AACE INTERNATIONAL RECOMMENDED PRACTICE

87R-14

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

AACE INTERNATIONAL

AACE® International Recommended Practice No. 87R-14

COST ESTIMATE CLASSIFICATION SYSTEM – AS APPLIED FOR THE PETROLEUM EXPLORATION AND PRODUCTION INDUSTRY

TCM Framework: 7.3 – Cost Estimating and Budgeting

Rev. August 7, 2020

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Any terms found in AACE Recommended Practice 10S-90, *Cost Engineering Terminology*, supersede terms defined in other AACE work products, including but not limited to, other recommended practices, the *Total Cost Management Framework*, and *Skills & Knowledge of Cost Engineering*.

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TABLE OF CONTENTS

1. PURPOSE

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

This recommended practice provides guidelines for applying the principles of estimate classification specifically to project estimates for engineering, procurement, and construction (EPC) work for the petroleum exploration and production industries. It supplements the generic cost estimate classification RP 17R-97[2] by providing:

- A section that further defines classification concepts as they apply to the petroleum exploration and production industries.
- A section on the geopolitical nature and investment regulation of petroleum exploration and production projects that impact the estimating process and its basis definition deliverables.
- A chart that maps the extent and maturity of estimate input information (project definition deliverables) against the class of estimate.

As with the generic RP, the intent of this document is to improve communications among all of the stakeholders involved with preparing, evaluating, and using project cost estimates, specifically for the petroleum exploration and production industries.

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

This document is intended to provide a guideline, not a standard. It is understood that each enterprise may have its own project and estimating processes, terminology, and may classify estimates in other ways. This guideline provides a generic and generally acceptable classification system for the petroleum exploration and production industries that can be used as a basis to compare against. This recommended practice should allow each user to better assess, define, and communicate their own processes and standards in the light of generally-accepted cost engineering practice.

As a final note regarding purpose, users must be aware of the industry's well documented history of challenges with overruns of budget authorization, appropriation, or funding estimates. The intent of this RP is to help improve upon past performance.

2. INTRODUCTION

For the purposes of this addendum, the term *petroleum exploration and production industries* is assumed to include any firm encompassing "all the steps involved in finding, producing, processing, transporting, and marketing of oil and natural gas."[1]

The projects are generally bigger, cost more and are in remote and challenging environments where risks and the cost variability are greater than in the manufacturing and processing industries.

This recommended practice is intended to cover petroleum exploration and production (E&P) projects covering drilling, completion, gathering systems, and processing to a marketable product, including all associated process and infrastructure facilities within the scope of the project. Infrastructure facilities may be especially significant. Offshore facilities, such as subsea systems, fixed platforms, and floating facilities, are covered by this RP. Early seismic and exploration studies may be expensed and excluded from this RP. All facilities downstream of the production facilities are also excluded.

This guideline reflects generally-accepted cost engineering practices. This recommended practice was based upon the practices of national oil and gas companies (NOCs) and international oil and gas companies (IOCs) who are engaged in petroleum exploration and production (upstream) projects around the world, as well as published references and standards.

This RP applies to a variety of project delivery methods such as traditional design-bid-build (DBB), design-build (DB), construction management for fee (CM-fee), construction management at risk (CM-at risk), and private-public partnerships (PPP) contracting methods.

3. GEOPOLITICAL NATURE AND REGULATION OF PETROLEUM EXPLORATION AND PRODUCTION INDUSTRIES

The geopolitical nature and significant risks in the petroleum E&P project industries increase the public profile and influence the capital cost estimating process, including the interpretation of estimate classifications. Examples of regulatory bodies which are applicable to the petroleum E&P industries include:

- National departments of energy.
- Society of Professional Engineers.
- Society of Petroleum Evaluation Engineers.
- World Petroleum Council.
- United States Securities and Exchange Commission (SEC).
- Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE).
- American Petroleum Institute.
- American Society of Mechanical Engineers.
- Environmental protection agencies.
- Maritime and coast guard agencies.

In estimating the capital costs for petroleum E&P projects consideration must be given to the political and regulatory environment. The political and regulatory environment includes relations with developing nations, which may impose additional regulations and taxes on the investment; or in the worst case, may expropriate the investment.

Geopolitical circumstances for petroleum E&P projects may directly or indirectly impact the interpretation of the status and quality of project definition deliverables and hence estimate classifications. Examples of status considerations include:

- Petroleum E&P projects are often in remote locations and have unique logistical and environmental issues.
- Resources are often seen as national legacies with attendant political, legal and socio-economic considerations.
- Improved petroleum prices and/or extraction technologies may lead to reacquisition of leases that have unforeseen environmental legacies and regulatory implications.
- Feasibility studies may tend to focus on technical issues and less on business and project delivery issues associated with the political and/or regulatory environment (e.g., execution strategy and planning deliverables).
- Drilling and completion risks can change as the drilling program progresses, especially involving multi-year drilling programs.
- Site specific factors, such as lease boundaries and expirations, can affect development plans.
- The industry historically has been characterized by the interplay of significant swings in supply and demand.

4. COST ESTIMATE CLASSIFICATION MATRIX FOR THE PETROLEUM EXPLORATION AND PRODUCTION INDUSTRIES

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

Upstream scope development and decision making must be aligned with petroleum resources definitions, classification, and categorization. Industry guidelines for that purpose are defined in the *Guidelines for Application of the Petroleum Resources Management System (PRMS)* by the Society of Petroleum Engineers (SPE)[7]. These guidelines are complex and must be read directly to get a full understanding, but the following discussion summarizes the ties between petroleum resource and estimate classification.

Per the SPE, the PRMS is a project-based system, where a project: "Represents the link between the petroleum accumulation and the decision-making process, including budget allocation…In general, an individual project will represent *a specific maturity level at which a decision is made on whether or not to proceed*". The PRMS guidelines explain in detail the unique portfolio nature of resource development (upstream) projects and the need to evaluate the complex integration and phasing of resources and development alternatives.

The PRMS has two distinct dimensions: *"(1) the development project…and, in particular, the chance of commerciality of that project; and (2) the range of uncertainty in the petroleum quantities that are forecast to be produced and sold in the future from that development project*." The PRMS addresses commerciality with discounted cash flow/net present value methods incorporating the capital expenditure, the operating expenditure, and forecasted sales of petroleum quantities.

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

	Primary Characteristic	*Secondary Characteristic*		
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges at an 80% confidence interval
Class 5	0% to 2%	Conceptual planning	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Screening options	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Funding authorization	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Project control	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Fixed price bid check estimate	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Table 1 – Cost Estimate Classification Matrix for the Petroleum Exploration and Production Industries

This matrix and guideline outline an estimate classification system that is specific to petroleum E&P industries. Refer to Recommended Practice 17R-97[2] for a general matrix that is non-industry specific, or to other cost estimate classification RPs for guidelines that will provide more detailed information for application in other specific industries. These will provide additional information, particularly the *Estimate Input Checklist and Maturity Matrix* which determines the class in those industries. See Professional Guidance Document 01, *Guide to Cost Estimate Classification.* [12]

Table 1 illustrates typical ranges of accuracy ranges that are associated with the petroleum E&P industries. The +/- value represents typical percentage variation at an 80% confidence interval of actual costs from the cost estimate after application of appropriate contingency (typically to achieve a 50% probability of project cost overrun versus underrun) for given scope. Depending on the technical and project deliverables (and other variables) and risks associated with each estimate, the accuracy range for any particular estimate is expected to fall within the ranges identified. However, this does not preclude a specific actual project result from falling outside of the indicated range of ranges identified in Table 1. In fact, research indicates that for weak project systems and complex or otherwise risky projects, the high ranges may be two to three times the high range indicated in Table 1. [13]

It should be noted that the average quality and accessibility of reservoirs in production are declining, and processing complexity is increasing; therefore, the high end of the expected accuracy range may be higher than is currently stated in this RP.

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

- Level of familiarity with technology.
- Unique/remote nature of project locations and conditions and the availability of reference data for those.
- Complexity of the project and its execution.
- Quality of reference cost estimating data.
- Quality of assumptions used in preparing the estimate.
- Experience and skill level of the estimator.
- Estimating techniques employed.
- Time and level of effort budgeted to prepare the estimate.
- Market and pricing conditions.
- Currency exchange.
- The accuracy of the geotechnical data.
- Geo-political, environmental, and other regulatory circumstances.
- Socio-economic conditions.

Systemic risks such as these are often the primary drivers of accuracy, especially during the early stages of project definition. As project definition progresses, project-specific risks (e.g. risk events and conditions) become more prevalent (or better known) and also drive the accuracy range.

Another concern in estimates is potential organizational pressure for a predetermined value that may result in a biased estimate. The goal should be to have an unbiased and objective estimate both for the base cost and for contingency. The stated estimate ranges are dependent on this premise and a realistic view of the project. Failure to appropriately address systemic risks (e.g. technical complexity) during the risk analysis process, impacts the resulting probability distribution of the estimated costs, and therefore the interpretation of estimate accuracy.

Petroleum E&P projects are very sensitive to volatility in oil and gas pricing as well as geopolitical issues. Early geological studies may be highly speculative and entail a lot of uncertainty as to the commercial viability of a new E&P project. Conversely, a project may have a history of feasibility studies from current and previous owners that can be readily revived to meet securities disclosure rules when the technology and oil and gas prices improve sufficiently to spark interest among investors.

Figure 1 illustrates the general relationship trend between estimate accuracy and the estimate classes (corresponding with the maturity level of project definition). Depending upon the technical complexity of the project, the availability of appropriate cost reference information, the degree of project definition, and the inclusion of appropriate contingency determination, a typical Class 5 estimate for a petroleum exploration and production industry project may have an accuracy range as broad as -50% to +100%, or as narrow as -20% to +30%. However, note that this is dependent upon the contingency included in the estimate appropriately quantifying the uncertainty and risks associated with the cost estimate. Refer to Table 1 for the accuracy ranges conceptually illustrated in Figure 1. [14]

August 7, 2020

Figure 1 also illustrates that the estimating accuracy ranges overlap the estimate classes. There are cases where a Class 5 estimate for a particular project may be as accurate as a Class 3 estimate for a different project. For example, similar accuracy ranges may occur if the Class 5 estimate of one project that is based on a repeat project with good cost history and data and, whereas the Class 3 estimate for another is for a project involving new technology. It is for this reason that Table 1 provides ranges of accuracy values. This allows consideration of the specific circumstances inherent in a project and an industry sector to provide realistic estimate class accuracy range percentages. While a target range may be expected for a particular estimate, the accuracy range should always be determined through risk analysis of the specific project and should never be pre-determined. AACE has recommended practices that address contingency determination and risk analysis methods. [15]

If contingency has been addressed appropriately approximately 80% of projects should fall within the ranges shown in Figure 1. However, this does not preclude a specific actual project result from falling inside or outside of the indicated range of ranges identified in Table 1. As previously mentioned, research indicates that for weak project systems, and/or complex or otherwise risky projects, the high ranges may be two to three times the high range indicated in Table 1.

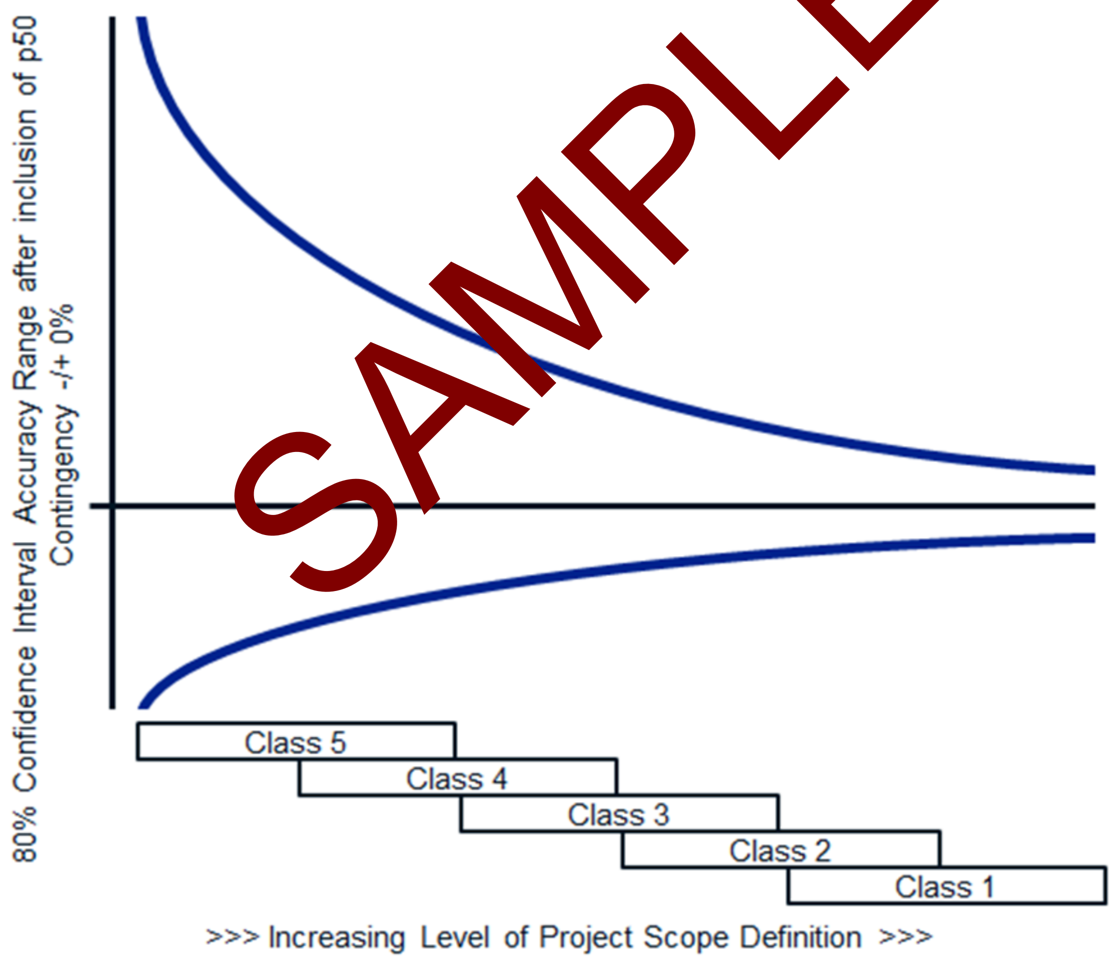

Figure 1 – Illustration of the Variability in Accuracy Ranges for Petroleum E&P Industry Estimates

August 7, 2020

5. DETERMINATION OF THE COST ESTIMATE CLASS

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

6. CHARACTERISTICS OF THE ESTIMATE CLASSES

The following tables (2a through 2e) provide detailed descriptions of the five estimate classifications as applied in the petroleum E&P industries. They are presented in the order of least-defined estimates to the most-defined estimates. These descriptions include brief discussions of each of the estimate characteristics that define an estimate class.

For each table, the following information is provided:

- **Description:** A short description of the class of estimate, including a brief listing of the expected estimate inputs based on the maturity level of project definition deliverables.
- **Maturity Level of Project Definition Deliverables (Primary Characteristic):** Describes a particularly key deliverable and a typical target status in stage-gate decision processes, plus an indication of approximate percent of full definition of project and technical deliverables. Typically, but not always, maturity level correlates with the percent of engineering and design complete.
- **End Usage (Secondary Characteristic):** A short discussion of the possible end usage of this class of estimate.
- **Estimating Methodology (Secondary Characteristic):** A listing of the possible estimating methods that may be employed to develop an estimate of this class.
- **Expected Accuracy Range (Secondary Characteristic):** Typical variation in low and high ranges after the application of contingency (determined at a 50% level of confidence). Typically, this represents about 80% confidence that the actual cost will fall within the bounds of the low and high ranges if contingency appropriately forecasts uncertainty and risks.
- **Alternate Estimate Names, Terms, Expressions, Synonyms:** This section provides other commonly used names that an estimate of this class might be known by. These alternate names are not endorsed by this recommended practice. The user is cautioned that an alternative name may not always be correlated with the class of estimate as identified in Tables 2a-2e.

CLASS 5 ESTIMATE

Description:
Class 5 estimates are generally prepared based on very limited information, and subsequently have wide accuracy ranges. Class 5 estimates are generally based on unclarified contingent resources defined by preliminary exploration drilling and appraisal and general experience with related projects to comply with disclosure standards. This would include a simple geological model and estimated recovery and quality of products produced. A simple drilling and completion plan is then prepared that covers drilling method; gross production schedules; nominal facility capacity; assumed block flow diagrams and process rates; and conceptual definition of infrastructure needs. Substructure design concepts are selected. There may be a minimum of coring work and geotechnical, analogues or other back up studies available. No design drawings or equipment specifications may be prepared beyond some rough notes and sketches by the project engineer, perhaps little more than proposed plant type, capacity and location. Class 5 estimates, due to the requirements of end use, may be prepared within a very limited amount of time and with little effort expended—sometimes requiring less than an hour to prepare.

Maturity Level of Project Definition Deliverables:
Key deliverable and target status: Field developed schematic and assumed drilling plan agreed by key stakeholders. List of key design basis assumptions. 0% to 2% of full project definition.

End Usage:
Class 5 estimates are prepared for any number of strategic business planning purposes, such as but not limited to market studies, assessment of initial viability, evaluation of alternate schemes, rough project screening, project location studies, and long-range capital planning.

Estimating Methodology:
Class 5 estimates generally rely on available internal and industry data for similar previous projects. Gross unit costs may be applied to drilling and completion. Factoring techniques may be used to extend major facility costs to include all equipment, commodities, and gross unit costs applied to building volumes, pipeline and other elements. Cost/capacity methods may be used for some plant elements. Indirect costs are factored from directs based on internal and industry experience with typical cost ratios and other parametric and modeling techniques utilized.

Expected Accuracy Range:
Typical accuracy ranges for Class 5 estimates are
-20% to -50% on the low side, and +30% to +100% on the high side, depending on the technological, geographical and geological and reservoir complexity of the project, appropriate reference information and other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks. Declining quality and accessibility of reservoirs may be driving higher risks. The uncertainty varies by work type so that moderate ranges apply to structures, wider ranges apply to earthworks and infrastructure and narrower ranges apply to machinery (assuming applicable procurement data is available from similar past projects).

Alternate Estimate Names, Terms, Expressions, Synonyms:
Preliminary economic assessment, geological study estimate, order of magnitude estimate, capacity factor estimate, conceptual study, venture analysis, scoping study, preliminary evaluation.

Table 2a – Class 5 Estimate

August 7, 2020

CLASS 4 ESTIMATE

Description:
Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. A Class 4 estimate is usually carried out using development unclarified contingent resources defined by drilling confirmation of the reservoir zone(s). A preliminary geological model and preliminary well plan are required, including supporting facilities optimization, geotechnical and hydro-geological studies, etc. Structure maps, single rock properties for major reservoir layers are available. A feasible drilling and completions concept is available. Potential drilling and completion hazards are identified. For offshore projects preliminary meta ocean data are acquired. The fluids test work and production profile from analogs should determine the probable process flow sheet and approximate material balance, and identify the major equipment. Engineering would comprise at a minimum: general arrangement (GA) drawings, equipment lists for major equipment, nominal facility capacity, block schematics, and process flow diagrams (PFDs) for the main process systems.

Maturity Level of Project Definition Deliverables:
Key deliverable and target status: Process flow diagram (PFD) issued for design for facilities and preliminary drilling plan for the well construction. Rig category is identified. 1% to 15% of full project definition.

End Usage:
Class 4 estimates are vitally important to E&P investors internationally. Recoverable reserves cannot be identified as economic without an estimate of at least this class. They are held to disclosure requirements by the involved securities jurisdictions and are subject to analysis by third party reviewers. The estimates are used for ranking and screening of options, analyzing technical and economic feasibility and then identifying the preferred option(s) for the final feasibility study (Class 3 estimate) prior to project sanction.

Estimating Methodology:
Major equipment costs are based on recent budget prices from vendors using preliminary requirements. Facility costs are estimated by approximate quantity take-offs from the general arrangement drawings and applying unit cost factors. Onshore earthworks, substructures, and infrastructure are not well defined but allowances can be set based on preliminary contours for overland piping lengths and overhead electrical power lines, etc. Equipment installation is estimated by a combination of quantity take-offs and unit cost factors based on the available scope definition. Offshore structures and installations are based on preliminary estimates of quantities, fabrication locations, and installation durations. The same method also applies to indirect costs (as a % of directs).

Expected Accuracy Range:
Typical accuracy ranges for Class 4 estimates are -15% to -30% on the low side and +20% to +50% on the high side, depending on the technological, geographical and geological complexity of the project, appropriate reference information, and other risks (after the inclusion of an appropriate contingency determination). The uncertainty varies by work type with moderate ranges applying to structures and plant commodities, wider ranges applying to earthworks and infrastructure and narrower ranges applying to equipment installation.

Alternate Estimate Names, Terms, Expressions, Synonyms:
Pre-feasibility or preliminary feasibility, intermediate economic study estimate, equipment factor estimate, conceptual estimate.

Table 2b – Class 4 Estimate

CLASS 3 ESTIMATE

Description:
Class 3 estimates are generally prepared to form the basis for budget authorization, appropriation, and/or funding. A Class 3 estimate is prepared using development pending contingent resources (or justified for development reserves) as defined within acceptable confidence limits. Final drilling and completion program is approved. Casing and mud program is finalized. Preliminary analysis of shallow hazards, fracture gradient, and pore pressure data is sufficient. Preliminary well design is available. Engineering is expected to provide general arrangement drawings (GAs), issued for design piping and instrument diagrams (P&ID's) and single line electrical drawings**.** For onshore projects, plot plans and layout drawings provide primary definition. Whereas, for offshore projects, topside deck arrangement, module fabrication, substructure design, marine transport, and subsea requirements provide primary definition. Remedial action plan resulting from HAZOPs is identified.

Maturity Level of Project Definition Deliverables:
Key deliverable and target status: Piping and instrumentation diagrams (P&IDs) issued for design for plant and final surface and bottom hole locations are identified for drilling. Completions and stimulation plans are defined. Rig, heavy transport, heavy lift, lay, and temporary accommodation vessel candidates are identified and inspected. Soil or sea bed strengths are known. Loads and weights are known for offshore platform substructures and decks. Weather and environmental conditions are confirmed. 10% to 40% of full project definition.

End Usage:
Class 3 estimates are typically prepared to support full project funding requests for internal and/or external investment. By default, the Class 3 estimate is the initial baseline for project and change control until superseded by the updated project control estimate (Class 2).

Estimating Methodology:
Class 3 estimates are generally based on detail take-offs and estimates for significant cost items for direct and indirect costs where detailing can be done (e.g., pipe fittings not detailed). Major equipment and fabrication contracts are priced based on supplier quotations. Construction (bulks, labor and equipment) are estimated based on local pricing and trade agreements covering the available quantity take-offs. For offshore projects, transportation and installation bids have been received. Platform costs are based on definitive deck and substructure weights. Flow, transfer, and export lines are based on platform and drilling locations, and sales points. Onshore mass earthwork and infrastructure such as transport pipelines and power transmission lines are based on take-off from preliminary contours and routing. Less significant costs may be factored such as small bore pipe as a % of large bore. Individual well AFEs are prepared. Local labor requirements for crew are determined. Logic driven schedule is formulated. Development, depletion, and reservoir surveillance plans are finalized. Preliminary logistics plan is developed.

Expected Accuracy Range:
Typical accuracy ranges for Class 3 estimates are -10% to -20% on the low side, and +10% to +30% on the high side, depending on the technological, geographical and geological complexity of the project, appropriate reference information, and other risks (after inclusion of an appropriate contingency determination). The uncertainty varies by work type with moderate ranges applying to structures and plant commodities, wider ranges applying to earthworks and infrastructure and narrower ranges applying to equipment installation.

Alternate Estimate Names, Terms, Expressions, Synonyms:
Feasibility estimate, sanction estimate, bankable feasibility estimate, final feasibility estimate, initial budget (or baseline) estimate, preliminary control estimate, forced detail estimate, design basis memorandum (DBM).

Table 2c – Class 3 Estimate

August 7, 2020

CLASS 2 ESTIMATE

Description:
A Class 2 estimate is based upon a detailed well design and production schedule using justified or approved for development reserves and contains all of the input of a Class 3 estimate with regard to process information. Class 2 scope definitions will include all the information contained in Class 4 and Class 3 estimates as well as additional engineering information as the project proceeds into the execution phase such as detail project execution plan and schedules, accurate topographic maps, actual surveys of the plant site and foundation data, etc. Meta ocean data is confirmed and hindcast studies are completed. Wellhead and downhole equipment specifications are defined. Casing and mud program are finalized.

Maturity Level of Project Definition Deliverables:
Key deliverable and target status: All specifications and datasheets complete including for instrumentation. Major design drawings, such as P&IDs, are released for construction. Well design with production profiles are finalized.
30% to 75% of full project definition.

End Usage:
Class 2 estimates are typically prepared as the detailed contractor control baseline (and update to owner's control baseline) against which all actual costs and resources will now be monitored for variations to the budget, and form a part of the change management program.

Estimating Methodology:
Class 2 estimates generally involve a high degree of deterministic estimating methods. Class 2 estimates are prepared in great detail as needed to support bidding, project administration and change control. Most of the equipment will have been ordered or have firm quotes. For onshore projects, earthwork and infrastructure such as transport pipelines and power transmission lines are based on take-off from definitive contours and routing. For offshore projects, flow, transfer, and export lines are based on final subsea architecture, confirmed bathymetry and routing. Some subcontracts for early works may be underway. For those areas of the project still undefined, an assumed level of detail takeoff (forced detail) may be developed to use as line items in the estimate rather than factored allowances. A resource-loaded network schedule is used especially for indirects and equipment. Drilling rigs are scheduled.

Expected Accuracy Range:
Typical accuracy ranges for Class 2 estimates are -5% to -15% on the low side, and +5% to +20% on the high side, depending on the technological, geographical and geological complexity of the project, appropriate reference information, and other risks (after the inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks.

Alternate Estimate Names, Terms, Expressions, Synonyms:
Definitive cost estimate, project control estimate (PCE), revised baseline estimate, detailed control estimate, execution phase estimate, fall-out detail estimate.

Table 2d – Class 2 Estimate

CLASS 1 ESTIMATE

Description:
Class 1 estimates are generally prepared for discrete parts or sections of the total project rather than for the entire project based on extensive design definition. Reserves will be proven with drilling usually underway either approved for development or in production. The detail estimate may be used by subcontractors for bidding or by owners for check estimates for various purposes.

Maturity Level of Project Definition Deliverables:
Key deliverable and target status: All deliverables in the maturity matrix complete. 65% to 100% of full project definition.

End Usage:
Class 1 estimates are used by contractors to support their bids or by owners as a check on bids received. The estimates may be used by both parties to support their contract negotiations, change control process, and/or to analyze and resolve claims and disputes.

Estimating Methodology:
Class 1 estimates generally involve the highest degree of deterministic estimating methods, and require a significant amount of effort. Class 1 estimates are prepared in great detail, usually on a selected portion of the project scope. All items in the estimate are usually unit cost line items based on actual design quantities.

Expected Accuracy Range:
Typical accuracy ranges for Class 1 estimates are -3% to -10% on the low side, and +3% to +15% on the high side, depending on the technological, geographical and geological complexity of the project, appropriate reference information, and other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks.

Alternate Estimate Names, Terms, Expressions, Synonyms:
Full detail estimate, tender check estimate, firm price, bottoms-up estimate, detailed engineering estimate, detailed control estimate, forced detail estimate, change order estimate

Table 2e – Class 1 Estimate

7. ESTIMATE INPUT CHECKLIST AND MATURITY MATRIX

Table 3 maps the extent and maturity of estimate input information (deliverables) against the five estimate classification levels. This is a checklist of basic deliverables found in common practice in the petroleum E&P industries. The maturity level is an approximation of the completion status of the deliverable. The degree of completion is indicated by the following descriptors:

General Project Data:

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

- **Preliminary (P)**: Project definition has begun and progressed to at least an intermediate level of completion. Review and approvals for its current status has occurred.

- **Defined (D)**: Project definition is advanced, and reviews have been conducted. Development may be near completion with the exception of final approvals.

Technical Deliverables:

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

- **Started (S):** Work on the deliverable has begun. Development is typically limited to sketches, rough outlines, or similar levels of early completion.

- **Preliminary (P):** Work on the deliverable is advanced. Interim, cross-functional reviews have usually been conducted. Development may be near completion except for final reviews and approvals.

- **Complete (C):** The deliverable has been reviewed and approved as appropriate.

MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES	ESTIMATE CLASSIFICATION				
	CLASS 5	**CLASS 4**	**CLASS 3**	**CLASS 2**	**CLASS 1**
	0% to 2%	**1% to 15%**	**10% to 40%**	**30% to 75%**	**65% to 100%**
GENERAL PROJECT DATA:					
A. SCOPE:					
Non-Process Facilities (Infrastructure, Ports, Pipeline, Power Transmission, etc.)	**P**	**P**	**D**	**D**	**D**
Project Scope of Work Description	**P**	**P**	**D**	**D**	**D**
Byproduct and Waste Disposal	**NR**	**P**	**D**	**D**	**D**
Site Infrastructure (Access, Construction Power, Camp etc.)	**NR**	**P**	**D**	**D**	**D**
Project Maturity (Guidelines for Application of the PRMS [7])	**NR** (Unclarified)	**NR/P** (Development Unclarified)	**P** (Development Pending)	**P/D** (Approved for Development)	**D** (On Production)
B. CAPACITY					
Facility Output / Production Profile	**P**	**P**	**D**	**D**	**D**

August 7, 2020

MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES	ESTIMATE CLASSIFICATION				
	CLASS 5	CLASS 4	CLASS 3	CLASS 2	CLASS 1
	0% to 2%	1% to 15%	10% to 40%	30% to 75%	65% to 100%
Plant Production / Facility (includes power facilities)	P	P	D	D	D
Electrical Power Requirements (when not the primary capacity driver)	NR	P	D	D	D
C. PROJECT LOCATION:					
Plant / Platform / Drilling	P	P	D	D	D
Well Surface and Bottom Hole	P	P	D	D	D
D. REQUIREMENTS:					
Codes and/or Standards	NR	P	D	D	D
Communication Systems	NR	P	D	D	D
Fire Protection and Life Safety	NR	P	D	D	D
Environmental Monitoring	NR	NR	P	P	D
E. TECHNOLOGY SELECTION:					
Process Technology	P	P	D	D	D
F. STRATEGY:					
Contracting / Sourcing	NR	P	D	D	D
Escalation	NR	P	D	D	D
G. PLANNING:					
Development, Depletion, and Reservoir Surveillance Plan / Schedule	P	P	D	D	D
Well Construction Plans	P	P	D	D	D
Logistics Plan	P	P	P	D	D
Reserve Determination (Guidelines for Application of the PRMS [7])	NR/P (Possible)	P (Probable)	D (Proven)	D (Proven)	D (Proven)
Decommissioning Plan	NR	P	D	D	D
Integrated Project Plan[1]	NR	P	D	D	D
Project Code of Accounts	NR	P	D	D	D
Project Master Schedule	NR	P	D	D	D
Regulatory Approval & Permitting	NR	P	D	D	D
Risk Register	NR	P	D	D	D
Stakeholder Consultation / Engagement / Management Plan	NR	P	D	D	D
Work Breakdown Structure	NR	P	D	D	D
Startup and Commissioning Plan	NR	P	P/D	D	D

[1] The integrated project plan (IPP), project execution plan (PEP), project management plan (PMP), or more broadly the project plan, is a high-level management guide to the means, methods and tools that will be used by the team to manage the project. The term integration emphasizes a project life cycle view (the term execution implying post-sanction) and the need for alignment. The IPP covers all functions (or phases) including engineering, procurement, contracting strategy, fabrication, construction, commissioning and startup within the scope of work. However, it also includes stakeholder management, safety, quality, project controls, risk, information, communication and other supporting functions. In respect to estimate classification, to be rated as *defined*, the IPP must cover all the relevant phases/functions in an integrated manner aligned with the project charter (i.e., objectives and strategies); anything less is *preliminary*. The overall IPP cannot be rated as *defined* unless all individual elements are defined and integrated.

August 7, 2020

MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES	ESTIMATE CLASSIFICATION				
	CLASS 5	CLASS 4	CLASS 3	CLASS 2	CLASS 1
	0% to 2%	1% to 15%	10% to 40%	30% to 75%	65% to 100%
H. STUDIES:					
Geology	P	P	D	D	D
Geotechnical and Fluids Characteristics	P	P	D	D	D
Environmental Impact / Sustainability Assessment	NR	P	D	D	D
Environmental / Existing Conditions	NR	P	D	D	D
Meteorology and/or Oceanographic / Subsea	NR	P	D	D	D
Soils and Hydrology	NR	P	D	D	D
TECHNICAL DELIVERABLES:					
Block Flow Diagrams	S/P	C	[illegible]	C	C
Field Development Schematics	S/P	P/C	C	C	C
Equipment Datasheets	NR/S	P	C	C	C
Equipment Lists: Electrical	NR/S	[illegible]	C	C	C
Equipment Lists: Process / Utility / Mechanical	NR/S	P	C	C	C
Process Flow Diagrams (PFDs)	NR	P/C	C	C	C
Design Specifications	NR	S/P	C	C	C
Electrical One-Line Drawings	NR	S/P	C	C	C
General Equipment Arrangement Drawings	NR	S/P	C	C	C
Heat & Material Balances	NR	S/P	C	C	C
Instrument List	NR	S/P	C	C	C
Piping & Instrument Diagrams (P&IDs)	NR	S/P	C	C	C
Plot Plans / Facility Layouts	NR	S/P	C	C	C
Utility Flow Diagrams (UFDs)	NR	S/P	C	C	C
Construction Permits	NR	S/P	P/C	C	C
Civil / Site / Structural / Architectural Discipline Drawings	NR	S/P	P	C	C
Demolition Plan and Drawings	NR	S/P	P	C	C
Erosion Control Plan and Drawings	NR	S/P	P	C	C
Fire Protection and Life Safety Drawings and Details	NR	S/P	P	C	C
Weight Reports / Bill of Quantities	NR	S/P	P	P/C	C
Rig / Marine Vessel Specifications	NR	S	P/C	C	C
Well Designs	NR	S	P	C	C
Electrical Schedules	NR	NR/S	P	P/C	C
Instrument and Control Schedules	NR	NR/S	P	P/C	C
Instrument Datasheets	NR	NR/S	P	P/C	C
Piping Schedules	NR	NR/S	P	P/C	C
Piping Discipline Drawings	NR	NR/S	S/P	C	C
Spare Parts Listings	NR	NR	P	P/C	C
Electrical Discipline Drawings	NR	NR	S/P	P/C	C
Facility Emergency Communication Plan and Drawings	NR	NR	S/P	P/C	C

MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES	ESTIMATE CLASSIFICATION				
	CLASS 5	CLASS 4	CLASS 3	CLASS 2	CLASS 1
	0% to 2%	1% to 15%	10% to 40%	30% to 75%	65% to 100%
Information Systems / Telecommunication Drawings	NR	NR	S/P	P/C	C
Instrumentation / Control System Discipline Drawings	NR	NR	S/P	P/C	C
Mechanical Discipline Drawings	NR	NR	S/P	P/C	C

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

8. BASIS OF ESTIMATE DOCUMENTATION

The basis of estimate (BOE) typically accompanies the cost estimate. The basis of estimate is a document that describes how an estimate is prepared and defines the information used in support of development. A basis document commonly includes, but is not limited to, a description of the scope included, methodologies used, references and defining deliverables used, assumptions and exclusions made, clarifications, adjustments, and some indication of the level of uncertainty.

The BOE is, in some ways, just as important as the estimate since it documents the scope and assumptions; and provides a level of confidence to the estimate. The estimate is incomplete without a well-documented basis of estimate. See AACE Recommended Practice 34R-05 *Basis of Estimate* for more information [16].

9. PROJECT DEFINITION RATING SYSTEM

An additional step in documenting the maturity level of project definition is to develop a project definition rating system. This is another tool for measuring the completeness of project scope definition. Such a system typically provides a checklist of scope definition elements and a scoring rubric to measure maturity or completeness for each element. A better project definition rating score is typically associated with a better probability of achieving project success.

Such a tool should be used in conjunction with the AACE estimate classification system; it does not replace estimate classification. A key difference is that a project definition rating measures overall maturity across a broad set of project definition elements, but it usually does not ensure completeness of the key project definition deliverables required to meet a specific class of estimate. For example, a good project definition rating may sometimes be achieved by progressing on additional project definition deliverables, but without achieving signoff or completion of a key deliverable.

AACE estimate classification is based on ensuring that key project deliverables have been completed or met the required level of maturity. If a key deliverable that is indicated as needing to be complete for Class 3 (as an example) has not actually been completed, then the estimate cannot be regarded as Class 3 regardless of the maturity or progress on other project definition elements.

An example of a project definition rating system is the *Project Definition Rating Index* developed by the Construction Industry Institute. It has developed several indices for specific industries, such as IR113-2 [17] for the process industry and IR115-2 [18] for the building industry. Similar systems have been developed by the US Department of Energy [19].

10. CLASSIFICATION FOR LONG-TERM PLANNING AND ASSET LIFE CYCLE COST ESTIMATES

As stated in the Purpose section, classification maps the phases and stages of project cost estimating. Typically, in a phase-gate project system, scope definition and capital cost estimating activities flow from framing a business opportunity through to a capital investment decision and eventual project completion in a more-or-less steady, short-term (e.g., several years) project life-cycle process.

Cost estimates are also prepared to support long-range (e.g., perhaps several decades) capital budgeting and/or asset life cycle planning. Asset life cycle estimates are also prepared to support net present value (e.g., estimates for initial capital project, sustaining capital, and decommissioning projects), value engineering and other cost or economic studies. These estimates are necessary to address sustainability as well. Typically, these long-range estimates are based on minimal scope definition as defined for *Class 5*. However, these asset life cycle "conceptual" estimates are prepared so far in advance that it is virtually assured that the scope will change from even the minimal level of definition assumed at the time of the estimate. Therefore, the expected estimate accuracy values reported in Table 1 (percent that actual cost will be over or under the estimate including contingency) are not meaningful because the Table 1 accuracy values explicitly *exclude scope change*. For long-term estimates, one of the following two classification approaches is recommended:

- If the long-range estimate is to be updated or maintained periodically via a controlled, documented life cycle process that addresses scope and technology changes to estimates over time (e.g., nuclear or other licensing may require that future decommissioning estimates be periodically updated), the estimate is rated as *Class 5* and the Table 1 accuracy ranges are assumed to apply for the specific scope included in the estimate at the time of estimate preparation. Scope changes are explicitly excluded from the accuracy range.

- If the long-range estimate is performed as part of a process or analysis where scope and technology change is not expected to be addressed in routine estimate updates over time, the estimate is rated as *Unclassified* or as *Class 10* (if a class designation is required to meet organizational procedures), and the Table 1 accuracy ranges cannot be assumed to apply. The term *Class 10* is specifically used to distinguish these long-range estimates from the relatively short time-frame *Class 5* through *Class 1* capital cost estimates identified in Table 1 and this RP; and to indicate the order-of-magnitude difference in potential expected estimate accuracy due to the infrequent updates for scope and technology. Unclassified (or Class 10) estimates are not associated with indicated expected accuracy ranges.

In all cases, a *Basis of Estimate* should be documented so that the estimate is clearly understood by those reviewing and/or relying on them later. Also, the estimating methods and other characteristics of Class 5 estimates generally apply. In other words, an *Unclassified* or *Class 10* designation must not be used as an excuse for unprofessional estimating practice.

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APPENDIX: UNDERSTANDING ESTIMATE CLASS AND COST ESTIMATE ACCURACY

Despite the verbiage included in the RP, often, there are still misunderstandings that the class of estimate, as defined in the RP above, defines an expected accuracy range for each estimate class. This is incorrect. The RP clearly states that "while a target range may be expected for a particular estimate, the accuracy range should always be determined through risk analysis of the specific project and should never be predetermined." Table 1 and Figure 1 in the RP are intended to illustrate only the general relationship between estimate accuracy and the level of project definition. For the petroleum exploration and production industries, typical estimate ranges described in RP 87R-14 above are shown as a range of ranges:

- Class 5 Estimate:
    - High range typically ranges from +30% to +100%
    - Low range typically ranges from -20% to -50%
- Class 4 Estimate:
    - High range typically ranges from +20% to +50%
    - Low range typically ranges from -15% to -30%
- Class 3 Estimate:
    - High range typically ranges from +10% to +30%
    - Low range typically ranges from -10% to -20%
- Class 2 Estimate:
    - High range typically ranges from +5% to +20%
    - Low range typically ranges from -5% to -15%
- Class 1 Estimate:
    - High range typically ranges from +3% to +15%
    - Low range typically ranges from -3% to -10%

As indicated in the RP, these +/- percentage numbers associated with an estimate class are intended as rough indicators of the accuracy relationship. They are merely a useful simplification given the reality that every individual estimate will be associated with a unique probability distribution correlated with its specific level of uncertainty. As indicated in the RP, estimate accuracy should be determined through a risk analysis for each estimate.

It should also be noted that there is no indication in the RP of contingency determination being based on the class of estimate. AACE has recommended practices that address contingency determination and risk analysis methods (for example RP 40R-08, *Contingency Estimating – General Principles* [3]). Furthermore, the level of contingency required for an estimate is not the same as the upper limits of estimate accuracy (as determined by a risk analysis).

The results of the estimating process are often conveyed as a single value of cost or time. However, since estimates are predications of an uncertain future, it is recommended that all estimate results should be presented as a probabilistic distribution of possible outcomes in consideration of risk.

Every estimate is a prediction of the expected final cost or duration of a proposed project or effort (for a given scope of work). By its nature, an estimate involves assumptions and uncertainties. Performing the work is also subject to risk conditions and events that are often difficult to identify and quantify. Therefore, every estimate presented as a single value of cost or duration will likely deviate from the final outcome (i.e., statistical error). In simple terms, this means that every point estimate value will likely prove to be wrong. Optimally, the estimator will analyze the uncertainty and risks and produce a probabilistic estimate that provides decision makers with the probabilities of over-running or under-running any particular cost or duration value. Given this probabilistic nature of an estimate, an estimate should not be regarded as a single point cost or duration. Instead, an estimate actually

August 7, 2020

reflects a range of potential outcomes, with each value within this range associated with a probability of occurrence.

Individual estimates should always have their accuracy ranges determined by a quantitative risk analysis study that results in an estimate probability distribution. The estimate probability distribution is typically skewed. Research shows the skew is typically to the right (positive skewness with a longer tail to the right side of the distribution) for large and complex projects. In part, this is because the impact of risk is often unbounded on the high side.

High side skewness implies that there is potential for the high range of the estimate to exceed the median value of the probability distribution by a higher absolute value than the difference between the low range of the estimate and the median value of the distribution.

Figure A1 shows a positively skewed distribution for a sample cost estimate risk analysis that has a point base estimate (the value before adding contingency) of \$89.5. In this example, a contingency of \$4.5 (approximately 5%) is required to achieve a 50% probability of underrun, which increases the final estimate value after consideration of risk to \$93. Note that this example is intended to describe the concepts but not to recommend specific confidence levels for funding contingency or management reserves of particular projects; that depends on the stakeholder risk attitude and tolerance.

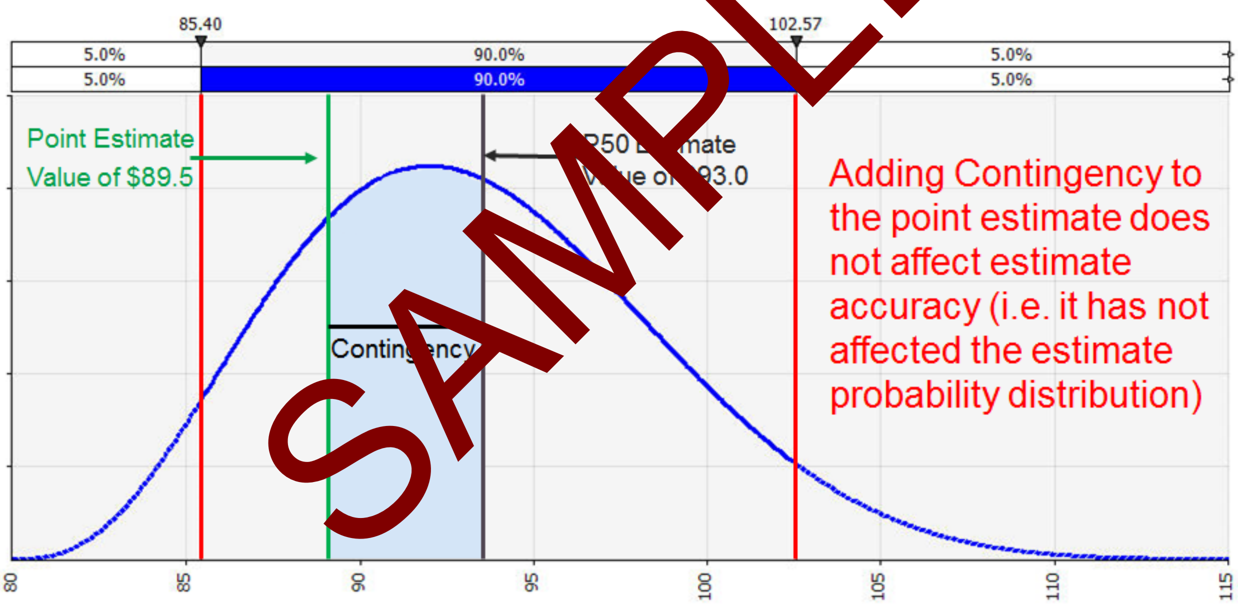

Figure – A1: Example of an Estimate Probability Distribution at a 90% Confidence Interval

Note that adding contingency to the base point estimate does not affect estimate accuracy in absolute terms as it has not affected the estimate probability distribution (i.e., high and low values are the same). Adding contingency simply increases the probability of underrunning the final estimate value and decreases the probability of overrunning the final estimate value. In this example, the estimate range with a 90% confidence interval remains between approximately \$85 and \$103 regardless of the contingency value.

As indicated in the RP, expected estimate accuracy tends to improve (i.e., the range of probable values narrows) as the level of project scope definition improves. In terms of the AACE International estimate classifications, increasing levels of project definition are associated with moving from Class 5 estimates (lowest level of scope definition) to Class 1 estimates (highest level of scope definition), as shown in Figure 1 of the RP. Keeping in mind that accuracy is an expression of an estimate's predicted closeness to the final actual value; anything included in that final actual cost, be it the result of general uncertainty, risk conditions and events, price escalation, currency or anything else within the project scope, is something that estimate accuracy measures must communicate in some manner. With that in mind, it should be clear why standard accuracy range values are not applicable to individual estimates.

The level of project definition reflected in the estimate is a key risk driver and hence is at the heart of estimate classification, but it is not the only driver of estimate risk and uncertainty. Given all the potential sources of risk and uncertainty that will vary for each specific estimate, it is simply not possible to define a range of estimate accuracy solely based on the level of project definition or class of estimate.