expert opinion of suitably qualified subject matter experts.

- Examine the sub-elements or assumed values that contribute to the cost estimate value.
- Review all assumptions made and documented in the basis of estimate to isolate those assumptions that seem most uncertain or most critical to the viability of the resultant estimate.
- Evaluate the results of the sensitivity output from the Monte Carlo simulation model that assessed cost estimate uncertainty and risks when time permits. Visual output depicted from "tornado charts" show the relative contribution of each simulation-model variable to the final cumulative probability profile. It should be noted, however, that the elements highlighted in such tornado charts may or may not be the most critical elements for a true sensitivity analysis and usually do not represent an all-inclusive listing of such elements.

In summary, GAO best practices for sensitivity analysis necessitates satisfying the following tests:

- The cost estimate was accompanied by a sensitivity analysis that identified the effect of changing key cost driver assumption and factors:

  - Well-documented sources that support the assumptions or factor ranges used in analyses;
  - The sensitivity analysis was part of a quantitative risk assessment and was not based on arbitrary plus or minus percentages;
  - Cost-sensitive assumptions and factors were further examined to see whether design changes should be implemented to mitigate risk;
  - Sensitivity analysis was used to create a range of best- and worst-case costs;
  - Assumptions and performance characteristics listed in the technical baseline description, as well as ground rules and assumptions, were tested for sensitivity, especially those assumptions and characteristics least understood or at risk of changing; and,
  - Results were well documented and presented to management for decisions.

- The following activities were taken during the sensitivity analysis:

  - Key cost drivers were identified;
  - Cost elements representing the highest percentage of cost were determined and their parameters and assumptions were examined;
  - The total cost was re-estimated by varying each parameter between its minimum and maximum range;
  - Results were documented and the re-estimate was repeated for each parameter that was a key cost driver; and,
  - Outcomes were evaluated for parameters most sensitive to change.

- The sensitivity analysis provided a range of possible costs, a point estimate, and a method for performing what-if analysis.

6.4.5.6 Estimate Uncertainty

Estimate uncertainty is part of the risk analysis process for the development of contingency estimates as was illustrated in Figure 6-6. 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 AACE International, Table 6-4, or other estimating guidance. Estimate uncertainty contributes to both cost and schedule contingency.

Table 6-4 could be used for both cost and schedule estimate uncertainty and should be done separately for evaluating quantitative impacts on project contingency.

Table 6-4. Estimate Uncertainty Range as a Function of Estimate Class

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%

6.4.5.7 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 6-7 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.

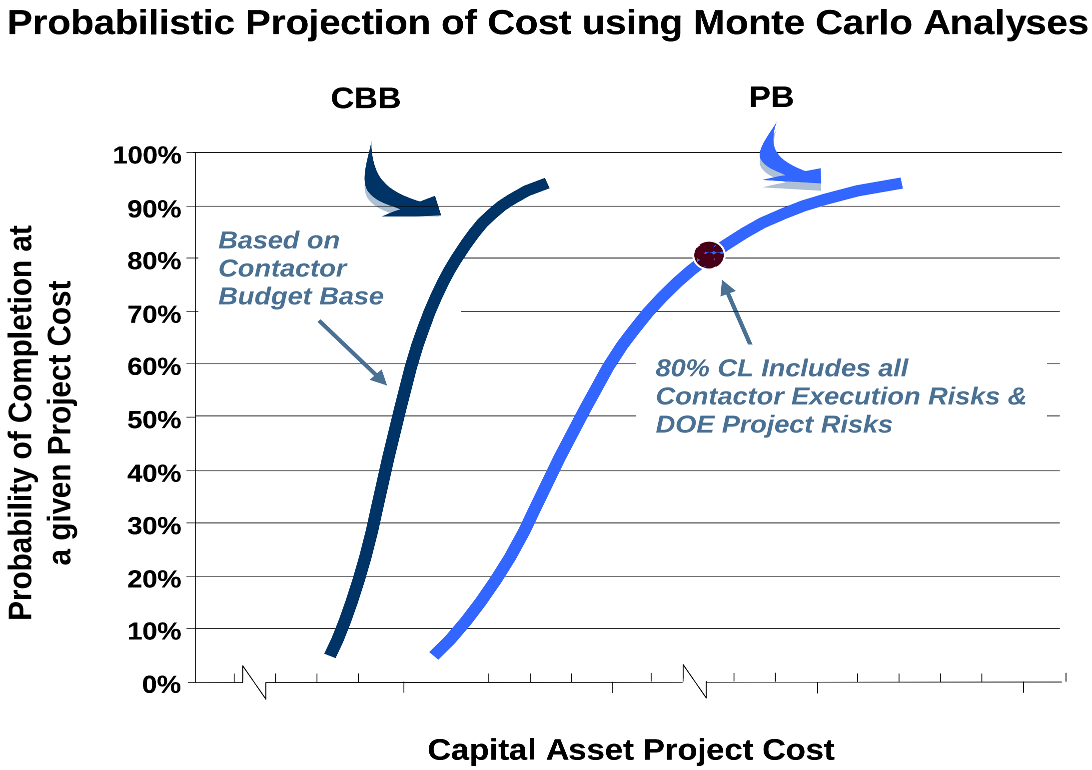

Figure 6-7. S-Curves of Contractor CBB and DOE Performance Baseline

6.4.5.8 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 margin, which cannot add time or schedule duration to the contracted end date.

6.4.5.9 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 6-8 illustrates how contingency budget projections can be depicted

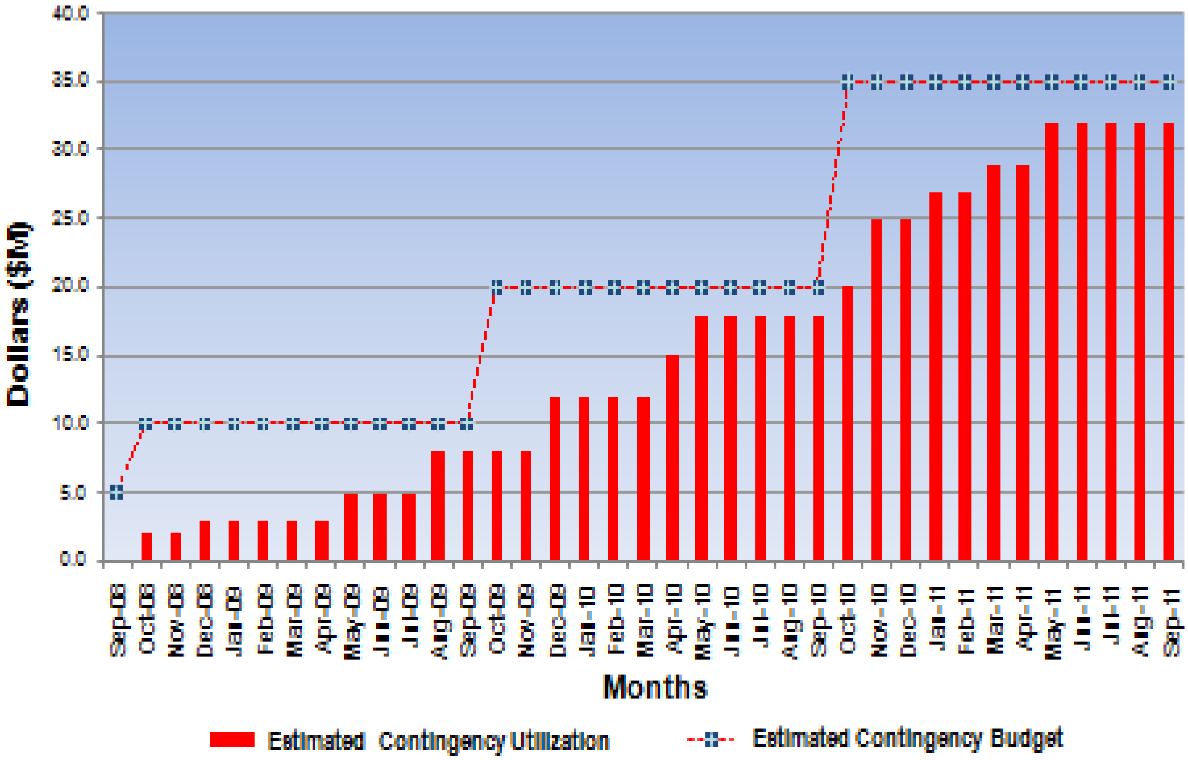

Figure 6-8. Contingency Budget Projection

6.4.5.10 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.

6.4.5.11 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., AACE International), 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;
- Delphi techniques;
- Interviews of staff, crafts, retirees, and others familiar with similar work activities at the site or similar sites; and,
- 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 D.

DOE cost estimates, and the BOEs that support them, should include an assessment of the realism and reasonableness of the primary cost elements comprising the cost estimate. 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

A well-documented estimate is one of GAO's best practices for high-quality cost estimates for the following reasons:[19]

1. Complete and detailed documentation is essential for validating and defending a cost estimate.
2. 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.
3. 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.
4. 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.

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[19] GAO-09-3SP

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. Concrete examples of scope assumptions include, but are not limited to changes in the seismic criteria, safety criteria, materials, method of construction, siting, orientation, construction methods assumed, and open air versus enclosed D&D.

  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**—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, a breakdown may indicate that 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 but reference to the original documentation must be made. 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, assumptions, or inclusions 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.

- **Risk Register**—discusses sources of risk and uncertainty, including critical assumptions, associated with the estimate. Identifies 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**—lists contacts for questions about the estimate. Estimate preparers and reviewers should be identified in the cost estimate documentation.

- **Documentation of Review and Approval**—demonstrates that the estimate was reviewed and approved.

- **Location of Estimate Files and Reference Information**—identifies the locations 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—**clarifies 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 should include:

- Direct costs
- Indirect costs
- Contingency
- Escalation

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 6-2 and 6-3. 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 inform budget development. There is a distinction between cost estimates and budget allocations. The cost estimate provides the expected cost while the budget forms the basis for measuring work execution over time. If the cost changes due to scope changes, funding profile changes, or other drivers, the cost estimate may need to be updated to support development of a new budget.

7.0 COST ESTIMATING OUTPUTS

This Guide defines traditional output from the Cost Estimating Process. Outputs include, the traditional change control process, economic and cost-benefit analysis, value engineering, earned-value, and final project cost reports.

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 Presenting the Estimate to Management

Cost estimates are a primary input into the DOE decision-making and project approval CD process. A cost estimate is not considered valid until DOE management has approved it. Since many cost estimates are developed to support a DOE budget request or make a decision between competing alternatives, it is vital that a high quality cost estimate be intentionally planned to anticipate management concerns and inspire confidence in the desired outcome.

The *preferred* presentation format is designed to allow management to gain confidence in the practitioner's cost estimating process and the estimate itself:

1. Cost practitioner should initially convey how the estimate was developed, including risks associated with the underlying data and methods. The presentation should contain enough detail for easy defense as to why the estimate is credible, well-documented, accurate and comprehensive.

2. The presentation should be clear and complete, making it easy for those unfamiliar with the estimate to comprehend its level of competence. The presenter should focus on the key cost drivers and the final cost estimate's outcome. Slides with visuals should be available to answer more probing questions. A GAO best practice is to provide the presentation in a consistent format to facilitate management's understanding the completeness of the cost estimate, as well as its high quality. A decision maker who is familiar with the presentation format is better able to concentrate on the presentation's content, and on the cost estimate, rather than focusing on the format itself.

3. Results should be communicated succinctly to fortify management confidence in the ground rules, methods, and results and in the process that was followed to develop the estimate. The presentation must include program and technical information specific to the program, along with displays of budget implications, contractor staffing levels, and related industrial base considerations. The following elements are recommended for inclusion in the presentation:

    - Title page, presentation date and the name of the person(s) receiving the presentation;
    - Estimate purpose – why it was developed and what approval is needed;
    - A brief program overview – its physical and performance characteristics and acquisition strategy, sufficient to understand its technical foundation and objectives;
    - Estimating ground rules and assumptions;
    - Copies of the cost estimate both at the detail level and rolled up WBS level;
    - LCCE time phased in constant-year dollars and tracked to any previous estimate;
    - For each WBS cost element, show the estimating method for cost drivers and high value items;
    - Show a breakout of cost elements and their percentage of the total cost estimate to identify key cost drivers;

- Sensitivity analysis, interpreting results carefully if there is a high degree of sensitivity;
- Discussion of risk and uncertainty analysis, including:
  - (1) cost drivers, the magnitude of outside influences, contingencies, and the confidence interval surrounding the point estimate and the corresponding S curve showing the range within which the actual estimate should fall;
  - (2) other historic data for reality checks; and,
  - (3) how uncertainty, bounds, and distributions were defined;
- Comparison to an independent cost estimate, explaining differences and results;
- Comparison of the budget needs or LCCE, expressed in current-year dollars, to the funding profile, including contingency reserve based on the risk analysis and any budget shortfall and its effect;
- Concerns or challenges the audience should be aware of;
- Conclusions, recommendations, and associated level of confidence in the estimate; and,
- When presenting LCCEs to management, the presenter should include separate sections for each program phase—research and development, procurement, operations and support, disposal—and should provide the same type of information as the cost estimate documentation contains. In addition, the presentation should provide the summary information, main conclusions, and recommendations first, followed by detailed explanations of the estimating process.

4. Cost practitioner should conclude the presentation by asking management to formally accept the cost estimate. Acceptance, along with any feedback from management, should be acted on immediately and documented in the cost estimate documentation package.

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. Note that cost analysis and price analysis have different meanings. This Guide focuses on cost analysis.

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 cost estimating and analysis can be found through the Society for Cost Estimating and Analysis (SCEA) at http://www.sceaonline.org/.

More information on cost engineering can be found through AACE International, at http://web.aacei.org/

8.0 COST ESTIMATING EXPECTATIONS

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 should follow accepted standards such as the GAO 12 steps of a high quality cost estimating process (GAO-09-3SP) in accordance with other guiding DOE policy*. There could be more expectations, depending on the program, project, contract type, specific budget requirements, or other situations.

Organization of some cost elements may be specified (e.g. resources, material, other direct costs, and sub-contract costs). 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 Uniformat II and Masterformat, for construction projects. The environmental cost element structure (ECES), an ASTM standard for environmental projects, is another common coding structure. Project data sheets (PDSs) for budget formulation and other coding formats should be produced, according to program office requirements.

More information on the Uniformat II can be found at http://www.uniformat.com/

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

More information on the ECES can be found at https://www.emcbc.doe.gov/Office/ProjectManagement

More information on OMB's Exhibit 300 forms can be found in OMB A-11, Part 7 at https://www.whitehouse.gov/omb/circulars_a11_current_year_a11_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.

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 CE, PM will conduct an Independent Cost Review (ICR).

Prior to CD-1, for projects with a TPC ≥ $100M, PM 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 ≥ $100M, PM will develop an ICE. The ICE will support validation of the Performance Baseline (PB).

Prior to CD-3, for projects with a TPC ≥ $100M, PM will develop an ICE.

In addition to the specific requirements placed on PM in DOE O 413.3B, a project may be well-served by having its own cost estimate 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.

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

PM, 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—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—this equates to the ICR as required in DOE O 413.3B.
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—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—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—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.

Appendix A: Acronyms and Definitions

A/E	Architect/Engineer
AACE	AACE International
ANSI	American National Standards Institute
AS	Acquisition Strategy
ASTM	American Society for Testing Materials
BOE	Basis of Estimate
CD	Critical Decision
CER	Cost Estimating Relationship
CFO	Chief Financial Officer
CFR	Code of Federal Regulations
CM	Construction Management
CO	Contracting Officer
DoD	Department of Defense
DOE	Department of Energy
EIR	External Independent Review
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
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
PM	Office of Project Management
PME	Project Management Executive
PMB	Performance Measurement Baseline
R&D	Research and Development
TEC	Total Estimated Cost
TPC	Total Project Cost
VE	Value Engineering
WBS	Work Breakdown Structure

Refer to *DOE Project Management Terms and Acronyms*, for additional information.
https://community.max.gov/x/TYFUQw

Appendix B: 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; and,
- 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, Chg4, Program and Project Management for the Acquisition of Capital Assets, dated 10-13-2017.
- DOE O 430.1C, Real Property Asset Management, dated 8-19-16.
- 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*, Appendix J, Principles of Budgeting for Capital Asset Acquisitions and the Capital Programming Guide, 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/information flows with technology to achieve 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,
    - A 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, including:

- Develop and maintain an integrated Agency-accounting and financial management system, including financial reporting and internal controls, which:
    - Comply with applicable accounting principles, standards, and requirements and internal control standards;
    - Comply with such policies and requirements as may be prescribed by the Director of OMB;
    - Comply with any other requirements applicable to such systems;
    - Ensure information is complete, reliable, consistent, and timely, which is prepared on a uniform basis and which is responsive to the financial information needs of Agency management;
    - Development and reporting of cost information;
    - Integration of accounting and budgeting information; and,
    - Systematic measurement of performance.

- Direct, manage, and provide policy guidance and oversight of Agency financial management personnel, activities, and operations, including:
    - 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;
    - Development of Agency financial management budgets;
    - Recruitment, selection, and training of personnel to carry out Agency financial management functions;
    - Approval and management of Agency financial management systems design or enhancement projects; and,
    - 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. The spirit and intent of Information Technology Management Reform Act (ITMRA)[20] 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.

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[20] The DAU Glossary provides more information on the Clinger-Cohen Act and ITMRA. https://dap.dau.mil/glossary/pages/2041.aspx

Table B-1. Relevant Cost Estimating and Earned Value 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) Major System Acquisition, 48 CFR part 34, subpart 34.2, Earned Value Management System (EVMS)

Source: GAO and DOD

Table B-2. Relevant Cost Estimating and Earned Value Policy

Applicable Agency	Name of Policy
All Federal agencies	Office of Management and Budget (OMB) Circular No. A-11, *Preparation, Submission, and Execution of the Budget*, July 2017
All Federal agencies	Office of Management and Budget (OMB) Circular No. A-94, *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs*, 10-29-92
All Federal agencies	Office of Management and Budget (OMB) Circular No. A-109, *Major Systems Acquisitions*, April 5, 1976
All Federal agencies	Office of Management and Budget (OMB) Memorandum for Chief Information Officers, No. M-05-23, *Improving Information Technology (IT) Project Planning and Execution*, August 4, 2005
All Federal agencies	Office of Management and Budget (OMB) *Capital Programming Guide*, Supplement to Circular A-11, Part 7, *Preparation, Submission and Execution of the Budget*, 2011

Source: GAO, OMB, and DOD

Appendix C: 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, updated 10-13-2017, originally approved* 11-29-10, promotes the systematic acquisition of projects and emphasizes the necessity for managing successful projects. DOE O 413.3B defines the Critical Decision process, which establishes protocol, authorities, and consistency between the DOE programs.

- DOE O 430.1C, *Real Property Asset Management (RPAM)*, dated 8-19-16, 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 D: 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.[21]

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. They 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 have 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.

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[21] 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, 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 - Cost and schedule estimators, cost engineers, and risk managers should join the integrated project team and begin engaging with the project early. 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 E: 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, the following is an example of a five-year project. The Tables E-1 through E-4 present the stages necessary for calculating cost escalation. Note that major activity groupings defined as "scheduled activity."

Table E-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	10/1/12	6	3/30/13	1/1/13
A1B	Definitive Design (Title II Design)	200	4/1/13	6	9/30/13	7/1/13
A1C	Design During Construction (Title III Design)	100	10/1/13	36	9/30/16	7/1/15
B2A	Equipment Procurement (General Services)	200	10/1/14	24	9/30/16	10/1/15
B2B	Equipment Procurement (Long-Lead, GFE)	2,500	3/30/13	18	9/30/14	1/1/14
B2C	Facility Construction	6,000	10/1/14	37	9/30/16	10/1/15
C1A	Project Management	500	10/1/12	48	9/30/16	10/1/14
C1B	Construction Management	250	10/1/12	48	9/30/16	10/1/14
C1C	Project Support	250	10/1/12	48	9/30/16	10/1/14
	Total	**10,100**				

Table E-2 provides illustrative escalation rates. 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 2015 is determined from the 2013, 2014 and 2015 escalation percentages as follows: 1.021 (2013 percentage) x 1.025 (2014 percentage) x 1.029 (2015 percentage) = 1.076. Thus, 1.076 would be the factor to multiply costs estimated in 2012 and expected to occur in 2015.

Table E-2. DOE Escalation Rates (notional for illustrative purposes)

	Project Categories *									
FY	**Construction**		**EM**		**IT**		**O&M**		**R&D**	
2012	Index	%	Index	%	Index	%	Index	%	Index	%
2013	1.021	2.1	1.02	2	1.008	0.8	1.018	1.8	1.023	2.3
2014	1.046	2.5	1.047	2.7	1.017	0.9	1.045	2.6	1.051	2.8
2015	1.076	2.9	1.075	2.7	1.022	0.5	1.073	2.7	1.08	2.7
2016	1.106	2.8	1.103	2.6	1.032	1	1.101	2.6	1.108	2.6
2017	1.135	2.6	1.13	2.4	1.041	0.8	1.127	2.4	1.136	2.5

Table E-3 provides a table of notional 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 in December 2011 and expected to occur in July 2015 would be 9.17%.

Table E-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													
2012	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%
2013	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%
2014	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%
2015	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%
2016	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%
2017	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%
2018	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 E-4 provides a notional 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 E-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	10/1/12	6	3/30/13	1/1/13	2.64%	103
A1B	Definitive Design (Title II Design)	200	4/1/13	6	9/30/13	7/1/13	3.71%	207
A1C	Design during Construction (Title III Design)	100	10/1/13	36	9/30/16	7/1/15	9.17%	109
B2A	Equipment Procurement (General Services)	200	10/1/14	24	9/30/16	10/1/15	9.95%	220
B2B	Equipment Procurement (Long-Lead, GFE)	2,500	3/30/13	18	9/30/14	1/1/14	4.90%	2,623
B2C	Facility Construction	6,000	10/1/14	37	9/30/16	10/1/15	9.95%	6,597
C1A	Project Management	500	10/1/12	48	9/30/16	10/1/14	6.85%	534
C1B	Construction Management	250	10/1/12	48	9/30/16	10/1/14	6.85%	267
C1C	Project Support	250	10/1/12	48	9/30/16	10/1/14	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).

Resources for Cost Escalation

Bureau of Labor Statistics
http://www.bls.gov/bls/escalation.htm

Producer Price Index (PPI) Guide to Contract Escalation
www.bls.gov/ppi/ppiescalation.htm

Consumer Price Index for Escalation
http://www.bls.gov/cpi/cpi1998d.htm

Employment Cost Index for Escalation
www.bls.gov/ncs/ect/escalator.htm

Employment Cost Trends Home Page
http://www.bls.gov/ect/

Construction Economics – Engineering News Record
http://www.enr.com/economics

> Note: The Non-IT Capital Asset Budget Guidance[22] has been updated to include past ENR construction indices. The cost estimate escalation assumption includes the following statement: “Some of the annual and monthly indices including (ENR construction Cost index) have been documented by the USDA NRCS.[23] The USDA NRCS link provides a spreadsheet with past ENR construction cost index (CCI), one of several indices published by ENR. Rule of thumb; generally CCI escalation represents more than 3-4%.

Cost Index | Turner Construction Company
http://www.turnerconstruction.com/cost-index

Industrial producer price index overview
http://ec.europa.eu/eurostat/

Power Capital Costs Index - IHS.com
https://www.ihs.com/info/cera/ihsindexes/

DOE Escalation Rates for Energy
http://energy.gov/eere/femp/energy-escalation-rate-calculator-download

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[22] https://powerpedia.energy.gov/wiki/Non-IT_Capital_Asset_Budget_Guidance

[23] http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/econ/prices/

Appendix F: Example of Life-Cycle Cost Analysis

This Appendix presents the Life Cycle Cost Analysis (LCCA) as excerpted from the DOE PM document, *Life Cycle Cost Handbook, Guidance for Life cycle Cost Estimation and Analysis* (September 2014). The Handbook provides the reader with procedures, information, examples, and tools to develop consistent and defensible life-cycle cost estimates (LCCE) and perform appropriate life-cycle cost analyses (LCCA) for capital projects.

The Department of Energy has affirmed that the LCCA in conjunction with the Alternatives of Analysis process may be used to determine the most cost effective option among alternatives, and to fully document the selection process. **In cases where all alternatives have the same annual effects or benefits, a cost effectiveness analysis can be performed where only the discounted monetized cost is analyzed. For example, analyses of alternatives of defense systems or programs eliminating a problem (e.g. toxic waste, unsafe conditions) often fall into this category.**,

The process used to conduct LCCA comprises those tasks that enable a comparative investigation of competing project or program alternatives. The process begins with developing a life-cycle cost estimate for each alternative, generally including all costs for all project phases.

An LCCA seeks to find the best value solution by linking each alternative to how it satisfies a strategic objective. The analysis presents facts and supporting details in addition to assessments of cost. The process is sometimes defined as a business case analysis or cost-benefit analysis, but in this appendix it will consistently be termed LCCA. An LCCA considers not only all the life-cycle costs that an LCCE identifies but also quantifiable and non-quantifiable benefits when they differ among alternatives and can be assessed. The LCCA should be unbiased by considering all practical alternatives and should not be developed solely for supporting a particular solution. Moreover, it should be rigorous enough that independent auditors can review it and clearly understand why a particular alternative was chosen.

For each alternative, the LCCA should be documented with the following information:

- Relative life-cycle costs and benefits;
- Methods and rationale for quantifying the life-cycle costs and benefits, including definition of assumptions, analyzing alternatives, applying escalation, and discounting for net present value (NPV);
- Effect and value of cost, schedule, and performance tradeoffs;
- Sensitivity to changes in assumptions and discount rates; and,
- Risk factors.

In addition to supporting an investment decision made in support of a Critical Decision, the LCCA should be considered a living document and updated often to reflect changes in scope, schedule, or budget. In this way, the LCCA is a valuable tool for validating decisions to sustain or enhance the enterprise through ongoing value engineering assessments.

If the project sponsor expects alternatives to have differing performance levels (e.g., differing production rates, research and development throughput or quality), the project should monetize the performance levels to include them in the analysis of alternatives.

Project Analysis

The principal technique for evaluating project alternatives is to calculate the NPV for each project alternative considered (e.g., site selection, materials of construction, development timespan) in developing a project. The project analysis compares the costs and benefits (when there is a perceived benefit difference among the alternatives) of each alternative. For example, for a given environmental remediation project the least expensive alternative may be to leave waste in place and cap it, versus treatment and shipment for disposal. The long-term costs of Surveillance and Maintenance (S&M) would need to be included in this example. In another example, a method for tritium production might consider particle accelerator production, versus irradiation of lithium rods. These alternatives would entail very different concepts, types of cost, and timespans.

To avoid perceived bias, care must be taken in assigning monetary values to future benefits. This is particularly true when evaluating an alternative that produces a seemingly better result. For example, in high-technology science projects, an alternative may provide “better science” than competing alternatives’ technologies. Assigning monetary values to “better” conditions can be controversial and a major determinant in the alternative selection. Thus, the measurement of relative value must be carefully done and fully documented. In every case, all the costs for the competing solutions and benefits to be derived are determined and brought to an NPV figure.

The cornerstone of NPV calculations is the selection and application of an appropriate discount rate. The discount rate is a percentage applied to expenditures expected to be made in the future (or payments received in the future) that converts the future amount to its equivalent today. Estimation of the present value of future benefits/costs is highly sensitive to the choice of a discount rate. OMB *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs* (Circular No. A-94) gives specific guidance on discount rates for evaluating federal programs whose benefits and costs are distributed over time. As described in the circular, a “real” discount rate of 7 percent should currently be used, as this rate approximates the marginal pretax rate of return on an average investment in the private sector in recent years. Changes in this rate will be reflected in future updates of the circular, and the current circular should always be used for DOE LCCAs.

Before defining the “real” discount rate, an understanding of the “nominal” interest rate is needed. The nominal interest rate is simply the stated interest rate guaranteed by an issuer. It is the actual monetary price that borrowers pay to use a lender’s money. The “real” interest rate is so named because it states the “real” rate that the lender or investor receives after inflation is taken into account; that is, the interest rate that exceeds the inflation rate. If a bond that compounds annually has a 6 percent nominal yield and the inflation rate is 4 percent, then the real rate of interest is only 2 percent.

In essence,

Nominal interest rate – Inflation = Real interest rate

> *Tip: When using constant year dollars, without escalation added, a real discount rate should be used to calculate NPV. When escalated, or as-spent, dollars are being used for the analysis, a nominal (or higher) discount rate should be used.*

A commanding knowledge of the project's cost-driving parameters is required to analyze the alternatives. It is important to understand what is driving the costs and the time phasing of those costs for each alternative. Developing an LCCA may greatly assist in understanding the cost drivers and thus directly influence a project's design and implementation planning.

Funding constraints are a major consideration in most DOE and National Nuclear Security Administration (NNSA) programs, and they must be assessed within the context of LCCA development. Such constraints can force schedule considerations that may make a less attractive alternative the favorable selection in terms of NPV, such as when funding constraints slow a program component schedule to the extent that out-year expenditures appear more favorable when brought to a present day basis.

NPV is computed by assigning monetary values to benefits and costs, discounting future benefits and costs using an appropriate discount rate, and subtracting the total of discounted costs from the total of discounted benefits. (As mentioned, solutions with equal benefits need consider only costs) The process transforms gains and losses occurring at different times to a common unit of measurement. A discussion of the mathematical process used to calculate NPV for two competing alternatives is provided in the Example 3-1.

Example 3-1. Comparative Life Cycle Costs

In this example, both Project A and Project B are assumed to be production facilities that provide an equally acceptable product over a 20-year useful life. Project B requires a shorter and less expensive construction span, but runs at a higher operating cost, is expected to be more expensive to disposition (i.e., develops a higher environmental liability), and has no salvage value. Project B yields an excess capacity than can generate $5 million per year revenue stream.

Capital Project A

Element	Estimated Cost						
Capital Project Cost	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Total**
Project Management	6,000,000	7,000,000	8,000,000	5,000,000	2,850,000	-	28,850,000
Design	25,000,000	15,000,000	-	-	-	-	40,000,000
Procurement	5,000,000	20,000,000	5,000,000			-	30,000,000
Construction	-	15,000,000	40,000,000	85,000,000	30,000,000	-	170,000,000
Title III	-		3,000,000	3,000,000	2,500,000	-	8,500,000
Transition to Ops	-			5,000,000	35,000,000	-	40,000,000
	36,000,000	57,000,000	56,000,000	98,000,000	70,350,000	-	317,350,000
Operations and Maintenance Cost							
Annual O&M (Assume 20 years @ $50,000,000/year)						50,000,000	1,000,000,000
Periodic Capital Replacements (Assume $20,000,000 each in year 10, 15, and 20)						-	60,000,000
Final Disposition Cost							
Deactivation/Decommissioning in year 26							50,000,000
Salvage Value							(5,000,000)
Total-Life Cycle Cost (net of all costs less salvage value)							**1,422,350,000**

Capital Project B

Element	Estimated Cost					
Capital Project Cost	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Total**
Project Management	3,500,000	7,000,000	5,500,000	-		16,000,000
Design	17,000,000	13,000,000	-	-		30,000,000
Procurement	4,000,000	15,000,000	-	-		19,000,000
Construction	-	60,000,000	70,000,000	-		130,000,000
Title III	-	4,000,000	3,000,000	-		7,000,000
Transition to Ops	-			30,000,000		30,000,000
	24,500,000	99,000,000	78,500,000	30,000,000		232,000,000
Operations and Maintenance Cost						
Annual O&M (Assume 20 years @ $58,000,000/year)					58,000,000	1,160,000,000
Periodic Capital Replacements (Assume $20,000,000 each in operating year 7 and 14)				-		40,000,000
Revenue						
Annual income from excess production Assume $5M/year for operating life of plant					(5,000,000)	(100,000,000)
Final Disposition Cost						
Deactivation/Decommissioning						95,000,000
Salvage Value						-
Total-Life Cycle Cost (net of all costs less revenue)						**1,427,000,000**

A simple comparison of life-cycle cost indicates the alternatives are nearly equivalent, although Project A appears to be the more desirable from a cost standpoint, $1,422,350,000 for Project A versus $1,427,000,000 for Project B.

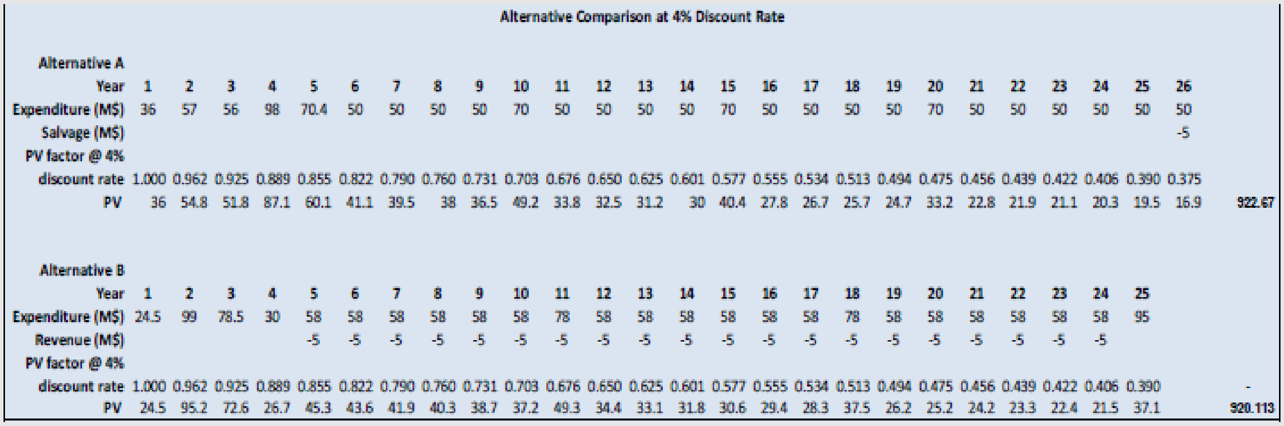
Conducting an LCCA for the two alternatives is then done in order to take into account the time value of money. Development of NPV figures for alternatives is based on the formula PV = 1/(1+r)t where r is the discount rate, and t is the number of years in advance when an expenditure is made, or a payment received. To illustrate the use of a PV factor, at a discount rate of 10 percent per year, the PV factor is 0.621 for year 5, meaning the present value of $1 spent or received at year 5 is $0.621.

> *Tip: Although present value tables are commonly available and useful, Appendix G provides a formatted spreadsheet that computes, from discount rate and time inputs chosen by the user, PV costs of future expenditures developed from the 1/(1+r)t relationship.*

Comparing capital project A and B on an NPV basis begins with calculating the present worth of each expenditure or payment (salvage value of alternative A, revenue stream of alternative B) and summing them, as done in the Example 3-2.

Example 3-2
Calculating the Net Present Value

For illustrative purposes, a discount rate of 4% is used in this example.



Alternative Comparison at 4% Discount Rate

Alternative A

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	
Expenditure (M$)	36	57	56	98	70.4	50	50	50	50	70	50	50	50	50	70	50	50	50	50	70	50	50	50	50	50	50	
Salvage (M$)																										-5	
PV factor @ 4% discount rate	1.000	0.962	0.925	0.889	0.855	0.822	0.790	0.760	0.731	0.703	0.676	0.650	0.625	0.601	0.577	0.555	0.534	0.513	0.494	0.475	0.456	0.439	0.422	0.406	0.390	0.375	
PV	36	54.8	51.8	87.1	60.1	41.1	39.5	38	36.5	49.2	33.8	32.5	31.2	30	40.4	27.8	26.7	25.7	24.7	33.2	22.8	21.9	21.1	20.3	19.5	16.9	**922.67**

Alternative B

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	
Expenditure (M$)	24.5	99	78.5	30	58	58	58	58	58	58	78	58	58	58	58	58	58	78	58	58	58	58	58	58	95	
Revenue (M$)					-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5	-5		
PV factor @ 4% discount rate	1.000	0.962	0.925	0.889	0.855	0.822	0.790	0.760	0.731	0.703	0.676	0.650	0.625	0.601	0.577	0.555	0.534	0.513	0.494	0.475	0.456	0.439	0.422	0.406	0.390	-
PV	24.5	95.2	72.6	26.7	45.3	43.6	41.9	40.3	38.7	37.2	49.3	34.4	33.1	31.8	30.6	29.4	28.3	37.5	26.2	25.2	24.2	23.3	22.4	21.5	37.1	**920.113**

As shown in the above table, Project B becomes the best cost alternative on a NPV basis, $920,113,000 to $922,670,000.

Another example of a LCCA is presented in Example 3-3. This example uses the LCCE for the hypothetical radiological laboratory that was used to illustrate LCCE principles earlier in this guide. Note that the estimate values used for this analysis do not include any allowances for estimate uncertainty or risk.

Example 3-3. LCCA Comparison of Alternatives

This example compares the costs to construct a new, more efficient radiological laboratory at an existing DOE site to replace an aging, less efficient laboratory.

Other elements and assumptions used for this analysis include the following items:

- The annual O&M costs for the existing facility are 25% higher than those of the new facility, because more work shifts will be needed in the existing facility to match the needed capacity (for which the new facility will be designed to achieve).
- It will be possible to continue to operate the existing facility for the remaining period needed, after some near-term modifications (which will not disrupt operations), and periodic upgrades over the remaining life that will be somewhat higher than the new facility will require.
- For the new facility option, the old facility final disposition (after a short S&M period) will need to be completed.
- It is assumed the S&M and final disposition costs will be the same for both facilities.

The results of the NPV calculations are presented in Appendix E.1. In summary, the analysis shows that, on a present value basis, it is slightly more economical to keep operating the existing facility ($358M) than it would be to design and construct a new, more efficient facility ($367M).

Occasionally, it will become apparent that certain costs related to a given alternate are likely to change. In such cases, it may be possible to conduct a revised comparative analysis that addresses only the components that have changed. However, it is always preferable to conduct a full comparative analysis of alternatives to ensure that all variables have been considered, and full documentation remains intact to support the program decision selection.

Program Analysis

This section discusses the composition and use of a life-cycle baseline as an instrument to manage a program comprising multiple projects and other elements, for example, laboratory support and research and development contracts. A program-level life-cycle cost baseline can be used to document a program’s critical cost, schedule, and performance parameters, and express them in measurable, quantitative terms that must be met in order to accomplish the program’s goals. By tracking and measuring actual program performance against this baseline, the program’s management is alerted to potential problems, such as cost growth or requirements creep and can take early corrective action. As a point of reference, to develop budget estimates for operating programs, NNSA has implemented a planning, programming, budgeting, and evaluation (PPBE) process that provides a framework for the agency to plan, prioritize, fund, and evaluate program activities.

A program life-cycle baseline must be comprehensive. A formalized program WBS structure is required to provide a clear picture of what needs to be accomplished, where and when cross-cutting milestones must be achieved, and how the work will be done and to provide a basis for identifying resources and tasks for developing a cost estimate. Without a program-level work WBS, there is no assurance that a life-cycle cost estimate will capture all relevant costs, which can lead to cost overruns and schedule delays.

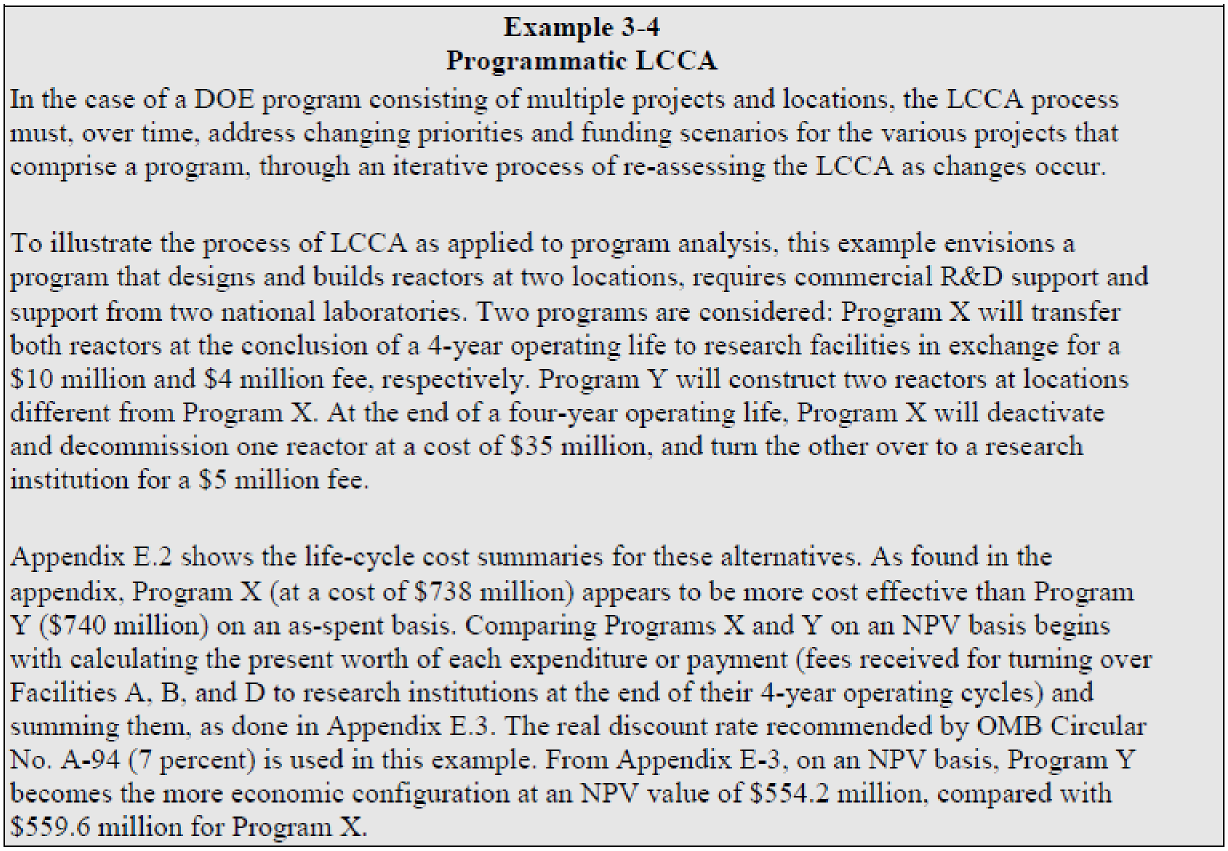
The program life-cycle baseline must be well-documented. Documentation is best when prepared as a single document to describe data sources and steps taken in developing the estimate—such as applying escalation rates, the basis for labor costs, sources of procurements, application of overhead, and other indirect costs—so that the estimate could be replicated by someone other than the preparers. Benefits and the methodology for assessing associated dollar values of benefits, attributed to each alternative, should also be documented, along with an explanation of how benefits support the mission need. Changes in baseline ground rules and assumptions should be evaluated promptly, and the affected cost estimates adjusted accordingly.

The program life-cycle baseline must be accurate. A formal system for tracking and reporting cost and schedule performance (earned value system) to update the estimate is essential to provide early identification of when, how much, and why the program cost more or less than planned.

The program life-cycle baseline must be credible. This is best accomplished by:

- Conducting an independent cost estimate to provide an unbiased test of whether the estimate is reasonable
- Providing a formal sensitivity analysis to examine the effects of changing assumptions and ground rules
- Developing a risk and uncertainty analysis to assess variability in point estimates due to factors such as errors and estimator bias

The basic concepts of LCCA are identical for use in evaluating both the elements of programs and projects. That is, LCCA always compares the NPV of competing alternatives.



Example 3-4
Programmatic LCCA

In the case of a DOE program consisting of multiple projects and locations, the LCCA process must, over time, address changing priorities and funding scenarios for the various projects that comprise a program, through an iterative process of re-assessing the LCCA as changes occur.

To illustrate the process of LCCA as applied to program analysis, this example envisions a program that designs and builds reactors at two locations, requires commercial R&D support and support from two national laboratories. Two programs are considered: Program X will transfer both reactors at the conclusion of a 4-year operating life to research facilities in exchange for a $10 million and $4 million fee, respectively. Program Y will construct two reactors at locations different from Program X. At the end of a four-year operating life, Program X will deactivate and decommission one reactor at a cost of $35 million, and turn the other over to a research institution for a $5 million fee.

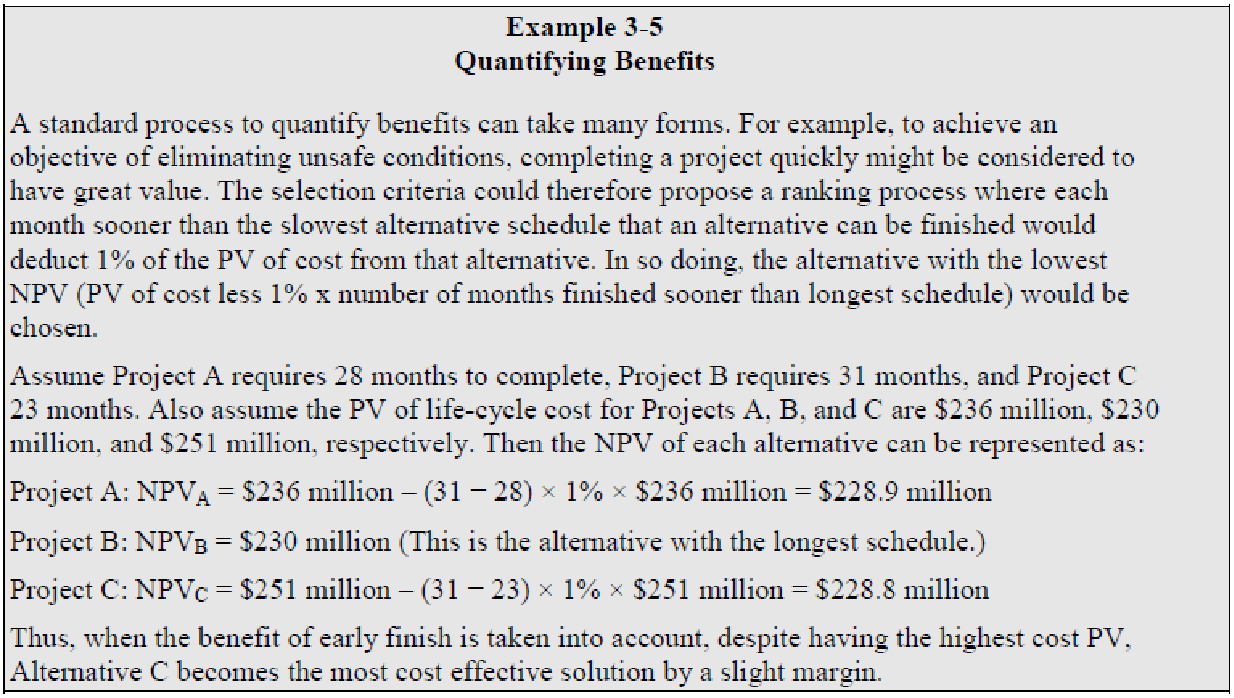
Appendix E.2 shows the life-cycle cost summaries for these alternatives. As found in the appendix, Program X (at a cost of $738 million) appears to be more cost effective than Program Y ($740 million) on an as-spent basis. Comparing Programs X and Y on an NPV basis begins with calculating the present worth of each expenditure or payment (fees received for turning over Facilities A, B, and D to research institutions at the end of their 4-year operating cycles) and summing them, as done in Appendix E.3. The real discount rate recommended by OMB Circular No. A-94 (7 percent) is used in this example. From Appendix E-3, on an NPV basis, Program Y becomes the more economic configuration at an NPV value of $554.2 million, compared with $559.6 million for Program X.

Alternative Selection Considerations

Simply stated, the best solution among alternatives is the one with the lowest NPV. When the alternatives offer varying levels of benefits, or when placing a specific dollar value on benefits is difficult to assess, selection of the best alternative is more challenging. In general, the process for identifying benefits should include the following actions:

- Use a standard process to quantify the benefits and effectiveness of each alternative and document this process
- Quantify the benefits and effectiveness resulting from each alternative over that alternative's full life cycle, if possible
- Explain how each measure of benefit and effectiveness supports the mission need

These actions should be included in the baseline documentation.



Example 3-5
Quantifying Benefits

A standard process to quantify benefits can take many forms. For example, to achieve an objective of eliminating unsafe conditions, completing a project quickly might be considered to have great value. The selection criteria could therefore propose a ranking process where each month sooner than the slowest alternative schedule that an alternative can be finished would deduct 1% of the PV of cost from that alternative. In so doing, the alternative with the lowest NPV (PV of cost less 1% x number of months finished sooner than longest schedule) would be chosen.

Assume Project A requires 28 months to complete, Project B requires 31 months, and Project C 23 months. Also assume the PV of life-cycle cost for Projects A, B, and C are $236 million, $230 million, and $251 million, respectively. Then the NPV of each alternative can be represented as:

Project A: $NPV_A = \$236 \text{ million} - (31 - 28) \times 1\% \times \$236 \text{ million} = \$228.9 \text{ million}$

Project B: $NPV_B = \$230 \text{ million}$ (This is the alternative with the longest schedule.)

Project C: $NPV_C = \$251 \text{ million} - (31 - 23) \times 1\% \times \$251 \text{ million} = \$228.8 \text{ million}$

Thus, when the benefit of early finish is taken into account, despite having the highest cost PV, Alternative C becomes the most cost effective solution by a slight margin.

Tip: Providing a thorough explanation of the methodology used in assessing benefits to a program alternative not only clarifies the selection team’s criteria, but also helps to allay concerns that the selection process was biased.

Example 3-6. Cost Avoidance Benefits

In another example, alternatives are assessed for competing projects considered for improving site security at a national laboratory. The projects are assumed to offer differing levels of benefits. The assessment therefore must find a means to measure a value for the unequal benefits to be achieved.

First, assume that the relative level of improved site security can be equated to the relative reductions in frequency and severity of undesirable events, such as unauthorized IT system access (external or internal), unauthorized physical access, and disasters affecting the site infrastructure (fire, flood, etc.) Each undesirable event can have specific costs associated with it, such as productivity losses resulting from virus attacks or from intruder caused stoppages, legal liability from unauthorized system access, etc. Relative benefits would comprise the sum of such costs avoided by each alternative solution.

Assume two competing site security improvement schemes, Project P and Project Q, are contemplated, with equivalent as-spent capital construction costs. Further, assume that both schemes can be brought into operation after a 3-year installation schedule; that is, through completion of all project phases, including procurement and construction.

The only difference in Projects P and Q lies in their ability to avoid “upset” costs. Their differing approaches (Project P is more heavily concerned with physical security and Project Q more with IT improvements) lead to differing types and amounts of cost avoidance benefits.

Assume that the benefits can be distilled to two types of cost avoidance; namely, avoidance of plant stand-downs caused by unauthorized intrusions, estimated to cost $2 million each, and IT compromises leading to total system outages and loss of data, estimated to cost $4 million each. Further, assume the plant currently experiences on average an unauthorized intrusion stand-down every 2 years and an IT compromise every 2 years.

Project P, with its focus on physical security is expected to yield one intrusion stand-down in the 5th year of its 10-year operating life. It is also expected to yield one IT compromise every 3 years, occurring in the 3rd, 6th, and 9th years of operating life.

Project Q, structured more heavily towards IT security, is expected to experience five intrusion stand-downs occurring in the 2nd, 4th, 6th, 8th, and 10th years of operating life, and one IT compromise in the 5th year of operations.

In the LCC Handbook Appendix E.4, PVs are calculated for the historical upsets costs over the operating life of the plant security improvements, compared to PVs of the expected upset costs under Project P and Q. As can be seen, the historical cost PV is expected to be $15.57 million if no improvements are made to plant security. Project P would result in $8.63 million in upset costs, and Project Q in $9.15 million. The savings produced by Project P would therefore be $15.57 million − $ 8.63 million = $ 6.94 million. Project Q would produce $15.57 million − $9.15 million = $6.42 million in avoided cost. Because Project P produces greater benefits (cost savings), it would be the best solution, if all other costs are equivalent, as assumed.

DOE Order 413.3B and its associated guides and handbooks addressing Analysis of Alternatives, Systems Engineering, Acquisition Strategy, and Cost Estimating provide best practices for the analysis and comparison of alternatives.

LCCA Cost Tools

To assist the user in preparing NPV calculations of alternatives and to provide consistency in their formatting, LCC Handbook Appendix G provides an Excel spreadsheet template that can be used to enter the variables of an LCCA. The template will yield a finished product that will be complete and consistent with other LCCAs.

As provided, it includes yearly life-cycle costs by project phase for two alternative programs. The yearly values represent the escalated, as-spent amount estimated by the user. There is also a single cell where the user enters the discount rate upon which to base the analysis. The spreadsheet then automatically calculates NPV for each alternative.

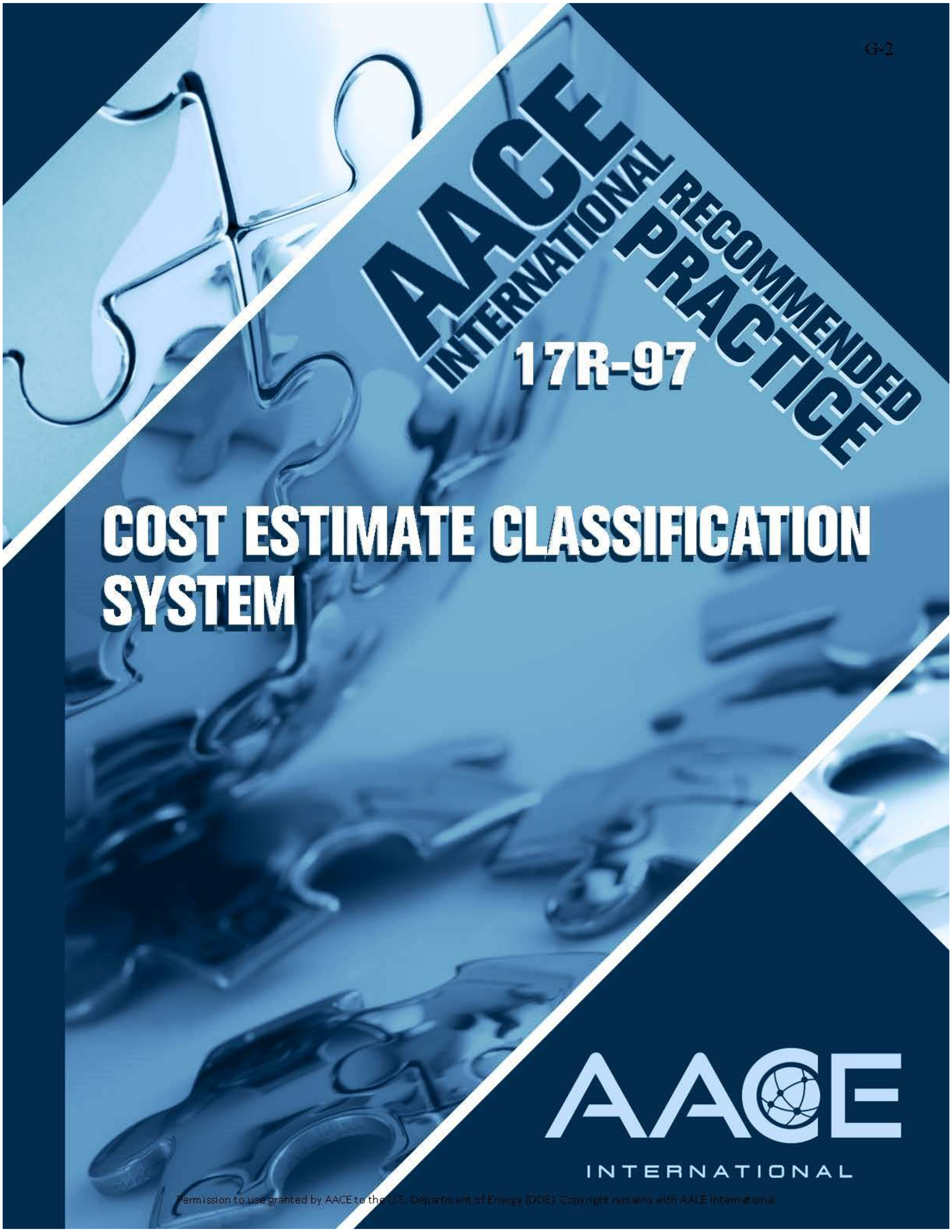
The LCC Handbook Appendix G is both an example of how the spreadsheet is used and the actual analytical tool for use in developing an LCCA. As the example, the spreadsheet depicts two program alternatives, A and B. Shaded areas of the spreadsheet contain entries made by a user. In this case, the user has selected 7 percent as the appropriate discount rate, and has entered annual as-spent cost estimates that amount to life-cycle costs of $639 million and $643 million for A and B, respectively. The spreadsheet then calculates NPV for each alternative, amounting to $431.5 million and $436 million for A and B, respectively. Users of the spreadsheet need simply delete the example figures and insert their own cost estimates in place of the sample figures.

The National Institute of Standards & Technology’s Building Life Cycle Cost (BLCC) software provides an additional resource for life cycle costing (LCC). This software tool incorporates material from several documents discussed in this Guide. For further information, including BLCC program downloads and discussion, see https://energy.gov/eere/femp/building-life-cycle-cost-programs.

Appendix G: Cost Estimate Classifications (AACE International)

AACE International Recommended Practice 17R-97, Cost Estimate Classification System

AACE International Recommended Practice 18-R-97, Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries



AACE INTERNATIONAL RECOMMENDED PRACTICE

17R-97

COST ESTIMATE CLASSIFICATION SYSTEM

AACE INTERNATIONAL

AACE International Recommended Practice No. 17R-97

COST ESTIMATE CLASSIFICATION SYSTEM

TCM Framework: 7.3 – Cost Estimating and Budgeting

Rev. November 29, 2011

Note: As AACE International recommended practices evolve over time, please refer to web.aacei.org for the latest revisions.

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Disclaimer: The opinions expressed by the authors and contributors to this recommended practice are their own and do not necessarily reflect those of their employers, unless otherwise stated.

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AACE® International Recommended Practice No. 17R-97

COST ESTIMATE CLASSIFICATION SYSTEM

TCM Framework: 7.3 – Cost Estimating and Budgeting

November 29, 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 the maturity level of project definition deliverables as the primary characteristic to categorize estimate classes; and
- reflects generally-accepted practices in the cost engineering profession.

An intent of the guideline 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 enjoyed reasonably broad acceptance within the engineering and construction communities and within the process industries. However, in the 1980s, empirical research on the correlation of the maturity level of project definition and cost growth and schedule slip led to better understanding of project risks and the wide implementation of project phase or stage-gate scope development processes [3]. This recommended practice guide and its addenda, in consideration of this research improve upon the earlier standards by:

1. providing a classification method applicable across all industries;
2. unambiguously identifying, cross-referencing, benchmarking, and empirically evaluating the multiple characteristics related to the class of cost estimate; and
3. aligning with typical phase-gate project scope definition practices.

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 the maturity level of project definition deliverables, 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 maturity level of project definition deliverables. The other characteristics are "secondary."

Categorizing cost estimates by maturity level 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.

	Primary Characteristic	***Secondary Characteristic***			
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical +/- range relative to index of 1 (i.e. Class 1 estimate) [a]	**PREPARATION EFFORT** Typical degree of effort relative to least cost index of 1 [b]
Class 5	0% to 2%	Screening or feasibility	Stochastic (factors and/or models) 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 75%	Control or bid/tender	Primarily deterministic	1 to 3	5 to 20
Class 1	65% 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%.

Table 1 – Generic Cost Estimate Classification Matrix

Five cost estimate classes have been established. While the maturity 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 maturity 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.

Table 1 provides a summary of the characteristics of the five estimate classes. The maturity level of definition is the sole determining (i.e., primary) characteristic of Class. In Table 1, the maturity is roughly indicated by a % of complete definition; however, it is the maturity of the defining deliverables that is the determinant, not the percent. The specific deliverables, and their maturity or status can only be defined in the context of the specific industry project scope.

DETERMINATION OF THE COST ESTIMATE CLASS

The cost estimator makes the determination of the estimate class based upon the maturity level of project definition based on the status of specific key planning and design deliverables. The percent design completion may be correlated with the status, but the percentage should not be used as the Class determinate. While the determination of the status may (and hence class) is somewhat subjective, having standards for design input data, completeness and quality of the design deliverables will serve to make the determination more objective.

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 maturity level of project definition deliverables (the primary characteristic) is provided.

Maturity Level of Project Definition Deliverables (Primary Characteristic)

This characteristic is based upon the maturity or the extent of definition of key types of planning, design and other input information and deliverables available to the estimating process. Such inputs include project scope definition, requirements documents, specifications, project plans and schedules, drawings, calculations, learnings 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 type of estimates used in that industry. The set of deliverables becomes more definitive and complete as the level of project definition (i.e., project engineering) progresses; therefore, the percent completion will be somewhat correlated with the maturity level (see Table 1) However, percent completion metrics lack necessary information as to whether key deliverables have met quality goals or been completed in the proper sequence. A maturity matrix of key deliverables and their required status for each class (e.g., issued for design) is the recommended characteristic determinant.

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 degree 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 are often based on factors, metrics, models, etc. With deterministic methods, the independent variable(s) are more or less a definitive measure of the item being estimated (can include quotes, bids, etc.). A deterministic methodology reduces the level of conjecture inherent in an estimate. As the maturity 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 in 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 maturity level of project definition deliverables increases, the expected accuracy of the estimate tends to improve, as indicated by a tighter +/- range.

Note that in table 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.

In addition to the maturity level of project definition, estimate accuracy is also driven by other systemic risks such as:

- 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.

Systemic risks such as these are often the primary driver of accuracy; however, project-specific risks (e.g. risk events) also drive the accuracy range [3].

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 maturity level of project definition deliverables 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 maturity level of project definition deliverables was provided above. This section explores those trends in more detail. Typically, there are commonalties 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 maturity level of project definition deliverables is the "driver" of the other characteristics. Typically, all of the secondary characteristics have the maturity 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" is driven my many project risks and "methodology" can vary markedly from one industry to another, and even from estimator to estimator within a given industry.

Maturity Level of Project Definition Deliverables

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 correlated to the maturity level or percent of project definition achieved, but maturity level does not express required quality or sequence information. The variations in the deliverables required for an estimate in specific industries 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 maturity level of project definition and subsequent estimate maturity level is significantly determined by how well the equipment and process flow 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 stakeholder's identity. For instance, an owner company may use a given class 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 stakeholder's 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 maturity 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 maturity level of project definition deliverables to support a deterministic method. This may be due to the lower level of effort required to prepare an estimate using stochastic methods.

Expected Accuracy Range

The accuracy range of an estimate is dependent upon risk. A number of characteristics of the estimate input information and the estimating process are systemic risks. The extent and the maturity of the input information is a highly important determinant of accuracy. However, there are systemic risk 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 a significant impact 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 maturity 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 systemic determinants of accuracy, such as technology, quality of reference cost data, quality of the estimating process, and skill and knowledge of the estimator vary. Finally, project-specific risks (e.g., risk events) also affect accuracy. 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 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 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 Table 1 in relationship to the identified characteristics. The maturity level of project definition deliverables determines the estimate class. For this RP, Table 1 provides generally indicative percent completions, but in industry-specific addenda RPs, design deliverable versus status matrix tables will be included which are the determinate of class. The other four characteristics are secondary characteristics that are generally correlated with the maturity level of project definition deliverables, as discussed above.

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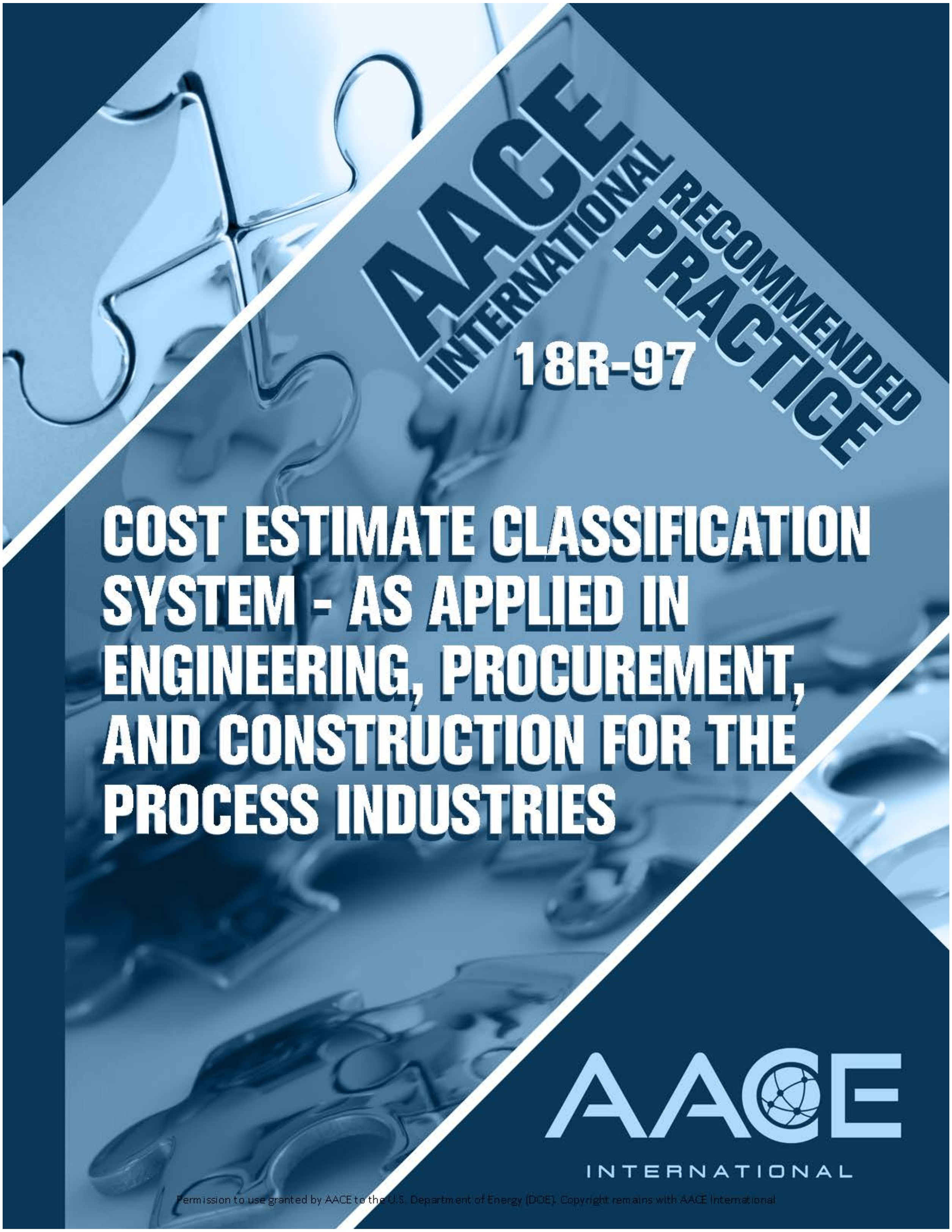

AACE INTERNATIONAL RECOMMENDED PRACTICE

18R-97

COST ESTIMATE CLASSIFICATION SYSTEM - AS APPLIED IN ENGINEERING, PROCUREMENT, AND CONSTRUCTION FOR THE PROCESS INDUSTRIES

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AACE International Recommended Practice No. 18R-97

COST ESTIMATE CLASSIFICATION SYSTEM – AS APPLIED IN ENGINEERING, PROCUREMENT, AND CONSTRUCTION FOR THE PROCESS INDUSTRIES

TCM Framework: 7.3 – Cost Estimating and Budgeting

Rev. March 1, 2016

Note: As AACE International Recommended Practices evolve over time, please refer to www.aacei.org for the latest revisions.

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TCM Framework: 7.3 – Cost Estimating and Budgeting

March 1, 2016

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 project scope definition maturity and quality matrix, which can be applied across a wide variety of process industries.

This addendum to the generic recommended practice (17R-97) 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 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 recommended practice, the 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 provide the process industry with a project definition deliverable maturity matrix that is not provided in 17R-97. It also provides an approximate representation of the relationship of specific design input data and design deliverable maturity to the estimate accuracy and methodology used to produce the cost estimate. The estimate accuracy range is driven by many other variables and risks, so the maturity and quality of the scope definition available at the time of the estimate is not the sole determinate of accuracy; risk analysis is required for that purpose.

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 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, water treatment, metallurgical, converting, and similar industries.

This addendum specifically does not address cost estimate classification in non-process industries such as commercial building construction, environmental remediation, transportation infrastructure, hydropower, "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.

This guideline reflects generally-accepted cost engineering practices. This RP 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. These classifications are also supported by empirical process industry research of systemic risks and their correlation with cost growth and schedule slip[8].

COST ESTIMATE CLASSIFICATION MATRIX FOR THE PROCESS INDUSTRIES

A purpose of cost estimate classification is to align the estimating process with project stage-gate scope development and decision making processes.

Table 1 provides a summary of the characteristics of the five estimate classes. The maturity level of project definition is the sole determining (i.e., primary) characteristic of class. In Table 1, the maturity is roughly indicated by a percentage of complete definition; however, it is the maturity of the defining deliverables that is the determinant, not the percent. The specific deliverables, and their maturity or status are provided in Table 3. The other characteristics are secondary and are generally correlated with the maturity level of project definition deliverables, as discussed in the generic RP [2]. The post sanction classes (Class 1 and 2) are only indirectly covered where new funding is indicated. Again, the characteristics are typical and may vary depending on the circumstances.

	Primary Characteristic	*Secondary Characteristic*		
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** 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
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 75%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Table 1 – Cost Estimate Classification Matrix for Process Industries

This matrix and guideline outline an estimate classification system that is specific to the process industries. Refer to the generic estimate classification RP[1] 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 provide additional information, particularly the project definition deliverable maturity matrix which determines the class in those particular industries.

Table 1 illustrates typical ranges of accuracy ranges that are associated with the process industries. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of contingency (typically to achieve a 50% probability of project overrun versus underrun) for given scope. Depending on the technical and project deliverables (and other variables) and risks associated with each estimate, the accuracy range for any particular estimate is expected to fall into the ranges identified (although extreme risks can lead to wider ranges).

In addition to the degree of project definition, estimate accuracy is also driven by other systemic risks such as:

- 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.
- Unique/remote nature of project locations and the lack of reference data for these locations.
- The accuracy of the composition of the input and output process streams.

Systemic risks such as these are often the primary driver of accuracy, especially during the early stages of project definition. As project definition progresses, project-specific risks (e.g. risk events) become more prevalent and also drive the accuracy range[3]. Another concern in estimates is potential pressure for a predetermined value that may result in a biased estimate. The goal should be to always have an unbiased and objective estimate. The stated estimate ranges are dependent on this premise and a realistic view of the project.

Failure to appropriately address systemic risks (e.g. technical complexity) during risk analysis impacts the resulting probability distribution of the estimate costs, and therefore the interpretation of estimate accuracy.

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, similar accuracy ranges may occur if the Class 5 estimate of one project that is based on a repeat project with good cost history and data and, whereas the Class 3 estimate for another is for a project involving new technology. It is for this reason that Table 1 provides ranges of accuracy range values. This allows application of the specific circumstances inherent in a project, and an industry sector, to provide realistic estimate class accuracy range percentages. While a target range may be expected of a particular estimate, the accuracy range is determined through risk analysis of the specific project and is never pre-determined. AACE has recommended practices that address contingency determination and risk analysis methods.

If contingency has been addressed appropriately, approximately 80% of projects should fall within the ranges shown in Figure 1. However, this does not preclude a specific actual project result from falling inside or outside of the bands shown in Figure 1 indicating the expected accuracy ranges.

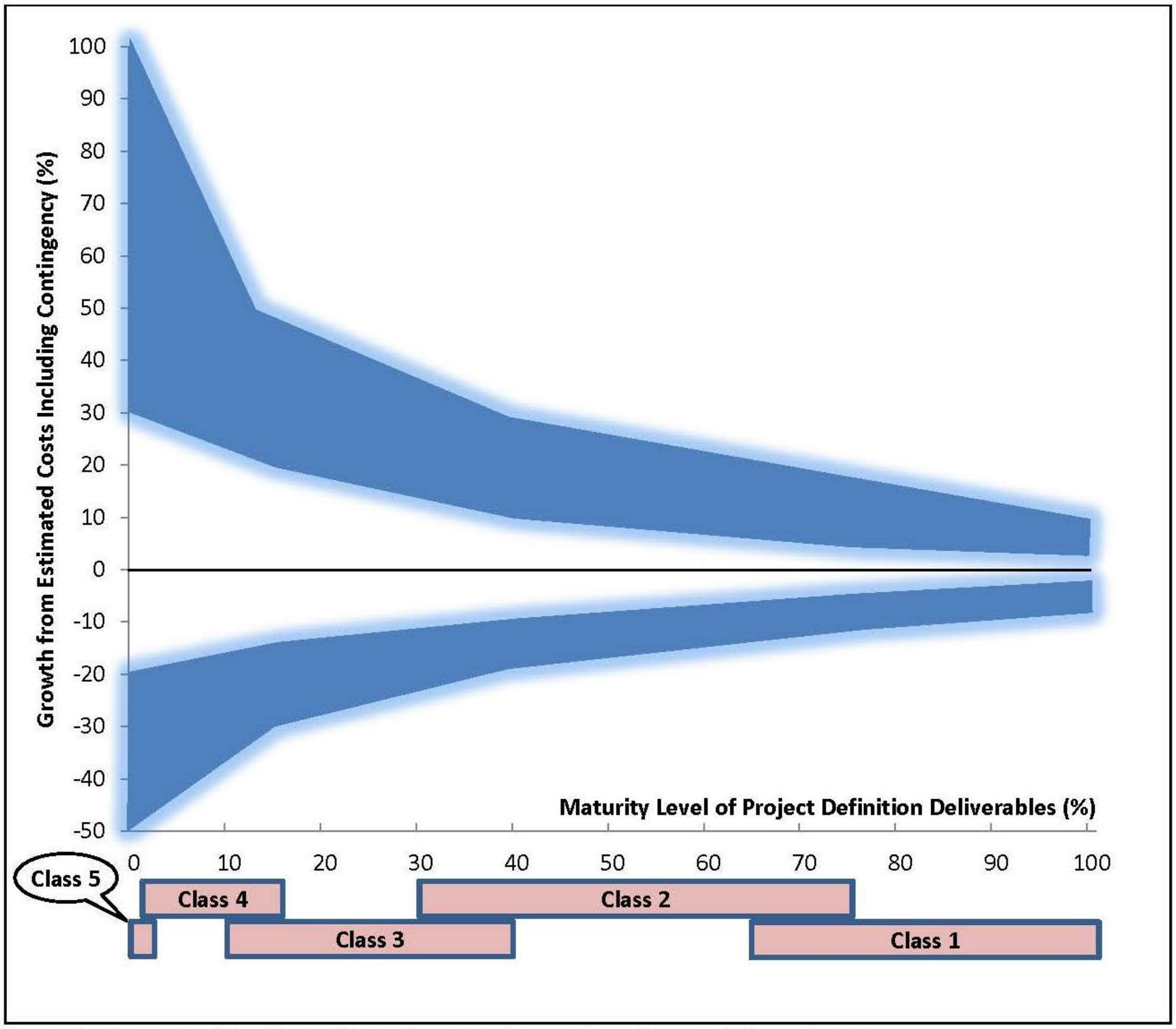

Figure 1 – Example of the Variability in Accuracy Ranges for a Process Industry Estimate

DETERMINATION OF THE COST ESTIMATE CLASS

The cost estimator makes the determination of the estimate class based upon the maturity level of project definition based on the status of specific key planning and design deliverables. The percent design completion may be correlated with the status, but the percentage should not be used as the estimate class determinant. While the determination of the status (and hence the estimate class) is somewhat subjective, having standards for the design input data, completeness and quality of the design deliverables will 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 maturity level of project definition deliverables.
- **Maturity Level of Project Definition Deliverables Required (Primary Characteristic):** Describes a particularly key deliverable and a typical target status in stage-gate decision processes, plus an indication of approximate 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 (Secondary Characteristic):** A short discussion of the possible end usage of this class of estimate.
- **Estimating Methodology (Secondary Characteristic):** A listing of the possible estimating methods that may be employed to develop an estimate of this class.
- **Expected Accuracy Range (Secondary Characteristic):** Typical variation in low and high ranges after the application of contingency (to achieve a 50% probability of project overrun versus underrun). Typically, this represents about 80% confidence level that the actual cost will fall within the bounds of the low and high ranges. The estimate confidence level or accuracy range is driven by the reliability of the scope information available at the time of the estimate in addition to the other variables and risk identified above.
- **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.

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 systematic 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. **Maturity Level of Project Definition Deliverables:** Key deliverable and target status: Block flow diagram agreed by key stakeholders. List of key design basis assumptions. 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 Methodology:** 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 other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks. **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. **Maturity Level of Project Definition Deliverables:** Key deliverable and target status: Process flow diagrams (PFDs) issued for design. 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 Methodology:** Class 4 estimates generally use factored 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 other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks. **Alternate Estimate Names, Terms, Expressions, Synonyms:** Screening, top-down, feasibility (pre-feasibility for metals processes), authorization, factored, pre-design, pre-study.

Table 2b – Class 4 Estimate

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. Remedial action plan resulting from HAZOPs is identified. **Maturity Level of Project Definition Deliverables:** Key deliverable and target status: Piping and instrumentation diagrams (P&IDs) issued for design. 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 Methodology:** Class 3 estimates generally involve more deterministic estimating methods than conceptual methods. They usually involve predominant use of unit cost line items, although these may be at an assembly level of detail rather than individual components. Factoring 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 other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks. **Alternate Estimate Names, Terms, Expressions, Synonyms:** Budget, scope, sanction, semi-detailed, authorization, preliminary control, concept study, feasibility (for metals processes) development, basic engineering phase estimate, target estimate.

Table 2c – Class 3 Estimate

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 75% 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. **Maturity Level of Project Definition Deliverables:** Key deliverable and target status: All specifications and datasheets complete including for instrumentation. 30% to 75% of full project definition. **End Usage:** Class 2 estimates are typically prepared as the detailed contractor control baseline (and update to 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. Some organizations may choose to make funding decisions based on a Class 2 estimate.	**Estimating Methodology:** 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 other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks. **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

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, overall engineering is from 65% to 100% complete (some parts or packages may be complete and others not), and would comprise virtually all engineering and design documentation of the project, and complete project execution and commissioning plans. **Maturity Level of Project Definition Deliverables:** Key deliverable and target status: All deliverables in the maturity matrix complete. 65% 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 Methodology:** 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 other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks. **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

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 completion status of the deliverable. The completion is indicated by the following descriptors:

General Project Data:

- **Not Required:** May not be required for all estimates of the specified class, but specific project estimates may require at least preliminary development.
- **Preliminary**: Project definition has begun, and progressed to at least an intermediate level of completion. Review and approvals for its current status has occurred.
- **Defined**: Project definition is advanced and reviews have been conducted. Development may be near completion with the exception of final approvals.

Engineering Deliverables:

- **Not Required (NR)**: Deliverable may not be required for all estimates of the specified class, but specific project estimates may require at least preliminary development.
- **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.

	ESTIMATE CLASSIFICATION				
	CLASS 5	**CLASS 4**	**CLASS 3**	**CLASS 2**	**CLASS 1**
MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES	**0% to 2%**	**1% to 15%**	**10% to 40%**	**30% to 75%**	**65% to 100%**
General Project Data:					
Project Scope Description	Preliminary	Preliminary	Defined	Defined	Defined
Plant Production/Facility Capacity	Preliminary	Preliminary	Defined	Defined	Defined
Plant Location	Preliminary	Preliminary	Defined	Defined	Defined
Soils & Hydrology	Not Required	Preliminary	Defined	Defined	Defined
Integrated Project Plan	Not Required	Preliminary	Defined	Defined	Defined
Project Master Schedule	Not Required	Preliminary	Defined	Defined	Defined
Escalation Strategy	Not Required	Preliminary	Defined	Defined	Defined
Work Breakdown Structure	Not Required	Preliminary	Defined	Defined	Defined
Project Code of Accounts	Not Required	Preliminary	Defined	Defined	Defined
Contracting Strategy	Not Required	Preliminary	Defined	Defined	Defined
Engineering Deliverables:					
Block Flow Diagrams	S/P	P/C	C	C	C
Plot Plans	NR	S/P	C	C	C
Process Flow Diagrams (PFDs)	NR	P/C	C	C	C
Utility Flow Diagrams (UFDs)	NR	S/P	C	C	C
Piping & Instrument Diagrams (P&IDs)	NR	S/P	C	C	C
Heat & Material Balances	NR	P/C	C	C	C
Process Equipment List	NR	S/P	C	C	C
Utility Equipment List	NR	S/P	C	C	C
Electrical One-Line Drawings	NR	S/P	C	C	C
Design Specifications & Datasheets	NR	S/P	C	C	C
General Equipment Arrangement Drawings	NR	S	C	C	C
Spare Parts Listings	NR	NR	P	P	C
Mechanical Discipline Drawings	NR	NR	S/P	P/C	C
Electrical Discipline Drawings	NR	NR	S/P	P/C	C
Instrumentation/Control System Discipline Drawings	NR	NR	S/P	P/C	C
Civil/Structural/Site Discipline Drawings	NR	NR	S/P	P/C	C

Table 3 – Estimate Input Checklist and Maturity Matrix (Primary Classification Determinate)

March 1, 2016

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Appendix I: DOE Recommendations 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, 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 I-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 I-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;	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:**
• 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.	
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 I-2 outlines typical questions that should be answered to assess accuracy associated with various estimating techniques.

Table I-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, for projects that require an ICE, 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 makers 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 ICE is considered one of the best and most reliable validation methods. An ICE is conducted independently of the Project or Program by an outside organization external to the project’s decision making process. Preparing an ICE is an inherently government function.

GAO states that ICEs should be 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.

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 I-3 (taken from Table 27 in the GAO Cost Estimating and Assessments Guide, GAO-09-3SP) lists eight types of independent cost estimate reviews and describes what they entail.

Table I-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.
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	Conducted by an organization outside the acquisition chain, using the same detailed technical information as the program estimate, and 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	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 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.