APPENDIX B
COST ESTIMATING AND BEST PRACTICES

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS AND ACRONYMS

AACEI	Advancement of Cost Engineering International
CER	cost estimating relationship
CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
EEDB	Energy Economic Data Base
EO	Executive Order
EVM	earned-value management
GAO	Government Accountability Office
ICE	independent cost estimate
ICR	independent cost review
LCC	life-cycle cost
LCCE	life-cycle cost estimate
LOE	level of effort
NRC	U.S. Nuclear Regulatory Commission
PERT	program evaluation and review technique
RP	recommended practices
WBS	work breakdown structure

COST ESTIMATING AND BEST PRACTICES

B.1 PURPOSE

The purpose of this appendix is to provide uniform guidance and best practices for the methods and procedures recommended for use by the U.S. Nuclear Regulatory Commission (NRC) staff when preparing cost estimates, including, but not limited to, those for regulatory analyses, backfit analyses, and environmental analyses. The appendix describes practices relative to estimating a life-cycle cost (LCC). 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 industry standards on best practices and processes for cost estimating, including practices promulgated by the Government Accountability Office (GAO) in its guide, “Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs,” issued April 2009 (GAO, 2009). In GAO-15-98, “NRC Needs to Improve Its Cost Estimates by Incorporating More Best Practices,” issued December 2014 (GAO, 2014), the GAO specifically recommended that NRC cost estimating guidance be aligned with relevant cost estimating best practices identified in GAO-15-98 to ensure that future cost estimates are prepared in accordance with relevant cost estimating best practices. This appendix includes recommendations from GAO-15-98.

B.2 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 that support Commission decisionmaking. The cost estimating principles and processes described in this appendix meet or exceed Federal and NRC requirements while referring to industry standards and best practices, where appropriate.

High-quality cost estimates should satisfy four characteristics established by industry best practices—they should be credible, well documented, accurate, and comprehensive (GAO, 2009):

- **Credible when the assumptions and estimates are realistic**—The estimate has been cross-checked and reconciled with independent cost estimates, the level of confidence associated with the point estimate[1] has been identified, and a sensitivity analysis[2] has been conducted.

- **Well-documented**—The supporting documentation includes a narrative explaining the process, sources, and methods used to create the estimate, and the estimate identifies the underlying data and assumptions used to develop the estimate.

- **Accurate**—The actual costs deviate little from the assessment of costs likely to be incurred.

- **Comprehensive**—The estimate accounts for all possible costs associated with a project, it is structured in sufficient detail to ensure that costs are neither omitted nor duplicated, and 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 (Table B-7) contains a cross-reference of the 12 key GAO estimating steps (GAO, 2009) and their implementing tasks to the sections of this appendix that discuss the NRC guidance for accomplishing those steps.

B.2.1 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.

---

1 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.

2 A sensitivity analysis is 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.

- 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.

B.2.2 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 to ensure the development of accurate and credible cost estimates. These best practices represent an overall process of established, repeatable methods that result in high-quality cost estimates that 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 that can be used to make informed decisions. Table B-1 lists the 12 steps, extracted from GAO-09-3SP (GAO, 2009).

Table B-1 The 12 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.

Step	Description	Associated Tasks
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.
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,[a] and 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.

Step	Description	Associated Tasks
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. • 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.

Step	Description	Associated Tasks
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 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 (GAO, 2009).

B.3 COST ESTIMATING INPUTS

Cost estimate development is initiated by inputs to the process. These inputs are process elements that can either occur one time or be iterative. Internal NRC reviews or external feedback may identify the need to revise 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.3.1 Project Requirements

Cost estimates are performed for regulatory analyses, backfitting analyses, and environmental analyses. Each analysis may have specific, detailed, or different requirements based on the intended purpose of the analysis.

B.3.2 Documentation Requirements

The analyst should document scope assumptions, regulatory baseline determinations, and likely alternatives. The analyses consider the accuracy of supporting estimates and project-specific evaluations.

B.4 COST ESTIMATING CHARACTERISTICS AND CLASSIFICATIONS

B.4.1 Planning the Cost Estimates

Table B-2 describes the planning steps required to produce credible cost estimates.

Table B-2 Basic Characteristic of Credible Cost Estimates

Cost Estimate Planning Step	Description
Clear Identification of Task	The cost analyst should receive the scope description, ground rules and assumptions, and technical and performance characteristics. Clearly identify estimate constraints and conditions to ensure the preparation of a well-documented estimate.
Broad Participation in Preparing Estimates	Stakeholders should participate in providing requirements, system parameters, and cost data based on stated regulatory objectives. Independently verify external data 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 performance characteristics of the new scope.
Standardized Structure for the Estimate	Use 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 the cost estimate properly and realistically reflects economic escalation (i.e., inflating the price of goods and services using an appropriate consumer price index to account for changes in prices over time). Clearly note assumptions. Identify the source of escalation information and explain and justify the applicability of the rates.
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	Conduct an independent review of an estimate as a crucial step to establishing confidence in the estimate. Ensure that the independent reviewer verifies, modifies, and validates 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. Give appropriate justification and explanation for such changes.

Source: Based on GAO-09-3SP, Table 1 (GAO, 2009).

B.4.2 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.

As a project evolves, it typically becomes more defined. Likewise, 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 (AACEI 2011a) and 2011 RP No. 18R-97 (AACEI 2011b). Table B-3 lists the five suggested cost estimate classifications, 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 [a,b]
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: Based on U.S. Department of Energy (DOE), "Cost Estimating Guide," Table 4.3 (DOE, 2011).

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 RP No. 17R-97, there is no absolute standard range on any estimate or class of estimates. The common plus or minus 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, other affecting 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, the estimate should be developed using a combination of estimate classifications. 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 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.4.3 Cost Estimate Ranges

When preparing cost estimates for early conceptual designs, it is important to recognize that variations in the basis for the design will have the greatest impact on costs. Estimating tools and methods, while important, should not be the main focus 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 toward establishing a better design basis than 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, 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. The analyst should reflect such uncertainty in the estimate range and not by increasing 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.

NRC regulatory analysis cost estimates do not use either of these types of contingency (GAO, 2009). The use of sensitivity analysis and uncertainty analysis (discussed in Appendix C, “Treatment of Uncertainty,” to NUREG/BR-0058, Revision 5) provides a means to determine the contingency amount required for a project budget. Therefore, the analyst should not add contingency to the upper range cost estimate.

B.5 COST ESTIMATING METHODS

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.5.1 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. These types of estimates 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. Analysts typically use a work statement and set of drawings or specifications to identify activities that make up the project. Nontraditional estimates may use a WBS, team input, and work statement to identify the activities that make up the work.

The analyst separates each activity into detailed tasks to itemize and quantify labor hours, material costs, equipment costs, and subcontract costs. 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). The analyst should include contingencies when performing a sensitivity analysis for a regulatory analysis (i.e., a high estimate). Appendix C, “Treatment of Uncertainty,” to NUREG/BR-0058 discusses the concept of sensitivity analysis as a subset of contingency analysis.

The analyst may revise the estimate 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, or unit-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. The NRC staff does not use cost estimates in regulatory analyses to estimate regulatory burden to develop work packages or planning packages, nor does it update the estimate 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. The 2012 DOE “Work Breakdown Structure Handbook” is a suitable reference for use in developing a product-oriented WBS.

The advantages of 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

The disadvantages of using activity-based, detailed, or unit-cost estimating methods include the following:

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

B.5.2 Parametric-Estimating Techniques

A parametric model is a useful tool for preparing early conceptual estimates when there is little technical data or engineering deliverables to provide a basis for using more detailed estimating methods. 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 the dependent variable, cost. 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 CERs.

B.5.2.1 Cost Estimating Relationships

CERs, also known as cost models, composites, or assemblies and subassemblies, are developed from historical data for similar systems or subsystems. Analysts use a CER 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. For a CER 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.

The advantages of using the parametric cost estimating include the following:

- **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. Analysts can use this information to provide a confidence level for the estimate based on the CER's predictive capability.

The disadvantages of using parametric-estimating techniques include the following:

- **Database requirements**—The underlying data should be consistent and reliable. While 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.5.2.2 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 capacity of the proposed plant by a dollars-per-megawatt value obtained by calculating the dollars-per-megawatt construction costs of recently completed nuclear power plants.

B.5.2.3 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.5.2.4 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. The screening method (Class 5 estimate) is most often used. While the capacity-factored method is most often used to estimate the cost of entire facilities, it 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 = costs of the two similar plants
$Capacity_A$ and $Capacity_B$ = capacities of the two plants
e = 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 of less than 1, economies of scale are achieved such that as plant capacity increases by a percentage (e.g., 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 1. At this point, it becomes as economical to build two plants of a smaller size as it is 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, with 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.5.2.5 Ratio or Factor Method

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

For example, if a plant that cost $1,000,000 to construct has major equipment that costs of $250,000, then the plant cost-to-equipment cost factor would be 4.0, as illustrated below:

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

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 $2,400,000 ($600,000 x 4.0).

B.5.3 Other Estimating Methods

B.5.3.1 Level-of-Effort Method

A form of parametric estimating is based on level of effort (LOE). Historically, LOE is used to determine future repetitive costs based on past cost data (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. Because 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 example, 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 and fee, and other assumptions.

B.5.3.2 Specific-Analogy Method

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

The specific-analogy method 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 to cross-check 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 the 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 $1,406 = $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.

The advantages of using the analogy method include the following:

- The method can be applied 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.

The disadvantages of using the analogy method include 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 in GAO-09-3SP highlights what can happen when technical parameter assumptions are too optimistic (GAO, 2009).

B.5.3.3 Expert-Opinion Method

Expert opinion is an estimating technique in which analysts consult experts about 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). 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. Cost analysts should verify experts' credentials before relying on their opinions. Cost analysts should not ask experts to estimate costs outside their expertise.

One method for forecasting cost based on expert opinion is the Delphi method. For the Delphi method, a group (e.g., six or more experts) receives 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 facilitate a final consensus, if feasible.

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

- Expert opinion can be used if no historical data are 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:

- Experts might lack objectivity.
- One expert might try to dominate the discussion and sway the group toward his or her opinion.
- There is a possibility of an impasse.
- This approach is not considered very accurate or valid as a primary estimating method.

Because of its subjectivity and lack of supporting documentation, expert opinion should be used sparingly, as a last resort. GAO Case Study 35 in GAO-09-3SP (GAO, 2009) shows how relying on expert opinion as a main source for a cost estimate is unwise.

B.5.3.4 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. It is important to note 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.

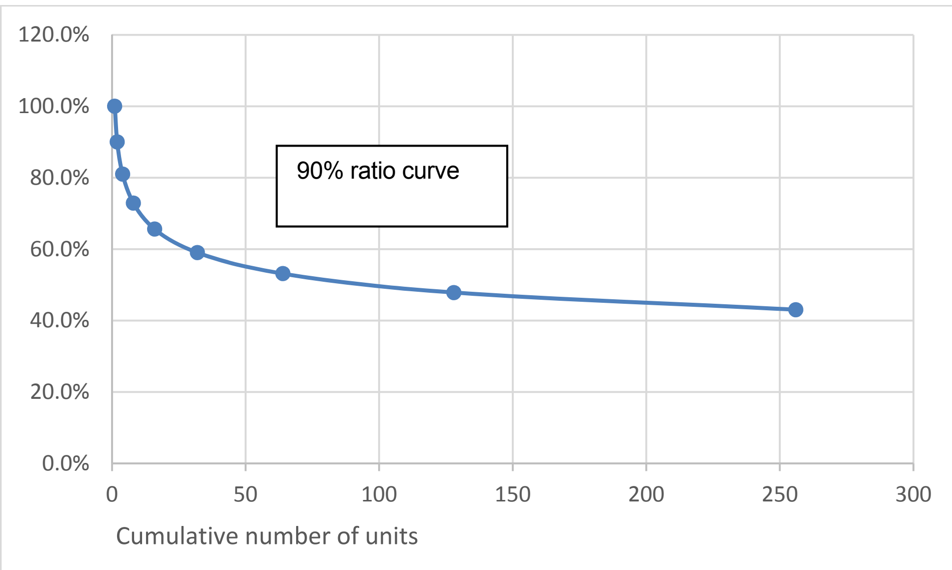

Figure B-1 A Learning Curve

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 is 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 across projects. When labor hour reductions of the first units are known, the analyst can calculate an accurate percentage reduction and extend it to subsequent units. If no data exist, it may be risky to assume that learning-curve savings will be experienced.

Both traditional and nontraditional projects can use the learning-curve estimating. 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.6 METHODS OF ESTIMATING OTHER LIFE-CYCLE COSTS

Different methods may be used to estimate other project and program support costs (e.g., design, engineering, inspections, and regulatory review). This section describes some common methods.

B.6.1 Count-Deliverables Method

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

B.6.2 Full-Time-Equivalent Method

The number of individuals anticipated to perform specific functions of a project forms the basis for this method. The analyst estimates the cost by calculating the labor-hour quantity and multiplying it by the cost per labor hour and the duration of the project function.

B.6.3 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 the estimated construction costs. Nontraditional, first-of-a-kind projects may be higher, while simple construction, such as buildings, will be lower (on the order of 6 percent); the more safety and regulatory intervention 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.7 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. All costs borne by all groups should be included to measure the total value of what should be forgone to undertake each alternative and to avoid errors in answering the economic questions.

B.7.1 Overview of the Cost Estimating Process

Section B.2.2 of this appendix explains the overall cost estimating process model. This section discusses the cost estimating development process following the 12-step model recommended by the GAO (GAO, 2009) as it applies to regulatory decisionmaking. Table B-1 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.7.2 Estimate Planning

The estimate planning task (input in Table B-1) 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 or techniques
- conducting an estimate kickoff meeting

These activities are conducted in the following steps:

- **Develop Estimate-Purpose Statement**—State the purpose in precise, unambiguous terms. Indicate why the estimate is being prepared and how the estimate is to be used. Describe 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**—Provide a detailed description of the work included in the estimate. 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 will 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.

Regulations can be either prescriptive or performance-based. Prescriptive requirements specify features, actions, or programmatic elements to be included in the design or process as the means for achieving a desired objective. Performance-based requirements rely upon measurable (or calculable) outcomes (i.e., performance results) to be met but provide 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 principles: (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 (NRC, 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 those 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 or methodologies the analyst will use, 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.7.3 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.7.3.1 Sources of Cost Estimate Data

Because all cost estimating methods are data driven, the cost analyst should know the best data sources (see 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, only secondary data 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 include the following:

- **Estimating Manuals**—The construction industry produces numerous costing manuals to assist in the pricing of work. Robert Snow Means Co. "Cost Data Books" and Richardson Construction Estimating Standards 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. Table B-5 lists these documents.

Table B-5 List of NRC Cost Studies

Document No.	Title
Nuclear Power Plant Construction Costs	
NUREG/CR-5160	"Guidelines for the Use of the EEDB [Energy Economic Data Base] 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"

Document No.	Title
Nuclear Power Plant Worker Radiation Dose Estimating Method	
NUREG/CR-5035	"Data Base of System-Average Dose Rates at Nuclear Power Plants"

- **Databases**—Commercial databases are readily available and provide the cost analyst with the ability to retrieve cost estimating data. The Energy Economic Data Base (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. Cost analysts should use LOE activity cost estimates minimally 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; that is, 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. The analyst should document any formalized procedure used.

- **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 relying on information from 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.

- **Learning-Curve Data**—As described in Section B.5.3.4, 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 (see Table B-5) 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.7.3.2 Cost Estimate Development Considerations

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

- 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 the following specific inputs:

- 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

The cost analyst will be able to use this information, whether provided by others or developed by the cost analyst as an assumption, to determine the appropriate estimating techniques to employ.

B.7.4 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 the analyst coordinate scope development, documentation, and control with the cost estimate production as key iterative processes. In general, the production of a cost estimate has 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 detailed items or models that make up the activities.
- Assign measurable quantities to the detailed 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, the cost analyst should follow three steps 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, as follows:

Step 1— Estimate the amounts and types of equipment, materials, and labor that the proposed action will affect, including physical equipment, craft labor, and professional staff labor for design, engineering, quality assurance, and licensing associated with the action. If the action requires work in a radiation zone, the estimate should account for the extra labor required by radiation exposure limits and low worker efficiency from 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.5.1.

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 as secondary costs. Additional information on cost categories, especially for reactor facilities, appears in NUREG-0248, "Commercial Electric Power Cost Studies, Part 8, Total Generating Costs: Coal and Nuclear Plants," issued 1979; and UCSD-CER-13-01 "ARIES Cost Account Documentation," issued June 2013. Indirect costs are typically absorbed by society and not subject to accounting on the owner's financial statement. Indirect costs include environmental costs (e.g., lost wetlands and other habitats, soiling of property from pollution), societal costs (e.g., lost productivity, medical costs), 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 are available 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 the proposed action is adopted.

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-4627, "Generic Cost Estimates: Abstracts from Generic Studies for Use in Preparing Regulatory Impact Analyses," Revision 2, 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 making independent assumptions 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/CR-5160 (Robinson, et al., 1988)) to prepare a detailed account of implementation costs.

B.7.4.1 Work-Breakdown Structure

The analyst should develop a WBS because it details the work necessary to accomplish the proposed regulatory action. Going through the process of WBS development helps to clearly identify the activities needed to be performed and ensure that they are 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

The logic of a "100-percent rule" is 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 level) 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 that have 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 across many programs. The more data that are available for creating the cost estimate, the higher the confidence level. As this process indicates, and as described in this appendix, the development of a WBS and cost estimates is a highly iterative and interrelated process.

B.7.4.2 Collect, Validate, and Adjust Data

NRC cost estimates can use many possible sources of data. 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.7.3.1. The cost analyst should always carefully examine data before using it in a cost estimate. The estimate should display historical data over a period of a few years (not just a single year) that are separated 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 (described in Section B.7.4.3) 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 if 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, and the legitimacy of the component unit prices.

B.7.4.3 Select Cost Estimating Methods or Models

The analyst may use a number of techniques 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:

(1) **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.

(2) **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). This technique uses a currently fielded system, similar in design and operation to the proposed system, 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). The cost analyst can make such adjustments 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.

(3) **Engineering Estimate**—This technique uses discrete estimates of labor and material costs for maintenance and other support functions. The cost analyst breaks down the system being estimated into lower-level subsystems and components, each of which is estimated separately. The analyst then aggregates the component costs, with additional factors for integration, 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; regulated entities continue to use these methods after the regulation is promulgated.

(4) **Extrapolation of Actual Costs**—With this technique, analysts use actual cost experience or trends (from prototypes, engineering development models, and early production items)

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.

(5) **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. Analysts often use analogy estimates as cross-checks, even for mature systems.

B.7.4.4 Estimate Costs

With the completion of the steps described earlier in Section B.7.4, 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 selected cost estimation techniques 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 stages, 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.7.4.5 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 that licensees take to implement changes to their facilities to comply with a new or revised regulation. Although these uncertainties cannot be eliminated, the cost estimate should address them. 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 or minus percentages but rather by a careful assessment of the underlying uncertainties.

B.7.4.6 Cost Estimate Results

The cost analyst should formally document the cost estimate. 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 analysis or similar report.

B.7.5 Cost Estimate Review

The cost analyst should ensure that the cost estimates are 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, and the 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 completeness.

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, as shown in step 7 of Table B-1.

The review should document the following:

- the name of the reviewer(s)—office, agency, contractor affiliation (as appropriate)
- the date of the review

B.7.6 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.7.7 Cost Estimate Documentation

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

- Complete and detailed documentation is essential for validating and defending a cost estimate.

- Documenting the estimate with a detailed, step-by-step process provides enough documentation so that someone unfamiliar with the estimate could recreate or update it.

- 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.

- 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

All cost estimates should have an accompanying cost estimate package or report (e.g., a regulatory analysis). All cost estimate packages 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 best practices for preparing cost estimates for developing and managing capital program costs. When documenting cost estimates for other purposes, the analyst should use a graded approach to estimate packaging and reporting, keeping the scope limited to the intended function of the estimate (GAO, 2009).

The cost estimate should contain the following information:

- **Estimate Purpose Statement**—This provides 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**—This summarizes the technical scope of the project, including what is included in the project as well as what is not included.

- **Qualifications and Assumptions**—This lists the key estimate qualifications and cost assumptions that bound 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 would significantly influence the estimate but is not clearly identified in the problem statement or alternative description(s). This information also describes the major assumptions and exclusions that affect the estimate or the accuracy of the estimate.

  Once the qualifications and assumptions are identified, the cost analyst should identify key information for reviewers or users of the estimates, those areas where scope descriptions have deficiencies, and areas where key information is missing and has to be assumed. The analyst should describe and document the qualifications and assumptions to a level practicable and should clearly describe them 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.8 COST ESTIMATING OUTPUTS

B.8.1 Baselines

Typically, NRC cost estimates are performed to analyze proposed regulatory changes and are used to quantify the incremental impacts of this change. The problem statement should justify the need for regulatory action within the context of what would prevail if regulatory action were not taken. This justification requires assumptions about 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.8.2 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, rather, 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 (EO) 12866, "Regulatory Planning and Review," dated October 4, 1993, requires executive agencies to prepare a regulatory analysis for all significant regulatory actions. Significant regulatory actions defined in EO 12866 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 regulatory actions, as defined in EO 12866. In general, each NRC office should ensure that all mechanisms the staff uses 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, and on cost estimating and analysis, can be found through the International Cost Estimating and Analysis Association at http://www.iceaaonline.com/.

More information on cost engineering can be found through the AACEI at http://www.aacei.org/.

B.9 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.9.1 Summary of Expectations

An NRC cost estimate, regardless of purpose, classification, or technique employed, should demonstrate sufficient quality to indicate 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's 12-step cost estimating development process (GAO, 2009), as applicable.

Common elements of good cost estimates are expected to be constant. Enclosure B-1 summarizes suggested review criteria.

B.9.2 Independent Cost Estimates

In December 2014, the GAO published GAO-15-98 (GAO, 2014), which examines the extent to which the NRC's cost estimating procedures support development of reliable cost estimates and follow specific best practices identified in GAO-09-3SP (GAO, 2009). As a result of these evaluations, the 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. The GAO recommended, among other aspects, that the NRC demonstrate the credibility of its cost estimates by cross-checking agency results with independent cost estimates developed by others, providing confidence levels, and conducting a sensitivity analysis to identify the variables that most affect cost estimates.

In response to the GAO concerns and recommendations, the NRC conducted a pilot program to have selected independent cost estimates performed for the same proposed action. The NRC, based on this pilot will use of independent cost estimates to cross-check NRC cost-benefit analyses on a case-by-case basis.

B.10 REFERENCES

Association for Advancement of Cost Engineering International (AACEI), "Cost Estimate Classification System: TCM Framework: 7.3—Cost Estimating and Budgeting," Recommended Practice No. 17R-97, 2011a.

AACEI, "Cost Estimate Classification System—As Applied in Engineering, Procurement, and Construction: TCM Framework: 7.3—Cost Estimating and Budgeting," Recommended Practice No. 18R-97, 2011b.

Ball, J.R., et al., "A Handbook for Cost Estimating: A Method for Developing Estimates of Cost for Generic Actions for Nuclear Power Plants," NUREG/CR-3971, October 1984. Agencywide Documents Access and Management System (ADAMS) Accession No. ML072320183 (nonpublic).

Ball, J.R., "A Handbook for Quick Cost Estimates: A Method for Developing Quick Approximate Estimates of Costs for Generic Actions for Nuclear Power Plants," NUREG/CR-4568, April 1986. ADAMS Accession No. ML090020304 (nonpublic).

Beal, S., et al., "Data Base of System-Average Dose Rates at Nuclear Power Plants," NUREG/CR-5035, 1987.

Clark, R. et al., "Generic Cost Estimates for the Disposal of Radioactive Wastes," NUREG/CR-4555, 1988.

Code of Federal Regulations, Title 10, *Energy*, Part 50, "Domestic Licensing of Production and Utilization Facilities." Available at http://www.nrc.gov/reading-rm/doc-collections/cfr/part050/.

Cronin, F.J., et al., "Improved Cost-Benefit Techniques in the U.S. Nuclear Regulatory Commission," NUREG/CR-3194, 1983.

Office of the President, "Executive Order 12866 of September 30, 1993: Regulatory Planning and Review," *Federal Register*, Vol. 58, October 4, 1993, (FR 51735-51668). Available at https://www.gpo.gov/fdsys/pkg/FR-1993-10-04/pdf/FR-1993-10-04.pdf.

"Richardson Construction Estimating Standards database." Available at http://www.costdataonline.com/.

Riordan, B., "Labor Productivity Adjustment Factors: A Method for Estimating Labor Construction Costs Associated with Physical Modifications to Nuclear Power Plants," NUREG/CR-4546, March 1986 (nonpublic).

Robert Snow Means Co., Inc. "Cost Data Books," Construction Publishers & Consultants. Accessed at https://www.rsmeans.com/products/books.aspx.

Robinson, et.al., "Guidelines for the Use of the EEDB at the Sub-Component and Subsystem Level," NUREG/CR-5160, May 1988.

Sciacca, F., et al., "Generic Methodology for Estimating the Labor Cost Associated with the Removal of Hardware, Materials, and Structures from Nuclear Power Plants," SEA Report 84-116-05-A:1, 1986.

Sciacca, F., “Generic Cost Estimates: Abstracts from Generic Studies for Use in Preparing Regulatory Impact Analyses,” NUREG/CR-4627, Revision 2, February 1992.

Simon, G., et al., “Validation of Generic Cost Estimates for Construction-Related Activities at Nuclear Power Plants,” NUREG/CR-5138, Final Report, 1988.

Smith, H.M. and Ziegler, E.J., “Engineering and Quality Assurance Cost Factors Associated with Nuclear Plant Modification,” NUREG/CR-4921, 1987.

“The Identification and Estimation of the Cost of Required Procedural Changes at Nuclear Power Plants,” under contract NRC-33-84-407-006.

United Engineers and Constructors, Inc., “Commercial Electric Power Cost Studies, Part 8, Total Generating Costs: Coal and Nuclear Plants,” NUREG-0248, 1979.

U.S. Department of Energy (DOE), “Cost Estimating Guide,” DOE G 413.3-21, May 09, 2011. Available at https://www.directives.doe.gov/directives-documents/400-series/0413.3-EGuide-21.

DOE, “Work Breakdown Structure Handbook,” August 16, 2012. Available at http://energy.gov/sites/prod/files/DOE%20WBS%20Handbook%20%202012-08-16.pdf.

U.S. Government Accountability Office (GAO), “GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs.” GAO-09-3SP, March 2009. Available at http://www.gao.gov/assets/80/77175.pdf.

GAO, “Nuclear Regulatory Commission—NRC Needs to Improve Its Cost Estimates by Incorporating More Best Practices,” Report to Congressional Requesters, GAO-15-98, December 2014. Available at http://www.gao.gov/assets/670/667501.pdf.

U.S. Nuclear Regulatory Commission (NRC), “Nuclear Energy Cost Data Base: A Reference Data Base for Nuclear and Coal-fired Power Plant Power Generating Cost Analysis,” DOE/NE-0044/3, 1985.

NRC, “Backfit Considerations,” SECY-93-086, June 30, 1993. ADAMS Accession No. ML003760758 (nonpublic).

NRC, “White Paper on Risk-Informed and Performance-Based Regulation,” Staff Requirements Memorandum (SRM) to SECY-98-144 (SRM-SECY-98-144), March 1, 1999. ADAMS Accession No. ML003753601.

Wagner, L.M., “ARIES Cost Account Documentation,” UCSD-CER-13-01, June 2013. Available at http://aries.ucsd.edu/LIB/REPORT/ARIES-ACT/UCSD-CER-13-01.pdf.

ENCLOSURE B-1: COST ESTIMATE REVIEW CRITERIA

When reviewing the U.S. Nuclear Regulatory Commission (NRC) cost estimates, at a minimum, reviewers should use the generic criteria described in this enclosure. To be considered complete, the estimates should address all criteria. If all criteria are reasonably addressed, then the estimates represented may be considered quality, reasonable, and as accurate as possible. The estimates should also have been prepared by following the U.S. Government Accountability Office (GAO) 12-step process for developing a cost estimate (GAO, 2009), as recommended in this appendix.

The generic review criteria include the following:

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

- **Scope of the Problem**—Ensure that the cost estimate discusses the scope of the problem in terms of the classes of licensees or facilities being affected, including the number and size of facilities in the affected classes. The estimate should note any difference between the NRC and Agreement State licensees and identify the implications of taking no action (i.e., maintaining the status quo). Verify that the planning phase size and cost estimating modeling are commensurate with the scope of the problem and the alternatives identified. The cost estimate should be activity based, to the extent practicable.

- **Costs**—Ensure that the estimate includes all costs appropriately and documents and references all unit rates. The quantification should employ monetary terms whenever possible. Verify that the dollar values use constant dollar values (i.e., dollars of constant purchasing power).

- **Contingency**—Ensure that the estimate includes contingency appropriately in the uncertainty analysis, based on apparent project risks or a project risk analysis, to the greatest possible extent. Contingency should have a documented basis. Contingency may be calculated using a deterministic or probabilistic approach; verify that the method employed is 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. Consider the potential impact and the probability of occurrence when evaluating project risk.

  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 have less significant size and complexity.

  When performing an uncertainty analysis, verify that the cost analysis includes contingencies on the low estimate and the high estimate and not for the best estimate.

ENCLOSURE B-2: DEFINITIONS

The following are definitions of terms used within Appendix B.

Activity-based costing

- 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 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)—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—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 code of accounts 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; 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., from the 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—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, from 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—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; those risks 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; lessons can be gathered at any point during the life of the project or program

Level of effort (LOE)—a form of parametric estimating. 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 LOE). 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—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 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—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—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 probability distribution function represents the number of times a certain estimated cost or benefit is achieved

Productivity—the consideration of 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 the two 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 to 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 risks are the highest

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

(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; repeating the process for many trials allows creation of a frequency distribution 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

ENCLOSURE B-3: INDEPENDENT COST REVIEW AND INDEPENDENT COST ESTIMATE GUIDANCE

General Guidance

Independent cost review (ICR) and independent cost estimate (ICE) teams should 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, the team members should clearly understand 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 the project team uses. 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 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; would vary by project size and complexity)

Activity	Typical Duration (weeks)
Establish ICR or 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 or 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 an Independent Cost Review and Independent Cost Estimate

The following data needs are typical for supporting an ICR or ICE and should be addressed with consideration for the stage and nature of the project:

- Project status and management and technical briefings should include, but not be limited to, the following:
    - project history and overview
    - technical baseline
    - current project status
    - major issues and problems

- project organization
- work-breakdown structure (WBS)

- Project schedule should include, but not be limited to, the following:
  - milestones
  - critical path

- Design and estimate documentation/backup should include, but not be limited to, the following:
  - project information, such as:
    - facilities descriptions
    - plot plans and layout drawings
    - piping and instrumentation drawings, process diagrams
    - electrical one-line drawings
    - system descriptions
  - design-basis documentation
    - cost estimate summary
    - cost estimate details
    - cost estimate backup data, such as:
  - vendor quotes
  - labor rates
  - productivity factors
  - estimate basis and assumptions
  - overhead and markup assumptions and calculations
  - labor estimates

- ICR/ICE results should include, but not be limited to, the following:
  - current estimate
  - estimate basis (all major components)
  - contingency analysis (and supporting risk and uncertainty analysis)
  - escalation
  - major assumptions
  - resource availability and leveling analysis

Reconciliation of Independent Cost Review and Independent Cost Estimate 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 includes the ICE contractor's report as support for the draft ICE report.

- 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 reviews 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.

Independent Cost Estimate Report Contents

The ICE report should contain the following:

- 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

ENCLOSURE B-4: EXPECTATIONS FOR QUALITY COST ESTIMATES

Expectations for Quality Cost-Benefit Analyses

It is important that analysts validate that cost-benefit elements are credible and can be justified by acceptable estimating methods, adequate data, and detailed documentation. This step ensures that a high-quality cost-benefit analysis is developed and presented to management. This process verifies that the cost-benefit analysis adequately reflects the incremental changes to the regulatory baseline and provides a reasonable estimate of the costs and benefits resulting from these changes. It also confirms that the cost-benefit analysis is traceable, accurate, and reflects realistic assumptions.

Cost Estimating Best Practices

There are four characteristics of a high-quality, reliable cost-benefit analysis. These characteristics are that the cost-benefit analysis is: (1) well-documented, (2) comprehensive, (3) accurate, and (4) credible. Each of these four characteristics is briefly described below.

- The cost-benefit analysis must be thoroughly documented, including input data, clearly detailed calculations and results, and explanations of why particular methods and references were chosen. Data should be cited to their source documents.

- The cost-benefit analysis must be comprehensive and have sufficient detail to ensure that analyzed cost-benefit elements are neither omitted nor double counted. Additionally, assumptions used in the cost-benefit analysis are documented and justified.

- The analyst should ensure that the cost-benefit estimates are unbiased, not overly conservative or overly optimistic, and are based on an assessment of most likely costs and benefits. The analysis contains few, if any, mathematical mistakes; and if any exist, they are minor.

- Any limitations of the analysis because of uncertainty, data bias, or assumptions are discussed. Major assumptions are analyzed and sensitivity analysis may be performed to determine how sensitive the results are to changes in the assumptions. Uncertainty analysis is performed to determine the level of confidence associated with the results. The analysis results are reviewed for concurrence and approval. An independent cost estimate (ICE) may be performed to determine whether other estimating methods produce similar results.

Table B-7 shows how the 12 steps of a high-quality cost estimating process can be mapped to these four characteristics of a high-quality, reliable cost-benefit analysis.

Table B-7 Twelve Steps of High-Quality Cost Estimating Mapped to the Characteristics of a High-Quality Cost-Benefit Analysis

Cost-benefit analysis characteristic	Cost estimating step [a]
Well documented. The analysis is thoroughly documented, including inputs, clearly detailed calculations and results, and explanations for choosing a particular method or reference. Well documented characteristics include: • Data are traced back to the source documentation • Includes a technical baseline description • Documents all steps in developing the estimates so that a cost analyst could recreate the analysis with the same result • Documents all data sources including how the data were normalized • Describes the estimating methodology and rationale used to estimate costs and benefits.	1. Define the estimate's purpose. 3. Define program characteristics. 5. Identify ground rules and assumptions. 6. Obtain data. 10. Document the estimate. 11. Present the estimate to management for approval.
Comprehensive. The analysis level of detail is sufficient to ensure that cost-benefit elements necessary to model the incremental changes are neither omitted nor double counted. This is demonstrated by ensuring that the analysis: • Details all cost-influencing ground rules and assumptions • Describes each cost-benefit element	2. Develop an estimating plan. 4. Determine the estimating structure.

Cost-benefit analysis characteristic	Cost estimating step [a]
Accurate. The analysis is unbiased, not overly conservative or overly optimistic, and based on an assessment of most likely costs and benefits. This is demonstrated by ensuring that the analysis: • Has few, if any, mathematical mistakes, and any mistakes are minor • Has been validated for errors like double counting and omitted costs • Identified and analyzed cost drivers • Is timely • Is updated to reflect changes in technical or regulatory assumptions and information from public outreach, feedback, or comments, and from phases or milestones	7. Develop a point estimate and compare it to an independent cost estimate. 12. Update the estimate to reflect actual costs and changes.
Credible. Discusses any limitations of the analysis from uncertainty or biases surrounding data or assumptions: • Major assumptions are realistic and varied, and other outcomes are recomputed to determine their sensitivity to changes in assumptions • Risk and uncertainty analysis is performed to determine the level of risk associated with the estimate • An independent cost estimate is developed to determine if other estimating methods produce similar results	7. Develop a point estimate and compare it to an independent cost estimate. 8. Conduct a sensitivity analysis. 9. Conduct a risk and uncertainty analysis.

[a] Cost estimating steps are from Table B-1 of this appendix.

Validating Cost-Benefit Analyses

If assumptions are optimistic, then the cost-benefit analysis could be unrealistic. As a result, the costs may be underestimated. One way to avoid this issue is to ensure that cost-benefit analyses are generated early in the process so that the analyses can benefit from both internal U.S. Nuclear Regulatory Commission (NRC) and public comment. This increases the confidence that the cost-benefit analysis is reasonable and as accurate as possible.

The following steps should be taken to verify the quality of a cost-benefit analysis:

1. Determine That the Cost-Benefit Analysis Is Well Documented

Cost-benefit analyses are considered valid if they are well documented, they can be reproduced or updated, and inputs can be traced to their original sources. Well-documented analyses increase its credibility and help support management's decisionmaking. The documentation should identify the primary methods, calculations, results, assumptions, and data sources used to generate the analysis.

Cost-benefit analysis documentation should be detailed sufficiently to provide an accurate assessment of the document's quality based on the following characteristics:

- Data sources are identified and cited
- Assumptions are identified and justified
- The estimating method(s) used are described and documented

These qualities should allow a qualified analyst to replicate or update the analysis.

2. Determine That the Cost-Benefit Analysis Is Comprehensive

Analysts should make sure that the cost-benefit analysis is complete and accounts for all costs and benefits that are likely to occur. The analyst should confirm the document's completeness, its consistency, and the realism of its inputs and results to ensure that all pertinent costs and benefits are included and that the results are technically reasonable. In addition, the cost-benefit analysis should be documented in sufficient detail to ensure that cost-benefit elements are neither omitted nor double counted.

To determine whether a cost-benefit analysis is comprehensive, the cost-benefit analysis review and concurrence process should ensure that the cost-benefit analysis meets its intended purpose. During the review and concurrence process, the reviewer verifies that the cost-benefit analysis adequately evaluates the proposed regulatory change, using a methodology that accounts for changes in costs and benefits resulting from the proposed regulatory changes over the time period in which cost and benefits would be incurred. In addition, the reviewers on concurrence should satisfy themselves that all assumptions, applicability statements, and scope exclusions are identified, explained, and reasonable.

3. Determine That the Cost-Benefit Analysis Is Accurate

Cost-benefit analyses are accurate when they are not overly conservative or too optimistic, when they are based on an assessment of most likely costs and benefits, when inputs are properly normalized to the base year, and when the analysis contains few, if any, mistakes. In addition, when inputs, alternatives, timing, or other assumptions change, the cost-benefit analysis is revised to reflect the current status.

Validating that a cost-benefit analysis is accurate requires thoroughly understanding and investigating how the cost-benefit analysis was prepared. For example, all cost-benefit elements should be checked to verify that the calculations are accurate and account for all costs and benefits, including indirect costs and benefits. Moreover, inputs should be normalized so that data are expressed consistently and accurately in constant, base year dollars. In addition, checking modelling calculations and data input is imperative to validate the cost-benefit model accuracy.

Besides these basic checks for accuracy, the estimating technique used and the distribution selected for each cost-benefit element should be reviewed to make sure it is appropriate. Depending on the methodology used in the cost-benefit analysis, several questions should be used to assess the cost-benefit analysis accuracy. Table B-8 provides typical questions that should be used to assess accuracy associated with various estimating techniques.

Table B-8 Questions for Checking the Accuracy of the Cost-Benefit Analysis

Technique	Questions
Analogy	• Are the analogous data from reliable sources? • Did technical experts validate the data applicability and the scaling factor, if used? • Can any unusual requirements invalidate the use of this analogous data for this application? • Are the parameters used to develop an analogous factor similar to the changes being estimated? • What adjustments are made to account for differences between how the data was originally used and how the data is used in this application? Are they logical, credible, and acceptable?
Data Collection	• How old are the data? Are the data still relevant for its intended use? • Is there enough knowledge about the data source to determine if it can be used to estimate accurate costs and benefits for the intended use? • Has a data scatter plot been developed to determine whether any outliers, relationships, correlations, or trends exist? • Were descriptive statistics generated to describe the data, such as the mean, standard deviation, and coefficient of variation? • If data outliers were removed, did the data fall outside three standard deviations? Was the removal of outlier data identified and justified? Were comparisons made to historical data to show the outliers were an anomaly? • Were the data properly normalized?
Engineering Buildup	• Was each work breakdown structure (WBS) cost element defined in enough detail to use this method correctly? • Are data adequate to accurately estimate the cost or benefit of each WBS cost-benefit element? • Did experts help determine or provide input for the estimates of each cost-benefit element? • Is each WBS cost-benefit element composition defined? • Were labor rates based on credible sources (e.g., national wage data, NRC payroll data)? Did the labor rates include only variable costs (e.g., salary, pension, insurance premiums, and legally required benefits), which is directly related to the implementation, operation, and maintenance of incremental changes resulting from proposed regulatory actions? [a] • Is a detailed and accurate materials and parts list available? Was it used?
Expert Opinion	• Do quantitative historical data support the estimates received from expert opinion? • Did the estimate account for the possibility that bias influenced the results or that the lower and upper bounds estimated by experts tend to represent the 15 percent and 85 percent level, respectively, of all possible outcomes? [b]

Technique	Questions
Extrapolate from actuals (e.g., averages, learning curves, or estimates at completion)	• Were cost reports (e.g., NRC dynamic web site) that were extracted from historical actuals validated as appropriate for use in this application? • Was the cost element at least 25% complete before using its data as an extrapolation? How was the data normalized? • Were functional experts consulted to validate the appropriateness of using this cost data in this application? • Are recurring and nonrecurring costs and benefits separated to avoid double counting? • How are first unit costs of the learning curve determined? What historical data are used to determine the learning curve slope? • Are recurring and nonrecurring costs separated when the learning curve was developed? • How are partial units treated in the learning curve equation, if applicable?
Parametric	• Was a valid cost estimating relationship (e.g., CER), between historical costs and the physical and performance characteristics established? • How logical is the relationship between key cost drivers and cost? • Was the CER used to develop the estimate validated and accepted? • How old are the data? Are the data still relevant for use in this intended application? • Do the independent variables fall within the CER data range? • What is the level of variation in the CER? How well does the CER explain the variation and how much of the variation does the model not explain? • Do any outliers affect the overall fit? • How significant is the relationship between cost and its independent variables? • How well does the CER predict costs?

[a] Labor rates are burdened consistent with the methodology in Abstract 5.2 of NUREG/CR-4627. Fully burdened labor rates are generally not used in performing regulatory analyses or backfit analyses.

[b] GAO-09-3SP, "Expert Opinion, pages 161 and 162.

Validating Parametric Cost Estimating Relationships and Cost-Benefit Models

Cost estimating relationships (CERs) and cost-benefit models are validated to demonstrate that they can predict costs and benefits within an acceptable range of accuracy. To do this, data from historical programs similar to the new program should be collected to determine whether the CER selected is a reliable predictor of costs and benefits. In performing this review, the analyst should review the technical parameters for the historical programs to determine whether they are similar to the cost-benefit analysis being performed. For the CER to be accurate, the new and historical programs should have similar functions, objectives, and program factors, like acquisition strategy, or results could be misleading.

Before a parametric model is used in a cost-benefit analysis, the model should be calibrated and validated to ensure that it is based on current, accurate, and complete data and is therefore a good predictor of cost and benefits. Validation with calibration gives confidence that the model is a reliable estimating technique. To evaluate a model's ability to predict costs and benefits, the analyst can perform a variety of assessment tests. One test is to compare calibrated values with independent data that were not included in the model's calibration. Comparing the model's results to the independent test data's known value provides a useful benchmark for how accurately the model can predict costs or benefits. An alternative approach is to use the model to prepare an estimate and then compare its result with an independent cost estimate (ICE), which is based on another estimating technique.

4. Determine That the Cost-Benefit Analysis Is Credible

Credible cost-benefit analyses clearly identify limitations resulting from uncertainty or bias surrounding the data or assumptions. The analyst should evaluate major assumptions to determine how sensitive outcomes are to changes in the assumptions. In addition, an uncertainty analysis should be performed to quantify the level of uncertainty associated with the results.

To determine a cost-benefit analysis's credibility, key cost-benefit elements should be identified and evaluated to determine whether additional resources should be applied to reduce the uncertainty. It is also important to determine how sensitive the results are to changes in key assumptions and inputs. Typically, the analyst uses a tornado diagram to identify key cost-benefit elements that drive changes in the mean value of the net benefit. This uncertainty information enables management to know the confidence in the results, the range of potential changes in the net benefit results, and the key drivers that could cause these changes.

The uncertainty analysis adds to the credibility of the cost-benefit analysis, because it identifies the level of confidence associated with achieving the result. The uncertainty analysis produces more realistic results because it assesses the variability in the cost-benefit analysis results from changes in inputs, assumptions, or other effects. An uncertainty analysis gives the decisionmakers perspective on the potential variability of the calculated results should facts, circumstances, and assumptions change. By performing an uncertainty analysis, the analyst can quantify the degree of uncertainty, and the net benefit result can be expressed with a range of potential costs or benefits that is qualified by a factor of confidence.

Other ways to reinforce the credibility of the cost-benefit analysis are to issue the analysis for public comment, use a different estimating method to determine whether similar results are produced, or perform an independent cost estimate. Using any of these methods increases the level of confidence in the cost-benefit analysis, thereby leading to greater credibility.

An independent cost estimate (ICE) is considered one of the best and most reliable validation methods. An ICE is typically performed by a separate organization or specialized function (e.g., a program office) that cannot be influenced by the office that performed the cost-benefit analysis. An ICE provides an independent view of expected costs and benefits that tests the cost-benefit analysis's results for reasonableness. Therefore, an ICE can provide decisionmakers with additional insight and confidence in the net benefit results—in part, because an ICE typically uses different methods and data sources and may be less affected by organizational bias.

The ICE has the same scope as the cost-benefit analysis so that the results are comparable. One benefit of performing an ICE is that it provides an independent estimate of each cost-benefit element and its resulting net benefit. If the ICE is performed by a contractor, the ICE team may not have insight or access to the details in which the proposed regulatory change may be required to be implemented, so the ICE team may be forced to estimate the costs and benefits at a higher level or to use analogous estimating techniques. It is important that the results from the cost-benefit analysis and the ICE team are reconciled and that the differences in results are understood and documented.

ENCLOSURE B-5: CROSS-REFERENCE TO GAO-09-3SP

Table B-9 provides a cross-reference of the Government Accountability Office's (GAO's) 12-step process for developing a cost estimate and the implementing tasks[3] to the section of this appendix that contains guidance for accomplishing those steps.

Table B-9 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.	
		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.

3 Figure 1, "The Cost Estimating Process," in the main document identifies the GAO project phase. Table 2, "The Twelve Steps of a High-Quality Cost Estimating Process," in the main text (and Table B-1) lists the GAO best practice and the GAO associated task from GAO-09-3SP, "GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs," issued 2009 (GAO, 2009).

GAO Project Phase	GAO Best Practice	GAO Associated Task	Where Conformance to GAO Practice is Demonstrated
		Choose the best estimating method for each WBS element.	
		Identify potential cross-checks for likely cost and schedule drivers.	
		Develop a cost estimating checklist.	
	Step 5: *Identify ground rules and assumptions*.	Clearly define what the estimate includes and excludes.	The concepts related to ground rules and 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.	
		Interview data sources and document all pertinent information, including an assessment of data reliability and accuracy.	
		Store data for future estimates.	

GAO Project Phase	GAO Best Practice	GAO Associated Task	Where Conformance to GAO Practice is Demonstrated
	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 this 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 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.	

GAO Project Phase	GAO Best Practice	GAO Associated Task	Where Conformance to GAO Practice is Demonstrated
		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.	
	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.	

GAO Project Phase	GAO Best Practice	GAO Associated Task	Where Conformance to GAO Practice is Demonstrated
		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 reflect actual costs and changes.	Update the estimate to reflect changes in technical or program assumptions or keep it current as the program passes through new phases or milestones.	Estimate updates to reflect changes in assumptions 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.[a]	
		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.	

[a] The shaded boxes are not applicable to regulatory analysis cost estimates used to evaluate proposed actions affecting entities that the U.S. Nuclear Regulatory Commission (NRC) regulates. The NRC regulatory analyses are not intended to be living documents to monitor or control project costs. Updates to regulatory analysis estimates end when the NRC either finalizes and issues or withdraws the regulatory action.