APPENDIX B

COST ESTIMATING AND BEST PRACTICES

APPENDIX B

COST ESTIMATING AND BEST PRACTICE

B.1 Definitions

The following are definitions of terms used within Appendix B.

Activity-based costing (ABC)

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

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

Allowance – an amount included in a base-cost estimate to cover known but undefined requirements.

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

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

Baseline – a quantitative definition of cost, schedule, and technical performance that serves as a standard for estimating incremental costs and benefits of alternatives.

Basis (basis of estimate, or BOE) – documentation that describes how an estimate was developed and defines the information used in support of its development.

Benchmark – a standard by which performance may be measured.

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

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

Buried contingency – costs that may have been hidden in the details of an estimate. To reviewers, buried contingency often implies inappropriately inflated quantities, lowered productivity, or other means to increase estimated costs or benefits. Buried contingency should not be used.

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

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

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

Construction – a combination of engineering, procurement, erection, installation, assembly, demolition, or fabrication to create a new facility or to alter, add to, rehabilitate, dismantle, or remove an existing facility; includes alteration and repair (dredging, excavating, and painting) of buildings, structures, or other real property and construction, demolition, and excavation conducted as part of environmental restoration or remediation.

Consequence – the outcome of an event.

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

Contingency or contingency reserve – an amount within an estimate that is derived from a structured evaluation of identified risks, to cover a likely future event or condition, arising from presently known or unknown causes, within a defined project scope. Contingency is not included within regulatory analyses for best estimates.

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

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

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

Cost-benefit analysis – the systematic, quantitative method of assessing the desirability of proposed regulatory actions.

Cost-effective analysis – one method to inform decisionmaking, in limited cases, when quantitative analyses are not possible or practicable (i.e., due to lack of methodologies or data) to consider the dollar value of the benefits provided by the alternatives under consideration.

Cost-effective analysis values policy consequences in monetary terms; the difference is that at least one policy consequence is not valued but, instead, is quantified in physical units. The analysis then quantifies the monetized value in terms of one physical unit. The alternative with the largest benefits per unit (or the smallest costs per unit) would normally be preferred.

Cost estimate – a documented statement of costs to be incurred to complete a proposed regulatory action.

Cumulative distribution function (CDF) – a statistical function based on the accumulation of the probabilistic likelihood of occurrences. In the case of the cost estimate uncertainty analysis, it represents the likelihood that, at a given percentage, the project cost will be at or below a given value. As an example, the x-axis might represent the range of potential cost estimate values evaluated by the Monte Carlo simulation and the y-axis might represent the project's probability of the costs being less than or equal to that value.

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

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

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

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

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

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

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

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

Historical cost information – a database of information from completed projects normalized to some standard (e.g., geographical, national average) and time-based (e.g., brought to current year data) using historical cost indices.
Improvements to land – site clearing, grading, drainage, and facilities common to a project as a whole (such as roads, walks, paved areas, fences, guard towers, railroads, and port facilities) but excluding buildings, structures, utilities, special equipment or process systems, and demolition, tunneling, and drilling that are a significant intermediate or end product of the project.

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

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

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

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

Key risk – a set of risks considered to be of particular interest to the project team. These key risks are those estimated to have the most impact on costs and benefits and could include project, technical, internal, external, and other subcategories of risk.

Lessons learned – a formal or informal set of "lessons" collected from project or program experience that can be applied to future projects or programs. They can be gathered at any point during the life of the project or program.

Level of effort – a form of parametric estimating. Level of effort (LOE) is used to determine future repetitive costs based on past cost data (e.g., If two employees spent 1,000 person-hours to develop a guidance document last year, then similar documents may need a similar level of effort). 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 number of workers for a specified amount of time). LOE estimates are normally based on hours and the number of full-time equivalents.

Life cycle – is the length of time over which an alternative is analyzed.

Management reserve – funds set aside for "known unknowns" that are tied to the contract's scope and managed at the contractor level. Unlike contingency reserve, which is funding related, management reserve is budget related. The value of the contract includes these known unknowns in the budget base, and the contractor decides how much money to set aside. Management reserve is not used in the U.S. Nuclear Regulatory Commission (NRC) regulatory analysis cost estimates.

Monte Carlo analysis – a method of calculation that approximates solutions to a variety of mathematical problems by performing statistical sampling experiments using a computer.

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

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

Probability – the likelihood of an event occurring, expressed as a qualitative or quantitative metric.

Probability distribution function (PDF) – a probability distribution, also described as a probability density function, representing the distribution of the probability of an outcome. As an example, the Monte Carlo analysis may be designed to estimate the cost of an alternative. The PDF represents the number of times a certain estimated cost or benefit is achieved.

Productivity – the consideration for factors that affect the efficiency of construction labor (e.g., location, weather, work space, coordination, schedule).

Program evaluation and review technique (PERT) distribution – a special form of the beta distribution with a minimum and maximum value specified. The shape parameter is calculated from the defined *most likely* value. The PERT distribution is similar to a triangular distribution, in that it has the same set of three parameters.

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

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

Range (cost estimate range) – an expected range of estimated costs or benefits for a proposed regulatory alternative. Ranges may be established based on a range of alternatives, confidence levels, or expected accuracy and are dependent on a proposed alternative’s stage of development, size, complexity, and other factors.

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

Risk – a factor or element that introduces an uncertainty of outcome, either positively or negatively, that could affect the cost estimate of the considered regulatory alternative. This narrow definition is limited for risk, as it pertains to performing cost-benefit analyses.

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

Risk analysis method – the technique used to analyze the risks associated with a regulatory alternative. Three categories of risk analysis methods are:

(1) Qualitative - based on project characteristics and historical data (e.g., check lists, scenarios)

(2) Risk models – a combination of risks assigned to parts of the estimate to define the risk of the total estimate

(3) Probabilistic models - combining risks from various sources and events (e.g., Monte Carlo, Latin hypercube, decision tree, influence diagrams).

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

S-curve (spending curve) –

- a graphic display of cumulative costs, labor hours, or other quantities plotted against time; named from the S-shaped curve (flatter at the beginning and end, steeper in the middle) produced on a project that starts slowly, accelerates, and then slows again
- a representation of costs over the life of a project

Sensitivity analysis – an analysis that 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." A sensitivity analysis is used to determine what variables most affect the mean cost estimate.

Simulation, (Monte Carlo) – a process for modeling the behavior of a stochastic (probabilistic) system. A random sampling technique is used to obtain trial values for key uncertain model input variables. By repeating the process for many trials, a frequency distribution is created that approximates the true probability distribution for the system's output.

Triangle distribution – a subjective distribution of a population for which there is limited sample data. It is based on knowledge of the minimum and maximum and a best estimate as to what the modal value might be. It is also used as an alternative to the Beta distribution or PERT distribution.

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

Unidentified risks (or unknown unknowns) – risks that were not anticipated or foreseen. Unidentified risks might originally be unanticipated, because the probability of the event is so small that its occurrence is virtually unimaginable. Alternatively, an unidentified risk might be one that falls into an unanticipated or uncontrolled risk-event category.

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

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

B.2 Purpose

The purpose of this appendix on cost estimating and best practices is to provide uniform guidance and best practices that describe the methods and procedures recommended for use at the U.S. Nuclear Regulatory Commission (NRC) in preparing cost estimates that are specific to all work, including, but not limited to, preparing cost estimates for regulatory analyses, backfit analyses, and environmental analyses. Practices relative to estimating a life-cycle cost (LCC) are described. LCCs include all anticipated costs associated with a project or program alternative throughout the life of a nuclear facility (i.e., from authorization through end-of-life-cycle operations).

This appendix does not impose new requirements, establish NRC policy, or instruct NRC staff in preparing cost estimates. Rather, this appendix provides information on accepted standard industry estimating best practices and processes—including practices promulgated by the Government Accountability Office (GAO), “Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs” (GAO-09-3SP, 2009). GAO has specifically recommended in GAO-15-98, “NRC Needs to Improve Its Cost Estimates by Incorporating More Best Practices,” dated December 2014 (Ref. B.2) that NRC cost estimating guidance be aligned with relevant cost estimating best practices identified in this GAO guide to ensure that future cost estimates are prepared in accordance with relevant cost estimating best practices.

B.3 Guidance Overview

High-quality cost estimates provide an essential element for successful project and program management. The main objective of this appendix is to provide guidance that should improve the quality of cost estimates supporting Commission decisionmaking. The cost estimating principles and processes provided herein meet or exceed Federal and NRC requirements while using industry standards and best practices, where appropriate.

High-quality cost estimates should satisfy four characteristics, as established by industry best practices—they should be credible, well documented, accurate, and comprehensive (Ref. B.1).

An estimate should be:

- <u>credible</u> when the assumptions and estimates are realistic; in other words, it has been cross-checked and reconciled with independent cost estimates, the level of confidence associated with the point estimate[6] has been identified, and a sensitivity analysis has been conducted (i.e., an examination of the effect of changing one variable relative to the cost estimate while all other variables are held constant, to identify which variable most affects the cost estimate);

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

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

This appendix contains industry best practices for carrying out these steps. Enclosure B-5 contains a cross reference of the 12 key GAO estimating steps (Ref. B.1) and their implementing tasks to the sections of this appendix that discuss NRC guidance for accomplishing those steps.

B.3.1 Purpose of a Cost Estimate

The purpose of a cost estimate is determined by its intended use (e.g., regulatory analyses, backfitting analyses, environmental analyses) and its intended use determines its scope and detail. Accordingly, the principal purposes of a regulatory cost estimate are to help ensure the following:

- Regulatory decisions made in support of statutory responsibilities are based on adequate information concerning the need for and consequences of proposed actions.
- Appropriate alternative approaches to achieve regulatory objectives are identified and analyzed.
- The proposed action is the clearly preferred alternative.
- Proposed actions subject to the backfit rule (Title 10 of the *Code of Federal Regulations* (10 CFR) 50.109, “Backfitting”), and not within the exceptions in 10 CFR 50.109(a)(4), provide a substantial increase in the overall protection of public health and safety and the common defense and security, and the direct and indirect costs of implementation are justified in view of this substantial increase in protection.

The Commission has stated that “substantial” means important or significant in a large amount, extent, or degree (SRM-SECY-93-086, 1993). Applying such a standard, the Commission would not ordinarily expect that the staff would attempt to impose a backfit that would result in an insignificant or small benefit to public health and safety, regardless of costs. On the other hand, the standard is not intended to be interpreted in a manner that would result in disapprovals of worthwhile safety or security improvements having costs that are justified in view of the increased protection that would be provided. This approach is flexible enough to allow for qualitative arguments to support the quantitative analysis that a given proposed rule would substantially increase safety consistent with Commission direction on the use of qualitative factors. The approach is also flexible enough to allow for arguments that consistency with national and international standards, or the incorporation of widespread industry practices, contributes either directly or indirectly to a substantial increase in safety. Such arguments concerning consistency with other standards, or incorporation of industry practices, would have to rest on the particulars of a given proposed rule. The Commission also believes that this approach of “substantial increase” is consistent with the agency’s policy of encouraging voluntary initiatives.

B.3.2 Overview of the Cost Estimating Process

Traditionally, cost estimates are produced by gathering input, developing the cost estimate and its documentation, and generating the necessary output. Table B-1 explains the steps in the GAO cost estimating process that should be followed if accurate and credible cost estimates are to be developed. These best practices represent an overall process of established, repeatable methods that result in high-quality cost estimates, which are comprehensive and accurate and that can be easily and clearly traced, replicated, and updated.

This cost estimating process contains 12 steps that should result in reliable and valid cost estimates, which can be used for making informed decisions. Table B-1 identifies all 12 steps in this process that have been extracted from GAO-09-3SP, “GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs.”

Table B-1 The Twelve Steps of a High Quality Cost Estimating Process

Step	Description	Associated tasks
1	Define the estimate’s purpose.	• Determine the estimate’s purpose, required level of detail, and overall scope. • Determine who will receive the estimate.
2	Develop an estimating plan.	• Determine the composition of the cost estimating team and develop the master schedule. • Determine who will do the independent cost estimate. • Outline the cost estimating approach. • Develop the estimate timeline.
3	Define program characteristics.	• In a technical baseline description document, identify the program’s purpose and its system and performance characteristics, as well as all system configurations. • Identify any technology implications. • Develop the program acquisition schedule and acquisition strategy. • Determine the relationship to other existing systems, including predecessor or similar legacy systems. • Identify support (e.g., manpower, training) and security needs and risk items. • Determine system quantities for development, test, and production. • Develop deployment and maintenance plans.
4	Determine the estimating structure.	• Define a work-breakdown structure (WBS) and describe each element in a WBS dictionary (a major automated information system may have only a cost-element structure). • Choose the best estimating method for each WBS element. • Identify potential cross-checks for likely cost and schedule drivers. • Develop a cost estimating checklist.
5	Identify ground rules and assumptions.	• Clearly define the scope of the estimate (i.e., what it includes and excludes). • Identify global and program-specific assumptions, such as the estimate’s base year, including time-phasing and life cycle. • Identify program schedule information by phase and program acquisition strategy. • Identify any schedule or budget constraints, inflation assumptions, and travel costs. • Specify equipment the government is to furnish, as well as the use of existing facilities or new modification or development. • Identify prime contractor and major subcontractors. • Determine technology refresh cycles, technology assumptions, and new technology to be developed. • Define commonality with legacy systems and assumed heritage savings. • Describe effects of new ways of doing business.

Step	Description	Associated tasks
6	Obtain data.	• Create a data collection plan with emphasis on collecting current and relevant technical, programmatic, cost, and risk data. • Investigate possible data sources. • Collect data and normalize them for cost accounting, inflation, learning, and quantity adjustments. • Analyze the data for cost drivers, trends, and outliers and compare results against rules of thumb and standard factors derived from historical data. • Interview data sources and document all pertinent information, including an assessment of data reliability and accuracy. • Store data for future estimates.
7	Develop a point estimate and compare it to an independent cost estimate.	• Develop the cost model, estimating each WBS element, using the best methodology from the data collected, including all estimating assumptions. • Express costs in constant year dollars. • Time-phase the results by spreading costs in the years they are expected to occur, based on the program schedule. • Sum the WBS elements to develop the overall point estimate. • Validate the estimate by looking for errors like double counting and omitted costs. • Compare the estimate against the independent cost estimate and examine where and why there are differences. • Perform cross-checks on cost drivers to see if the results are similar. • Update the model as more data become available or as changes occur and compare results against previous estimates.
8	Conduct a sensitivity analysis.	• Test the sensitivity of cost elements to changes in estimating input values and key assumptions. • Identify effects on the overall estimate of changing the program schedule or quantities. • Determine which assumptions are key cost drivers and which cost elements are most affected by changes.
9	Conduct a risk and uncertainty analysis.	• Determine and discuss with technical experts the level of cost, schedule, and technical risk associated with each WBS element. • Analyze each risk for its severity and probability. • Develop minimum, most likely, and maximum ranges for each risk element. • Determine the type of risk distributions and reason for their use. • Ensure that risks are correlated. • Use an acceptable statistical analysis method (e.g., Monte Carlo simulation) to develop a confidence interval around the point estimate. • Identify the confidence level of the point estimate. • Identify the amount of contingency funding and add this to the point estimate to determine the risk-adjusted cost estimate. • Recommend that the project or program office develop a risk-management plan to track and mitigate risks.
10	Document the estimate.	• Document all steps used to develop the estimate so that a cost analyst unfamiliar with the program can recreate it quickly and produce the same result. • Document the purpose of the estimate, the team that prepared it, and who approved the estimate and on what date. • Describe the program, its schedule, and the technical baseline used to create the estimate. • Present the program’s time-phased life-cycle cost. • Discuss all ground rules and assumptions.

Step	Description	Associated tasks
		• Include auditable and traceable data sources for each cost element and document for all data sources how the data were normalized. • Describe in detail the estimating methodology and rationale used to derive each WBS element's cost (prefer more detail over less). • Describe the results of the risk, uncertainty, and sensitivity analyses and whether any contingency funds were identified. • Document how the estimate compares to the funding profile. • Track how this estimate compares to any previous estimates.
11	Present the estimate to management for approval.	• Develop a briefing that presents the documented life-cycle cost estimate (LCCE). • Include an explanation of the technical and programmatic baseline and any uncertainties. • Compare the estimate to an independent cost estimate (ICE) and explain any differences. • Compare the LCCE or ICE to the budget with enough detail to easily defend it by showing how it is accurate, complete, and high in quality. • Focus in a logical manner on the largest cost elements and cost drivers. • Make the content clear and complete, so that those who are unfamiliar with it can easily comprehend the basis for the estimate results. • Make backup slides available for more probing questions. • Act on and document feedback from management. • Seek acceptance of the estimate.
12	Update the estimate to reflect actual costs and changes.	• Update the estimate to reflect changes in technical or program assumptions to keep it current as the program passes through new phases and milestones. • Replace estimates with earned value management (EVM) and independent estimate at completion (EAC) from the integrated EVM system. • Report progress on meeting cost and schedule estimates. • Perform a post mortem and document lessons learned for those elements where actual costs or schedules differ from the estimate. • Document all changes to the program and how they affect the cost estimate.

[a] In a data-rich environment, the estimating approach should precede the investigation of data sources; in reality, a lack of data often determines the approach.
Source: GAO-09-3SP, Table 2

B.4 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. Internal NRC reviews or external feedback may identify the need to revisit various process elements to improve the quality of the cost estimate. Cost estimates that are developed early in the analysis of proposed regulatory alternatives may not be derived from detailed engineering designs and specifications, but the cost estimate should be sufficiently developed to support the intended purpose. During the life of the project, cost estimate inputs become increasingly definitive and reflect the scope and specificity defined for the project.

B.4.1 Project Requirements

Cost estimates are performed for regulatory analyses, backfitting analyses, and environmental analyses. Each analysis may have more specific, detailed, or different requirements.

B.4.2 Documentation Requirements

Scope assumptions, regulatory baseline determinations, and likely alternatives are documented. The analyses consider the accuracy of supporting estimates and project specific analysis.

B.5 Cost Estimating Characteristics And Classifications

B.5.1 Planning the Cost Estimates

Table B-2 describes the planning steps required to produce credible cost estimates (Ref. B.1).

Table B-2 Basic Characteristic of Credible Cost Estimates

Cost Estimate Planning Step	Description
Clear Identification of Task	The cost analyst should be provided with the scope description, ground rules and assumptions, and technical and performance characteristics. Estimate constraints and conditions should be clearly identified to ensure the preparation of a well-documented estimate.
Broad Participation in Preparing Estimates	Stakeholders should be involved in providing requirements, system parameters, and cost data based on stated regulatory objectives. External data should be independently verified for accuracy, completeness, and reliability.
Use of Valid Data	Use numerous sources of suitable and relevant 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 appropriate, continually refining it as the maturity of the scope develops and the regulatory actions become more defined. The WBS helps to ensure that no necessary 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) appropriate for the cost estimate. Identify uncertainties and develop an allowance to mitigate the cost effects of uncertainties.
Recognition of Escalation	Ensure that economic escalation (inflating the price of goods and services using an appropriate consumer price index to account for changes in prices over time) is properly and realistically reflected in the cost estimate. Assumptions need to be clearly noted. The source of escalation information should be identified and the applicability of the rates should be explained and 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 for the exclusion.
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 validate an estimate to ensure realism, completeness, and consistency.
Revision of Estimates for Significant Changes	Update estimates to reflect changes during the project. Large changes that affect costs can significantly influence decisions. Such changes should be appropriately justified and explained.

Source: GAO-09-3SP, Table 1, based upon GAO table (Ref. B.1)

B.5.2 Cost Estimate Classifications

Cost estimates have common characteristics. The most common characteristics are levels of definition, requirements, and techniques used. These characteristic levels are generally grouped into cost estimate classifications. Cost-estimate classifications may be used with any type of 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 the estimation (e.g., parametric vs. definitive), and (4) time constraints and other estimating variables.

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

Widely accepted cost estimate classifications are found in the Association for Advancement of Cost Engineering International (AACEI), 2011 Recommended Practices (RP) No. 17R-97 and 2011 RP No. 18R-97. The five suggested cost estimate classifications are listed in Table B-3, along with their primary and secondary characteristics and the estimate uncertainty range, as a function of the estimate class.

Table B-3 Cost Estimate Classification

	Primary Characteristic	***Secondary Characteristic***		
ESTIMATE CLASS	DEGREE OF PROJECT DEFINITION Expressed as % of complete definition	END USAGE Purpose of estimate	METHODOLOGY Typical estimating methodology	EXPECTED ACCURACY RANGE Typical variation in low and high ranges
Class 5	0% to 2%	Concept	Capacity factored, parametric models, judgment, or analogy	Low: -20% to -50% High: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Equipment factored, parametric models, judgment, or analogy	Low: -15% to -30% High: +20% to +50%
Class 3	10% to 40%	Budget authorization	Semi detailed unit costs	Low: -10% to -20% High +10% to +30%
Class 2	30% to 70%	Bid/tender	Detailed unit costs with forced detailed take-off	Low: -5% to -15% High +5% to +20%
Class 1	70% to 100%	Check estimate or bid/tender	Detailed unit costs with forced detailed take-off	Low: -3% to -10% High +3% to +15%

[a] The state of scope and requirements definition and the availability of applicable reference cost data can significantly affect the expected accuracy range.
[b] The expected accuracy range of low and high values represents the typical percentage variation of actual costs from the cost estimate after the application of contingency (typically at a 50-percent level of confidence) for a given scope).
Source: U.S. Department of Energy (DOE) Cost Estimating Guide, Table 4.3.

Table B-3 is intended only as an illustration of the general relationship between estimate accuracy and the level of specificity defined (e.g., level of project definition or level of engineering complete). As described in AACEI's Recommended Practices No. 17R-97, there is no absolute standard range on any estimate or class of estimates. The common +/- percent measure associated with an estimate is a useful simplification, given that each individual estimate is associated with a different level of uncertainty.

Although the level of project definition is an important determinant of estimate accuracy, there are other factors that also affect it. Some of these other factors include the quality of reference cost estimating data (i.e., material pricing, labor hours, labor wage rates), the quality of the assumptions used in preparing the estimate, the state of new technology in the project, the experience and skill level of the cost analyst, the specific estimating techniques used, the level of effort or time budgeted to prepare the estimate, and extraneous market conditions (e.g., periods of rapid price escalation, labor climate factors).

As a general rule, particularly for regulatory actions that are in the early stages of development, a combination of estimate classifications should be used to develop the estimate. In these situations, the analyst should use a combination of detailed unit cost estimating (Class 1) techniques for work that will be executed in the future, preliminary estimating (Class 3) techniques for work that is currently in the planning stages but less defined, and order of magnitude estimating (Class 5) techniques for future work that has not been well defined. For example, the regulatory basis phase is a Class 5 estimate, the proposed rule phase estimate is a Class 4 estimate, and the final rule phase is a Class 3 estimate, although specific cost elements within any of these three phases may be estimated at more detailed levels (e.g., Class 1 or Class 2).

B.5.3 Cost Estimate Ranges

When preparing cost estimates for early conceptual designs, it is important to realize that variations in the basis for the design will have the greatest impact on costs. Estimating tools and methods, while important, are not usually the main problem during the early stages of a project when estimate accuracy is poorest. In the early phases of defining and evaluating proposed regulatory requirements, effort should be directed towards establishing a better design basis than concentrating on using more detailed estimating methods.

The cost estimate range (lower and upper bounds) is determined by independently assessing the lower and upper cost estimate range for each cost element. In some situations, the range may, in part, be a function of scope variability (e.g., if a decision to add 5 or 10 submittals is pending) or could result from cost and schedule estimate uncertainties as part of the risk analysis.

The lower bound of the cost range may represent a scenario where the analyst has determined a low likelihood of impact and, therefore, it may not need additional resources to modify the current design or practice.

The upper bound of the cost range may represent a scenario where the analyst determined a large cost uncertainty associated with the required regulatory treatment for the modification, lack of specificity in the process steps or controls, or other cost drivers. Regardless, the cost estimates should be unbiased. Uncertainty should be reflected in the estimate range and not in padding the costs of each element or component of the estimate. GAO 09 3SP defines two types of contingency—contingency reserve and management reserve. Contingency reserve represents funds held at or above the program office for “unknown unknowns” that are outside a contractor’s control. In this context, contingency funding is added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows are likely to result in additional costs. Management reserve funds, in contrast, are for “known unknowns” that are tied to the contract’s scope and managed at the contractor level. Unlike contingency reserve, which is funding related, management reserve is budget related. The value of the contract includes these known unknowns in the budget base, and the contractor decides how much money to set aside. Neither one is used in NRC regulatory analysis cost estimates (Ref. B.1).

The use of sensitivity analysis and uncertainty analysis (discussed elsewhere) provides a means to determine the contingency amount required for a project budget. Therefore, contingency should not be added to the upper range cost estimate.

B.6 <u>Cost Estimating Methods</u>

Many cost estimating methods and techniques are available to use in performing a cost estimate. Depending on project scope, estimate purpose, level of project definition, and availability of cost estimating resources, the analyst may use one, or a combination, of these techniques. As shown in Table B-3, as the level of project definition increases, the estimating methodology tends to progress from conceptual (judgment, analogy, parametric) techniques to more detailed (activity-based, unit-cost) techniques. The following sections include techniques that may be employed in developing cost estimates.

B.6.1 Engineering-Buildup 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 used estimating techniques.

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

The analyst separates each activity into detailed tasks so that labor hours, material costs, equipment costs, and subcontract costs are itemized and quantified. Standard estimating practices use an action 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. Many of these factors may not be appropriate when performing an incremental cost estimate (e.g., regulatory analyses). When performing a sensitivity analysis for a regulatory analysis (i.e., a high estimate), the analyst should include contingencies. The concept of sensitivity analysis is discussed in Appendix C as a subset of contingency analysis.

The estimate may be revised as 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, are quantifiable, and are to be monitored, so that performance can be reported accurately. Cost estimates used in regulatory analyses to estimate regulatory burden are not used by the NRC to develop work packages or planning packages and are not updated after the Commission decision on the proposed action. Therefore, the NRC does not monitor those estimated costs.

Quantities should be objective, discrete, and measurable. These quantities provide the basis for an EVM of the work within the activities and the WBS. A handbook reference suitable for use in developing a product-oriented WBS is the 2012 U.S. Department of Energy (DOE) “Work Breakdown Structure Handbook.”

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

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

Disadvantages include the following:

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

B.6.2 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. A parametric estimate comprises cost estimating relationships (CERs) and other cost estimating functions that provide logical and repeatable relationships between independent variables, such as design parameters or physical characteristics and cost, the dependent variable. Capacity factor and equipment factor are simple examples of parametric estimates; however, sophisticated parametric models typically involve several independent variables or cost drivers. Parametric estimating relies on the collection and analysis of previous project cost data to develop the cost estimating relationships.

B.6.2.1 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 cost or price by using an established relationship with an independent variable. For example, a CER of design hours per drawing may be applied to the estimated number of drawings to determine total design hours. Identifying an independent variable (driver) that demonstrates a measurable relationship with contract cost or price develops a CER. That CER may be mathematically simple (e.g., a simple ratio), or it may involve a complex equation.

Parametric estimates are commonly used in conceptual and check estimates. A limitation on the use of CERs is that, to be most effective, the cost analyst should understand 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 (e.g., system, subsystem component). 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 CER's predictive capability.

There are also disadvantages to parametric-estimating techniques, including the following:

- **Database requirements**—The underlying data should 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 analyst is accepting the database on faith, thereby increasing the estimate's risk.

- **Currency**—CERs should be periodically updated to capture the most current cost, technical, and programmatic data.

- **Relevancy**—Using data outside the CER range may cause errors, because the CER loses its predictive capability for data outside the development range.

- **Complexity**—Complicated CERs (e.g., nonlinear CERs) may make it difficult to readily understand the relationship between cost and its independent variables.

B.6.2.2 End-Product-Unit Method

The end-product-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 the location or timing of the work.

Consider an example of estimating the cost of reviewing a routine submittal. From a previous estimate, the total cost was found to be $150,000 to review 10 submittals, or $15,000 per submittal. For a new reporting requirement of similar complexity, the estimated cost would be $15,000 per review for two submittals or $30,000. As another example, when estimating the overnight construction cost (construction costs without loan costs) of a nuclear power plant, the generally accepted industry practice is to multiply the planned megawatt (MW) capacity of the proposed plant by a dollars per MW value obtained by calculating the dollars per MW construction costs of recently completed nuclear power plants.

B.6.2.3 Physical-Dimension Method

The physical-dimension method is used when enough historical data are available from similar work, based on the area or volume of that work. The method uses the relationship of the physical dimensions 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 the location or timing of the work. For example, the total cost of a previous project was $150,000 for a 1,000-square-foot foundation. A new foundation is to be 3,000 square feet. Using the dollar per square-foot value from the previous project yields a value of $150 per square foot (i.e., $150,000 divided by 1,000 square feet). The estimated cost of the new foundation is $450,000 (i.e., $150 per square foot x 3,000 square feet).

B.6.2.4 Capacity-Factored Method

The capacity-factored method is used during the feasibility stage of a project, when enough historical data are available from similar work, based on the capacity of that work. The method uses the relationship of the capacity of existing work data to that of the capacity of similar new work. It accounts for economies of scale but not the location or timing of the work and provides a sufficiently accurate means of determining whether a proposed project, regulatory action, or alternative should be continued. This screening method (Class 5 estimate) is most often used. The capacity-factored method is most often used to estimate the cost of entire facilities but may also be applied at the system or equipment level.

When estimating using the capacity-factored method, the cost of a new plant is derived from the cost of a similar plant of a known capacity, with similar operational characteristics (e.g., batch processing, base load) but not necessarily the same end products. Although the end products do not need to be the same, the products should be relatively similar.

The method uses a nonlinear relationship between capacity and cost, as shown in the following equation:

$$\frac{\$B}{\$A} = \left[\frac{Capacity_B}{Capacity_A}\right]^e$$

where: $A and $B are the costs of the two similar plants.
$Capacity_A$ and $Capacity_B$ are the capacities of the two plants.
e is the exponent or proration factor.

The exponent “e” used in the capacity-factor equation is the slope of the log curve that is drawn to reflect the change in the cost of a plant as it is made larger or smaller. These curves are typically drawn from the data points of the known costs of completed plants. With an exponent less than 1, scales of economy are achieved such that, as plant capacity increases by a percentage (say, by 20 percent), the costs to build the larger plant increase by less than 20 percent. This methodology of using capacity factors is sometimes referred to as the scale-of-operations method or the six-tenths-factor method because of the reliance on an exponent of 0.6, if no other information is available.

The value of the exponent e typically lies between 0.5 and 0.85, depending on the type of plant, and should be analyzed carefully for its applicability to each estimating situation. As plant capacity increases to the limits of existing technology, the exponent approaches a value of one. At this point, it becomes as economical to build two plants of a smaller size as to build one large plant.

Companies may not make proration factor data available, and recent studies are sparse. However, if the proration factor used in the estimating algorithm is relatively close to the actual value, and if the plant being estimated is relatively close in size to the similar plant of known cost, then the potential error is certainly well within the level of accuracy that would be expected from a stochastic method.

A purely stochastic method is one where the state is randomly determined, having a random probability distribution or pattern that may be analyzed statistically but may not be predicted precisely. In this regard, it can be classified as nondeterministic (i.e., "random"), so that the subsequent state of the system is determined probabilistically.

B.6.2.5 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 the location or timing of the work.

To illustrate, if a plant that cost $1,000,000 to construct has major equipment that costs $250,000, then the plant cost to equipment cost factor is:

$$plant\ cost\ to\ equipment\ cost\ factor = \frac{plant\ cost}{equipment\ cost} = \frac{\$1{,}000{,}000}{\$250{,}000} = 4.0$$

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 4.0 = $2,400,000.

B.6.3 Other Estimating Methods

B.6.3.1 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, (e.g., If two employees spent 1000 person-hours to develop a guidance document last year, then similar documents may need a similar level of effort). 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 number of workers for a specified amount of time). LOE estimates are normally based on hours and the number of full-time equivalents. Since they are perceived to have little objective basis, LOE estimates are often subject to scrutiny. The key to LOE estimates is that they should generally be based on a known scope of similar work.

Numerous cost elements may affect an LOE estimate. For instance, using the LOE method to estimate the costs for installing a new pump may raise questions about the impacts of radiological contamination or security issues and related productivity adjustments. Other cost factors that need to be considered are indirect costs, overhead costs, profit/fee, and other assumptions.

B.6.3.2 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. The analogy method uses actual costs from a similar program with adjustment to account for the difference between the requirements of the existing and new systems. A cost analyst typically uses this method early in a program’s life cycle, when insufficient actual cost data are available but the technical and program definition is good enough to make the necessary adjustments (e.g., regulatory basis and possibly during the proposed rule stage).

Adjustments should be made as objectively as possible, by using factors (sometimes scaling parameters) that represent differences in size, performance, technology, or complexity. The cost analyst should identify the important cost drivers, determine how the old item relates to the new item, and decide how each cost driver affects the overall cost. All estimates based on the analogy method, however, should pass a reasonable person test. That is, the sources of the analogy and any adjustments should be logical, credible, and acceptable to a reasonable person. In addition, because analogies are one-to-one comparisons, the historical and new systems should have a strong parallel.

Analogy relies a great deal on expert opinion to modify the existing system data to approximate the new system. If possible, the adjustments should be quantitative rather than qualitative, avoiding subjective judgments. An analogy is often used as a cross-check for other methods. Even when an analyst is using a more detailed cost estimating technique, an analogy can provide a useful check. Table B-4 shows how the analogy method is used.

Table B-4 Example of Analogy Cost Estimating Method

Parameter	Existing system	New system	Cost of new system (assumes a linear relationship)
Diesel-driven air compressor	F-100	F-200	
Cubic feet per minute	100	175	
Cost	$1,406	unknown	(175/100) x $1406 = $2,461

The equation in Table B-4 assumes a linear relationship between the air compressor cost and its output. However, there should be a compelling scientific or engineering reason why the air compressor cost is directly proportional to its output. Without more data, it is hard to know what parameters are the true drivers of cost. Therefore, when using the analogy method, it is important that the cost analyst research and discuss with experts the reasonableness of technical program drivers to determine whether they are significant cost drivers.

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

- 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.
- The tie to historical data is simple enough to be readily understood.

There are, however, also some disadvantages in using the analogy method, such as the following:

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

The last disadvantage can be better explained with an example. If a cost analyst assumes that a new component will be 20 percent more complex but cannot explain why, this adjustment factor is unacceptable. The complexity should be related to the system's parameters (e.g., the new system will have 20 percent more data processing capacity or will weigh 20 percent more). GAO Case Study 34 highlights what can happen when technical parameter assumptions are too optimistic (Ref. B.1).

B.6.3.3 Expert-Opinion Method

The expert-opinion method is commonly used to fill gaps in a relatively detailed WBS when one or more experts are the only qualified source of information. Expert opinion is an estimating technique whereby experts are consulted regarding the cost of a program, project, subproject, task, or activity. The expert opinion technique is most appropriate in the early stages of a project (i.e., regulatory bases or proposed rule cost estimates). Cost analysts should verify experts' credentials before relying on their opinions. Cost analysts should not ask experts to estimate costs outside their expertise.

For example, the Delphi method is used to forecast cost based on expert opinion. A group (e.g., six or more experts) is given a specific, usually quantifiable, question. Each expert sees the estimates produced by others and the rationale supporting the estimates and then can modify previous estimates until a group consensus is reached. If, after multiple rounds, there is no consensus, the original question may be broken into smaller parts for further rounds of discussion, or a mediator may be used to facilitate a final consensus, if feasible.

Such techniques may be used for either portions of or entire estimates and activities for which there is no other defensible basis. The advantages of using an expert opinion are as follows:

- It can be used in cases 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.
- It can be useful as a cross-check for CERs that require data significantly beyond the data range.
- It can be blended with other estimation techniques within the same WBS element.
- It can be applied in all acquisition phases.

The disadvantages associated with an expert opinion include the following:

- 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.
- The possibility of impasse exists.
- This approach is not considered very accurate or valid as a primary estimating method.

The bottom line is that, because of its subjectivity and lack of supporting documentation, expert opinion should be used sparingly. The GAO Case Study 35 (Ref. B.1) shows how relying on expert opinion as a main source for a cost estimate is unwise.

B.6.3.4 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). This observation led to the formulation of the learning-curve equation $Y = AX^b$ and the concept of a constant learning curve slope b that captures the change in Y given a change in X. The constant slope b is given by the formula b = log (slope)/log 2.

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 B-1 illustrates a hypothetical learning curve.

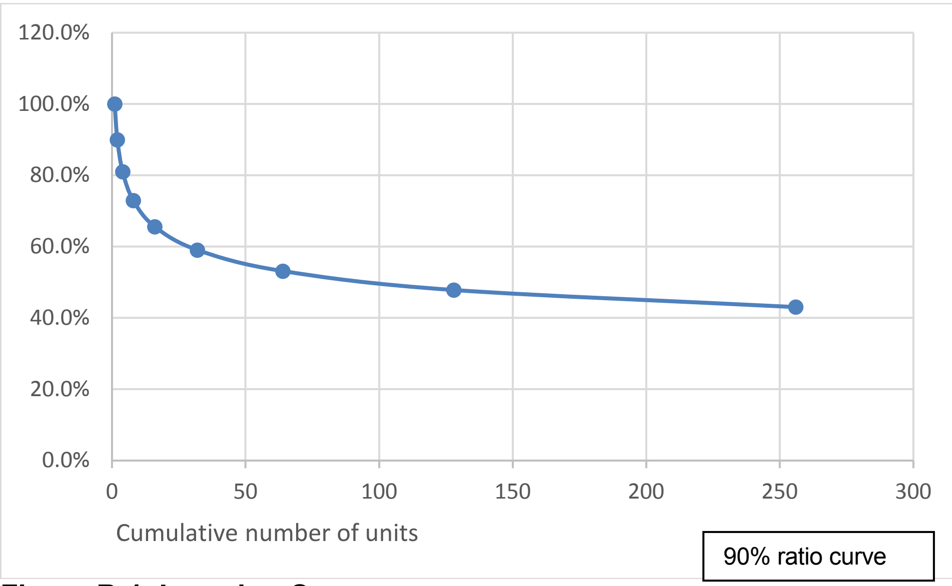

Figure B-1 Learning Curve

Figure B-1 shows how an item's cost gets cheaper as its quantities increase. For example, if the learning curve slope is 90 percent and it takes 1,000 hours to produce the first unit, then it will take 900 hours to produce the second unit. Every time the quantity doubles—for example, from 2 to 4, 4 to 8, 8 to 16—the resource requirements will reduce according to the learning-curve slope.

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 of 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 exist, 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.

B.7 Methods Of Estimating Other Life-Cycle Costs

Different methods may be used to estimate other project/program support costs (e.g., design, engineering, inspections, and regulatory review). Some common methods are described below.

B.7.1 Count-Deliverables Method

The cost analyst calculates the number of deliverables (e.g., drawings, specifications, procurements, license amendment requests, safety evaluations) representing a specific project. The more complex a project is, the more deliverables it will require, meaning that the associated costs will be higher.

B.7.2 Full-Time-Equivalent Method

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

B.7.3 Percentage Method

The cost analyst calculates a certain percentage of the direct costs and assigns this amount to the other project functions (i.e., design, project management). Some possible benchmarks include the following:

- Total design percentages are usually 15 to 25 percent of estimated construction costs. Nontraditional, first of a kind projects may be higher, while simple construction, such as buildings, will be lower than this range (on the order of 6 percent); the more safety and regulatory intervention is involved, the higher the percentage.
- Project management costs range from 5 to 15 percent of the other estimated project costs, 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.

B.8 Cost Estimating Development Process

Cost is defined as the resources that will be consumed if an objective is undertaken. The value of consumed resources, which can be quantified, is measured in dollars. This makes different cost elements comparable with themselves, as well as with benefits. In addition, because resource value indicates what resources are required for a particular proposed objective, it is a measure of the cost of other objectives that cannot be pursued. Each alternative method of accomplishing the regulatory objective will have its own associated cost. Costs include all incremental capital, labor, and natural resources required to undertake each alternative, whether they are explicitly paid out of pocket, involve an opportunity cost, or constitute an external cost that is imposed on third parties. Costs may be borne by the NRC, other governmental agencies, industry, the general public, or some other group. Inclusion of all costs borne by all groups is required to measure the total value of what should be forgone to undertake each alternative and to avoid errors in answering the economic questions.

B.8.1 Overview of the Cost Estimating Process

The overall cost estimating process model was explained in Section B.2.2. The cost estimating development process discussed in this section follows the 12-step model recommended by GAO

(Ref. B.1) as it applies to regulatory decisionmaking. Table B-1, located in Section B.2.2, identifies the implementing tasks related to the GAO 12-step cost estimating development process. Systematically performing these tasks enhances the reliability and validity of cost estimates.

B.8.2 Estimate Planning

The estimate planning task (input in Table B-1, Estimating Process) includes the following:

- establishing when the estimate is required
- determining who will prepare the estimate
- producing a plan or schedule for estimate completion
- selecting and notifying individuals whose input is required
- collecting scoping documents
- selecting estimating technique(s)
- conducting an estimate kickoff meeting

Develop Estimate-Purpose Statement—The purpose 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 cost drivers. In many cases, this activity will be performed in conjunction with the NRC rulemaking project manager and his or her working group.

Develop Technical Scope—The technical scope summary should provide a detailed description of the work included in the estimate. 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. For performance-based rulemaking, the cost analyst needs to work closely with the rulemaking project manager and his or her team to develop in sufficient detail how the proposed regulatory changes could be implemented.

A regulation can be either prescriptive or performance based. A prescriptive requirement specifies features, actions, or programmatic elements to be included in the design or process, as the means for achieving a desired objective. A performance based requirement relies upon measurable (or calculable) outcomes (i.e., performance results) to be met but provides more flexibility to the licensee as to the means of meeting those outcomes. A performance-based regulatory approach is one that establishes performance and results as the primary basis for regulatory decisionmaking and incorporates the following attributes: (1) measurable (or calculable) parameters (i.e., direct measurement of the physical parameter of interest or of related parameters that can be used to calculate the parameter of interest) exist to monitor system, including facility and licensee, performance, (2) objective criteria to assess performance are established based on risk insights, deterministic analyses, and performance history, (3) licensees have flexibility to determine how to meet the established performance criteria in ways that will encourage and reward improved outcomes, and (4) a framework exists in which the failure to meet a performance criterion, while undesirable, will not, in and of itself, constitute or result in an immediate safety concern (SRM-SECY-98-144, 1999).

Determine Approaches to be Used to Develop the Estimate—Decide on the estimating techniques and methodologies that will be used to develop the cost estimate, such as the ones described in Section B.5.

The cost analyst completes this task when he or she has a concise statement of the regulatory problems. The statement describes exactly what the problem is and why it exists, the extent of the problem and where it exists, and why it requires action. In this context, the cost analyst can develop his or her plan for deciding on the measure of the proposed regulatory change safety importance, what regulatory alternatives are available to address the issue, what cost benefit attributes are affected, the estimating methodology(ies) that will be used, and potential sources of data. The cost analyst completes this task when he or she has a clear plan for preparing the cost estimate and can describe these planning elements in the regulatory analysis.

B.8.3 Cost Estimate Inputs

It is essential that cost analysts plan for and gain access–where feasible–to cost, technical, and program data to develop a complete understanding of the underlying data needed to prepare a comprehensive, well-documented, accurate, and credible cost estimate. This section describes sources of cost estimate data and development considerations.

B.8.3.1 Sources of Cost Estimate Data

Because all cost estimating methods are data-driven, the cost analyst should know the best data sources (Input into Table B-1, step 6). Whenever possible, cost analysts should use primary data sources. Primary data are obtained from the original source, are considered the best in quality, and are the most useful. Secondary data are derived, rather than obtained directly from a primary data source. Because secondary data 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 (e.g., proprietary data) that may further complicate their use, as full details and explanations may not be available. Cost analysts should understand if and how data were changed before determining if the data will be useful or how that data can be adjusted for use. Of course, it is always better to use actual costs, rather than estimates, because actual costs represent the most accurate data available.

In many cases, secondary data may be all that are available. Therefore, the cost analyst should 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 (Ref. B.10) and Richardson Construction Estimating Standards (Ref. B.11) are two readily available estimating manuals. There are other estimating manuals that are available from other federal agencies and should be used when appropriate.

NRC Technical Documents—The NRC has sponsored several studies on generic costs associated with the construction activity at nuclear power plants. These generic studies are intended to provide tools and methods to assist cost analysts in the estimation of costs resulting from new and revised regulatory requirements and are listed in Table B-5.

Table B-5 List of NRC Cost Manual

Document No.	Title
Nuclear Power Plant Construction Costs	
NUREG/CR-5160	Guidelines for the Use of the EEDB at the Sub-Component and Subsystem Level
NUREG/CR-4546	Labor Productivity Adjustment Factors: A Method for Estimating Labor Construction Costs Associated with Physical Modifications to Nuclear Power Plants
SEA Report 84-116-05-A:1	Generic Methodology for Estimating the Labor Cost Associated with the Removal of Hardware, Materials, and Structures from Nuclear Power Plants
NUREG/CR-4921	Engineering and Quality Assurance Cost Factors Associated with Nuclear Plant Modification
NRC Cost Estimating Methods, Reference Assumptions, and Data	
DOE/NE-0044/3	Nuclear Energy Cost Data Base: A Reference Data Base for Nuclear and Coal-fired Power Plant Power Generating Cost Analysis
NUREG/CR-3971	A Handbook for Cost Estimating: A Method for Developing Estimates of Cost for Generic Actions for Nuclear Power Plants
NUREG/CR-4627	Generic Cost Estimates: Abstracts from Generic Studies for Use in Preparing Regulatory Impact Analyses
NUREG/CR-4568	A Handbook for Quick Cost Estimates: A Method for Developing Quick Approximate Estimates of Costs for Generic Actions for Nuclear Power Plants
NUREG/CR-4555	Generic Cost Estimates for the Disposal of Radioactive Wastes
NUREG/CR-3194	Improved Cost-Benefit Techniques in the U.S. Nuclear Regulatory Commission
Under contract NRC-33-84-407-006	The Identification and Estimation of the Cost of Required Procedural Changes at Nuclear Power Plants
NUREG/CR-5138	Validation of Generic Cost Estimates for Construction-Related Activities at Nuclear Power Plants
Nuclear Power Plant Worker Radiation Dose Estimating Method	
NUREG/CR-5035	Data Base of System-Average Dose Rates at Nuclear Power Plants

Data Bases—Commercial data bases provide the cost analyst with the ability to retrieve cost estimating data. Commercial data bases are readily available. See the Energy Economic Data Base (EEDB). The EEDB provides complete plant construction cost estimates for boiling-water reactors and pressurized-water reactors. The generic cost estimating methods developed for the NRC use the EEDB cost data as a basis for estimating the costs of physical modifications to nuclear plants.

Industry Estimates—Industry estimates provide for a greater confidence of real time accuracy, although the cost analyst should use caution when using industry-supplied cost estimates. As when using secondary data, the cost analyst should seek to understand how the data were normalized, what the data represent, how old the data are, and whether the estimates were generated with incomplete or preliminary information. Other times, only a few industry estimates may be provided, which could potentially skew the cost data.

Level-of-Effort Data—As discussed in Section B.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 and are 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. Use of LOE activity cost estimates should be kept at a minimum for Class 1 and 2 estimates.

Expert Opinions (Subject-Matter Experts)—As described in Section B.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 collected should include a list of the experts consulted, their relevant experience, and the basis for their opinions. If a formalized procedure was used, it should be documented.

Benchmarking—Benchmarking is a way to establish rule-of-thumb estimates. Benchmarks may be useful when other means of establishing reasonable estimates are unavailable. Benchmark examples include the statistic indicating that design should be 6 percent of the construction cost for noncomplex 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 the following:

- 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.
- Licensee facility work should cost approximately Z percent of current, local, commercial work.

Team/Individual Judgment Data—Team or individual judgment data are used when the maturity of the scope has not been fully developed 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 persons 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 or individual judgment should be used sparingly.

The Learning-Curve Data—As described in Section B.B.6.3.4 , 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. NUREG/CR-5138 provides guidance on learning-curve factors, based on nuclear power plant modification activities, and gives guidelines for selecting the appropriate factors and their use.

B.8.3.2 Cost Estimate Development Considerations

When assigned the task of developing a cost-benefit estimate, the cost analyst should gather general project information, including:

- project background
- project scope
- pertinent contract or subcontract information, if applicable
- estimate purpose, classification, how the estimate will be used, and techniques anticipated
- project schedule

If the assignment is for a regulatory analysis supporting the evaluation of a proposed regulatory action, such as for rulemaking, the cost analyst would collect specific inputs, such as the following:

- draft *Federal Register* notice
- draft rule language
- statements of consideration
- applicable guidance documents
- WBS, if generated
- historical information and other sources of information, including previous regulatory analyses and cost estimates
- project assumptions
- industry cost estimates

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

B.8.4 Cost Estimate Preparation

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. In general, cost estimate production includes several steps that should be based on requirements, purpose, use, classification, and technique, including the following:

- Identify the scope of work, activities, and tasks.
- Document all bases of such factors as the estimate, assumptions, allowances, and risks during the estimating process.
- For detailed engineering estimates, perform quantity takeoffs and field walkdowns, if applicable.
- Develop the detail items or models that make up the activities.
- Assign measurable quantities to the detail items or models.
- Obtain 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 allowances.
- Determine if (and to what extent) risks should be mitigated with activities (or assumptions) in the cost estimate.
- Consider other inputs, including peer reviews or independent cost estimates, as appropriate.

However, for cost estimates for proposed regulatory actions, the scope of the cost estimate is to compute the incremental costs to implement the proposed regulatory action. These incremental costs measure the additional costs imposed by regulation in that they are costs that would not have been incurred in the absence of that regulation. In general, there are three steps that the cost analyst should follow to estimate these incremental costs:

(1) Estimate the amount and types of equipment, materials, and labor that will be affected by the proposed regulatory action.
(2) Estimate the costs associated with implementation and operation.
(3) If appropriate, discount the implementation costs, then sum.

In preparing an estimate of industry implementation costs, the analyst should also carefully consider all cost categories that may be affected by implementing the action. Examples of categories include the following:

- land and land-use rights
- structures
- hydraulic, pneumatic, and electrical equipment
- radioactive waste disposal
- health physics
- monitoring equipment
- personnel construction facilities, equipment, and services
- engineering services
- recordkeeping
- procedural changes
- license modifications
- staff training and retraining
- administration
- facility shutdown and restart
- replacement power (power reactors only)
- reactor fuel and fuel services (power reactors only)
- items for averting illness or injury (e.g., bottled water or job safety equipment)

Transfer payments should not be included.

For the standard analysis, the cost analyst should use consolidated information to estimate the cost for implementing the action.

Step 1 - Estimate the amounts and types of equipment, materials, and labor that will be affected by the proposed action, including not only physical equipment and craft labor, but professional staff labor for design, engineering, quality assurance, and licensing associated with the action. If the action requires work in a radiation zone, the analyst should account for the extra labor required by radiation exposure limits and low worker efficiency due to awkward radiation protection gear and tight quarters.

When performing a sensitivity analysis, but not for the best estimate, the analyst should include contingencies as discussed in Section B.B.5.2 .

Step 2 - Estimate the costs associated with implementation, both direct and indirect. Direct costs include materials, equipment, and labor used for the construction and initial operation of the facility during the implementation phase. The analyst should identify any significant secondary costs that may arise. One-time component replacement costs and associated labor costs should be accounted for here. For additional information on cost categories, especially for reactor facilities, see PNL-2648 (1978), NUREG-0248 (1979), and UCSD-CER-13-01 (2013). Indirect costs include cost that are typically absorbed by society and not subject to accounting on the owner's financial statement. Indirect costs include environmental costs (lost wetlands and other habitats, soiling of property from pollution, etc.), societal costs (lost productivity, medical costs, etc.), and other intangible costs that may occur. Indirect costs tend to be harder to quantify and often involve significant effort from the analyst. However, many indirect cost categories have been the subject of economic study and values can be found in the literature.

Step 3 - If appropriate, discount the costs, and then sum. If costs occur at some future time, they should be discounted to yield present values. If all costs occur in the first year or if present value costs can be directly estimated, discounting is not required. Generally, implementation costs would occur shortly after adoption of the proposed action.

When performing cost-benefit analyses for nonreactor facilities, the analyst may encounter difficulty in finding consolidated information on industry costs comparable to that for power reactors. Comprehensive data sources, such as NUREG/CR-4267 (1992), are generally unavailable for nonreactor facilities. The types of nonreactor facilities are quite diverse. Furthermore, within each type, the facility layouts typically lack the limited standardization of the reactor facilities. These combine to leave analysts pretty much “on their own” in developing industry implementation costs for nonreactor facilities. Specific data may be best obtained through direct contact with knowledgeable sources for the facility concerned, possibly even the facility personnel themselves.

For a major effort beyond the standard analysis, the analyst should obtain very detailed information, in terms of the cost categories and the costs themselves. The analyst should seek cost data from NRC contractors or industry sources experienced in this area (e.g., architect-engineering firms). The incremental costs of the action should be defined at a finer level of detail. The analyst should refer to the code of accounts in the EEDB (NUREG-0248) or PNL-2648 to prepare a detailed account of implementation costs.

B.8.4.1 Work-Breakdown Structure

A WBS should be developed, because it defines in detail the work necessary to accomplish the proposed regulatory action. By going through the process of WBS development, the activities needed to be performed are clearly identified and appropriately sequenced. This then forms a basis for estimating the resources and costs needed to accomplish the regulatory action. That process, in turn, provides a basis for estimating activity durations and resource requirements. Establishing a product-oriented WBS is a best practice, because it shows how elements relate to one another, as well as to the overall end product.

The 100-Percent Rule

A 100-percent rule states that “the next level of decomposition of a WBS element (child level) should represent 100 percent of the work applicable to the next higher (parent) element.” This is considered a best practice by many experts in cost estimating, because a product-oriented WBS following the 100-percent rule ensures that all costs for all deliverables are identified. Failing to include all work for all deliverables can lead to unrealistic cost estimates. To avoid this problem, standardizing the WBS is a best practice in organizations where there is a set of program types that are standard and typical. This enables an organization to simplify the development of the top-level program WBSs by publishing the standard. It also facilitates an organization’s ability to collect and share data from common WBS elements among many programs. The more data that are available for creating the cost estimate, the higher the confidence level will be. As this process indicates, the development of structure WBS and cost estimates is a highly iterative and interrelated process.

B.8.4.2 Collect, Validate, and Adjust Data

Many possible sources of data can be used in NRC cost estimates. Regardless of the source, the validation of the data (relative to the purpose of its intended use) always remains the responsibility of the cost analyst. In some cases, the data will need to be adjusted or normalized. For example, in analogy estimates, the reference system cost should be adjusted to account for any differences—in system characteristics (technical, physical, complexity, or hardware cost), support concepts, or operating environment—between the reference system and the proposed system being estimated.

For most cost elements, historical cost data are available as discussed in Section B.B.8.3.1 . Data should always be carefully examined before use in a cost estimate. Historical data should be displayed over a period of a few years (not just a single year) and stratified by organization or location. This should be done so that abnormal outliers in the data can be identified, investigated, and resolved as necessary. In some cases, it may also be necessary to ensure that the content of the data being used is consistent with the content of what is being estimated (to avoid any gaps in coverage).

For example, historical cost data may contain information based on the use of past technologies, so it is essential to make appropriate adjustments to account for differences between the new system and the existing system with respect to such things as design characteristics, manufacturing processes (automation versus hands-on labor), and types of material used. This is where statistical methods, like regression, that analyze cost against time and performance characteristics can reveal the appropriate technology based adjustment.

Data that can be used for detailed bottoms-up engineering buildup estimates often come from contractor databases. The cost analyst should validate these types of data before use, possibly on a sampling basis. This is especially important in cases when the proposed regulatory action being estimated is not mature (i.e., incomplete design details). The validation should address the completeness of the estimate, the realism of component reliability and maintainability estimates, the legitimacy of the component unit prices, and so forth.

B.8.4.3 Select Cost Estimating Methods or Models

A number of techniques may be employed to estimate the costs of a proposed regulatory action. The suitability of a specific approach will depend to a large degree on the maturity of the proposed regulatory solution and the level of detail of the available data. Most regulatory analysis estimates are accomplished using a combination of five estimating techniques:

- **Parametric**. The parametric technique uses regression or other statistical methods to develop CERs (an equation or algorithm used to estimate a given cost element using an established relationship with one or more independent variables). The relationship may be mathematically simple or it may involve a complex equation (often derived from regression analysis of historical systems or subsystems). The CERs should be current, applicable to the system or subsystem in question, and appropriate for the range of data being considered.

- **Analogy**. An analogy is a technique used to estimate a cost based on historical data for one or more analogous system(s) or to estimate a cost for a subsystem (such as an engineered containment filtered vent subsystem). In this technique, a currently fielded system, similar in design and operation to the proposed system, is used as a basis for the analogy. The cost of the proposed system is then estimated by adjusting the historical cost of the current system to account for differences (between the proposed and current systems). Such adjustments can be made through the use of factors (sometimes called scaling parameters) that represent differences in size, performance, technology, reliability and maintainability, complexity, or other attributes. Adjustment factors based on quantitative data are usually preferable to adjustment factors based on judgments from subject-matter experts.

- **Engineering Estimate**. This technique uses discrete estimates of labor and material costs for maintenance and other support functions. The system being estimated normally is broken down into lower-level subsystems and components, each of which is estimated separately. The component costs, with additional factors for integration, are then aggregated using simple algebraic equations to estimate the cost of the entire system (hence the common name “bottoms-up” estimate). For example, system maintenance costs could be calculated for each system component using data inputs such as system operating tempo, component mean time between maintenance actions, component mean labor hours to repair, and component mean material cost per repair. Engineering estimates require extensive knowledge of a system’s (and its components’) characteristics and a significant amount of detailed data. These methods are normally employed for mature programs and are used by regulated entities after the regulation is promulgated.

- **Extrapolation of Actual Costs**. With this technique, actual cost experience or trends (from prototypes, engineering development models, and early production items, or early adopters) are used to project future costs for the same system at other facilities. Such projections may be made at various levels of detail, depending on the availability of data.

- **Cost Factors**. Cost factors are applicable to certain cost elements not related to the proposed system characteristics. Often, cost factors are simple per capita factors that are applied to direct (i.e., unit-level) labor to estimate indirect cost elements, such as general training and education, coordination, or quality assurance.

In many instances, it is a common practice to employ more than one cost estimating method, so that a second method can serve as a cross-check to the preferred method. Analogy estimates are often used as cross-checks, even for mature systems.

B.8.4.4 Estimate Costs

With the completion of the steps described earlier, the actual computations of the cost estimate can begin. The time and energy in front-end planning for the estimate will help to minimize the amount of midcourse corrections and wasted effort. In actual practice, the planning process may be more iterative than the sequence of discrete steps described earlier. Nevertheless, the basic principles remain valid and important.

The cost-estimation techniques selected typically depend on the stage of the proposed regulatory change (e.g., regulatory basis, proposed rule, or final rule) and the availability and specificity of the supporting regulatory guidance. In the earlier phases, cost estimates are commonly based on analogies and parametric CERs. In some cases, as the proposed regulatory change definition is refined, the use of analogies and CERs may be improved by increasing the level of detail of the cost estimate—for some cost elements, making distinct estimates for major subsystems and components.

B.8.4.5 Conduct Uncertainty Analysis

For any proposed regulatory action, estimates of future costs are subject to varying degrees of uncertainty. These uncertainties result from the use of different cost estimating methods, variability in facility design, and differing approaches which licensees use to implement changes to their facilities to comply with a new or revised regulation. Although these uncertainties cannot be eliminated, they should be addressed in the cost estimate. For each major concern, it is useful to quantify its degree of uncertainty and its effect on the cost estimate.

Typically, the cost analyst identifies the relevant cost elements and their associated cost drivers and then examines how costs vary with changes in the cost-driver values. For example, a sensitivity analysis might examine how the maintenance cost varies with different assumptions about system reliability and maintainability values. In good sensitivity analyses, the cost-driver values are not changed by arbitrary plus/minus percentages but rather by a careful assessment of the underlying uncertainties.

B.8.4.6 Cost Estimate Results

A cost estimate should be formally documented. The documentation serves as a permanent record of source data, methods, and results, and should be easy to read and well organized to allow any reviewer to understand the estimate. The key standard is that an outside professional cost analyst should be able to review the data and methods employed and understand the results.

The documentation should address all aspects of the cost estimate: the ground rules and assumptions, the description of the alternatives evaluated, the selection of cost estimating methods, the data sources, the actual estimate computations, and the results of the uncertainty analyses. The documentation may be provided within a regulatory analyses or similar report.

B.8.5 Cost Estimate Review

Cost estimates should be peer reviewed for quality and reasonableness before release. Reviews can be either objective, subjective, or a combination of both. As a minimum, NRC cost estimates should address the review criteria listed in Enclosure B-1.

NRC regulatory analyses, and the cost estimates that support them, should include an assessment of cost realism and reasonableness. To test the reasonableness and realism of a cost estimate, an NRC cost analyst will review the regulatory analysis, the cost estimate, the and supporting documentation to analyze whether the estimate is sufficient with regard to the validity of cost assumptions, the rationale for the cost estimate methodology, and whether it is complete.

This review should provide an unbiased check of the assumptions, productivity factors, and cost data used to develop the estimate. This is a vital step in providing consistent, professionally prepared cost estimates. Refer to Step 7 of Table 2: “The Twelve Steps of a High Quality Cost Estimating Process,” contained in GAO-09-3SP.

The review should be documented to indicate the following:

- the name of the reviewer(s)—Office/Agency/Contractor affiliation
- the date of the review

B.8.6 Estimate Reconciliation

Reconciliation may be necessary to account for changes made in a proposed rulemaking or guidance documents or the availability of new data. Reconciliations should cover all aspects of the cost estimating documentation (i.e., 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 cost estimate documentation.

B.8.7 Cost Estimate Documentation

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

- First, complete and detailed documentation is essential for validating and defending a cost estimate.
- Second, documenting the estimate in detail, step by step, provides enough documentation so that someone unfamiliar with the estimate could recreate or update it.
- Third, good documentation helps with analyzing changes in costs and contributes to the collection of cost and technical data that can be used to support future cost estimates.
- Finally, a well-documented cost estimate is essential to ensure that an effective independent review is valid and credible. It also supports reconciling differences with an independent cost estimate and improving the understanding of the cost elements and their differences so that decisionmakers can be better informed.

Cost Estimate Package

A cost estimate package or report (i.e., a regulatory analysis or a backfitting analysis) 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. GAO-09-3SP provides good practices for preparing cost estimates for developing and managing capital program costs. When documenting cost estimates for other purposes, a graded approach to cost estimate packaging and reporting should be used, with its scope limited to the intended function of the estimate (Ref. B.1).

- **Estimate Purpose Statement**—It states the reason the estimate was prepared and includes the following steps:

    - Determine the estimate’s purpose.
    - Determine the level of detail required.
    - Determine who will receive the estimate.
    - Identify the overall scope of the estimate.

- **Technical-Scope Summary—**It summarizes the technical scope of the project, including what is included in the project as well as what is not included.

- **Qualifications and Assumptions**—These are the key estimate qualifications and cost assumptions that provide a “bounding” of the estimate and scope. 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 (e.g., general access, confined space, contaminated building), and any other information that significantly influences the estimate but is not clearly identified in the problem statement or alternative description(s). Major assumptions and exclusions that affect the estimate or the accuracy of the estimate are also described.

- In completing this activity, the cost analyst should identify areas where scope descriptions have deficiencies, or where key information is missing and has to be assumed. Key information is identified for those reviewing or using the estimate. Qualifications and assumptions should be described and documented to the level practicable, and they should be clearly described so an individual not intimately involved with the estimate can understand the estimate's basis.

  - **Method and Justification for Use of Labor Rates—**This explains how labor rates were selected and applied.

  - **Method and Justification for Use of Contingencies—**This is an explanation of how contingencies were determined and applied.

  - **Method and Justification for Use of Escalation—**This explains the escalation rates used, how they were obtained, why they were selected, and how they were applied.

  - **Documentation of Review and Concurrence—**This shows evidence that the estimate was reviewed and received concurrence.

B.9 Cost Estimating Outputs

B.9.1 Baselines

Typically, NRC cost estimates are performed to analyze proposed regulatory changes and are used to quantify the incremental impacts of this change. In the problem statement, the need for regulatory action should be justified within the context of what would prevail if regulatory action were not taken. This justification requires assumptions as to whether, and to what degree, voluntary practices may change in the future. In general, the no-action alternative serves as the regulatory baseline and is central to the estimation of incremental costs and benefits.

B.9.2 Analysis

The regulatory analysis process, including the supporting cost-benefit analysis, is intended to be an integral part of the NRC's decisionmaking that systematically provides complete disclosure of the relevant information supporting a regulatory decision. The process should not be used to produce after-the-fact rationalizations to justify decisions already made, nor to unnecessarily delay regulatory actions. The conclusions and recommendations included in a regulatory analysis document are neither final nor binding but are intended to enhance the soundness of decisionmaking by NRC managers and the Commission.

The NRC performs regulatory analyses to support numerous NRC actions affecting reactor and materials licenses. Executive Order (E.O.) 12866 requires that a regulatory analysis be prepared for all significant regulatory actions. Significant regulatory actions are defined in E.O. 12866 to include actions that are "likely to result in a rule that may: (1) have an annual effect on the economy of $100 million or more or adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or State, local, or tribal governments or communities; (2) create a serious inconsistency or otherwise interfere with an action taken or planned by another agency; (3) materially alter the budgetary impact of entitlements, grants, user fees, or loan programs or the rights and obligations of recipients thereof; or (4) raise novel legal or policy issues arising out of legal mandates, the President's priorities, or the principles set forth in this Executive Order."

The NRC requires regulatory analyses for a broader range of regulatory actions than for significant rulemakings, as defined in E.O. 12866. In general, each NRC office should ensure that all mechanisms used by the NRC staff to establish or communicate generic requirements, guidance, requests, or staff positions that would affect a change in the use of resources by its licensees include an accompanying regulatory analysis. This requirement applies to actions initiated internally by the NRC or by a petition to the NRC. These mechanisms include rules, bulletins, generic letters, cost-benefit guides, orders, standard review plans, branch technical positions, and standard technical specifications.

More information on parametric cost estimates, including the parametric estimating initiative Parametric Estimating Handbook, can be found through the International Society of Parametric Analysts, at http://www.ispa-cost.org/ (Ref. B.29).

More information on cost estimating and analysis can be found through the Society for Cost Estimating and Analysis, at http://www.sceaonline.net/ (Ref. B.30)

More information on cost engineering can be found through the AACEI, at http://www.aacei.org/ (Ref. B.31)

B.10 Cost Estimating Expectations

This section summarizes what could be expected from the use of NRC cost estimates that are prepared to support regulatory analyses, backfitting analyses, and environmental analyses.

B.10.1 Summary of Expectations

An NRC cost estimate, regardless of purpose, classification, or technique employed, should demonstrate sufficient quality to infer that it is appropriate for its intended use, is complete, and has been subjected to internal checks and reviews. It should also be clear, concise, reliable, fair, reasonable, and accurate, within some probability or confidence levels. In addition, it is expected to have followed accepted standards, such as the GAO 12 steps of a high-quality cost estimating process (Ref. B.1), as applicable.

Common elements of good cost estimates are expected to be constant. Suggested review criteria are summarized in Enclosure B-1.

B.10.2 Independent Cost Estimates

In December 2014, the GAO published GAO-15-98, "Nuclear Regulatory Commission—NRC Needs to Improve Its Cost Estimates by Incorporating More Best Practices." GAO-15-98 examines the extent to which NRC's cost estimating procedures support development of reliable cost estimates and follow specific best practices identified in GAO-09-3SP, "GAO Cost Estimating and Managing Capital Program Costs." As a result of these evaluations, GAO recommended that the NRC align its cost estimating procedures with the relevant cost estimating best practices in GAO-09-3SP and ensure that future cost estimates are prepared in accordance with relevant cost estimating best practices. GAO recommended, among other aspects, that the NRC demonstrate the credibility of its cost estimates by cross-checking agency results with ICEs developed by others, providing confidence levels, and conducting a sensitivity analysis to identify the variables most affecting cost estimates.

In response to the GAO concerns and recommendations, the NRC has initiated a pilot program to have selected ICEs performed for the same proposed action. NRC management will decide whether an ICE will be performed to cross-check NRC cost-benefit analyses.

B.11 Cost Estimate Review Criteria

When reviewing the U.S. Nuclear Regulatory Commission (NRC) cost estimates, these generic criteria are suggested as a minimum. To be complete, all criteria should be addressed, 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 U.S. Government Accountability Office (GAO) 12 steps for a high-quality estimating process (GAO-09-3SP), as recommended in this document.

Work-Breakdown Structure (WBS) – If a WBS is used, the technical definition, the cost estimate, and the implementation schedule should be consistent. The use of a common WBS should be considered for consistency between cost estimates.

Scope of the Problem – The scope of the problem should be discussed in terms of the classes of licensees or facilities being affected, including their numbers, sizes, and so forth. Any distinction between the NRC and Agreement State licensees should be made. The implications of taking no action (i.e., maintaining the status quo) should be identified. The planning phase size and cost estimating modeling should be commensurate with the scope of the problem and the alternatives identified. The cost estimate should be activity based, to the extent practicable.

Costs – All costs should be included appropriately and unit rates should be documented and referenced. The quantification should employ monetary terms whenever possible. Dollar values should be established using constant dollar values (i.e., dollars of constant purchasing power).

Contingency – Contingency should be included appropriately in the uncertainty analysis, based on apparent project risks or a project risk analysis, to the greatest 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 an 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. 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 that are well defined and with less significant size and complexity.

When performing an uncertainty analysis, the cost analysis should include contingencies on the low estimate and the high estimate and not for the best estimate.

B.13 Independent Cost Review And Independent Cost Estimate Guidance

General Guidance

- Independent cost review (ICR) and independent cost estimate (ICE) teams need to be comprised of individuals with appropriate experience and credentials. Ideally, teams will include individuals with appropriate industry certifications (e.g., professional engineer, certified cost engineer, project management professional) and subject matter experts knowledgeable in the areas addressed by the project (in particular any unique technical areas or project execution strategies).

- It is important to establish a charter or scope of work that clearly defines the boundaries of the ICR and ICE teams. For example, it should be clearly understood that the purpose of an ICR or ICE is to establish an independent cost estimate for a project, based on the same execution strategy, conditions, technical scope, and schedule as used by the project team. It is not appropriate for an ICR or ICE team, for example, to question the regulatory need or develop new alternatives and then generate an estimate based on these new strategies, scope, or alternatives. The ICR or ICE team may propose or recommend alternatives based on observation and expert opinion; however, attempting to use those alternatives to compare to project estimates is not appropriate.

Table B-6 provides a typical schedule for performing either an ICR or an ICE.

Table B-6 ICR/ICE Schedule (suggested; varies by project size and complexity)

Activity	Typical Duration (weeks)
Establish ICR/ICE requirements and approved budget.	1–2
Develop task order and complete negotiations with ICE contractor.	2–4
Hold kickoff meeting and initial site briefings.	1–2
Develop ICR/ICE and draft report.	2–10 (varies with project and ICE type)
Reconcile ICE and project estimate.	1–2
Complete and issue final report.	1–4
Overall Duration	**8–24**

Typical Information Requirements for ICR/ICE

The following lists some typical data needs to support an ICR or ICE. These needs should be addressed in light of the stage of the project and its nature.

(1) Project status and management/technical briefings should include, but not be limited to:
   a. project history and overview
   b. technical baseline
   c. current project status
   d. major issues and problems
   e. project organization
   f. work-breakdown structure (WBS)

(2) Project schedule should include, but not be limited to:

a. milestones
b. critical path

(3) Design and estimate documentation/backup should include, but not be limited to:

a. project information, such as:
   i. facilities descriptions
   ii. plot plans and layout drawings
   iii. piping and instrumentation drawings, process diagrams
   iv. electrical one-line drawings
   v. system descriptions
b. design-basis documentation
c. cost estimate summary
d. cost estimate details
e. cost estimate backup data, such as:
   i. vendor quotes
   ii. labor rates
   iii. productivity factors
   iv. estimate basis and assumptions
   v. overhead and markup assumptions and calculations
   vi. labor estimates

(4) ICR/ICE results should include, but not be limited to:

a. current estimate
b. estimate basis (all major components)
c. contingency analysis (and supporting risk and uncertainty analysis)
d. escalation
e. major assumptions
f. resource availability and leveling analysis

Reconciliation of ICR/ICE and Project Estimate

- A draft of the ICE report is generated, representing the consensus of both the U.S. Nuclear Regulatory Commission (NRC) project manager and the ICE contractor, and including the ICE contractor's report as backup.
- The ICE report includes the team leader's programmatic observations and comments.
- The draft ICE report is transmitted to the project office for review and comments.
- The ICE team leader will review the comments with the support contractor to determine whether the major differences between the project estimate and the ICE can be resolved in a teleconference or if a face-to-face meeting is required for reconciliation.
- Reconciliations include the following:

  - Concentrate on major cost differences or items of special interest.
  - Reconciliation does not necessarily mean consensus.
  - An attempt should be made to keep reconciliations nonadversarial.
  - If data are presented at the reconciliation that proves the ICE is in error, the ICE should be changed. The project team should adhere to this rule as well.

- A final draft ICE report will be developed to reflect any changes resulting from the reconciliation meeting.

ICE Report Contents

- Executive Summary
- Background (including project cost/baseline history)
- Project Status
- Technical Baseline Description
- Information Available to the ICE Team
- Cost Estimate Methodology(s) Used
- Comparison of Project Estimate and the ICE by WBS
- Variance Analysis
- Contingency Analysis
- Conclusions
- Recommendations

B.14 Expectations For Quality Cost Estimates

A later draft will provide guidance for checking the quality of cost estimates to meet the four characteristics of high quality cost estimates (credible, well-documented, accurate, and comprehensive) and the reasonableness of the cost estimating techniques employed.

B.15 Cross-Reference To GAO-09-3SP

This enclosure provides a cross-reference of the 12 key Government Accountability Office (GAO) estimating steps and their implementing tasks[7] to the section of this document containing guidance for accomplishing those steps.

Table B-7 Cross-Reference to GAO-09-3SP Best Practices

GAO Project Phase	GAO Best Practice	GAO Associated Task	Where Conformance to GAO Practice is Demonstrated
INITIATION AND RESEARCH—Your audience, what you are estimating, and why you are estimating it are of the utmost importance.	Step 1: *Define the estimate's purpose.*	Determine the estimate's purpose, required level of detail, and overall scope.	Guidance related to the purpose of the estimate can be found in Section B.2.1.
		Determine who will receive the estimate.	
	Step 2: *Develop an estimating plan.*	Determine the cost estimating team and develop its master schedule.	Guidance related to planning the estimate development can be found in Section B.4.1.
		Determine who will do the independent cost estimate.	
		Outline cost estimating approach.	
		Develop the estimating timeline.	
ASSESSMENT—Cost assessment steps are iterative and can be accomplished in varying order or concurrently.	*Step 3: Define the program characteristics*	In a technical baseline description document, identify the program's purpose and its system and performance characteristics and all system configurations.	Guidance related to program characteristics and requirements for cost estimates are discussed in Section B.3.
		Describe technology implications.	
		Describe acquisition schedule and strategy.	

7 The GAO project phase is identified in Figure 1, "The Cost Estimating Process," from the main text. The GAO best practice and GAO associated task is listed in Table 2, "The Twelve Steps of a High-Quality Cost Estimating Process," from the main text (Ref. B.1).

GAO Project Phase	GAO Best Practice	GAO Associated Task	Where Conformance to GAO Practice is Demonstrated
		Describe relationship to other existing systems, including predecessor or similar legacy systems.	
		Define support (e.g., manpower, training) and security needs and risk items.	
		Develop system quantities for development, test, and production.	
		Develop system quantities for development, test, and production.	
		Define deployment and maintenance plans.	
	Step 4: *Determine the estimating structure.*	Define a work-breakdown structure (WBS) and describe each element in a WBS dictionary (a major automated information system may have only a cost-element structure).	Guidance relative to estimate structure is found in Sections B.2.2 and B.7.4.1.
		Choose the best estimating method for each WBS element.	
		Identify potential cross-checks for likely cost and schedule drivers.	
		Develop a cost estimating checklist.	
	Step 5: *Identify ground rules and assumption*s.	Clearly define what the estimate includes and excludes.	The concepts related to ground rules and assumptions are discussed in Section B.7.4 and in Tables B-1, B-2, and B-5.
		Identify global and program-specific assumptions, such as the estimate's base year, including time-phasing and life cycle.	
		Identify the estimate's base year, including time-phasing and life cycle.	
		Identify program schedule information by phase and program acquisition strategy.	
		Identify any schedule or budget constraints, inflation assumptions, and travel costs.	
		Specify equipment the government is to furnish, as well as the use of existing facilities or new modifications or development.	
		Identify the prime contractor and major subcontractors. Determine technology refresh cycles, technology assumptions, and new technology to be developed.	
		Define the commonality with legacy systems and assumed heritage savings.	
		Describe the effects of new ways of doing business.	
	Step 6: *Obtain data.*	Create a data collection plan with emphasis on collecting current and relevant technical, programmatic, cost, and risk data.	Estimate data sources and associated guidance can be found in Sections B.4, B.7.3, and B.7.4 and in Table B-1.
		Investigate possible data sources.	
		Collect data and normalize them for cost accounting, inflation, learning, and quantity adjustments.	
		Analyze the data for cost drivers, trends, and outliers and compare results against rules of thumb and standard factors derived from historical data.	

GAO Project Phase	GAO Best Practice	GAO Associated Task	Where Conformance to GAO Practice is Demonstrated
		Interview data sources and document all pertinent information, including an assessment of data reliability and accuracy.	
		Store data for future estimates.	
	Step 7: *Develop a point estimate and compare it to an independent cost estimate.*	Develop the cost model, estimating each WBS element, using the best methodology from the data collected, and including all estimating assumptions.	The techniques available for estimate development are described in Section B.5 and the estimate development process itself is discussed extensively in Section B.7.4. Independent cost estimates are discussed in Sections B.7.4 and B.7.7 and more extensively in Section B.9.2.
		Express costs in constant year dollars.	
		Time-phase the results by spreading costs in the years they are expected to occur.	
		Sum the WBS elements to develop the overall point estimate.	
		Validate the estimate by looking for errors like double counting and omitted costs.	
		Compare the estimate against the independent cost estimate and examine where and why there are differences.	
		Perform cross-checks on cost drivers to see if results are similar.	
		Update the model as more data become available or as changes occur and compare results against previous estimates.	
ANALYSIS—The confidence in the point or range of the estimate is crucial to the decisionmaker.	Step 8: *Conduct a sensitivity analysis.*	Test the sensitivity of cost elements to changes in estimating input values and key assumptions.	The concept of a sensitivity analysis is discussed in Sections B.4.3 and B.7.4.5 as a subset of the uncertainty analysis. However, the requirements for such analyses can also be found throughout the guidance document.
		Identify effects on the overall estimate of changing the program schedule or quantities.	
		Determine which assumptions are key cost drivers and which cost elements are affected most by changes.	
	Step 9: *Conduct a risk and uncertainty analysis.*	Determine and discuss with technical experts the level of cost, schedule, and technical risk associated with each WBS element.	An explanation of the U.S. Nuclear Regulatory Commission's (NRC's) guidance relative to risk and uncertainty analysis and contingency allowances can be found in Section B.7.4.5.
		Analyze each risk for its severity and probability.	
		Develop minimum, most likely, and maximum ranges for each risk element.	
		Determine type of risk distributions and reason for their use.	
		Ensure that risks are correlated.	
		Use an acceptable statistical analysis method (e.g., Monte Carlo simulation) to develop a confidence interval around the point estimate.	
		Identify the confidence level of the point estimate.	
		Identify the amount of contingency funding and add this to the point estimate to determine the risk-adjusted cost estimate.	

GAO Project Phase	GAO Best Practice	GAO Associated Task	Where Conformance to GAO Practice is Demonstrated
		Recommend that the project or program office develop a risk-management plan to track and mitigate risks.	
	Step 10: *Document the estimate.*	Document all steps used to develop the estimate so that a cost analyst unfamiliar with the program can recreate it quickly and produce the same result.	Estimate documentation is discussed in Section B.7.7.
		Document the purpose of the estimate, the team that prepared it, and who approved the estimate and on what date.	
		Describe the program, its schedule, and the technical baseline used to create the estimate.	
		Present the program's time-phased life-cycle cost.	
		Discuss all ground rules and assumptions.	
		Include auditable and traceable data sources for each cost element and document, for all data sources, how the data were normalized.	
		Describe in detail the estimating methodology and rationale used to derive each WBS element's cost (prefer more detail over less).	
		Describe the results of the risk, uncertainty, and sensitivity analyses and whether any contingency funds were identified.	
		Document how the estimate compares to the funding profile.	
		Track how this estimate compares to any previous estimates.	
PRESENTATION – Documentation and presentation make or break a cost estimating decision outcome.	*Step 11: Present the estimate to management for approval.*	Develop a briefing that presents the documented life-cycle cost estimate (LCCE).	Guidance related to the presentation of estimate results can be found in Sections B.7.4.6 and B.7.7.
		Include an explanation of the technical and programmatic baseline and any uncertainties	
		Compare the estimate to an independent cost estimate (ICE) and explain any differences.	
		Compare the LCCE or ICE to the budget with enough detail to easily defend it by showing how it is accurate, complete, and of high quality.	
		Focus in a logical manner on the largest cost elements and cost drivers.	
		Make the content clear and complete, so that those who are unfamiliar with it can easily comprehend the competence that underlies the estimate results.	
		Make backup slides available for more probing questions.	
		Act on and document feedback from management.	
		Request acceptance of the estimate.	
	Step 12: Update the estimate to	Update the estimate to reflect changes in technical or program assumptions or keep	Estimate updates to reflect changes in assumptions

GAO Project Phase	GAO Best Practice	GAO Associated Task	Where Conformance to GAO Practice is Demonstrated
	reflect actual costs and changes.	it current as the program passes through new phases or milestones.	or to incorporate new information is discussed in Sections B.2.2, B.4.1, and B.7.7.
		Replace estimates with earned value management (EVM) and ICE from the integrated EVM system.[8]	
		Report progress on meeting cost and schedule estimates.	
		Perform a post mortem and document lessons learned for elements where actual costs or schedules differ from the estimate.	
		Document all changes to the program and how they affect the cost estimate.	

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