# Indonesia Oil & Gas Cost Estimating vs International "Best-Tested and Proven" Practices – A Benchmarking Study [1]

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## ABSTRACT

The cost estimation process for the downstream oil and gas industry in Indonesia by the company have not been effective and accurate. The purpose of this paper is to choose the appropriate best tested and proven standards and references in the cost estimating process. In the analysis, various standards are benchmarked against the GAO Cost Estimating & Assessment Guide. A scoring model developed using Multi-Attributes Decision Making (MADM) non-compensatory and compensatory method with GAO as the basis. The results found that GAO Cost Estimating & Assessment Guide is superior to the others. GAO can be adopted to prepare a credible and accurate cost estimate for the company. The company is recommended to improve its cost estimating method using the 80/20 rule and then re-assess against the GAO. The process is carried out continuously until management is satisfied with the results.

**Key words:** Downstream Oil & Gas, Cost Estimate, Best-Tested and Proven in Cost Estimating, GAO Cost Estimating & Assessment Guide

## INTRODUCTION

Data from AT Kearney (2017)[2], 6 out of 10 projects experienced over-budget and behind schedule, including 100 major global companies in the oil and gas, chemicals, metals and mining, and utility industries. Leading companies have measured and realized this underperformance. Then commitment to finding the best forms and methods for embedded best practices and disciplined execution for the success of the project. In addition, it also shows that 60% of capital projects experience a 10% cost and schedule overrun, and around 30% experience cost and schedule overrun up to 25%. Developing a credible cost estimate is challenging due to many factors. In downstream oil & gas, the cost estimates are out of range due to various reasons.

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[2] ATKearney. (2017). Excellence in Capital Projects: A Goal Yet to be Achieved.

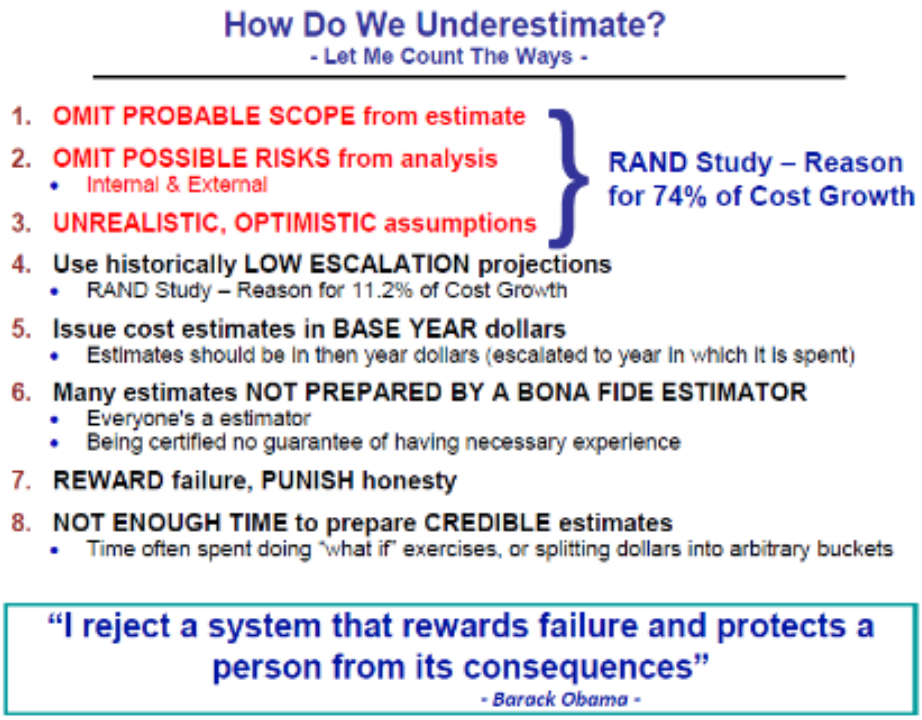


Figure 1 – Factors causing inaccuracy of estimates[3,4]

In this paper, the author tried to build awareness to the owners about the best tested & proven practices which to be followed in developing cost estimates. There are many references available for cost estimating in that GAO Cost Estimating & Assessment Guide seems the best to compare the owner cost estimates with the best practices and adopt for the owner developing cost estimates. Ten projects have been selected for the assessment with the GAO Cost Estimating & Assessment Guide.

Good best practices should be followed if accurate and credible cost estimates are to be developed. By following the overall process of cost estimating stated in best practices such as established, repeatable methods, comprehensive, accurate, replicated and updated to produce accurate and credible estimates. In this paper, GAO's were chosen as a reference for the selection of the best -practices that would be recommended for companies.

[3] RAND Corporation. (2011). Root Cause Analysis of Nunn-Mccurdy Breaches.
[4] Butts, G. (2010, February). Mega Projects Estimate - A History of Denial.

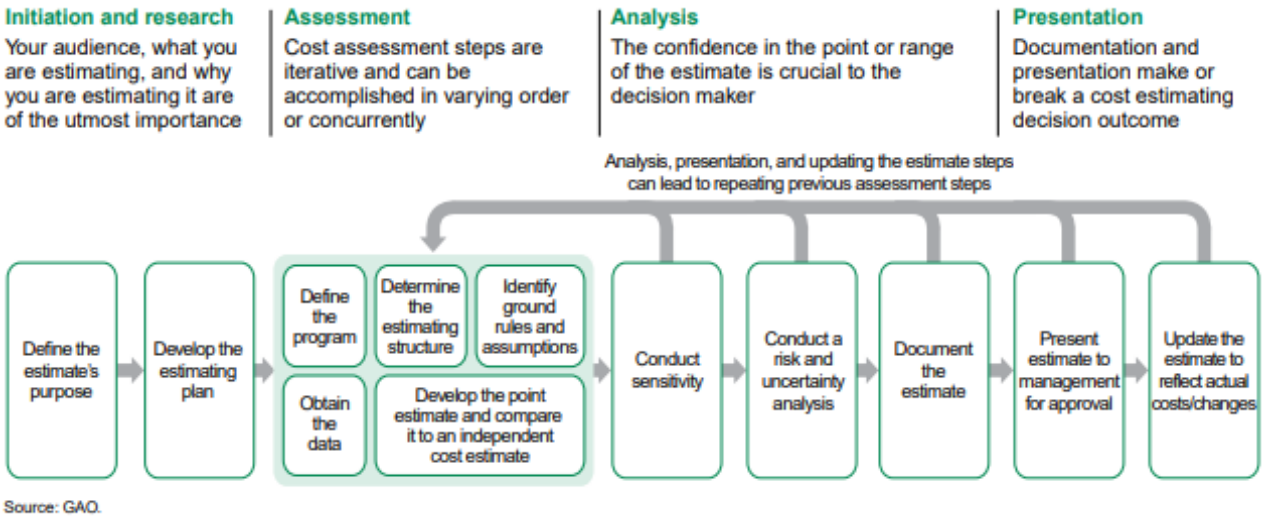


Figure 2 – Cost estimating processes by GAO[5]

The basic characteristics of effective cost estimating have been studied and highlighted many times. GAO concluded with the "Basic Characteristics of Credible Cost Estimates." As per GAO:

| Characteristic | Description |
|---|---|
| Clear identification of task | Estimator must be provided with the system description, ground rules and assumptions, and technical and performance characteristics<br>Estimate's constraints and conditions must be clearly identified to ensure the preparation of a well-documented estimate |
| Broad participation in preparing estimates | All stakeholders should be involved in deciding mission need and requirements and in defining system parameters and other characteristics<br>Data should be independently verified for accuracy, completeness, and reliability |
| Availability of valid data | Numerous sources of suitable, relevant, and available data should be used<br>Relevant, historical data should be used from similar systems to project costs of new systems; these data should be directly related to the system's performance characteristics |

[5] United States Government Accountability Office. (2009, March). GAO Cost Estimating and Assessment guide.

| Characteristic | Description |
|---|---|
| Standardized structure for the estimate | A standard work breakdown structure, as detailed as possible, should be used, refining it as the cost estimate matures and the system becomes more defined<br>The work breakdown structure ensures that no portions of the estimate are omitted and makes it easier to make comparisons to similar systems and programs |
| Provision for program uncertainties | Uncertainties should be identified and allowance developed to cover the cost effect<br>Known costs should be included and unknown costs should be allowed for |
| Recognition of inflation | The estimator should ensure that economic changes, such as inflation, are properly and realistically reflected in the life-cycle cost estimate |
| Recognition of excluded costs | All costs associated with a system should be included; any excluded costs should be disclosed and given a rationale |
| Independent review of estimates | Conducting an independent review of an estimate is crucial to establishing confidence in the estimate; the independent reviewer should verify, modify, and correct an estimate to ensure realism, completeness, and consistency |
| Revision of estimates for significant program changes | Estimates should be updated to reflect changes in a system's design requirements. Large changes that affect costs can significantly influence program decisions |

Source: GAO.

Figure 3 – Basic Characteristics of Credible Cost Estimates[6]

In this paper, the author demonstrates the best practices that to be followed for the project cost estimating by adopting characteristics in GAO Cost Estimating and Assessment Guide. A scoring model using Multi Attributes Decision Making (Non-Compensatory and Compensatory Model) has been developed for benchmarking and assessing company cost estimate development against the best practice. Thereby, the accuracy and credibility of the company cost estimate can be determined and can be proposed as proper feedback to the management about the importance of adopting the best practice for developing cost estimates.

This research should find the answers to the questions below:

- How can we rate the GAO standard for best cost estimating practices among other standards?
- What are the best practices in cost estimating to be followed by the company?
- How do the checklist recommendations that companies must follow for improvement refer to this benchmarking?

[6] The United States. Government Accountability Office. (2009). GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs. Washington, DC: Government Printing Office.

## METHODOLOGY

### Step 1- PROBLEM RECOGNITION: COMPARISON OF COMPANY METHOD OF COST ESTIMATION VS "BEST TESTED AND PROVEN" PRACTICES

Management does not want a cost estimate that is smaller than the actual real cost that causes over-budgeted, it is better for the cost estimate for the feasibility study needs to be done with a probability level of 90 (P90)[7]. Cost estimation data using the current method from the company then compared with the cost estimation classification as in Table-1. The results of the measurement of accuracy and precision compared to expected range accuracy can be seen as shown in Figure-4. From the results, the cost estimate results show results that are low accuracy and low precision.

| | *Primary Characteristic* | *Secondary Characteristic* | | |
|---|---|---|---|---|
| **ESTIMATE CLASS** | **MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** Expressed as % of complete definition | **END USAGE** Typical purpose of estimate | **METHODOLOGY** Typical estimating method | **EXPECTED ACCURACY RANGE** Typical variation in low and high ranges |
| **Class 5** | 0% to 2% | Concept screening | Capacity factored, parametric models, judgment, or analogy | L: -20% to -50%<br>H: +30% to +100% |
| **Class 4** | 1% to 15% | Study or feasibility | Equipment factored or parametric models | L: -15% to -30%<br>H: +20% to +50% |
| **Class 3** | 10% to 40% | Budget authorization or control | Semi-detailed unit costs with assembly level line items | L: -10% to -20%<br>H: +10% to +30% |
| **Class 2** | 30% to 75% | Control or bid/tender | Detailed unit cost with forced detailed take-off | L: -5% to -15%<br>H: +5% to +20% |
| **Class 1** | 65% to 100% | Check estimate or bid/tender | Detailed unit cost with detailed take-off | L: -3% to -10%<br>H: +3% to +15% |

Table 1 – Cost Estimate Classification for Petroleum and Process Industry[8]

[7] Prasad, Rashmi. Et.al. (2011). AACE International Recommended Practice No. 43R-10 Risk Analysis and Contingency Determination Using Parametric Estimating – Example Models as Applied for The Process Industries. United States of America: AACE International

[8] Carlik, C.W.et.al.(2015). AACE International Recommended Practice No. 87R-14 Cost Estimate Classification System – As Applied for The Petroleum Exploration and Production Industry. United States of America: AACE International.

| Num. | Project Name | Estimated Budget | Actual Cost | Percentage of Estimated Budget vs Actual Cost (%) | Cost Range Accuracy (%) | Schedule Range Accuracy (%) | Estimate Class | Maturity (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | Project A | 285.000.000 | 374.630.000 | 131 | -31 | 20 | Class 4 | 15 |
| 2 | Project B | 214.200.000 | 193.800.000 | 90 | 10 | 11 | Class 4 | 10 |
| 3 | Project C | 29.551.000 | 13.400.000 | 45 | 55 | 10 | Class 4 | 15 |
| 4 | Project D | 15.430.000 | 11.910.000 | 77 | 23 | 9 | Class 4 | 15 |
| 5 | Project E | 8.601.000 | 9.650.000 | 112 | -12 | 25 | Class 3 | 35 |
| 6 | Project F | 48.704.000 | 78.357.000 | 161 | -61 | 11 | Class 3 | 25 |
| 7 | Project G | 25.417.000 | 23.226.000 | 91 | 9 | 3 | Class 3 | 35 |
| 8 | Project H | 14.503.000 | 22.168.000 | 153 | -53 | 22 | Class 2 | 65 |
| 9 | Project I | 19.790.000 | 22.937.000 | 116 | -16 | 4 | Class 2 | 70 |
| 10 | Project J | 27.920.000 | 29.217.000 | 105 | -5 | 6 | Class 2 | 75 |

Table 2 – Company Internal Cost Budget[9]

Compared to data on the company, there are at least about 56% of projects experiencing 10% cost and schedule overrun and 36% experiencing up to 25% at 45 sample projects. This is a challenge for the company to be the focus of top performers for cost estimating on concept selection, FEED, and construction. This condition has a direct effect on increasing internal value, which is part of the improvement of the project management framework.

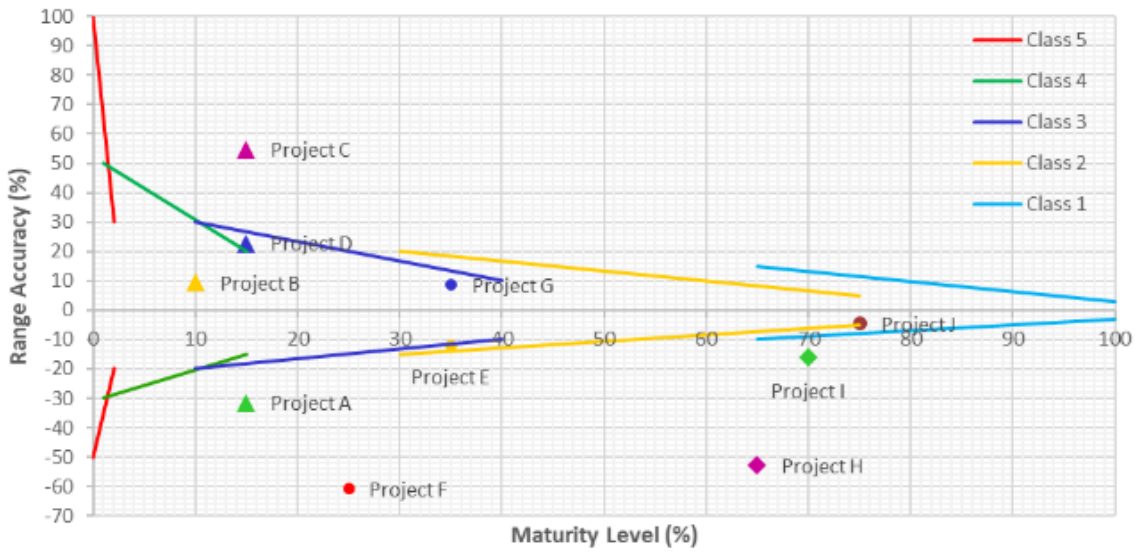


Figure 4 – Company Cost Range Accuracy[10,11]

[9] By Author
[10] By Author
[11] Department of Energy. (2011). Cost Estimating Guide.

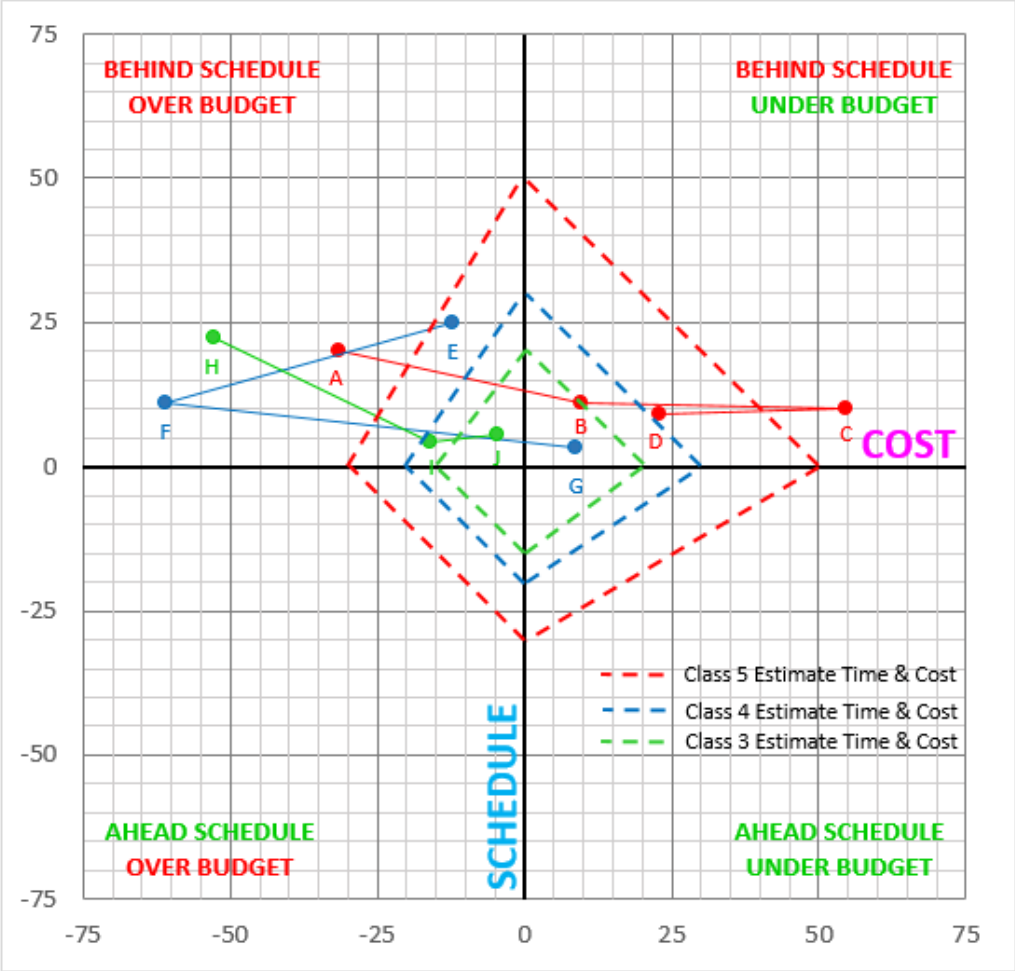


Figure 5 – Company Cost and Schedule Range Accuracy[12,13]

Figure 4 shows the accuracy of the project cost estimate compared to the range accuracy and project maturity level. In addition, the authors also show data that combines project performance in terms of cost and time in figure 5 compared to the range of accuracy for each estimated class. Both are the same data but with different appearances. Both of these images are intended to complement each other as in architectural drawings so that the resulting picture is complete.

The company needs to improve the accuracy and credibility of the cost estimate as per the author's findings. To fulfill the management's desire are for increased accuracy and credibility in cost estimates. There are several standards available to be assessed using Multi Attributes Decision Making and adopt for the purpose.

[12] By Author
[13] Giammalvo, Paul D (2015) Course Materials. Adapted from Adapted from Rizo, Chris (1999) "Precision, Accuracy and Reliability"

**Step 2- FEASIBLE ALTERNATIVES**

The alternatives selected to be assessed for this research are GAO Cost Estimating and Assessment Guide, GPC Compendium and Reference, TCM from AACE, PMBOK from PMI, and the Company Standard.

- **GAO Cost Estimating and Assessment Guide**
  "The reliable cost information is required and federal standards have been issued for the cost accounting that is needed to prepare that information. We developed the Cost Guide in order to establish a consistent methodology that is based on best practices, and that can be used across the federal government for developing, managing, and evaluating capital program cost estimates. For the purposes of this guide, a cost estimate is the summation of individual cost elements, using established methods and valid data, to estimate the future costs of a program, based on what is known today.

  The management of a cost estimate involves continually updating the estimate with actual data as they become available, revising the estimate to reflect changes, and analyzing differences between estimated and actual costs—for example, using data from a reliable earned value management (EVM) system."[14]

- **GPC Compendium and Reference**
  "This document has been designed to be a compilation of "best tested" and "proven practices" along with references and sample templates purposed for Project Control Practitioners operating in a global and pan-industry environment. This guide has been collated, organized, and proposed by an unparalleled array of experienced practitioners and comprises many pages of references. It serves as the Project Controls Compendium and Reference (CaR) with links to what Subject Matter Experts (SME) believe to be "best tested and proven" tools, techniques, and methodologies.

  This Guild of Project Controls Compendium and Reference (GPCCaR) has been created to serve the following purposes:
  1. To be used as a handy "Project Controls Reference"- a compendium of tools, techniques, methodologies, references, and templates developed by both owners and contractors, and;
  2. As the basis to prepare for one or more of the Guild of Project Controls certification exams, and;
  3. It provides standards to which practitioners are expected to adhere in order to be recognized by the Guild of Project Controls, and;

[14] The United States. Government Accountability Office. (2009). GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs. Washington, DC: Government Printing Office.

4. It also defines appropriate performance benchmarks and standards against which they would be measured and provides a tool for continued education and learning, and;
5. To be used in relation to Project Controls operations within any industry sector or global location."[15]

- **TCM from AACE**
  "Total cost management (TCM) is the effective application of professional and technical expertise to plan and control resources, costs, profitability, and risk. Simply stated, TCM is a systematic approach to managing cost throughout the life cycle of any enterprise, program, facility, project, product, or service. The TCM Framework is a representation of that systematic approach.

  The TCM Framework is a structured, annotated process map that explains each practice area of the cost engineering field in the context of its relationship to the other practice areas, including allied professions. It provides a process for applying the skills and knowledge of cost engineering. A key feature of the TCM Framework is that it highlights and differentiates the main cost management application areas: project control and strategic asset management."[16]

- **PMBOK from PMI**
  "PMI defines the project management body of knowledge (PMBOK) as a term that describes the knowledge within the profession of project management. The project management body of knowledge includes proven traditional practices that are widely applied as well as innovative practices that are emerging in the profession. The body of knowledge (BOK) includes both published and unpublished materials. This body of knowledge is constantly evolving. This PMBOK® Guide identifies a subset of the project management body of knowledge that is generally recognized as good practice.

  The Standard for Project Management is a foundational reference for PMI's project management professional development programs and the practice of project management. Because project management needs to be tailored to fit the needs of the project, the standard and the guide are both based on descriptive practices, rather than prescriptive practices. Therefore, the standard identifies the processes that are considered good practices on most projects most of the time."[17]

[15] Guild of Project Controls. (2015, October 3). GUILD of Project Control Compendium and Reference (CaR).
[16] Hollmann, J. K. (2006). Total Cost Management Framework: An Integrated Approach to Portfolio, Program, and Project Management (pp. 17-18). AACE International.
[17] Project Management Institute Project Management Institute. (2017). A Guide to the Project Management Body of Knowledge (PMBOK® Guide) — Sixth Edition and Agile Practice Guide (ENGLISH) (pp. 1-2). Newton Square, PA: Project Management Institute.

- **Company Standard**
  The specifications have been selected from the Company, which serves the guideline for developing the cost estimate.

**Step 3- DEVELOPMENT OF OUTCOMES**

For further analysis, the scoring attributes selected from GAO Best Practices Checklist to compare the alternative standards. Multi Attributes Decision Making (MADM) Non-Compensatory Model Dominance Method is used as a methodology to analyze the alternatives.

"Dominance is a useful screening method for eliminating inferior alternatives from the analysis. When one alternative is better than another with respect to all attributes, there is no problem in deciding between them. By comparing each possible pair of alternatives to determine whether the attribute values for one better than the other, it may be possible to eliminate one or more candidates from further consideration or even to select the single alternative that is clearly superior to all the others."[18]

The table showing detailed analysis of the non-compensatory model with scoring attributes from the GAO Best practices checklist is shown in the appendix. [19,20] The percentage at the attributes level is calculated by the ratio, as shown at the formula below.

$$\textbf{Attributes Percentage} = \frac{\textbf{Subtotal Attributes Score}}{\textbf{Total Alternatives Attributes Score}}$$

For the non-compensatory model analysis, it's clear that the GAO standard dominates all other selected alternatives. By this method of analysis, inferior alternatives shall be eliminated, and the most superior alternatives should be determined by adding the weighing technique.

[18] Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2014). Decision Making Considering Multiattributes. In Engineering Economy (16th ed., p. 580). Harlow, England: Pearson
[19] By Author
[20] Liu, J., Long, G., & Xu, X. (2017). A Method of Multi-attribute Decision Making Based On Basic Point and Weighting Coefficients Range. Procedia Computer Science, 107, 202-205.

| No. | Best Practices Checklist Associated Task | Alternatives | | | | |
|---|---|---|---|---|---|---|
| | | GAO | GPCCaR | AACE | PMI | Company |
| 1 | The Estimate | 10,77% | 10,77% | 9,23% | 7,08% | 2,46% |
| 2 | Purpose, Scope, and Schedule | 6,15% | 5,85% | 4,62% | 3,38% | 1,85% |
| 3 | Cost Assessment Team | 4,62% | 4,62% | 3,08% | 2,46% | 0,92% |
| 4 | Technical Baseline Description | 3,08% | 3,08% | 3,08% | 3,08% | 1,23% |
| 5 | Work Breakdown Structure (WBS) | 9,23% | 8,92% | 8,31% | 6,77% | 2,77% |
| 6 | Ground Rules and Assumptions | 6,15% | 5,54% | 4,00% | 3,69% | 0,62% |
| 7 | Data | 3,08% | 3,08% | 2,46% | 2,77% | 1,23% |
| 8 | Developing a Point Estimate | 6,15% | 4,92% | 3,08% | 2,46% | 0,62% |
| 9 | Estimating Software Costs | 6,15% | 0,00% | 0,00% | 0,00% | 0,62% |
| 10 | Sensitivity Analysis | 4,62% | 4,62% | 4,31% | 3,38% | 0,00% |
| 11 | Cost Risk and Uncertainty | 4,62% | 4,62% | 4,00% | 3,08% | 0,31% |
| 12 | Validating the Estimate | 6,15% | 6,15% | 5,85% | 4,92% | 1,23% |
| 13 | Documenting the Estimate | 3,08% | 2,46% | 2,46% | 2,46% | 0,92% |
| 14 | Presenting the Estimate to Management | 4,62% | 4,62% | 2,77% | 1,23% | 1,54% |
| 15 | Managing Program Costs: Planning | 7,69% | 7,69% | 7,08% | 2,46% | 0,00% |
| 16 | Managing Program Costs: Execution | 4,62% | 4,31% | 3,38% | 1,54% | 0,00% |
| 17 | Managing Program Costs: Updating | 9,23% | 8,92% | 7,69% | 5,54% | 0,31% |
| **TOTAL** | | **100,00%** | **90,15%** | **75,38%** | **56,31%** | **16,62%** |

Table 3 – Summary of Percentage Obtained in Each Attribute for All Alternatives[21]

### Step 4- SELECTION CRITERIA

The decision is based on the scoring attributes of alternatives standard. The highest score of alternatives will lead to the selection of the best standard for developing cost estimates. The criterion should serve to prepare accurate and credible, which equals or exceeds the standard requirements. The selection of feasible alternatives shall be made according to the scores obtained. The acceptance criteria for the alternatives are 50%. According to the scores obtained, the GAO, GPCCaR, AACE, and PMI will be further analyzed.

## FINDINGS

### Step 5- ANALYSIS AND COMPARISON OF ALTERNATIVES

For further analysis, the technique used is adding a weighting method. "Attributes weights should be determined in two steps following the completion of ordinal ranking. First, relative weights are assigned to each attribute according to its ordinal ranking. The second step is to normalize the relative ranking numbers by dividing each ranking number by the sum of all the

[21] By Author

rankings. It's a single-dimensional method since it includes performance ratings and importance weights of each attribute when evaluating alternatives."[22]

| No. | Best Practices Checklist Associated Task | Alternatives | | | | Relative Rank | Normalized Weight | Alternatives | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | GAO | GPCCaR | AACE | PMI | | | GAO | GPCCaR | AACE | PMI |
| 1 | The Estimate | 10,77% | 10,77% | 9,23% | 7,08% | 17 | 0,111 | 1,1966 | 1,1966 | 1,0256 | 0,7863 |
| 5 | Work Breakdown Structure (WBS) | 9,23% | 8,92% | 8,31% | 6,77% | 16 | 0,105 | 0,9653 | 0,9331 | 0,8688 | 0,7079 |
| 17 | Managing Program Costs: Updating | 9,23% | 8,92% | 7,69% | 5,54% | 15 | 0,098 | 0,9050 | 0,8748 | 0,7541 | 0,5430 |
| 15 | Managing Program Costs: Planning | 7,69% | 7,69% | 7,08% | 2,46% | 14 | 0,092 | 0,7039 | 0,7039 | 0,6476 | 0,2252 |
| 2 | Purpose, Scope, and Schedule | 6,15% | 5,85% | 4,62% | 3,38% | 13 | 0,085 | 0,5229 | 0,4967 | 0,3922 | 0,2876 |
| 6 | Ground Rules and Assumptions | 6,15% | 5,54% | 4,00% | 3,69% | 12 | 0,078 | 0,4827 | 0,4344 | 0,3137 | 0,2896 |
| 8 | Developing a Point Estimate | 6,15% | 4,92% | 3,08% | 2,46% | 11 | 0,072 | 0,4424 | 0,3539 | 0,2212 | 0,1770 |
| 9 | Estimating Software Costs | 6,15% | 0,00% | 0,00% | 0,00% | 10 | 0,065 | 0,4022 | 0,0000 | 0,0000 | 0,0000 |
| 12 | Validating the Estimate | 6,15% | 6,15% | 5,85% | 4,92% | 9 | 0,059 | 0,3620 | 0,3620 | 0,3439 | 0,2896 |
| 3 | Cost Assessment Team | 4,62% | 4,62% | 3,08% | 2,46% | 8 | 0,052 | 0,2413 | 0,2413 | 0,1609 | 0,1287 |
| 10 | Sensitivity Analysis | 4,62% | 4,62% | 4,31% | 3,38% | 7 | 0,046 | 0,2112 | 0,2112 | 0,1971 | 0,1549 |
| 11 | Cost Risk and Uncertainty | 4,62% | 4,62% | 4,00% | 3,08% | 6 | 0,039 | 0,1810 | 0,1810 | 0,1569 | 0,1207 |
| 14 | Presenting the Estimate to Management | 4,62% | 4,62% | 2,77% | 1,23% | 5 | 0,033 | 0,1508 | 0,1508 | 0,0905 | 0,0402 |
| 16 | Managing Program Costs: Execution | 4,62% | 4,31% | 3,38% | 1,54% | 4 | 0,026 | 0,1207 | 0,1126 | 0,0885 | 0,0402 |
| 4 | Technical Baseline Description | 3,08% | 3,08% | 3,08% | 3,08% | 3 | 0,020 | 0,0603 | 0,0603 | 0,0603 | 0,0603 |
| 7 | Data | 3,08% | 3,08% | 2,46% | 2,77% | 2 | 0,013 | 0,0402 | 0,0402 | 0,0322 | 0,0362 |
| 13 | Documenting the Estimate | 3,08% | 2,46% | 2,46% | 2,46% | 1 | 0,007 | 0,0201 | 0,0161 | 0,0161 | 0,0161 |
| TOTAL | | 100,00% | 90,15% | 75,38% | 56,31% | 153 | 1,000 | 7,0085 | 6,3690 | 5,3695 | 3,9035 |

Table 4 – Compensatory Single Dimensional Method for Analysis of the Selected Alternatives[23,24]

By using adding weighting technique[25] steps as follows.

- Add up the total of the relative rank of all attributes.
- Normalize the weighing of each attribute and give a perfect score 1,00.
- Scores of each alternative obtained product of the attributes' percentage in alternatives and normalized weight.

[22] Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2014). Decision Making Considering Multiattributes. In Engineering Economy (16th ed., p. 587). Harlow, England: Pearson
[23] By Author
[24] Decision-Making, Multi-Attribute. (n.d.). SpringerReference.
[25] Guild of Project Controls. (2015, October 3). GUILD of Project Control Compendium and Reference (CaR).

From this analysis, GAO scores 7,0085, which scores first among the other alternatives, and GPCCAR scores 6,3690 maintains the second position.

### Step 6- SELECTION OF PREFERRED ALTERNATIVES

From additive weighting technique analysis to select the best alternative among the selected alternatives, GAO Cost Estimating and Assessment Guide can be selected as the best alternative standards. This selected standard shall be used for the preparation of accurate and credible cost estimates for measuring accuracy against the standard range of error. It could be used as a checklist for evaluating the appropriateness of the cost estimating process.

### Step 7- PERFORMANCE MONITORING

From the GAO Cost Estimating and Assessment Guide, the associated task in the GAO checklist need to be considered for the company when preparing the cost estimates. From the GAO Cost Estimation and Assessment Guide, related tasks in the GAO checklist need to be considered by the company when preparing cost estimates. The improvement effort can be started from the biggest gap between the company and GAO, as shown in the Pareto chart below. The next monitoring can be done by re-assessment of what the company improvement has done with GAO.

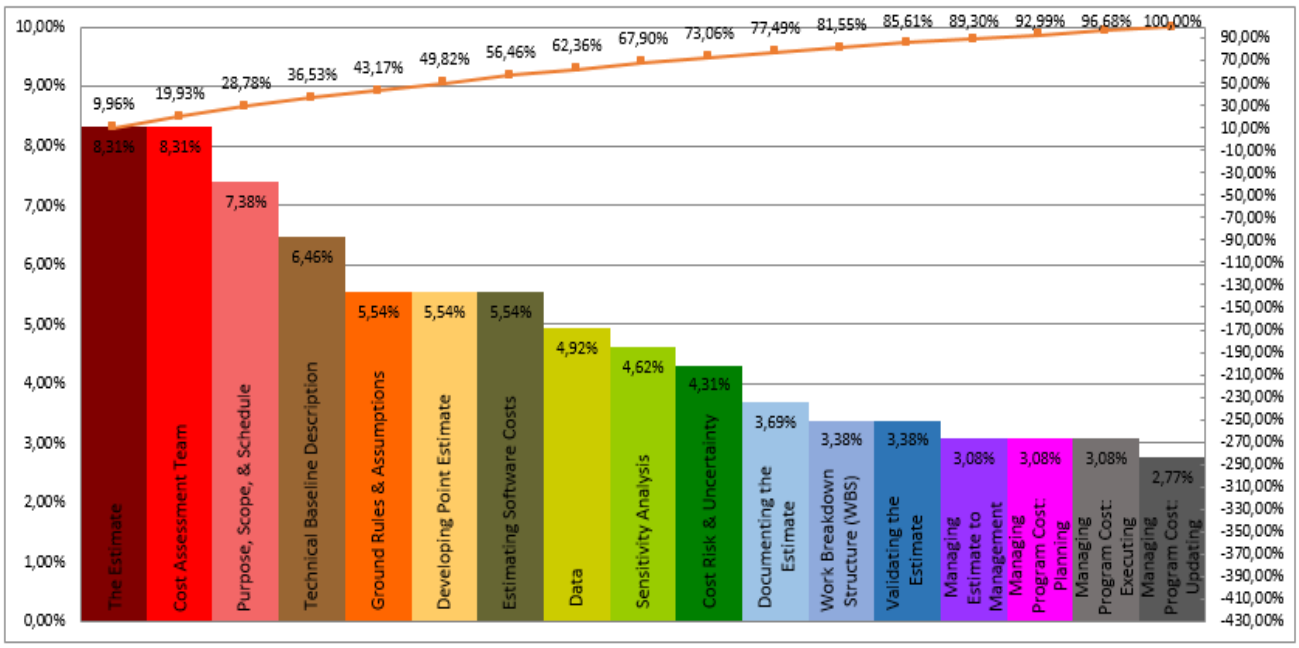


Figure 6 – Company Cost and Schedule Range Accuracy[26]

[26] By Author

## CONCLUSIONS & RECOMMENDATIONS

The objectives of this paper were to answers for the below-mentioned questions:

- How can we rate the GAO standard for best cost estimating practices among other standards?
  Referring to the results of the analysis using non-compensatory and compensatory Multi-Attributes Decision Making (MADM) shows clear results that GAO is the "best tested and proven" standard compared to other standards for cost estimating.

- What are the best practices in cost estimating to be followed by the company?
  The GAO Cost Estimating and Assessment Guide has covered all the best practices for the company's needs in conducting the cost estimates, as shown in the twelve steps of high-quality cost estimating process and best practices checklist to meet the basic characteristics of credible cost estimates.

  The improvement effort can be started from the biggest gap between the company and GAO, as shown in the Pareto chart in Figure 6. Based on the Pareto diagram shown above, which shows the gap between company vs. GAO. The company is recommended to improve its cost estimating method using the 80/20 rule[27] and then reassess against the GAO. The process is carried out continuously until management is satisfied with the results.

- How do the checklist recommendations that companies must follow for improvement refer to this benchmarking?
  As stated in answer to the second research question, that improvements will be made by referring to the 80/20 rule. The improvement effort can be started from the biggest gap between the company and GAO, as shown in the Pareto chart in Figure 6. In this study, the author also tried to make a checklist for cost estimators in the company, as presented in Appendix III.

  Pilot use checklist for both normal and non-normal operations (routine situations, for malfunctions, and for emergencies)[28]. The author also tries to make a checklist that adopts from the world of aviation in an effort to achieve a credible and accurate cost estimate in the company.[29,30]

[27] Rispoli, F. J., Zeng, S., Green, T., & Higbie, J. (2014). Even birds follow Pareto's 80-20 rule. Significance, 11(1), 37-38. doi:10.1111/j.1740-9713.2014.00725.x
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## FOLLOW ON RESEARCH

The study related to the "best-tested and proven" practice adaptation for companies needs to be developed with adjustments to the company's business processes. The method of making estimates is also an important factor that determines the credible and accurate estimation results for companies, the study of determining estimation methods and factors relevant to the company's business processes need to be developed.

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## APPENDICES

### Appendix I: GAO Cost Estimating and Assessment Guide Best Practices Checklist

| No. | Associated Task | Alternatives | | | | |
|---|---|---|---|---|---|---|
| | | GAO | GPCCaR | AACE | PMI | Company |
| | **The Estimate** | | | | | |
| 1 | The cost estimate type is clearly defined and is appropriate for its purpose. | 5 | 5 | 5 | 3 | 2 |
| | The cost estimate contains all elements suitable to its type—ICA, ICE, IGCE, LCCE, rough order of magnitude, total ownership cost: development, procurement, operating and support, disposal costs, and all sunk costs. | 5 | 5 | 3 | 3 | 0 |
| | All program costs have been estimated, including all life-cycle costs. | 5 | 5 | 5 | 2 | 1 |
| | The cost estimate is independent of funding source and appropriations. | 5 | 5 | 5 | 5 | 3 |
| | An affordability analysis has been performed at the agency level to see how the program fits within the overall portfolio.<br>- The agency has a process for developing cost estimates that includes the 12-step best practice process outlined in chapter 1.<br>- An overall agency portfolio sand chart displays all costs for every program. | 5 | 5 | 4 | 3 | 1 |
| | The estimate is updated as actual costs become available from the EVM system or requirements change. | 5 | 5 | 5 | 4 | 0 |
| | Post mortems and lessons learned are continually documented. | 5 | 5 | 3 | 3 | 1 |
| | **Subtotal of The Estimate** | 35 | 35 | 30 | 23 | 8 |
| | **Percentage of The Estimate** | 10,77% | 10,77% | 9,23% | 7,08% | 2,46% |
| | **Purpose, Scope, and Schedule** | | | | | |
| 2 | The estimate's purpose is clearly defined. | 5 | 5 | 5 | 3 | 3 |
| | Its scope is clearly defined. | 5 | 5 | 5 | 5 | 2 |
| | The level of detail the estimate is to be conducted at is consistent with the level of detail available for the program. For example, an engineering buildup estimate should be conducted only on a well-defined program. | 5 | 4 | 3 | 1 | 1 |
| | The team has been allotted adequate time and resources to develop the estimate. | 5 | 5 | 2 | 2 | 0 |
| | **Subtotal of Purpose, Scope, and Schedule** | 20 | 19 | 15 | 11 | 6 |
| | **Percentage of Purpose, Scope, and Schedule** | 6,15% | 5,85% | 4,62% | 3,38% | 1,85% |
| | **Cost Assessment Team** | | | | | |
| 3 | The estimating team's composition is commensurate with the assignment:<br>- The team has the proper number and mix of resources.<br>- Team members are from a centralized cost estimating organization.<br>- The team includes experienced and trained cost analysts.<br>- The team includes, or has direct access to, analysts experienced in the program's major areas.<br>- Team members' responsibilities are clearly defined.<br>- Team members' experience, qualifications, certifications, and training are identified.<br>- The team participated in on-the-job training, including plant and site visits. | 5 | 5 | 2 | 2 | 1 |
| | A master schedule with a written study plan has been developed. | 5 | 5 | 5 | 5 | 1 |
| | The team has access to the necessary subject matter experts. | 5 | 5 | 3 | 1 | 1 |
| | **Subtotal of Cost Assessment Team** | 15 | 15 | 10 | 8 | 3 |
| | **Percentage of Cost Assessment Team** | 4,62% | 4,62% | 3,08% | 2,46% | 0,92% |
| | **Technical Baseline Description** | | | | | |
| 4 | There is a technical baseline:<br>- The technical baseline has been developed by qualified personnel such as system engineers.<br>- It has been updated with technical, program, and schedule changes, and it contains sufficient detail of the best available information at any given time.<br>- The information in the technical baseline generally drives the cost estimate and the cost estimating methodology.<br>- The cost estimate is based on information in the technical baseline and has been approved by management. | 5 | 5 | 5 | 5 | 1 |
| | The technical baseline answers the following:<br>- What the program is supposed to do—requirements;<br>- How the program will fulfill its mission—purpose;<br>- What it will look like—technical characteristics;<br>- Where and how the program will be built—development plan;<br>- How the program will be acquired—acquisition strategy;<br>- How the program will operate—operational plan;<br>- Which characteristics affect cost the most—risk. | 5 | 5 | 5 | 5 | 3 |
| | **Subtotal of Technical Baseline Description** | 10 | 10 | 10 | 10 | 4 |
| | **Percentage of Technical Baseline Description** | 3,08% | 3,08% | 3,08% | 3,08% | 1,23% |
| | **Work Breakdown Structure (WBS)** | | | | | |
| 5 | A product-oriented WBS represents best practice. | 5 | 5 | 5 | 2 | 3 |
| | It reflects the program work that needs to be done. It<br>- clearly outlines the end product and major work for the program;<br>- contains at least 3 levels of indenture;<br>- is flexible and tailored to the program. | 5 | 5 | 4 | 4 | 0 |
| | The 100 percent rule applies: the sum of the children equals the parent.<br>- The WBS defines all work packages, which in turn include all cost elements and deliverables.<br>- In addition to hardware and software elements, the WBS contains program management and other common elements to make sure all the work is covered. | 5 | 5 | 5 | 5 | 0 |
| | Each system has one program WBS but may have several contract WBS's that are extended from the program WBS, depending on the number of subcontractors. | 5 | 5 | 3 | 3 | 0 |
| | The WBS is standardized so that cost data can be collected and used for estimating future programs. It<br>- facilitates portfolio management, including lessons learned;<br>- matches schedule, cost estimate, and EVM at a high level;<br>- is updated as changes occur and the program becomes better defined;<br>- includes functional activities within each element that are needed to support each product deliverable;<br>- is the starting point for developing the program's detailed schedule;<br>- provides a framework for identifying and monitoring risks and the effectiveness of contingency plans;<br>- provides for a common language between the government program management office, technical specialists, prime contractors, and subcontractors. | 5 | 4 | 5 | 3 | 3 |

| No. | Associated Task | Alternatives | | | | |
|---|---|---|---|---|---|---|
| | | GAO | GPCCaR | AACE | PMI | Company |
| | The WBS has a dictionary that:<br>- defines each element and how it relates to others in the hierarchy;<br>- clearly describes what is included in each element;<br>- describes resources and functional activities needed to produce the element product;<br>- links each element to other relevant technical documents. | 5 | 5 | 5 | 5 | 3 |
| | **Subtotal of Work Breakdown Structure (WBS)** | 30 | 29 | 27 | 22 | 9 |
| | **Percentage of Work Breakdown Structure (WBS)** | 9,23% | 8,92% | 8,31% | 6,77% | 2,77% |
| 6 | All ground rules and assumptions have been:<br>- Developed by estimators with input from the technical community.<br>- Based on information in the technical baseline and WBS dictionary.<br>- Vetted and approved by upper management.<br>- Documented to include the rationale behind the assumptions and historical data to back up any claims.<br>- Accompanied by a level of risk of each assumption's failing and its effect on the estimate. | 5 | 5 | 5 | 5 | 1 |
| | To mitigate risk,<br>- All GR&As have been placed in a single spreadsheet tab so that risk and sensitivity analysis can be performed quickly and efficiently.<br>- All potential risks including cost, schedule, technical, and programmatic (e.g., risks associated with budget and funding, start up activities, staffing, and organizational issues) have been identified and traced to specific WBS elements.<br>i. A schedule risk analysis has been performed to determine the program schedule's realism.<br>ii. A cost risk analysis, incorporating the results of the schedule risk analysis, has been performed to determine the program's cost estimate realism. | 5 | 5 | 5 | 4 | 0 |
| | Budget constraints, as well as the effect of delaying program content, have been defined.<br>- Peaks and valleys in time-phased budgets have been explained.<br>- Inflation index, source, and approval authority have been identified.<br>- Dependence on participating agencies, the availability of government furnished equipment, and the effects if these assumptions do not hold have been identified.<br>- Items excluded from the estimate have been documented and explained.<br>- Technology was mature before it was included; if its maturity was assumed, the estimate addresses the effect of the assumption's failure on cost and schedule. | 5 | 5 | 3 | 3 | 1 |
| | Cost estimators and auditors met with technical staff to determine risk distributions for all assumptions; the distributions were used in sensitivity and uncertainty analyses of the effects of invalid assumptions. Management has been briefed, and the results have been documented. | 5 | 3 | 0 | 0 | 0 |
| | **Subtotal of Ground Rules and Assumptions** | 20 | 18 | 13 | 12 | 2 |
| | **Percentage of Ground Rules and Assumptions** | 6,15% | 5,54% | 4,00% | 3,69% | 0,62% |
| | **Data** | | | | | |
| 7 | As the foundation of an estimate, data:<br>- Have been gathered from historical actual cost, schedule and program, and technical sources;<br>- Apply to the program being estimated;<br>- Have been analyzed for cost drivers;<br>- Have been collected from primary sources, if possible, and secondary sources as the next best option, especially for cross-checking results;<br>- Have been adequately documented as to source, content, time, units, assessment of accuracy and reliability, and circumstances affecting the data;<br>- Have been continually collected, protected, and stored for future use;<br>- Were assembled as early as possible, so analysts can participate in site visits to understand the program and question data providers. | 5 | 5 | 4 | 4 | 3 |
| | Before being used in a cost estimate, the data were:<br>- Fully reviewed to understand their limitations and risks;<br>- Segregated into nonrecurring and recurring costs;<br>- Validated, using historical data as a benchmark for reasonableness;<br>- Current and found applicable to the program being estimated;<br>- Analyzed with a scatter plot to determine trends and outliers;<br>- Analyzed with descriptive statistics;<br>- Normalized to account for cost and sizing units, mission or application, technology maturity, and content so they are consistent for comparisons;<br>- Normalized to constant base-year dollars to remove the effects of inflation, and the inflation index was documented and explained. | 5 | 5 | 4 | 5 | 1 |
| | **Subtotal of Data** | 10 | 10 | 8 | 9 | 4 |
| | **Percentage of Data** | 3,08% | 3,08% | 2,46% | 2,77% | 1,23% |
| | **Developing a Point Estimate** | | | | | |
| | The cost estimator considered various cost estimating methods:<br>- Analogy, early in the life cycle, when little was known about the system being developed:<br>i. Adjustments were based on program information, physical and performance characteristics, contract type.<br>- Expert opinion, very early in the life cycle, if an estimate could be derived no other way.<br>- The build-up method later, in acquisition, when the scope of work was well defined and a complete WBS could be determined.<br>- Parametrics, if a database of sufficient size, quality, and homogeneity was available for developing valid CERs and the data were normalized correctly.<br>i. Parametric models were calibrated and validated using historical data.<br>- Extrapolating from actual cost data, at the start of production. | 5 | 5 | 5 | 3 | 1 |

| No. | Associated Task | Alternatives | | | | |
|---|---|---|---|---|---|---|
| | | GAO | GPCCaR | AACE | PMI | Company |
| 8 | Cost estimating relationships were considered:<br>- Statistical techniques were used to develop CERs:<br>i. Higher R-squared;<br>- Statistical significance, for determining the validity of statistical relationships;<br>i. Significance levels of F and t statistics.<br>- Before using a CER, the cost estimator:<br>i. Examined the underlying data set to understand anomalies;<br>ii. Checked equations to ensure logical relationships;<br>iii. Normalized the data;<br>iv. Ensured that CER inputs were within the valid dataset range;<br>v. Checked modeling assumptions to ensure they applied to the program.<br>- Learning curve theory was applied if:<br>i. Much manual labor was required for production;<br>ii. Production was continuous or adjustments had to be made;<br>iii. Items to be produced required complex processes;<br>iv. Technological change was minimal between production lots;<br>v. The contractor's business process was being continually improved. | 5 | 3 | 1 | 3 | 0 |
| | Production rate and breaks in production were considered. | 5 | 4 | 0 | 0 | 0 |
| | The point estimate was developed by aggregating the WBS element cost estimates by one of the cost estimating methods.<br>i. Results were checked for accuracy, double-counting, and omissions and were validated with cross-checks and independent cost estimates. | 5 | 4 | 4 | 2 | 1 |
| | **Subtotal of Developing a Point Estimate** | 20 | 16 | 10 | 8 | 2 |
| | **Percentage of Developing a Point Estimate** | 6,15% | 4,92% | 3,08% | 2,46% | 0,62% |
| | **Estimating Software Costs** | | | | | |
| 9 | The software cost estimate followed the 12-step estimating process:<br>- Software was sized with detailed knowledge of program scope, complexity, and interactions, and the cost estimators worked with software engineers to determine the appropriate sizing metric.<br>- It was sized with source lines of code, function, object, feature point, or other counts. | 5 | 0 | 0 | 0 | 1 |
| | The software sizing method was appropriate:<br>- Source lines of code were used if requirements were well defined and if there was a historical database of code counts for similar programs and a standard definition for a line of code.<br>- Function points were used if detailed requirements and specifications were available, software did not contain many algorithmic functions, and an experienced and certified function point counter was available.<br>- COSMIC points were used if functional user requirements are known and the application is for business, real-time, embedded, or infrastructure software.<br>- Object points were used if computer-aided software engineering tools were used to develop the software.<br>- Reports, interfaces, conversions, extensions and forms / workflow were used for ERP programs.<br>- Use cases and use case points were used if system and user interactions were defined.<br>- Autogenerated and reused source lines of code were identified separately from new and modified code to account for pre- and postimplementation efforts.<br>- Several methods were used to size the software to increase the accuracy of the sizing estimate.<br>- The final software size was adjusted for growth based on historical data, and growth is continually monitored over time. | 5 | 0 | 0 | 0 | 0 |
| | Software cost estimates included:<br>- Development labor costs for coding and testing, other labor supporting software development, and nonlabor costs like purchasing hardware and licenses.<br>- Productivity factors for converting software size into labor effort, based on historical data and calibrated to match program size and development environment.<br>- Industry average productivity factors and risk ranges, if no historical data were available.<br>- Assumptions about productive labor hours in a day and work days in a year.<br>- Development schedules accounting for staff availability, prior task dependencies, concurrent and critical path activities, number and length of shifts, overtime allowance, down time, and worker locations.<br>- Costs for help desk support, database development, and corrective, adaptive, and preventive maintenance as part of the software's life cycle cost.<br>- Time and effort associated with rework to fix defects.<br>- Training cost estimators to calibrate parametric tools to match the program and model results cross-checking for accuracy.<br>- Estimators' accounting for integrating commercial off-the-shelf software into the system, including developing custom software and glue-code.<br>- Impact of risks facing ERP system implementations as outlined in table 18.<br>- Costs associated with interfacing bolt-on applications for ERP systems. | 5 | 0 | 0 | 0 | 1 |
| | IT infrastructure and services components of the software cost estimate included:<br>- Costs associated with the physical attributes of the IT infrastructure, the performance and complexity requirements, and economic considerations.<br>- Impact of risks affecting IT infrastructure, as outlined in table 19.<br>- Costs associated with labor and material nonrecurring and recurring efforts. | 5 | 0 | 0 | 0 | 0 |
| | **Subtotal of Estimating Software Costs** | 20 | 0 | 0 | 0 | 2 |
| | **Percentage of Estimating Software Costs** | 6,15% | 0,00% | 0,00% | 0,00% | 0,62% |

| No. | Associated Task | Alternatives | | | | |
|---|---|---|---|---|---|---|
| | | GAO | GPCCaR | AACE | PMI | Company |
| | **Sensitivity Analysis** | | | | | |
| 10 | The cost estimate was accompanied by a sensitivity analysis that identified the effects of changing key cost driver assumption and factors.<br>- Well-documented sources supported the assumption or factor ranges.<br>- The sensitivity analysis was part of a quantitative risk assessment and not based on arbitrary plus or minus percentages.<br>- Cost-sensitive assumptions and factors were further examined to see whether design changes should be implemented to mitigate risk.<br>- Sensitivity analysis was used to create a range of best and worst case costs.<br>- Assumptions and performance characteristics listed in the technical baseline description and GR&As were tested for sensitivity, especially those least understood or at risk of changing.<br>- Results were well documented and presented to management for decisions. | 5 | 5 | 4 | 3 | 0 |
| | The following steps were taken during the sensitivity analysis:<br>- Key cost drivers were identified.<br>- Cost elements representing the highest percentage of cost were determined and their parameters and assumptions were examined.<br>- The total cost was reestimated by varying each parameter between its minimum and maximum range.<br>- Results were documented and the reestimate was repeated for each parameter that was a key cost driver.<br>- Outcomes were evaluated for parameters most sensitive to change. | 5 | 5 | 5 | 5 | 0 |
| | The sensitivity analysis provided a range of possible costs, a point estimate, and a method for performing what-if analysis. | 5 | 5 | 5 | 3 | 0 |
| | **Subtotal of Sensitivity Analysis** | 15 | 15 | 14 | 11 | 0 |
| | **Percentage of Sensitivity Analysis** | 4,62% | 4,62% | 4,31% | 3,38% | 0,00% |
| | **Cost Risk and Uncertainty** | | | | | |
| 11 | A risk and uncertainty analysis quantified the imperfectly understood risks that are in the program and identified the effects of changing key cost driver assumptions and factors.<br>- Management was given a range of possible costs and the level of certainty in achieving the point estimate.<br>- A risk adjusted estimate that reflects the program's risks was determined.<br>- A cumulative probability density function, an S curve, mapped various cost estimates to a certain probability level and defensible contingency reserves were developed.<br>- Periodic risk and uncertainty analysis was conducted to improve estimate uncertainty. | 5 | 5 | 5 | 5 | 1 |
| | The following steps were taken in performing an uncertainty analysis:<br>- Program cost drivers and associated risks were determined, including those related to changing requirements, cost estimating errors, business or economic uncertainty, and technology, schedule, program, and software uncertainty.<br>i. All risks were documented for source, data quality and availability, and probability and consequence.<br>ii. Risks were collected from staff within and outside the program to counter optimism.<br>iii. Uncertainty was determined by cost growth factor, expert opinion (adjusted to consider a wider range of risks), statistics and Monte Carlo simulation, technology readiness levels, software engineering maturity models and risk evaluation methods, schedule risk analysis, risk cube (P-I matrix) method, or risk scoring.<br>- A probability distribution modeled each cost element's uncertainty based on data availability, reliability, and variability.<br>i. A range of values and their respective probabilities were determined either based on statistics or expressed as 3-point estimates (best case, most likely, and worst case), and rationale for choosing which method was discussed.<br>ii. Documentation of the rationale for choosing the probability distributions should be provided.<br>iii. Probability distribution reflects the risk shape and the tails of the distribution reflect the best and worst case spread as well as any skewness. Distribution bounds were adjusted to account for stakeholder bias using organization default values when data specific to the program are not available.<br>iv. If the risk driver approach is used, the data collected, including probability of occurrence and impact, were applied to the risks themselves.<br>v. Prediction interval statistical analysis was used for CER distribution bounds.<br>- The correlation between cost elements was accounted for to capture risk.<br>i. The correlation ensures that related cost elements move together during the simulation, resulting in reinforcement of the risks.<br>ii. Cost estimators examined the amount of correlation already existing in the model. If no correlation is present, an insertion of 0.25 correlation was added.<br>- A Monte Carlo simulation model was used to develop a distribution of total possible costs and an S curve showing alternative cost estimate probabilities.<br>i. High-priority risks were examined and identified for risk mitigation.<br>ii. Strength of correlated cost elements were examined and additional correlation added if necessary to account for risk.<br>- The probability associated with the point estimate was identified.<br>- Contingency reserves were recommended for achieving the desired confidence level.<br>i. The mean of the distribution tends to fall around the 55%–65% confidence level because the total cost distribution follows a lognormal trend (i.e., tendency to overrun rather than underrun costs).<br>ii. Budgeting to at least the mean of the distribution or higher is necessary to guard | 5 | 5 | 3 | 2 | 0 |

| No. | Associated Task | Alternatives | | | | |
|---|---|---|---|---|---|---|
| | | GAO | GPCCaR | AACE | PMI | Company |
| | - Contingency reserves were recommended for achieving the desired confidence level.<br>i. The mean of the distribution tends to fall around the 55%–65% confidence level because the total cost distribution follows a lognormal trend (i.e., tendency to overrun rather than underrun costs).<br>ii. Budgeting to at least the mean of the distribution or higher is necessary to guard against potential risk.<br>iii. The cost risk and uncertainty results were vetted through a core group of experts to ensure that the proper steps were followed.<br>iv. The estimate is continually updated with actual costs and any variances recorded to identify areas where estimating was difficult or sources of risks were not considered.<br>- The risk-adjusted cost estimate was allocated, phased, and converted to thenyear dollars for budgeting, and high-risk elements were identified to mitigate risks.<br>i. Results from the uncertainty analysis were used to prioritize risks based on probability and impacts as they affected the cost estimate. | | | | | |
| | A risk management plan was implemented jointly with the contractor to identify and analyze risk, plan for risk mitigation, and continually track risk.<br>- A risk database watch list was developed, and a contractor's EVM system was used for root cause analysis of cost and schedule variances, monitoring worsening trends, and providing early risk warning.<br>- Event-driven reviews, technology demonstrations, modeling and simulation, and risk-mitigation prototyping were implemented. | 5 | 5 | 5 | 3 | 0 |
| | **Subtotal of Cost Risk and Uncertainty** | **15** | **15** | **13** | **10** | **1** |
| | **Percentage of Cost Risk and Uncertainty** | **4,62%** | **4,62%** | **4,00%** | **3,08%** | **0,31%** |
| | **Estimates Againts Four Characteristics** | | | | | |
| 12 | It is comprehensive, includes all possible costs, ensures that no costs were omitted or double-counted, and explains and documents key assumptions.<br>- It completely defines the program, reflects the current schedule, and contains technically reasonable assumptions.<br>- It captures the complete technical scope of the work to be performed, using a logical WBS that accounts for all performance criteria and requirements. | 5 | 5 | 5 | 5 | 2 |
| | It was documented so well that it can easily be repeated or updated and traced to original sources by auditing.<br>- Supporting documentation identifies data sources, justifies all assumptions, and describes all estimating methods (including relationships) for all WBS elements.<br>- Schedule milestones and deliverables can be traced and are consistent with the documentation. | 5 | 5 | 4 | 3 | 1 |
| | It is accurate, not too conservative or too optimistic; is based on an assessment of most likely costs, adjusted properly for inflation; and contains few minor mistakes.<br>- WBS estimates were checked to verify that calculations were accurate and accounted for all costs and that proper escalation factors were used to inflate costs so they were expressed consistently and accurately.<br>- Questions associated with estimating techniques were answered to determine the estimate's accuracy.<br>- CERs and parametric cost models were validated to ensure that they were good predictors of costs, their data were current and applied to the program, the relationships between technical parameters were logical and statistically significant, and results were tested with independent data. | 5 | 5 | 5 | 3 | 1 |
| | Data limitations from uncertainty or bias were identified; results were crosschecked; an ICE was developed to see if results were similar.<br>- Major assumptions were varied and other outcomes recomputed to determine their sensitivity to changes in the assumptions.<br>- Risk and uncertainty analysis was conducted. | 5 | 5 | 5 | 5 | 0 |
| | **Subtotal of Validating the Estimates Against Four Characteristics** | **20** | **20** | **19** | **16** | **4** |
| | **Percentage of Validating the Estimates Against Four Characteristics** | **6,15%** | **6,15%** | **5,85%** | **4,92%** | **1,23%** |
| | **Documenting the Estimate** | | | | | |
| 13 | The documentation describes the cost estimating process, data sources, and methods step by step so that a cost analyst unfamiliar with the program could understand what was done and replicate it.<br>- Supporting data are adequate for easily updating the estimate to reflect actual costs or program changes and using them for future estimates.<br>- The documentation describes the estimate with narrative and cost tables.<br>- It contains an executive summary, introduction, and descriptions of methods, with data broken out by WBS cost elements, sensitivity analysis, risk and uncertainty analysis, management approval, and updates that reflect actual costs and changes.<br>- Detail addresses best practices and the 12 steps of high-quality estimates.<br>- The documentation is mathematically sensible and logical.<br>- It discusses contingency reserves and how they were derived from risk and uncertainty analysis and the LCCE funding profile. | 5 | 3 | 3 | 3 | 1 |
| | It includes access to an electronic copy, and both are stored so that authorized personnel can easily find and use them for other cost estimates. | 5 | 5 | 5 | 5 | 2 |
| | **Subtotal of Documenting the Estimate** | **10** | **8** | **8** | **8** | **3** |
| | **Percentage of Documenting the Estimate** | **3,08%** | **2,46%** | **2,46%** | **2,46%** | **0,92%** |
| | **Presenting the Estimate to Management** | | | | | |
| | The briefing to management:<br>- was simple, clear, and concise enough to convey its level of competence.<br>- illustrated the largest cost drivers, presenting them logically, with backup charts for responding to more probing questions.<br>- was consistent, allowing management to focus on the estimate's content. | 5 | 5 | 3 | 1 | 1 |

| No. | Associated Task | Alternatives | | | | |
|---|---|---|---|---|---|---|
| | | GAO | GPCCaR | AACE | PMI | Company |
| 14 | The briefing contained:<br>- A title page, outline, and brief statement of purpose of the estimate.<br>- An overview of the program's technical foundation and objectives.<br>- LCCE results in time-phased constant-year dollars, tracked to previous estimates.<br>- A discussion of GR&As<br>- The method and process for each WBS cost element, with estimating techniques and data sources.<br>- The results of sensitivity analysis and cost drivers that were identified.<br>- The results of risk and uncertainty analysis with confidence interval, S curve analysis, and bounds and distributions.<br>- The comparison of the point estimate to an ICE with discussion of differences and whether the point estimate was reasonable.<br>- An affordability analysis based on funding and contingency reserves.<br>- Discussion of any other concerns or challenges<br>- Conclusions and recommendations. | 5 | 5 | 3 | 2 | 1 |
| | Feedback from the briefing, including management's acceptance of the estimate, was acted on and recorded in the cost estimate documentation. | 5 | 5 | 3 | 1 | 3 |
| | **Subtotal of Presenting the Estimate to Management** | **15** | **15** | **9** | **4** | **5** |
| | **Percentage of Presenting the Estimate to Management** | **4,62%** | **4,62%** | **2,77%** | **1,23%** | **1,54%** |
| | **Managing Program Cost: Planning** | | | | | |
| 15 | A cost estimate was used to measure performance against the original plan, using EVM. | 5 | 5 | 4 | 1 | 0 |
| | EVM and risk management were tightly integrated to ensure better program outcomes.<br>- Strong leadership demands EVM be used to manage programs.<br>- Stakeholders make it clear that EVM matters and hold staff accountable for results.<br>- Management is willing to hear the truth about programs and relies on EVM data to make decisions on how to mitigate risk.<br>- Policy outlines clear expectations for EVM as a disciplined management tool and requires pertinent staff to be continuously trained in cost estimating, scheduling, EVM, and risk and uncertainty analysis. | 5 | 5 | 5 | 1 | 0 |
| | EVM is implemented at the program level so that both government and contractor know what is expected and are held accountable.<br>- EVM relied on the cost of completed work to determine true program status.<br>- EVM planned all work to an appropriate level of detail from the beginning.<br>- It measured the performance of completed work with objective techniques.<br>- It used past performance to predict future outcomes.<br>- It integrated cost, schedule, and performance with a single management control system.<br>- It directed management to the most critical problems, reducing information overload.<br>- It fostered accountability between workers and management. | 5 | 5 | 4 | 2 | 0 |
| | The EVM system complied with the agency's implementation of ANSI's 32 guidelines. | 5 | 5 | 5 | 2 | 0 |
| | The following steps in the EVM process were taken:<br>- The work's scope was defined with a WBS, and effort was broken into work and planning packages.<br>- The WBS and organizational breakdown structure were cross-walked to identify control accounts that show who will do the work.<br>- An acceptable technique was used to schedule work to resource load activities.<br>i. All activities were identified and sequenced, logically networked, clearly showing horizontal and vertical integration.<br>ii. Activities were resource loaded with labor, material, and overhead and durations were estimated with historical data when available, and float was identified.<br>iii. Program master schedule and critical path were identified.<br>iv. A schedule risk analysis was performed based on an 11-point schedule assessment.<br>v. Schedule reserve was chosen and prioritized for high-risk activities.<br>vi. The schedule was updated using logic and durations to determine dates and reflects accomplishments and is continuously analyzed for variances and changes to the critical path and completion date.<br>- Resources were adequate to complete each activity and were estimated to do the work, authorize budgets, and identify management reserve for high risk efforts.<br>- Objective methods for determining earned value were used. | 5 | 5 | 5 | 2 | 0 |
| | - The performance measurement baseline was developed for assessing program performance; EVM performance data were analyzed and variances from the baseline plan were recorded; the performance measurement baseline was updated.<br>- EACs were forecast using EVM.<br>- An integrated cost-schedule risk analysis was conducted.<br>- EACs from EVM were compared with an EAC from risk analysis.<br>- Management took action to mitigate risk.<br>- A preaward IBR was performed where provided for to verify the performance measurement baseline's realism and compliance with ANSI guidelines.<br>- Award fee criteria were developed to motivate the contractor to manage its contract with EVM to deliver the best possible product, were tied to specific contract events, and did not predetermine specific EVM measures.<br>- A performance based payment contract was considered for fixed-price contracts where technical effort and risk are low.<br>- The EVM system implemented was validated for compliance with the ANSI guidelines by independent and qualified staff and therefore can be considered to provide reliable and valid data from which to manage the program. | | | | | |
| | **Subtotal of Managing Program Cost: Planning** | **25** | **25** | **23** | **8** | **0** |
| | **Percentage of Managing Program Cost: Planning** | **7,69%** | **7,69%** | **7,08%** | **2,46%** | **0,00%** |

| No. | Associated Task | Alternatives | | | | |
|---|---|---|---|---|---|---|
| | | GAO | GPCCaR | AACE | PMI | Company |
| | **Managing Program Cost: Execution** | | | | | |
| 16 | An IBR verified that the baseline budget and schedule captured the entire scope of work, risks were understood, and available and planned resources were adequate.<br>- Separate IBRs were conducted at the prime contractor and all major subcontractors.<br>- A performance measurement baseline assessment made a comprehensive and value-added review of control accounts.<br>i. Before award, or not more than 6 months after, an IBR categorized risks by severity and provided team training.<br>ii. Work definition (including provisions for rework and retesting), schedule integration, resource identification, earned value measures, and baseline validation were matured and reviewed.<br>iii. Interviewers used a template in discussions with control account managers and identified where additional training was needed.<br>iv. An action plan for assigning responsibility for handling risks was developed, and a final program risk rating was based on a summary of all identified risks.<br>v. Management reserve was set aside that covered identified risks and care was taken to include risks identified during the IBR in the risk management plan.<br>vi. An EVM analyst monitored corrective action requests for closure.<br>vii. A memorandum for the record described the IBR findings. | 5 | 4 | 3 | 1 | 0 |
| | A contract performance report summarized EVM data.<br>- The data were reviewed monthly to track program progress, risks, and plans.<br>- Management used the data to<br>i. integrate cost and schedule performance data with technical measures;<br>ii. identify the magnitude and effect of problems causing significant variances;<br>iv. inform higher management of valid and timely program status and project future performance.<br>- Format 1 of the CPR reported data to at least level 3 of the WBS, and format 5 explained variances and the contractor's plans for fixing them. | 5 | 5 | 4 | 2 | 0 |
| | Program managers analyzed EVM data monthly and sequentially for variances and EACs.<br>- The EVM data were checked for validity and anomalies.<br>- Performance indexes were analyzed and plotted for trends and variances.<br>- Schedule variances were analyzed against the most recently statused schedule to see if problems were occurring on or near the critical path.<br>- Management reserve allocations in the WBS were examined and compared against risks identified in the cost estimate.<br>- A range of EACs was developed, using a generic index-based formula or relying on probable cost growth factors on remaining work, combined with an integrated cost schedule risk analysis.<br>- An independent date for program completion was determined, using schedule risk analysis that identifies which activities need to be closely monitored.<br>- Senior management used EVM data to answer basic program questions. | 5 | 5 | 4 | 2 | 0 |
| | **Subtotal of Managing Program Cost: Execution** | 15 | 14 | 11 | 5 | 0 |
| | **Percentage of Managing Program Cost: Execution** | 4,62% | 4,31% | 3,38% | 1,54% | 0,00% |
| | **Managing Program Cost: Updating** | | | | | |
| 17 | The cost estimate was updated with actual costs, keeping it current and relevant.<br>- Actual cost, technical, and schedule data were archived for future estimates. | 5 | 5 | 4 | 5 | 1 |
| | Authorized changes to the EVM performance measurement baseline were incorporated in a timely manner.<br>- It reflected current requirements.<br>- These changes were incorporated in a documented, disciplined, and timely manner so that budget, schedule, and work stayed together for true performance measurement.<br>- Changes were approved and implemented in a well-defined baseline control process. | 5 | 5 | 4 | 3 | 0 |
| | Regular EVM system surveillance ensured the contractor's effective management of cost, schedule, and technical performance and compliance with ANSI guidelines.<br>- The surveillance organization was independent and had authority to resolve issues.<br>- Surveillance staff had good knowledge about EVM and agency programs.<br>- An annual surveillance plan was developed and programs were chosen objectively.<br>- Findings and recommendations were presented to the program team for clarification, and the final surveillance report had an action plan to resolve findings quickly. | 5 | 5 | 5 | 3 | 0 |
| | The contractor's overtarget baseline or overtarget schedule was detailed, reasonable, and realistic; planned for costs, schedule, and management review; and described measures in place to prevent another OTB. | 5 | 5 | 3 | 1 | 0 |
| | Updated EACs and other EVM data were continually reported to management. | 5 | 5 | 4 | 3 | 0 |
| | EVM and CFSR–like data were examined regularly to identify problems and act on them quickly. | 5 | 4 | 5 | 3 | 0 |
| | **Subtotal of Managing Program Costs: Updating** | 30 | 29 | 25 | 18 | 1 |
| | **Percentage of Managing Program Costs: Updating** | 9,23% | 8,92% | 7,69% | 5,54% | 0,31% |
| | **Total Score (DOMINANCE)** | 325 | 293 | 245 | 183 | 54 |
| | **Total Percentage** | 100,0% | 90,2% | 75,4% | 56,3% | 16,6% |

**Appendix II: GAO Cost Estimating and Assessment Guide Best Practices Checklist**

### 1. Best Practices Checklist: The Estimate

- ☐ The cost estimate type is clearly defined and is appropriate for its purpose.
- ☐ The cost estimate contains all elements suitable to its type—ICA, ICE, IGCE, LCCE, rough order of magnitude, total ownership cost: development, procurement, operating and support, disposal costs, and all sunk costs.
  - ✓ AOA, CEA, EA, cost-benefit analysis: consistently evaluate all alternatives.
  - ✓ EA, cost-benefit analysis: portray estimates as present values.
- ☐ All program costs have been estimated, including all life-cycle costs.
- ☐ The cost estimate is independent of funding source and appropriations.
- ☐ An affordability analysis has been performed at the agency level to see how the program fits within the overall portfolio.
  - ✓ The agency has a process for developing cost estimates that includes the 12-step best practice process outlined in chapter 1.
  - ✓ An overall agency portfolio sand chart displays all costs for every program.
- ☐ The estimate is updated as actual costs become available from the EVM system or requirements change.
- ☐ Post mortems and lessons learned are continually documented.

### 2. Best Practices Checklist: Purpose, Scope, and Schedule

- ☐ The estimate's purpose is clearly defined.
- ☐ Its scope is clearly defined.
- ☐ The level of detail the estimate is to be conducted at is consistent with the level of detail available for the program. For example, an engineering build-up estimate should be conducted only on a well-defined program.
- ☐ The team has been allotted adequate time and resources to develop the estimate.

### 3. Best Practices Checklist: Cost Assessment Team

- ☐ The estimating team's composition is commensurate with the assignment (see SEI's checklists for more details).
  - ✓ The team has the proper number and mix of resources.
  - ✓ Team members are from a centralized cost estimating organization.
  - ✓ The team includes experienced and trained cost analysts.
  - ✓ The team includes, or has direct access to, analysts experienced in the program's major areas.
  - ✓ Team members' responsibilities are clearly defined.
  - ✓ Team members' experience, qualifications, certifications, and training are identified.
  - ✓ The team participated in on-the-job training, including plant and site visits.
- ☐ A master schedule with a written study plan has been developed.
- ☐ The team has access to the necessary subject matter experts.

### 4. Best Practices Checklist: Technical Baseline Description

- ☐ There is a technical baseline:
  - ✓ The technical baseline has been developed by qualified personnel such as system engineers.
  - ✓ It has been updated with technical, program, and schedule changes, and it contains sufficient detail of the best available information at any given time.
  - ✓ The information in the technical baseline generally drives the cost estimate and the cost estimating methodology.
  - ✓ The cost estimate is based on information in the technical baseline and has been approved by management.
- ☐ The technical baseline answers the following:
  - ✓ What the program is supposed to do—requirements;
  - ✓ How the program will fulfill its mission—purpose;
  - ✓ What it will look like—technical characteristics;
  - ✓ Where and how the program will be built—development plan;
  - ✓ How the program will be acquired—acquisition strategy;
  - ✓ How the program will operate—operational plan;
  - ✓ Which characteristics affect cost the most—risk.

## 5. Best Practices Checklist: Work Breakdown Structure

- ☐ A product-oriented WBS represents best practice.
- ☐ It reflects the program work that needs to be done. It
  - ✓ clearly outlines the end product and major work for the program;
  - ✓ contains at least 3 levels of indenture;
  - ✓ is flexible and tailored to the program.
- ☐ The 100 percent rule applies: the sum of the children equals the parent.
  - ✓ The WBS defines all work packages, which in turn include all cost elements and deliverables.
  - ✓ In addition to hardware and software elements, the WBS contains program management and other common elements to make sure all the work is covered.
- ☐ Each system has one program WBS but may have several contract WBSs that are extended from the program WBS, depending on the number of subcontractors.
- ☐ The WBS is standardized so that cost data can be collected and used for estimating future programs. It
  - ✓ facilitates portfolio management, including lessons learned;
  - ✓ matches schedule, cost estimate, and EVM at a high level;
  - ✓ is updated as changes occur and the program becomes better defined;
  - ✓ includes functional activities within each element that are needed to support each product deliverable;
  - ✓ is the starting point for developing the program's detailed schedule;
  - ✓ provides a framework for identifying and monitoring risks and the effectiveness of contingency plans;
  - ✓ provides for a common language between the government program management office, technical specialists, prime contractors, and subcontractors.
- ☐ The WBS has a dictionary that
  - ✓ defines each element and how it relates to others in the hierarchy;
  - ✓ clearly describes what is included in each element;
  - ✓ describes resources and functional activities needed to produce the element product;
  - ✓ links each element to other relevant technical documents.

## 6. Best Practices Checklist: Ground Rules and Assumptions

- ☐ All ground rules and assumptions have been
  - ✓ Developed by estimators with input from the technical community.
  - ✓ Based on information in the technical baseline and WBS dictionary.
  - ✓ Vetted and approved by upper management.
  - ✓ Documented to include the rationale behind the assumptions and historical data to back up any claims.
  - ✓ Accompanied by a level of risk of each assumption's failing and its effect on the estimate.
- ☐ To mitigate risk,
  - ✓ All GR&As have been placed in a single spreadsheet tab so that risk and sensitivity analysis can be performed quickly and efficiently.
  - ✓ All potential risks including cost, schedule, technical, and programmatic (e.g., risks associated with budget and funding, start up activities, staffing, and organizational issues) have been identified and traced to specific WBS elements.
    - ij A schedule risk analysis has been performed to determine the program schedule's realism.
    - ij A cost risk analysis, incorporating the results of the schedule risk analysis, has been performed to determine the program's cost estimate realism.
- ☐ Budget constraints, as well as the effect of delaying program content, have been defined.
  - ✓ Peaks and valleys in time-phased budgets have been explained.
  - ✓ Inflation index, source, and approval authority have been identified.
  - ✓ Dependence on participating agencies, the availability of government furnished equipment, and the effects if these assumptions do not hold have been identified.
  - ✓ Items excluded from the estimate have been documented and explained.
  - ✓ Technology was mature before it was included; if its maturity was assumed, the estimate addresses the effect of the assumption's failure on cost and schedule.
- ☐ Cost estimators and auditors met with technical staff to determine risk distributions for all assumptions; the distributions were used in sensitivity and uncertainty analyses of the effects of invalid assumptions. Management has been briefed, and the results have been documented.

## 7. Best Practices Checklist: Data

- ☐ As the foundation of an estimate, data
  - ✓ Have been gathered from historical actual cost, schedule and program, and technical sources;
  - ✓ Apply to the program being estimated;
  - ✓ Have been analyzed for cost drivers;
  - ✓ Have been collected from primary sources, if possible, and secondary sources as the next best option, especially for cross-checking results;
  - ✓ Have been adequately documented as to source, content, time, units, assessment of accuracy and reliability, and circumstances affecting the data;
  - ✓ Have been continually collected, protected, and stored for future use;
  - ✓ Were assembled as early as possible, so analysts can participate in site visits to understand the program and question data providers.
- ☐ Before being used in a cost estimate, the data were
  - ✓ Fully reviewed to understand their limitations and risks;
  - ✓ Segregated into nonrecurring and recurring costs;
  - ✓ Validated, using historical data as a benchmark for reasonableness;
  - ✓ Current and found applicable to the program being estimated;
  - ✓ Analyzed with a scatter plot to determine trends and outliers;
  - ✓ Analyzed with descriptive statistics;
  - ✓ Normalized to account for cost and sizing units, mission or application, technology maturity, and content so they are consistent for comparisons;
  - ✓ Normalized to constant base-year dollars to remove the effects of inflation, and the inflation index was documented and explained.

## 8. Best Practices Checklist: Developing a Point Estimate

- ☐ The cost estimator considered various cost estimating methods:
  - ✓ Analogy, early in the life cycle, when little was known about the system being developed:
    - ij Adjustments were based on program information, physical and performance characteristics, contract type.
  - ✓ Expert opinion, very early in the life cycle, if an estimate could be derived no other way.
  - ✓ The build-up method later, in acquisition, when the scope of work was well defined and a complete WBS could be determined.
  - ✓ Parametrics, if a database of sufficient size, quality, and homogeneity was available for developing valid CERs and the data were normalized correctly.
    - ij Parametric models were calibrated and validated using historical data.
  - ✓ Extrapolating from actual cost data, at the start of production.
- ☐ Cost estimating relationships were considered:
  - ✓ Statistical techniques were used to develop CERs:
    - ij Higher R-squared;
  - ✓ Statistical significance, for determining the validity of statistical relationships;
    - ij Significance levels of F and t statistics.
  - ✓ Before using a CER, the cost estimator
    - ij Examined the underlying data set to understand anomalies;
    - ij Checked equations to ensure logical relationships;
    - ij Normalized the data;
    - ij Ensured that CER inputs were within the valid dataset range;
    - ij Checked modeling assumptions to ensure they applied to the program.
  - ✓ Learning curve theory was applied if
    - ij Much manual labor was required for production;
    - ij Production was continuous or adjustments had to be made;
    - ij Items to be produced required complex processes;
    - ij Technological change was minimal between production lots;
    - ij The contractor's business process was being continually improved.
- ☐ Production rate and breaks in production were considered.
- ☐ The point estimate was developed by aggregating the WBS element cost estimates by one of the cost estimating methods.
  - ✓ Results were checked for accuracy, double-counting, and omissions and were validated with cross-checks and independent cost estimates.

## 9. Best Practices Checklist: Estimating Software Costs

- ☐ The software cost estimate followed the 12-step estimating process:
  - ✓ Software was sized with detailed knowledge of program scope, complexity, and interactions, and the cost estimators worked with software engineers to determine the appropriate sizing metric.
  - ✓ It was sized with source lines of code, function, object, feature point, or other counts.
- ☐ The software sizing method was appropriate:
  - ✓ Source lines of code were used if requirements were well defined and if there was a historical database of code counts for similar programs and a standard definition for a line of code.
  - ✓ Function points were used if detailed requirements and specifications were available, software did not contain many algorithmic functions, and an experienced and certified function point counter was available.
  - ✓ COSMIC points were used if functional user requirements are known and the application is for business, real-time, embedded, or infrastructure software.
  - ✓ Object points were used if computer-aided software engineering tools were used to develop the software.
  - ✓ Reports, interfaces, conversions, extensions and forms / workflow were used for ERP programs.
  - ✓ Use cases and use case points were used if system and user interactions were defined.
  - ✓ Autogenerated and reused source lines of code were identified separately from new and modified code to account for pre- and postimplementation efforts.
  - ✓ Several methods were used to size the software to increase the accuracy of the sizing estimate.
  - ✓ The final software size was adjusted for growth based on historical data, and growth is continually monitored over time.
- ☐ Software cost estimates included
  - ✓ Development labor costs for coding and testing, other labor supporting software development, and nonlabor costs like purchasing hardware and licenses.
  - ✓ Productivity factors for converting software size into labor effort, based on historical data and calibrated to match program size and development environment.
  - ✓ Industry average productivity factors and risk ranges, if no historical data were available.
  - ✓ Assumptions about productive labor hours in a day and work days in a year.
  - ✓ Development schedules accounting for staff availability, prior task dependencies, concurrent and critical path activities, number and length of shifts, overtime allowance, down time, and worker locations.

- ✓ Costs for help desk support, database development, and corrective, adaptive, and preventive maintenance as part of the software's life cycle cost.
- ✓ Time and effort associated with rework to fix defects.
- ✓ Training cost estimators to calibrate parametric tools to match the program and model results cross-checking for accuracy.
- ✓ Estimators' accounting for integrating commercial off-the-shelf software into the system, including developing custom software and glue-code.
- ✓ Impact of risks facing ERP system implementations as outlined in table 18.
- ✓ Costs associated with interfacing bolt-on applications for ERP systems.

☐ IT infrastructure and services components of the software cost estimate included

- ✓ Costs associated with the physical attributes of the IT infrastructure, the performance and complexity requirements, and economic considerations.
- ✓ Impact of risks affecting IT infrastructure, as outlined in table 19.
- ✓ Costs associated with labor and material nonrecurring and recurring efforts.

## 10. Best Practices Checklist: Sensitivity Analysis

☐ The cost estimate was accompanied by a sensitivity analysis that identified the effects of changing key cost driver assumption and factors.

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

☐ The following steps were taken during the sensitivity analysis:

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

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

## 11. Best Practices Checklist: Cost Risk and Uncertainty

- ☐ A risk and uncertainty analysis quantified the imperfectly understood risks that are in the program and identified the effects of changing key cost driver assumptions and factors.
  - ✓ Management was given a range of possible costs and the level of certainty in achieving the point estimate.
  - ✓ A risk adjusted estimate that reflects the program's risks was determined.
  - ✓ A cumulative probability density function, an S curve, mapped various cost estimates to a certain probability level and defensible contingency reserves were developed.
  - ✓ Periodic risk and uncertainty analysis was conducted to improve estimate uncertainty.
- ☐ The following steps were taken in performing an uncertainty analysis:
  - ✓ Program cost drivers and associated risks were determined, including those related to changing requirements, cost estimating errors, business or economic uncertainty, and technology, schedule, program, and software uncertainty.
    - ij All risks were documented for source, data quality and availability, and probability and consequence.
    - ij Risks were collected from staff within and outside the program to counter optimism.
    - ij Uncertainty was determined by cost growth factor, expert opinion (adjusted to consider a wider range of risks), statistics and Monte Carlo simulation, technology readiness levels, software engineering maturity models and risk evaluation methods, schedule risk analysis, risk cube (P-I matrix) method, or risk scoring.
  - ✓ A probability distribution modeled each cost element's uncertainty based on data availability, reliability, and variability.
    - ij A range of values and their respective probabilities were determined either based on statistics or expressed as 3-point estimates (best case, most likely, and worst case), and rationale for choosing which method was discussed.
    - ij Documentation of the rationale for choosing the probability distributions should be provided.

- ij Probability distribution reflects the risk shape and the tails of the distribution reflect the best and worst case spread as well as any skewness. Distribution bounds were adjusted to account for stakeholder bias using organization default values when data specific to the program are not available.
- ij If the risk driver approach is used, the data collected, including probability of occurrence and impact, were applied to the risks themselves.
- ij Prediction interval statistical analysis was used for CER distribution bounds.

✓ The correlation between cost elements was accounted for to capture risk.

- ij The correlation ensures that related cost elements move together during the simulation, resulting in reinforcement of the risks.
- ij Cost estimators examined the amount of correlation already existing in the model. If no correlation is present, an insertion of 0.25 correlation was added.

✓ A Monte Carlo simulation model was used to develop a distribution of total possible costs and an S curve showing alternative cost estimate probabilities.

- ij High-priority risks were examined and identified for risk mitigation.
- ij Strength of correlated cost elements were examined and additional correlation added if necessary to account for risk.

✓ The probability associated with the point estimate was identified.

✓ Contingency reserves were recommended for achieving the desired confidence level.

- ij The mean of the distribution tends to fall around the 55%–65% confidence level because the total cost distribution follows a lognormal trend (i.e., tendency to overrun rather than underrun costs).
- ij Budgeting to at least the mean of the distribution or higher is necessary to guard against potential risk.
- ij The cost risk and uncertainty results were vetted through a core group of experts to ensure that the proper steps were followed.
- ij The estimate is continually updated with actual costs and any variances recorded to identify areas where estimating was difficult or sources of risks were not considered.

✓ The risk-adjusted cost estimate was allocated, phased, and converted to then-year dollars for budgeting, and high-risk elements were identified to mitigate risks.

- ij Results from the uncertainty analysis were used to prioritize risks based on probability and impacts as they affected the cost estimate.

☐ A risk management plan was implemented jointly with the contractor to identify and analyze risk, plan for risk mitigation, and continually track risk.

✓ A risk database watch list was developed, and a contractor's EVM system was used for root cause analysis of cost and schedule variances, monitoring worsening trends, and providing early risk warning.

✓ Event-driven reviews, technology demonstrations, modeling and simulation, and risk-mitigation prototyping were implemented.

## 12. Best Practices Checklist: Validating the Estimate

The cost estimate was validated against four characteristics:

- ☐ It is comprehensive, includes all possible costs, ensures that no costs were omitted or double-counted, and explains and documents key assumptions.
  - ✓ It completely defines the program, reflects the current schedule, and contains technically reasonable assumptions.
  - ✓ It captures the complete technical scope of the work to be performed, using a logical WBS that accounts for all performance criteria and requirements.
- ☐ It was documented so well that it can easily be repeated or updated and traced to original sources by auditing.
  - ✓ Supporting documentation identifies data sources, justifies all assumptions, and describes all estimating methods (including relationships) for all WBS elements.
  - ✓ Schedule milestones and deliverables can be traced and are consistent with the documentation.
- ☐ It is accurate, not too conservative or too optimistic; is based on an assessment of most likely costs, adjusted properly for inflation; and contains few minor mistakes.
  - ✓ WBS estimates were checked to verify that calculations were accurate and accounted for all costs and that proper escalation factors were used to inflate costs so they were expressed consistently and accurately.
  - ✓ Questions associated with estimating techniques were answered to determine the estimate's accuracy.
  - ✓ CERs and parametric cost models were validated to ensure that they were good predictors of costs, their data were current and applied to the program, the relationships between technical parameters were logical and statistically significant, and results were tested with independent data.
- ☐ Data limitations from uncertainty or bias were identified; results were cross-checked; an ICE was developed to see if results were similar.
  - ✓ Major assumptions were varied and other outcomes recomputed to determine their sensitivity to changes in the assumptions.
  - ✓ Risk and uncertainty analysis was conducted.

### 13. Best Practices Checklist: Documenting the Estimate

- ☐ The documentation describes the cost estimating process, data sources, and methods step by step so that a cost analyst unfamiliar with the program could understand what was done and replicate it.
  - ✓ Supporting data are adequate for easily updating the estimate to reflect actual costs or program changes and using them for future estimates.
  - ✓ The documentation describes the estimate with narrative and cost tables.
  - ✓ It contains an executive summary, introduction, and descriptions of methods, with data broken out by WBS cost elements, sensitivity analysis, risk and uncertainty analysis, management approval, and updates that reflect actual costs and changes.
  - ✓ Detail addresses best practices and the 12 steps of high-quality estimates.
  - ✓ The documentation is mathematically sensible and logical.
  - ✓ It discusses contingency reserves and how they were derived from risk and uncertainty analysis and the LCCE funding profile.
- ☐ It includes access to an electronic copy, and both are stored so that authorized personnel can easily find and use them for other cost estimates.

### 14. Best Practices Checklist: Presenting the Estimate to Management

- ☐ The briefing to management
  - ✓ was simple, clear, and concise enough to convey its level of competence.
  - ✓ illustrated the largest cost drivers, presenting them logically, with backup charts for responding to more probing questions.
  - ✓ was consistent, allowing management to focus on the estimate's content.
- ☐ The briefing contained
  - ✓ A title page, outline, and brief statement of purpose of the estimate.
  - ✓ An overview of the program's technical foundation and objectives.
  - ✓ LCCE results in time-phased constant-year dollars, tracked to previous estimates.
  - ✓ A discussion of GR&As.
  - ✓ The method and process for each WBS cost element, with estimating techniques and data sources.
  - ✓ The results of sensitivity analysis and cost drivers that were identified.
  - ✓ The results of risk and uncertainty analysis with confidence interval, S curve analysis, and bounds and distributions.
  - ✓ The comparison of the point estimate to an ICE with discussion of differences and whether the point estimate was reasonable.
  - ✓ An affordability analysis based on funding and contingency reserves.
  - ✓ Discussion of any other concerns or challenges
  - ✓ Conclusions and recommendations.
- ☐ Feedback from the briefing, including management's acceptance of the estimate, was acted on and recorded in the cost estimate documentation.

**15. Best Practices Checklist: Managing Program Costs: Planning**

- ☐ A cost estimate was used to measure performance against the original plan, using EVM.
- ☐ EVM and risk management were tightly integrated to ensure better program outcomes.
  - ✓ Strong leadership demands EVM be used to manage programs.
  - ✓ Stakeholders make it clear that EVM matters and hold staff accountable for results.
  - ✓ Management is willing to hear the truth about programs and relies on EVM data to make decisions on how to mitigate risk.
  - ✓ Policy outlines clear expectations for EVM as a disciplined management tool and requires pertinent staff to be continuously trained in cost estimating, scheduling, EVM, and risk and uncertainty analysis.
- ☐ EVM is implemented at the program level so that both government and contractor know what is expected and are held accountable.
  - ✓ EVM relied on the cost of completed work to determine true program status.
  - ✓ EVM planned all work to an appropriate level of detail from the beginning.
  - ✓ It measured the performance of completed work with objective techniques.
  - ✓ It used past performance to predict future outcomes.
  - ✓ It integrated cost, schedule, and performance with a single management control system.
  - ✓ It directed management to the most critical problems, reducing information overload.
  - ✓ It fostered accountability between workers and management.
- ☐ The EVM system complied with the agency's implementation of ANSI's 32 guidelines.

- ☐ The following steps in the EVM process were taken:
  - ✓ The work's scope was defined with a WBS, and effort was broken into work and planning packages.
  - ✓ The WBS and organizational breakdown structure were cross-walked to identify control accounts that show who will do the work.
  - ✓ An acceptable technique was used to schedule work to resource load activities.
    - ij All activities were identified and sequenced, logically networked, clearly showing horizontal and vertical integration.
    - ij Activities were resource loaded with labor, material, and overhead and durations were estimated with historical data when available, and float was identified.
    - ij Program master schedule and critical path were identified.
    - ij A schedule risk analysis was performed based on an 11-point schedule assessment.
    - ij Schedule reserve was chosen and prioritized for high-risk activities.
    - ij The schedule was updated using logic and durations to determine dates and reflects accomplishments and is continuously analyzed for variances and changes to the critical path and completion date.
  - ✓ Resources were adequate to complete each activity and were estimated to do the work, authorize budgets, and identify management reserve for high-risk efforts.
  - ✓ Objective methods for determining earned value were used.
  - ✓ The performance measurement baseline was developed for assessing program performance; EVM performance data were analyzed and variances from the baseline plan were recorded; the performance measurement baseline was updated.
  - ✓ EACs were forecast using EVM.
  - ✓ An integrated cost-schedule risk analysis was conducted.
  - ✓ EACs from EVM were compared with an EAC from risk analysis.
  - ✓ Management took action to mitigate risk.
  - ✓ A preaward IBR was performed where provided for to verify the performance measurement baseline's realism and compliance with ANSI guidelines.
  - ✓ Award fee criteria were developed to motivate the contractor to manage its contract with EVM to deliver the best possible product, were tied to specific contract events, and did not predetermine specific EVM measures.
  - ✓ A performance based payment contract was considered for fixed-price contracts where technical effort and risk are low.
  - ✓ The EVM system implemented was validated for compliance with the ANSI guidelines by independent and qualified staff and therefore can be considered to provide reliable and valid data from which to manage the program.

**16. Best Practices Checklist: Managing Program Costs: Execution**

- ☐ An IBR verified that the baseline budget and schedule captured the entire scope of work, risks were understood, and available and planned resources were adequate.
  - ✓ Separate IBRs were conducted at the prime contractor and all major subcontractors.
  - ✓ A performance measurement baseline assessment made a comprehensive and value-added review of control accounts.
    - ij Before award, or not more than 6 months after, an IBR categorized risks by severity and provided team training.
    - ij Work definition (including provisions for rework and retesting), schedule integration, resource identification, earned value measures, and baseline validation were matured and reviewed.

- ij Interviewers used a template in discussions with control account managers and identified where additional training was needed.
- ij An action plan for assigning responsibility for handling risks was developed, and a final program risk rating was based on a summary of all identified risks.
- ij Management reserve was set aside that covered identified risks and care was taken to include risks identified during the IBR in the risk management plan.
- ij An EVM analyst monitored corrective action requests for closure.
- ij A memorandum for the record described the IBR findings.

☐ A contract performance report summarized EVM data.

- ✓ The data were reviewed monthly to track program progress, risks, and plans.
- ✓ Management used the data to
  - ij integrate cost and schedule performance data with technical measures;
  - ij identify the magnitude and effect of problems causing significant variances;
  - ij inform higher management of valid and timely program status and project future performance.
- ✓ Format 1 of the CPR reported data to at least level 3 of the WBS, and format 5 explained variances and the contractor's plans for fixing them.

☐ Program managers analyzed EVM data monthly and sequentially for variances and EACs.

- ✓ The EVM data were checked for validity and anomalies.
- ✓ Performance indexes were analyzed and plotted for trends and variances.
- ✓ Schedule variances were analyzed against the most recently statused schedule to see if problems were occurring on or near the critical path.
- ✓ Management reserve allocations in the WBS were examined and compared against risks identified in the cost estimate.
- ✓ A range of EACs was developed, using a generic index-based formula or relying on probable cost growth factors on remaining work, combined with an integrated cost schedule risk analysis.
- ✓ An independent date for program completion was determined, using schedule risk analysis that identifies which activities need to be closely monitored.
- ✓ Senior management used EVM data to answer basic program questions.

### 17. Best Practices Checklist: Managing Program Costs: Updating

- ☐ The cost estimate was updated with actual costs, keeping it current and relevant.
  - ✓ Actual cost, technical, and schedule data were archived for future estimates.
- ☐ Authorized changes to the EVM performance measurement baseline were incorporated in a timely manner.
  - ✓ It reflected current requirements.
  - ✓ These changes were incorporated in a documented, disciplined, and timely manner so that budget, schedule, and work stayed together for true performance measurement.
  - ✓ Changes were approved and implemented in a well-defined baseline control process.
- ☐ Regular EVM system surveillance ensured the contractor's effective management of cost, schedule, and technical performance and compliance with ANSI guidelines.
  - ✓ The surveillance organization was independent and had authority to resolve issues.
  - ✓ Surveillance staff had good knowledge about EVM and agency programs.
  - ✓ An annual surveillance plan was developed and programs were chosen objectively.
  - ✓ Findings and recommendations were presented to the program team for clarification, and the final surveillance report had an action plan to resolve findings quickly.
- ☐ The contractor's overtarget baseline or overtarget schedule was detailed, reasonable, and realistic; planned for costs, schedule, and management review; and described measures in place to prevent another OTB.
- ☐ Updated EACs and other EVM data were continually reported to management.
- ☐ EVM and CFSR–like data were examined regularly to identify problems and act on them quickly.

**Appendix III: Company Cost Estimator Checklist**

# Company name

## Cost Estimator Checklist

Date

**PROJECT NAME:**

CONFIDENTIAL

| Estimator Task/Activity Checklist | Status |
|---|---|
| **THE ESTIMATE:** | |
| Determine estimate's purpose:<br>Level 5 (Concept Screening); Level 4 (Feasibility Study); Level 3 (Capital Expenditure); Level 2 (Bid/Tender). | |
| Cost & schedule estimating team.<br>(Yes; No; N/A) | |
| Estimate deadline.<br>(dd/mm/yyyy) | |
| Life cycle cost has been developed and estimated?<br>(Yes; No; N/A) | |
| Define a suitable WBS for the estimate class.<br>(Yes; No; N/A) | |
| Post mortems and lesson learned are continually documented.<br>(Yes; No; N/A) | |
| Obtain and analyzed the data for cost drivers, trends, and compare the results with historical data.<br>(Yes; No; N/A) | |
| Develop point estimate and compare it to an independent cost estimate.<br>(Yes; No; N/A) | |
| Conduct sensitivity analysis for input values and key assumptions.<br>(Yes; No; N/A) | |
| Conduct risk and uncertainty analysis including cost, schedule, and technical risks.<br>(Yes; No; N/A) | |
| Document all steps used to develop the estimate.<br>(Yes; No; N/A) | |
| Present and explain the estimate to the management for approval.<br>(Yes; No; N/A) | |
| **WORK BREAKDOWN STRUCTURE (WBS):** | |
| Project WBS represent the best practices.<br>(Yes; No; N/A) | |

| Estimator Task/Activity Checklist | Status |
|---|---|
| Clearly outlines of major work.<br>(Yes; No; N/A) | |
| The WBS defines all work packages, which in turn include all cost elements and deliverables.<br>(Yes; No; N/A) | |
| The WBS is standardized so that cost data can be collected and used for estimating future programs.<br>(Yes; No; N/A) | |
| The WBS has a dictionary that defines each element and how it relates to others in the hierarchy.<br>(Yes; No; N/A) | |
| **MANAGING PROGRAM COST (UPDATING):** | |
| The cost estimate was updated with actual cost, technical, and schedule data were archived for future estimates.<br>(Yes; No; N/A) | |
| Authorized changes to the EVM performance measurement baseline were incorporated in a documented, disciplined, and timely manner so that budget, schedule, and work stayed together for true performance measurement.<br>(Yes; No; N/A) | |
| The contractor's overtarget baseline or overtarget schedule was detailed, reasonable, and realistic; planned for costs, schedule, and management review.<br>(Yes; No; N/A) | |
| **MANAGING PROGRAM COST (PLANNING):** | |
| A cost estimate was used to measure performance against the original plan, using EVM.<br>(Yes; No; N/A) | |
| EVM is implemented at the program level so that both government and contractor know what is expected and are held accountable.<br>(Yes; No; N/A) | |
| EVM and risk management were tightly integrated to ensure better program outcomes.<br>(Yes; No; N/A) | |
| **PURPOSE, SCOPE, AND SCHEDULE:** | |
| The estimate's purpose is clearly defined.<br>Level 5 (Concept Screening); Level 4 (Feasibility Study); Level 3 (Capital Expenditure); Level 2 (Bid/Tender). | |
| Its scope is clearly defined.<br>(Yes; No; N/A) | |

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| Estimator Task/Activity Checklist | Status |
|---|---|
| The level of detail the estimate is to be conducted at is consistent with the level of detail available for the program. (Yes; No; N/A) | |
| The team has been allotted adequate time and resources to develop the estimate. (Yes; No; N/A) | |
| **GROUND RULES & ASSUMPTIONS:** | |
| All ground rules and assumptions have been developed. (Yes; No; N/A) | |
| To mitigate risk, all potential risks including cost, schedule, and technical have been identified and traced to specific WBS elements. (Yes; No; N/A) | |
| Budget constraints, as well as the effect of delaying program content, have been defined. (Yes; No; N/A) | |
| Cost estimators and auditors met with technical staff to determine risk distributions for all assumptions. (Yes; No; N/A) | |
| **DEVELOPING A POINT ESTIMATE:** | |
| The cost estimator considered various cost estimating methods (Analogy, Expert Judgement, Build-up, Parametrics, and Extrapolating). (Yes; No; N/A) | |
| Cost estimating relationships were considered (Statistical, CER, and Learning Curve). (Yes; No; N/A) | |
| The point estimate was developed by aggregating the WBS element cost estimates by one of the cost estimating methods. (Yes; No; N/A) | |
| Cost estimators and auditors met with technical staff to determine risk distributions for all assumptions. (Yes; No; N/A) | |
| **ESTIMATING SOFTWARE COSTS:** | |
| The software cost estimate followed the 12-step estimating process. (Yes; No; N/A) | |
| The software sizing method was appropriate. (Yes; No; N/A) | |
| Software cost estimates included development labor cost, productivity, and schedules (Yes; No; N/A) | |

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| Estimator Task/Activity Checklist | Status |
|---|---|
| IT infrastructure and services components of the software cost estimate included physical attributes and risks. (Yes; No; N/A) | |
| **VALIDATING THE ESTIMATE:** | |
| It is comprehensive, includes all possible costs, ensures that no costs were omitted or double-counted, and explains and documents key assumptions. (Yes; No; N/A) | |
| It was documented so well that it can easily be repeated or updated and traced to original sources by auditing.. (Yes; No; N/A) | |
| It is accurate, not too conservative or too optimistic; is based on an assessment of most likely costs, adjusted properly for inflation; and contains few minor mistakes. (Yes; No; N/A) | |
| Data limitations from uncertainty or bias were identified. (Yes; No; N/A) | |
| **COST ASSESSMENT TEAM:** | |
| The team has the proper number and mix of resources. (Yes; No; N/A) | |
| Team members are from a centralized cost estimating organization. (Yes; No; N/A) | |
| The team includes experienced and trained cost analysts. (Yes; No; N/A) | |
| Team members' responsibilities are clearly defined. (Yes; No; N/A) | |
| Team members' experience, qualifications, certifications, and training are identified. (Yes; No; N/A) | |
| A master schedule with a written study plan has been developed. (Yes; No; N/A) | |
| The team has access to the necessary subject matter experts. (Yes; No; N/A) | |
| **SENSITIVITY ANALYSIS:** | |
| The cost estimate was accompanied by a sensitivity analysis that identified the effects of changing key cost driver assumption and factors. (Yes; No; N/A) | |
| Key cost drivers were identified. (Yes; No; N/A) | |

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| Estimator Task/Activity Checklist | Status |
|---|---|
| Cost elements representing the highest percentage of cost were determined and their parameters and assumptions were examined. (Yes; No; N/A) | |
| The total cost was reestimated by varying each parameter between its minimum and maximum range. (Yes; No; N/A) | |
| Results were documented and the reestimate was repeated for each parameter that was a key cost driver. (Yes; No; N/A) | |
| The sensitivity analysis provided a range of possible costs, a point estimate, and a method for performing what-if analysis. (Yes; No; N/A) | |
| The team has access to the necessary subject matter experts. (Yes; No; N/A) | |
| **COST RISKS & UNCERTAINTY:** | |
| A risk and uncertainty analysis quantified the imperfectly understood risks that are in the program and identified the effects of changing key cost driver assumptions and factors. (Yes; No; N/A) | |
| A probability distribution modeled each cost element's uncertainty based on data availability, reliability, and variability. (Yes; No; N/A) | |
| The correlation between cost elements was accounted for to capture risk. (Yes; No; N/A) | |
| A Monte Carlo simulation model was used to develop a distribution of total possible costs and an S curve showing alternative cost estimate probabilities. (Yes; No; N/A) | |
| The probability associated with the point estimate was identified. (Yes; No; N/A) | |
| Contingency reserves were recommended for achieving the desired confidence level. (Yes; No; N/A) | |
| The risk-adjusted cost estimate was allocated, phased, and converted to then year dollars for budgeting, and high-risk elements were identified to mitigate risks. (Yes; No; N/A) | |
| A risk management plan was implemented jointly with the contractor to identify and analyze risk, plan for risk mitigation, and continually track risk. (Yes; No; N/A) | |

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| Estimator Task/Activity Checklist | Status |
|---|---|
| **PRESENTING THE ESTIMATE TO THE MANAGEMENT:** | |
| The briefing to management was simple, clear, and concise enough to convey its level of competence. (Yes; No; N/A) | |
| The briefing to management illustrated the largest cost drivers, presenting them logically, with backup charts for responding to more probing questions. (Yes; No; N/A) | |
| The briefing contained explanation of estimating process. (Yes; No; N/A) | |
| Feedback from the briefing, including management's acceptance of the estimate, was acted on and recorded in the cost estimate | |
| **MANAGING PROGRAM COST (EXECUTION):** | |
| A performance measurement baseline assessment made a comprehensive and value-added review of control accounts. (Yes; No; N/A) | |
| A contract performance report summarized EVM data. (Yes; No; N/A) | |
| Program managers analyzed EVM data monthly and sequentially for variances and EACs. (Yes; No; N/A) | |
| **TECHNICAL BASELINE DESCRIPTION:** | |
| The technical baseline has been developed by qualified personnel. (Yes; No; N/A) | |
| It has been updated with technical, program, and schedule changes, and it contains sufficient detail of the best available information at any given time. (Yes; No; N/A) | |
| The information in the technical baseline generally drives the cost estimate and the cost estimating methodology. (Yes; No; N/A) | |
| The cost estimate is based on information in the technical baseline and has been approved by management. (Yes; No; N/A) | |
| The technical baseline answers the requirements, purpose, technical characteristics, development plan, operational plan, and risks. (Yes; No; N/A) | |

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| Estimator Task/Activity Checklist | Status |
|---|---|
| **DATA:** | |
| Data have been gathered from historical actual cost, schedule and program, and technical sources; (Yes; No; N/A) | |
| Data have been analyzed for cost drivers (Yes; No; N/A) | |
| Have been collected from primary sources, if possible, and secondary sources as the next best option, especially for cross-checking results; (Yes; No; N/A) | |
| Data were fully reviewed to understand their limitations and risks; (Yes; No; N/A) | |
| Data were validated, using historical data as a benchmark for reasonableness. (Yes; No; N/A) | |
| Data were analyzed with a scatter plot to determine trends and outliers, using descriptive statistics. (Yes; No; N/A) | |
| Data were normalized to account for cost and sizing units, mission or application, technology maturity, and content so they are consistent for comparisons. (Yes; No; N/A) | |
| A risk management plan was implemented jointly with the contractor to identify and analyze risk, plan for risk mitigation, and continually track risk. (Yes; No; N/A) | |
| **DOCUMENTING THE ESTIMATE:** | |
| The documentation describes the cost estimating process, data sources, and methods step by step so that a cost analyst unfamiliar with the program could understand what was done and replicate it. (Yes; No; N/A) | |
| It includes access to an electronic copy, and both are stored so that authorized personnel can easily find and use them for other cost estimates. (Yes; No; N/A) | |

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## About the Author

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**Joko Wisnugroho** is a project engineer with six years of professional experience in the oil and gas sectors. Currently, he works as an engineer at the national oil company of Indonesia. Several projects have been completed, such as fuel terminal, LPG terminal, pipeline, and other downstream projects. He holds a bachelor's degree in Mechanical Engineering from Bandung Institute of Technology (ITB) and currently completing his master's degree in project management at the University of Indonesia. He is attending a distance learning mentoring course, under the tutorage of Dr. Paul D. Giammalvo, CDT, CCE, MScPM, MRICS, GPM-m Senior Technical Advisor, PT Mitrata Citragraha, to attain Certified Cost Professional certification from AACE International.

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