In The Matter of the Application of San Diego Gas & Electric Company (U 902 G) and Southern California Gas Company (U 904 G) for a Certificate of Public Convenience and Necessity for the Pipeline Safety & Reliability Project

Application 15-09-013

Application No: A.15-09-013
Exhibit No.:
Witness: Ronn Gonzalez

CHAPTER II

PREPARED PHASE 2 DIRECT TESTIMONY OF

RONN GONZALEZ

ON BEHALF OF

SAN DIEGO GAS & ELECTRIC COMPANY

AND

SOUTHERN CALIFORNIA GAS COMPANY

**BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF CALIFORNIA**

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I. PURPOSE AND OVERVIEW

The purpose of my testimony is to describe the cost estimating methodology used to develop the Class Three cost forecasts for the 19 independent projects (Line 1600 projects) described in the Phase 2 direct testimony of Norm G. Kohls. SDG&E and SoCalGas (collectively, the Utilities) follow the best practices of American Association of Cost Engineers (AACE) International,[1] an industry leading organization in the field of cost estimating. The Utilities apply this cost estimating methodology to develop Class Three estimates for all Pipeline Safety Enhancement Plan (PSEP) projects, and the California Public Utilities Commission (Commission) previously approved its use to forecast PSEP costs in Decision (D.) 19-03-025 and D.19-09-051. The Utilities have applied the same methodology to the Line 1600 projects.

In Section II of my testimony, I briefly describe the nature and purpose of Class Three cost estimates and the Commission's previous approval of the Utilities' Class Three PSEP cost estimates. In Section III, I describe the Utilities' Class Three cost estimate methodology, why it is a superior estimating tool to relying on historical models or benchmarking data, and how the Utilities have applied this methodology to the Line 1600 cost estimates. Section IV discusses the appropriate inclusion of a risk assessment component in accordance with industry standards, how the Line 1600 cost estimates have included such a component, and the Utilities' treatment of the risk of a hydrotest failure.[2] Finally, Section V describes how the methodology used to develop the Line 1600 project forecasts reflects the lessons learned and continuous improvement from over five years of experience in developing PSEP cost forecasts.

Ordering Paragraph 4 and pages 38-40 of D.20.02-24 describe the information to be included with the cost forecast for the 19 individual projects included in the Line 1600 Plan

[1] AACE International was formerly known as the Association for the Advancement of Cost Engineering.
[2] The potential cost of one or more hydrotest failure(s) is not included in the overall estimate.

approved by the Safety and Enforcement Division (SED) on January 15, 2019. For ease of reference, Table 1 below identifies where the topics I am responsible for are included in my testimony (additional information on these topics may be found in other witnesses' testimony):

Topic	**Testimony Location**
D.20-02-024 Ordering Paragraph 4	
"Cost Estimating Methodology"	Section III
"Contingency Factor Assumptions"	Section IV
D.20-02-024; Pages 38-40	
"I. Whether Applicants' forecast of capital and operations and maintenance costs associated with the completion of the 19 Line 1600 pipeline segments is reasonable"	Sections II, III
"VII. Whether specific cost information, inputs and outputs of estimated tools, assumptions including contingency factors, and other methods of forecasting costs, in support of requested funding and/or forecasted costs for its projects, are reasonable"	Sections II, III, IV
"VIII. Whether risk models and risk-based decisions for the projects are reasonable"	Section IV
"IX. Whether cost comparisons of similar or previous work done by Applicants or other utilities, in order to determine the Applicants based cost estimates for the PSEP projects upon similar work in the industry are reasonable"	Section III

II. THE UTILITIES USED PROVEN PSEP COST FORECASTING METHODOLOGY FOR THE LINE 1600 PROJECTS

The Line 1600 projects followed the best practices and methods used to develop Class Three cost estimates for other PSEP projects, which have been approved in other regulatory proceedings.[3] Although different types of estimating methods may be used at various points in a project lifecycle, AACE International recognizes that Class Three estimates are most suitable for project funding. As described more in Section III, the Utilities' Class Three estimating process

[3] D.19-03-025 at 48 and D.19-09-051 at 203.

relies on experienced estimators who work closely with the Line 1600 Subject Matter Experts (SME) to build up costs based on approximately 30% engineering and design deliverables, detailed project execution plans (PEP), detailed scopes of work (SOW), project risk assessments, site location field visits, lessons learned and a mature cost estimating tool. Although each cost estimate follows the same process, each project is unique, and the costs are based on the specific characteristics of that project.

AACE International is an industry leading organization in the field of cost estimating and its recommended practices reflect best industry practices. AACE explains: "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."[4] AACE further describes Class Three as follows:

> "Class Three estimates are generally prepared to form the basis for budget authorization, appropriation, and/or funding. As such, they typically form the initial control estimate against which all actual costs and resources will be monitored. Typically, engineering is from 10% to 40% complete, and would comprise at a minimum the following: process flow diagrams, utility flow diagrams, preliminary piping and instrument diagrams, plot plan, developed layout drawings, and essentially complete engineering process and utility equipment lists. Class Three estimates generally involve more deterministic estimating methods than conceptual methods. They usually involve predominant use of unit cost line items, although these may be at an assembly level of detail rather than individual components. Factoring methods may be used to estimate less-significant areas of the project."[5]

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[4] AACE International Recommended Practice No. 18R-97 "Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries," attached as Attachment 1, at 5.

[5] AACE International Recommended Practice No. 18R-97 "Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries," attached as Attachment 1, at 9.

By contrast, AACE describes a Class Four estimate as "generally prepared based on limited information," with engineering "from 1% to 15% complete," and "typically used for project screening, determinations of feasibility, concept evaluation, and preliminary budget approval."[6] Rather than predominantly using unit cost line items as in Class estimates, Class Four estimates "generally use factored estimating methods," such as gross Three unit costs/ratios, and other parametric and modelling techniques."[7]

AACE International recognizes that using Class Three estimates to establish a basis for budget authorization is more appropriate than relying upon Class Four estimates used for high level decision making. The Utilities use Class Four estimates in early stages of a project's lifecycle to make higher level scoping decisions, for example deciding whether to test an existing pipeline versus replacing the asset with a new pipeline by using parametric or cost/mile factors based on previous projects of roughly similar conditions to get general cost approximations. These estimates are quicker to develop but lack the project specific characteristics needed to closely monitor and control the costs.

As discussed more in Section III, the Utilities develop their Class Three cost estimates using a "zero-based method." As recognized by the Commission, "A zero-based method utilizes a forecasting method that determines the projected budget for operations based on necessity rather than on historical spending. Management starts from zero and determines all expenses that

[6] AACE International Recommended Practice No. 18R-97 "Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries," attached as Attachment 1, at 8.
[7] AACE International Recommended Practice No. 18R-97 "Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries," attached as Attachment 1, at 8.

are necessary for operations. All expenses must be necessary in order to be included in the projected budget and no expenses are automatically added based on historical spending."[8]

The forecasting methodology used to develop the Line 1600 cost forecasts is the same as what was approved by the Commission in the PSEP Forecast Application (A.17-03-021) and the 2019 General Rate Case (A.17-10-008). In D.19-03-025, the Commission found the Utilities' Class Three cost estimates adequate to establish the reasonableness of the forecasted revenue requirement. Specifically, the Commission found:

- "Here, Applicants established that their forecasts are based on detailed and project-specific characteristics as identified and evaluated during the design and engineering phase of each project. The forecasts were developed by experienced individuals who have worked and/or implemented prior PSEP projects, and Applicants included detailed costs estimates for each project. The cost estimates include breakdown of costs for different components of each project." [9]

- "Applicants validated their forecasting methodology by engaging KPMG, an auditing firm. KPMG determined that Applicants' "estimating procedures are consistent with industry practice for developing an AACEi 56R-08, Class Three Estimate"[10] and the "estimating process and methods… are consistent with industry practice."[11]

- "Based on this record, Applicants have established by a preponderance of the evidence that their proposed forecasts/forecasted costs are just and reasonable. Applicants examined the unique attributes of each project, engaged in extensive engineering, design and planning work, and assigned costs to the various attributes of each project based on their knowledge as pipeline operators and actual experience executing PSEP."[12]

- "Based on this record, we find that Applicants heeded Commission direction in D.14-06-007, and prepared detailed plans for this Commission to consider in authorizing expenditures for the proposed PSEP projects. In addition, we find that Applicants' forecasts for the proposed PSEP projects are supported by completed engineering, design and planning activities related to these projects, following the

[8] D.19-09-051 at 53.
[9] D.19-03-025 at 48 (footnote omitted).
[10] At time of KPMG audit, 97R-18 had not been established therefore this standard was deemed appropriate.
[11] D.19-03-025 at 50 (footnote omitted).
[12] D.19-03-025 at 54.

> Commission's directive. In contrast, neither Cal Advocates nor TURN-SCGG's conducted as detailed an evaluation of the various components of each project and, as a result, their forecasts are less likely to correctly reflect the costs to be incurred in executing the twelve projects than the forecasts proposed by Applicants."[13]

All the cost estimates for the Line 1600 projects were developed consistent with the practices approved in D.19-03-025 and D.19-09-051. As detailed in Section V, the Line 1600 projects also leverage the lessons learned and processes that are continuously improved from previous experiences.

III. FOLLOWING AACE INTERNATIONAL CLASS THREE COST ESTIMATING METHODOLOGY, THE UTILITIES USED ZERO BASED ESTIMATING TO DEVELOP THE LINE 1600 COST ESTIMATES

As discussed in Section II, the Utilities follow the guidance of AACE International and develop Class Three estimates for budgetary purposes, such as the estimates for the Line 1600 projects. In this Section, I explain how the estimating team closely collaborated with the Line 1600 project team to develop Class Three cost estimates consistent with AACE International's recommended practices. I then explain how the Utilities' methodology is superior to comparing the Line 1600 projects to past projects through historical models or benchmarking data. Finally, I explain how the Utilities applied this methodology to the Line 1600 cost estimates presented in the Phase 2 Direct Testimony of Norm G. Kohls and the Workpapers attached thereto.

A. The Utilities' Class Three Cost Estimating Methodology

As discussed in Section II, the appropriate AACE International classification of a cost estimate depends upon the maturity of the project information and design. Class Three estimates utilize project information at between 10% to 40% definition level. At this definition level,

[13] D.19-03-025 at 53.

AACE International believes that there is the appropriate project-level information known to establish an overall project budget, which is then the basis for cost to be monitored.

To develop a Class Three estimate, the Utilities use a "zero-based" estimating methodology. Zero based estimating ensures that the estimating team has thought about how every dollar is expected to be spent based on a schedule for each project stage. Zero based cost estimates are time phased according to the schedule and are the basis for project cost controlling by cost item.

To proceed with a Class Three estimate, the estimating team requires the following information: 1) an approved package of estimating deliverables (approximately 30% Package); 2) SME and project stakeholder involvement; 3) the use of the current estimating tool; and 4) an estimating handoff and approval process. All PSEP projects estimated by SDG&E and SoCalGas follow the same process and methodology regardless of project scope, location or complexity.

1. Class Three Estimates Require a Thorough Deliverable Package.

To begin the process of estimating a project for budgetary funding, the Line 1600 project team submits to the estimating team an approved package of engineering deliverables (approximately 30% package). This package includes a SOW, PEP, a project risk register, a preliminary schedule, approximately 30% engineering drawings, the actual cost spent at the point of the start of the estimating effort and other stakeholder information that may impact the cost of the project. Each of these documents must be approved, assuring that the documents are carefully reviewed and meet company guidelines. Only after necessary documents are received, will the estimating team begin developing the estimate.

Each of the Line 1600 project team deliverables are used to establish cost. The scope description and PEP describe how an asset is planned to be constructed or remediated such as to test an existing pipeline or replace the asset. The PEP identifies the Line 1600 project team, the unique features of the job location, the means and methods to be used (such as open trench versus horizontal directional drilling), work hours, etc. Attached to the PEP is the risk register (a document that is continuously maintained and updated through the life of the project) that lists the potential risks of the project based on Line 1600 SME experience and lessons learned. The Line 1600 project team provides a high-level schedule that indicates major milestones such as construction start date, date the asset goes into service, moratorium periods, demobilization dates, etc.

All Line 1600 projects need to submit a reviewed and approved, approximately 30% engineering package that generally shows the pipeline alignment placed on a survey base map, the material to be used, and other special features such as vaults, valves, and horizontal directional drills (HDD). Subsequent requirements to the package also includes Line 1600 stakeholder forms that contain important information about the projects, such as environmental requirements or a list of the potentially required permits and their conditions. This information is critical to the process of establishing the forecasted Line 1600 project costs. The estimating team also receives the total Line 1600 actual cost charged to the project up to point of requesting the estimates. These actual costs may have supported preliminary Line 1600 studies such as to test or replace a pipeline and/or may have supported the development of the approximately 30% Line 1600 engineering package and other scoping efforts. These costs will be used as known values in the estimate. Each Line 1600 project has scoping costs associated with it.

2. <u>Class Three Estimates Require Subject Matter Expert And Stakeholder Involvement</u>

Expert Line 1600 stakeholder involvement is the most critical component to our estimating methodology. The Utilities involve and engage SMEs, various stakeholders, and functional support members to assist with establishing the cost and risks as they pertain to each individual project scope. Each functional Line 1600 team member establishes the effort required for their team to support each stage of the project. In addition, each functional expert assists with establishing the risks related to their function, the cost and schedule implications related to that risk, and the probability of the risk becoming actualized. The project team works proactively to create methods to mitigate the risks and address them prior to the risks becoming actual issues.

The estimating process requires assigning SMEs to the project team that is supporting the estimate. The team must participate in critical meetings and efforts including the estimate kick off meeting to make certain that the approximately 30% engineering package meets the requirements, field job walks, risk review and assessment meetings, final cost review and estimate handoff meetings. These steps assure that the process is being carried out consistently and that all SMEs are involved throughout the process.

The SMEs and project stakeholders who are typically involved in the establishment of the estimate are those who work in the areas of Project Execution, Engineering and Design, Environmental, Construction, Land and Permitting Services, Outreach, Compressed Natural Gas/Liquified Natural Gas (CNG/LNG), and Supply Management. The respective project support activities and deliverables of each of these stakeholders are described below:

a) Project Execution

Project Execution subject matter experts provide the following in support of estimate development:

- Validation of appropriate replacement diameter,
- Identification of taps and laterals within pressure test or replacement segments,
- Assessment of potential system and customer impacts and development of mitigation strategies,

- Identification of pipeline features to be cut out prior to a pressure test (e.g., pipeline anomalies, non-piggable features, and obsolete appurtenances),
- Identification of potential valve additions,
- Review and approval of scope of work, and
- Review and approval of project-specific pressure test procedures, when applicable.

b) Engineering Design

The key responsibility of Engineering Design is to perform the planning and engineering design work necessary to provide a scope of work with sufficient detail to develop Class Three project cost estimates. The scope of work is intended to facilitate the proximation of all identifiable cost components up to, and including, the completion of construction and close-out. The typical planning and engineering design scope includes the following considerations[14]:

- Assessment and validation of project extent/parameters,
- Physical visit to job site to gain familiarity with the area,
- Development of preliminary design for each work site,
- Development of pipeline profile,
- Subsurface investigation such as potholing for existing utilities,
- Identification of pressure test segments based on the minimum and maximum allowable test pressures in order to achieve required test pressures, and
- Identification of any special pipeline crossings for replacement projects (e.g., waterways, railroads, freeways, etc.).

c) Environmental

Environmental SMEs provide the following support during estimate development:

- Detailed analysis of recommended project routing to minimize environmental construction impacts and associated cost impacts,
- Identification of permit conditions and development of costs associated with securing any required environmental permits and mitigation costs, where applicable,
- Determination of water treatment costs, as applicable,
- Quantification of water transportation costs, as appropriate; and
- Development of cost estimates for required environmental construction monitoring, sampling/laboratory analysis, abatement, and hazardous material management and disposal.

[14] Some of these elements vary between replacement and pressure test projects.

d) Construction

The forecast of construction costs incorporates input from SDG&E and SoCalGas SMEs and impacted organizations including the following elements:

- Input from contractors with construction expertise,
- Field walk with all parties to capitalize on combined expertise for assessment of constructability issues, and
- Review of engineering design package to determine construction assumptions,
- Establishment of a construction schedule based on crew sizes, production rates, and location specific attributes.

e) Land and Municipal Permitting Services

Land Services provides the following in support of estimate development:

- Determination of applicable municipal permit requirements and associated costs, Identification of potential laydown/staging yards required for individual projects, and subsequent communication with landowners as required to determine availability, and
- Development of cost estimates associated with laydown yards, temporary construction easements, grants of easement, appraisals, title reports, etc.

f) Outreach

Outreach SMEs provide the following in support of estimate development:

- Determination of the project and construction impacts to the local communities, including nearby residents, businesses and stakeholders.
- Development of outreach plans to inform the public about the Line 1600 projects to ease the impacts of the projects on the local communities.
- Organizing community open houses to inform the public about the projects and provide a venue for questions and responses.
- Development of collateral, videos and photos of the Line 1600 projects to help illustrate and convey the projects and construction to the general public, stakeholders and elected officials.
- Development of cost estimates which consider, but are not limited to, contracted outreach support, mapping support, and additional customer notification support.

g) CNG/LNG Team

The CNG/LNG Team provides the following in support of estimate development:

- Provision of analyses on impacted customer natural gas loads to determine optimal process for keeping customers online, and

- Development of cost estimates for the provision of CNG/LNG.

h) Supply Management

- Supply Management provides material and logistics-related cost estimates based on a preliminary BOM developed by the project team.
- The contracting strategies and methods are recommended and assumed prior to developing the estimate.
- Logistics and material handling are also planned and assumed.

3. <u>The Utilities' Estimating Team Uses the Information and SME Input to Develop the Cost Estimate Using an Estimating Process and Tool Developed Over Years of Project Experience.</u>

The Utilities' estimating tool is a templatized spreadsheet that allows for the input of material, labor rates and hours, equipment, and project specific attributes that impact the cost of a project. Projects use and follow these templates and tools to maintain consistency. The estimating team collects and builds the estimate with the input of project deliverables, SME judgement and experiences, and any other information that may impact the cost of the project. The estimating team will start by reviewing the project team's estimating deliverables, including but not limited to the approximately 30% engineering design package, SOW, PEP, risk register, mapping files (e.g. Google Earth KMZ), etc.

The creation of the estimate is based on the estimator's take-offs from the engineering deliverables. The purpose of a take-off is to provide a comprehensive list of all the essential quantities of materials to complete a project. The expected construction activities that will be used in the development of the Construction Estimate are based on the quantity take-offs, PEP, and stakeholder input. Note that the Construction Estimate is only a subset of the total direct cost, just as the construction activity is only a subset of the entire project cost. The Construction Estimate is specific to the estimated cost for the mechanical contractor to perform their portion of the work, which in the case of the Line 1600 projects is to replace or hydrotest the pipe.

After take-offs are performed, the estimator will implement those take-offs/quantities to the construction contractor cost build up. Then they will group activities into a consistent work breakdown structures (WBS) based on the type of work being performed. Note, a WBS for a replacement project will be different then the WBS for a hydrotest project as they are made up of different activities. Next, the estimator adds labor, equipment, and subcontractors that the construction contractor is expected to utilize to perform its work. The estimated contractor hours are based on the current rate at the time the estimate was created. Escalation is included based on the project master schedule, which reflects when laborers are expected to perform certain construction activities. Upon completion of the construction estimate, it is inserted into the Total-Installed-Cost (TIC) Tool under the "Contractor Estimate" tab.

Additionally, during the process of developing the construction estimate, the estimator will build a construction schedule that matches the estimated cost. Among other things, this schedule will take into account many assumptions such as production rates (how quickly work can be performed), how many crews will be on the project, which items are critical path (i.e. required to be performed before another item can start), etc. Like the estimate, the construction schedules are based on PEPs, SME experience, site conditions such as any permitting and easement restrictions, contractibility, safety and public outreach concerns, to name a few. This construction schedule will ultimately be distributed to stakeholders and will be the basis of those stakeholder estimates which are schedule driven during the construction stage. This schedule becomes the detailed plan that the costs are based on. The schedule also determines the overhead costs and project loaders gathered during the construction phase of the project.

Once the Construction Estimate is complete, the estimator will begin to bring in and develop all other direct costs that are anticipated to be incurred during the project. This includes things such as pricing out the Bill of Materials (BOM) and estimating labor hours and service costs outside of the construction contractor, such as X-Ray services, project management hours, field management hours, etc. Concurrently, the estimator will bring in all stakeholder estimates associated with the projects. These stakeholder estimates are developed by the specific stakeholder and brought into their respective Excel tab on the TIC Tool.

Finally, the estimator(s) will meet with the project team and stakeholders at which time they will discuss risks and opportunities for costs associated with the project. The risk ranges are captured in a risk file, which is used to run a Monte Carlo Risk Simulation, resulting in an expected cost for the specific project's cost items.

Upon completion of the risk analysis, the results will be output and exported back into the TIC Tool on the "Risk Summary" and "Risk Detail" tabs. The TIC Tool is set with preexisting links to these tabs and will allocate risks according to the specific cost element on the "Estimate" tab. These costs are summed up into an expected cost (inclusive of risk) total on the "Project Summary" tab. These costs make up the Total Direct Estimated Cost for the project.

Once a Total Direct Estimated Cost has been developed, the estimate is used by the project controls team to add loaders and escalations in a cost forecasting application called TM1 Cognos. From there, a Total Cost including loaders and escalation is determined and brought back into the TIC Tool for visibility.

4. The Estimate Handoff Process

After the estimate is generated, the contingency is established and the direct dollars are loaded, the estimating team prepares to hand over the final Class Three cost estimate. The estimate is accompanied by a basis of estimate (BOE), an updated schedule, a current risk register, and a sign off sheet. The estimator meets with the project team and explains the basis of the estimate and answers any open questions. Once the project team and estimator are comfortable with the estimate being handed over, the team signs and dates the estimate coversheet. The estimate numbers are then entered in the Work Order Authorization form (WOA) to fully fund each of the 19 projects.

B. The Utilities' Class Three Cost Estimating Methodology Is More Accurate Than Predicting A Future Project's Cost Based Upon Past Projects' Costs

Project scopes and execution methods greatly vary, especially in a location such as San Diego County. Construction projects like the Line 1600 projects can have entire projects or even sections of projects that vary by typography, population density, environmental conditions, soil types, municipality restrictions, weather, and traffic patterns to name a few. Our Class Three estimating methodology factors in all of these challenges. Each project in the Line 1600 program accounts for the cost of each of their unique challenges. Other simple estimating methodologies that have been suggested in the past use crude parametric or average costs per unit often categorized as Class Four/Five by AACE International. The Line 1600 projects use project specific costs build ups such as crew size, material lists or take offs, equipment type, means and methods, location specific information to accurately estimate and control our project such that we have done our most to ensure our projections are as accurate as possible for each unique project.

Additionally, a Class Three estimate allows for superior control of the costs of the project after the estimate is completed and handed off to the Line 1600 Project team. As an example, if our estimate had our construction costs being lower than the actual bid, we could investigate and challenge the bidder to make certain that their purposed costs were valid. Another example might be our material costs, where material quoted to us is higher than our assumed costs. This might prompt the Utilities to seek out other material quotes to make certain the costs of the material we are procuring are reasonable and with our project budget.

Each Line 1600 project is unique in scope, size, complexity, and execution. The uniqueness of each Line 1600 project and the variability in cost components from project to project make such project-specific cost estimates the most accurate methodology to predict project costs. This method is consistent with the Commission's directive in D.14-06-007 (approving SDG&E's and SoCalGas PSEP) that: "It is only fair that ratepayers should have the benefit of detailed plans for this Commission to consider before authorizing or preapproving the expenditure of many hundreds of millions of dollars."[15] This decision followed assertions by The Utility Reform Network (TURN) and Southern California Generation Coalition (SCGC) that the Class Five or ClassFour estimates submitted by SoCalGas (and SDG&E) in that proceeding were too rudimentary for ratemaking.[16] In accordance with this directive and as specifically directed by D.20-02-024, the Utilities provide Class Three estimates here.

The Commission reaffirmed the value of zero based estimating in the Utilities' recent PSEP Forecast proceeding (A.17-03-021) and General Rate Case (A.17-10-008), stating:

- "Applicants successfully argued that cost drivers are not limited to pipeline diameter, length, urban versus rural environment, and geographic terrain. They come in many forms: soil conditions, installation requirements (the means and methods of installation details), permitting conditions, environmental consideration and mitigation, and underground facility density. Applicants explained that construction duration typically has the largest impact on overall project cost, and even projects of similar length and diameter can have drastically different construction durations depending on factors such as population density, permitting conditions, etc. These and many other factors were considered by experienced professionals in the detailed cost estimates prepared by Applicants. Neither TURN/SCGC nor Cal Advocates considered these factors. We agree that

[15] D.14-06-007 at 23.

[16] A.11-11-002, Opening Brief of The Utility Reform Network on Pipeline Safety Enhancement Plan Issues at pp. 76-79. TURN argued that the "Commission should defer adopting a forecast-based revenue requirement until it has the benefit of the more detailed engineering and design." *Id.* at p. 79. SCGC argued that "Applicants should be required to submit cost estimates in EAD proceedings that are no worse than Class Three estimates and hopefully much better," and later that the cost estimates "should be at least Class Three estimates." A.11-11-002, Southern California Generation Coalition Opening Brief at p. 30 and A.11-11-002, Southern California Generation Coalition Reply Brief at p. 5.

recognizing and considering the unique attributes of each PSEP project individually is more likely to result in a robust estimate than relying on a sample of completed projects that share two to four similar attributes."[17]

- "On the other hand, SoCalGas applies a more project-specific method to develop its forecast costs, which we find more appropriate in this instance and for the proposed projects specifically. SoCalGas provided what is referred to under the American Association of Cost Engineers (AACE International) cost estimate classification system as Class Three estimates for its proposed projects using around a 30 percent completion of engineering activities. SoCalGas explains that according to the AACE International classification system, Class Three estimates are generally prepared to form the basis for budget authorization or funding and typically form the initial control estimate against which all actual costs and resources will be monitored. Engineering is typically from 10 to 40 percent complete. This level of estimate contains more specific details and is generally more reliable than Class Four and Class Five estimates that are based on more limited information.

  As discussed earlier, SoCalGas' method for developing its project estimates included planning, engineering design, input from subject matter experts regarding project cost estimates, analysis of environmental impacts, inputs regarding construction, determination of required permits, analysis regarding natural gas loads, and supply management. The above activities are more project-specific and consider specific circumstances regarding each project. This level of detail allows us to better evaluate and review costs requested consistent with D.14-06-007, where the Commission stated that ratepayers should have the benefit of detailed plans for the Commission to consider before authorizing or pre-approving expenditures for PSEP projects.

  Cost estimates were developed using a zero-based method, which we find reasonable in this instance as specific needs for each project are better considered and incorporated into the forecast as opposed to basing costs on budget history.

  Based on all the above, we find SoCalGas' method and cost estimates to be reasonable, appropriate for the proposed projects, and supported by the testimony submitted."[18]

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[17] D.19-03-025 at 53.
[18] D.19-09-051 at 203-204.

C. The Utilities Applied Their Class Three Cost Estimating Methodology to the Line 1600 Cost Estimates

The Utilities applied their Class Three cost estimating methodology, described above, to each of the nineteen Line 1600 projects. I describe below as an example the process used to develop the TIC cost estimate for the Scripps-Poway Replacement Project.

The estimating team received the Scripps-Poway Package in February 2020 (Project Number 13). The package had sufficient documentation to proceed with the cost estimating process, including the PEP, SOW, an approved 30% engineering package, and other supporting information.

The project team then kicked off the effort in February 2020 with the estimating team and project stakeholders via a TIC kickoff meeting. In March 2020, representatives from the project team, the estimating team, and construction conducted a job walk. Subsequently, the estimating team began to build up the construction cost and develop the construction schedule. All materials, equipment, crew sizes and overhead support were inputted into the construction estimate. The construction estimate was then exported into the TIC Tool. Meanwhile, the remaining estimating deliverables were received such as actual project cost to date, Bill of Materials (BOM), and stakeholder input. With the TIC Tool inputs received, the estimating team drafted the TIC estimate.

In April 2020, the Monte Carlo Risk Meeting was set up and performed with the project team and stakeholders to establish contingency. Upon completion, the results were exported to the TIC Tool, the quality assurance and quality control process was performed, and a final review was set up with the Cost Estimating Team Lead in April 2020.

Following approval, the direct cost estimate was sent to project controls to be loaded and escalated. Concurrently, the estimating team developed the Basis of Estimate (BOE) as necessary to document important project assumptions and quantities. Upon completion and receipt of loaders via project controls, the escalated loaders were brought in as input to the TIC Tool.

Lastly, a TIC handoff document was developed and a TIC handoff meeting was setup and performed with the project team in May 2020, at which time estimate specifics, assumptions, and outputs of the cost estimate were presented and handed off to the project team. Upon completion, the fully loaded costs are incorporated into the WOA which is signed and approved by leadership to establish the project budget.

IV. THE LINE 1600 COST ESTIMATES INCLUDE A RISK ASSESSMENT COMPONENT, AS RECOMMENDED BY INDUSTRY BEST PRACTICES

As recognized by AACE International, industry best practices require explicit consideration of risks to project costs. In this Section, I first explain how the Utilities incorporate a risk component into their Class Three cost estimates and then discuss the risk component of the Line 1600 cost estimates.

A. The Utilities' Class Three Cost Estimating Methodology Includes Consideration of Risk.

The Utilities utilize a Risk Assessment Process to evaluate the project risks and opportunities that each project team has identified. Contingency and risk are related, but not synonymous with each other. AACE Risk.08 (Defining Risk and Contingency for Pipeline Projects) states:

> "Contingency is a cost element of an estimate to cover the probability of unforeseeable events to occur and that if they occur, they will likely result in additional costs within the defined project scope."[19]

Contingency is not meant to address extraordinary risk and "is not intended to provide for changes in the defined scope of a project (e.g., change in capacity or product slate) or for

[19] AACE International Transactions RISK.08 2009 Report "Defining Risk and Contingency for Pipeline Projects at RISK.08.7", attached as Attachment 2, at 7.

unforeseeable circumstances beyond management's control (e.g., 100-year storms or strikes against equipment vendors)."[20] Another example would be an unplanned hydrotest failure, which is addressed below in Section IV(C).

A risk assessment is the process of interviewing the project team and evaluating the identified risks of the engineering documents as well as the project team's experience in their related fields. The Risk Assessment process is strongly recommended compared to other contingency evaluations as it is more robust analysis taking input from project specific concerns from Line 1600 SMEs. The identification of the risks involved in the projects are essential to produce accurate estimates as well as to minimize exposure to potential adverse impacts. Conversely, the project will continue to gain definition as it matures, and the opportunities and risks will be reduced as more information is known and should be managed by the project team as the project is progressing.

1. Project Risks Are Expected and Must Be Proactively Managed

History has shown that project managers across all industries will, on average, underestimate the cost of a project. The quantification of the contingency amounts by cost item enables the project teams to manage contingency as projects progress during the engineering and project execution phase. AACE International has published recommended practices to account for this tendency to underestimate project costs in order to correct for them and therefore produce a more accurate cost estimate.

Further, the final total contingency amount is the result of a series of risk assessments and is critical to the development of accurate cost estimates:

[20] AACE International Transactions EST.03 2004 Report on "Exploring Techniques for Contingency Setting," attached as Attachment 3, at 1.

> "Identifying risk and determining an appropriate amount of contingency is a challenge that must be addressed to ensure accurate information is available to base critical financial decisions upon."[21]

The above passages are also noteworthy because *they apply to all classes of estimates* – from the rudimentary Class Five, to the ClassThree of the Utilities' estimates in this filing, to a Class One estimate for which much more detailed design and engineering has occurred. It is always recommended and expected that all cost estimates should contain a contingency element no matter the class of the estimate.

Contingency addresses anticipated costs that are not specifically defined, but nevertheless exist. In short, *contingency dollars are real expected costs that the industry dictates* should be included in a project's cost estimate to improve its accuracy and approximate the final actual cost. The need for contingency is based on real life experience across thousands and thousands of projects in different project areas across many industries.

In D.19-09-051 at 205, the Commission found the addition of contingency appropriate stating:

> "We agree with the addition of a risk assessment component in this instance to account for contingencies that may occur. The proposed projects are subject to many variables and projects have particular circumstances that add to the difficulty of making accurate cost estimates. The practice is also an industry-recommended practice that aims to increase the quality and accuracy of estimates, which we find appropriate for the proposed PSEP projects."

2. Contingency Is Based on SME Experience and Lessons Learned

The Utilities' methodology to determine risks is consistent with AACE's recommended practice. The AACE paper "AACE International Transactions Risk.08 – Defining Risk and Contingency for Pipeline Projects" states:

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[21] AACE International Transactions RISK.08 2009 Report "Defining Risk and Contingency for Pipeline Projects at RISK.08.7", attached as Attachment 2, at 1.

> Project specific risks are those that *are unique to a project's scope, strategies, attributes, and so on*. The nature of these risks and extent of their impact *are not consistent between projects in a given company* (emphasis added).[22]

The paper goes on to provide a recommendation of how to go about assessing risks that are unique to each individual project:

> Thus, to estimate project specific risks, the recommended practice is to use "expected value model."[23]

The Utilities employ a methodology of having subject matter experts within the PSEP project execution team work with risk assessment experts within the PSEP cost estimating team to review risk variables (assumptions on productivity for contractors, environmental costs, permit conditions, material costs, etc.). These experts discuss the known and unknown variances for these cost components (*e.g.*, discussing the probability of the contractor's productivity being less than planned and if so, the magnitude of the potential reduction in productivity, with similar questions for project-specific issues that drive material costs, environmental costs, land rights acquisitions, permit conditions, etc.). This team of cross-functional experts uses their experience and knowledge of the specific conditions of each particular project to develop a consensus opinion of potential outcomes.

3. The Utilities Use A Statistical Method and Model (TOOL) To Establish Contingencies

As part of the Utilities' estimate development, the estimator(s) in conjunction with the project team and stakeholders will evaluate and develop an appropriate contingency percentage based on analysis of opportunities and threats known and unknown at the time of the TIC

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[22] AACE International Transactions RISK.08 2009 Report "Defining Risk and Contingency for Pipeline Projects at RISK.08.8", attached as Attachment 2, at 8.
[23] AACE International Transactions RISK.08 2009 Report "Defining Risk and Contingency for Pipeline Projects at RISK.08.8", attached as Attachment 2, at 8.

estimate. As mentioned above, this is consistent with the industry best practice as identified by AACE International.[24]

While many methods exist to evaluate risk, the method utilized by the Utilities is known as a Risk Assessment Process. This process includes a risk meeting set up in conjunction with the project team and stakeholders to receive input on project specific risks and opportunities, which will ultimately be input and expressed as percentages in the Monte Carlo Risk Analysis and inherently drive contingency up or down on a project by project basis. **Each project has its own opportunities and threats to cost which are independent of other projects, and therefore it is expected that each project will have a different risk percentage from other projects.**

As risks are identified and quantified during the risk assessment meeting, the estimator(s) uses a Monte Carlo Simulator to work through different cost categories and allocate risks and opportunities based on the project team and stakeholders. Methodically discussing risks on a category by category basis allows for estimators to develop a more refined risk percentage that considers that some cost categories may result in more or less cost when compared to others.

In development of the risk, the estimator will bring in the base estimate from the TIC tool into the Risk Assessment Meeting. Note, within the Risk Assessment Process, actual costs incurred to date will be excluded from the analysis, as inherently there should be no risk on costs that have already occurred. Within the risk assessment process, the estimator will discuss the variables as related to risks and opportunities. Four different variables are discussed across the cost estimate: productivity variables, scope variables, price variables, and duration variables. As

[24] AACE International Recommended Practice No. 18R-97 "Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries," attached as Attachment 1.

the estimator and project team work through each variable, each item is viewed from the perspective of cost opportunities (potential for cost savings) and cost threats (potential for cost increase).

Risk allocation typically trends downward as more project definition is known, thus reducing the need for higher levels of contingency. A risk assessment process assists in defining the level of definition and overall project knowledge of the project team, which assists the estimator create a recommended contingency as a deliverable of the Risk Assessment Process.

Upon completion of the meeting and discussion of the variables, the estimator will run the Monte Carlo Risk Analysis. The simulation results are the summarized high level on the "Results Summary" tab of the Monte Carlo Risk Analysis file, which is then exported to the "Risk Summary" tab of the TIC tool. Additionally, the "Provision by Cost Item" in the Monte Carlo Risk Analysis file are exported into the "Risk Detail" tab of the TIC tool. It is within the "Risk Detail" tab of the TIC that the cost by category is allocated across the "Estimate" tab of the TIC Tool. The TIC tool then utilizes that risk percentage to calculate a risk cost per individual item.

In summary, the Risk Assessment Process and Monte Carlo Simulation are used in conjunction with project specific input from the project team and stakeholder to evaluate project threats and opportunities. Each project will be independent of other projects and specific to the project, scope, and information at time of the TIC estimate. The mean adjusted cost resulting from the Monte Carlo Risk Simulation is ultimately utilized and allocated on an item by item basis. The resulting output from the simulation is the Expected Cost Estimate.

B. The Utilities Included a Risk Component in the Line 1600 Class Three Cost Estimates.

In assessment of project risk, the estimating team utilized the process described in detail above. Each project evaluated risk independently and specific to that particular project's scope and execution methodology, among other aspects unique to the project. Continuing to use the Scripps-Poway Replacement Project as an example, a Monte Carlo Risk Meeting was held in April 2020, following the estimating walkthrough described above. The following were some risks and opportunities discussed specific to that project.

Low to moderate impact risk items were: construction contractor risk of additional support for clearing and grubbing yard, SDG&E and SCG labor risk for potential of extended closeout duration, and the risk of material market pricing increase. Some higher impact risk items were: risk of one bore or HDD at Branicole Lane and Mercy Road, risk of additional restoration requirements as known projects in the area have been required to repave entire streets which were already in poor conditions. In contrast, the following were some opportunities that arose during the Monte Carlo Risk Meeting: opportunity to save a day on seasoning, opportunity to save a couple days on the isolation window, and opportunity to utilize less slurry fill during abandonment.

To highlight the analysis, the low impact risk item for additional support for clearing and grubbing yard was a risk driver resulting in a risk percentage associated with the cost item of site preparation of 11.72%, or $6,013. Contrarily, a high impact risk item such as risk of HDD or Bore was one of the risk drivers that resulted in a pipeline installation risk for improved areas of 31.15%, or $3,302,073 for this particular cost category. Again, these cost item categories comprise many aspects, both known and unknown, and as such are just one of the many potential risks that may come to fruition. Note that while there are highs and lows within risk model, the cost estimate's contingency for Scripps Poway resulted in a risk percentage that is approximately 12% of total direct costs.

C. Potential for Hydrotest Failure

An inherent underlying risk of hydrotesting existing pipeline is a risk of a hydrotest failure at any given point along the alignment. It should be recognized that while a failure is possible, it cannot be known ahead of time if and where any hydrotest failure(s) may occur. Further, identification of a specific failure location and its associated costs ahead of time would be impractical and extremely variable with regards to cost and remediation efforts. Any effort to include hydrotest failure costs within an individual project or spread across multiple projects could in effect overinflate the majority or all the project cost estimates.

As such, the Utilities went about developing a Rough Order of Magnitude (ROM) study on a potential hydrotest failure. This study utilized a parametric estimating methodology using level of effort, on a few of many possible scenarios and locations where a failure may occur. As inferred above, these situations may not occur and, if one or many hydrotest failure(s) occur, they will likely not be limited to just the scenarios and cost ranges that follow.

The Utilities identified three contrasting scenarios of a hydrotest failure with varying levels of remediation difficulty. The study is meant to identify locations of separate cost ranges: low remediation effort, medium remediation effort, and high remediation effort. The results were as follows: low remediation effort around $1.4M (of which approx. $600k is associated with gas purchase from an alternative source), medium remediation effort around $2.5M (of which approx. $1M is associated with gas purchase from an alternative source), and high remediation effort around $3.3M (of which approx. $1.5M associated with gas purchase from an alternative source). Table 1 summarizes the estimated cost of remediation for the three contrasting scenarios.

Table 1 – Rough Order of Magnitude (ROM) of a Hydrotest Failure ($000's)

Remediation Effort	Hydrotest Failure Assumptions	ROM ($000's)
Low	• Up to 18,000 gallons of water released; no vacuum formed in pipeline. • Access via existing dirt roads. • Seven to eight days of response time required. • Potential action items post-hydrotest for land, environmental, CNG/LNG, and gas purchase required.	$1,400
Medium	• Up to 128,000 gallons of water released; no vacuum formed in pipeline. • Access via existing paved roads. • 12 to 14 days of response time required. • Potential action items post-hydrotest for land, environmental, CNG/LNG, and gas purchase required.	$2,500
High	• Up to 50,000 gallons of water released; no vacuum formed in pipeline. • Vegetation trimming, grading, and temporary stream crossings required for access. • 14 to 20 days of response time required. • Potential action items post-hydrotest for land, environmental, CNG/LNG, and gas purchase required.	$3,300

As addressed above, there are many situations and/or locations that may increase or decrease costs associated with hydrotest failure(s). The first is simply the number of failures that may occur and whether any occur at all. Next is the location of the failure-- factors such as ease of access could cause a quicker or extended remediation period, which will drive cost accordingly. Another factor is the locatability of a leak, specifically an easily identifiable leak will allow the SDG&Es crews to quickly address the failure vs. a pinhole leak or hard to find leak, which could potentially result in an extended remediation duration as crews spend more time in search of the leak. Other cost variability includes, but is not limited to, environmental factors (e.g. agriculture, land, wetland, or creek sensitivity; crop damage; presence of protected species, proximity to cultural resources) and land factors (e.g. property damage and damage claims, land rights could result in reroute, etc.).

V. SDG&E AND SOCALGAS STRIVE TO CONTINUOUSLY IMPROVE COST ESTIMATING METHODS AND BEST PRACTICES

A. 5 Years of Estimating PSEP Projects Has Improved the Tool

SoCalGas' estimating department has supported PSEP for over 5 years and has performed over 200 funding estimates. The estimating department routinely compares our Class Three estimates to the actual financial outcomes. Where there are discrepancies and gaps between forecasted costs and actual outcomes, estimate assessments to gain understanding are conducted. If errors or incorrect assumptions are the cause, we improve our processes and tools for future forecasts.

The PSEP cost estimating process has evolved over time. In 2011, the Utilities retained a third-party consultant to help develop an initial PSEP project cost estimating tool in response to the Commission's June 2011 directive to all California pipeline operators to file proposed pressure testing implementation plans in August 2011 that "include best available expense and capital cost projections for each Plan component." In 2013, the Utilities enhanced the cost estimating tool to increase the number of factors considered in deriving estimates, which enabled the utilities to prepare more comprehensive estimates. Since 2013, the Utilities have continued to enhance estimate accuracy by incorporating actual costs as they are incurred in the field, such as current material pricing, up to date construction labor rates, efficiencies and execution methods, etc.

The Utilities have also formed a dedicated estimating department to increase focus on the quality and accuracy of estimates. These continuous improvement enhancements have resulted in a more robust tool and process that incorporates the input of SMEs. These SMEs use their respective expertise and professional experience to provide assumptions about the scope and cost of the work to be performed within their areas of responsibility, and this input is critical to each estimate.

Notwithstanding the foregoing improvements and level of rigor, estimates remain estimates, and each PSEP project is unique. As such, the Utilities expect both foreseeable and unforeseeable conditions to be encountered during construction that may result in actual expenditures varying from estimates.

B. Rigorous Communication

SDG&E and SoCalGas have improved communication between the project and estimating teams as part of our continuous improvement initiatives. Rigor on estimating requests, including estimating milestones such as kick off meetings, job walks, risk meeting and estimating handovers, has been formalized to make certain all team members are in alignment. To assure that these processes are carried out, there are sign off sheets to document the approval of the process.

C. Lessons Learned

SDG&E and SoCalGas continue to improve our tools and processes based on our experiences and lessons learned. We factor in past experiences and unexpected outcomes into our risk assessments of future projects. This is done at the stakeholder level meeting. We account for construction, permitting, environmental, supply chain risks, etc. for possible impacts to future jobs. We also analyze and factor in the impact that risks have upon other risks (i.e. environmental risk impact on construction, permits, engineering, etc.).

VI. CONCLUSION

The Utilities' estimating methodology is mature and proven. All cost estimates for the Line 1600 projects were developed after the estimating teams received a thorough and approved approximately 30% design estimating deliverable package. Subject matter experts and project stakeholders were engaged to assess and plan the project execution and assess the risks and opportunities that could affect the project costs. The estimating team entered the data and information into our mature estimating tool and handed off the vetted and approved estimate to the project team. The Utilities' methodology is consistent with industry standards and best practices. Our establishment of risk-based contingency is based on history, subject matter experiences and industry wide accepted processes. We create our estimates to be the basis to control the project costs and to provide spending accountability.

To summarize, the Utilities developed detailed cost estimates in support of the Line 1600 projects cost forecast presented in the Phase 2 direct testimony of Norm G. Kohls. These forecasts necessarily include a risk assessment component that is appropriate and industry-accepted for the class of estimates developed.

VII. QUALIFICATIONS

My name is Ronn Gonzalez. My business address is 555 West Fifth Street, Los Angeles, California, 90013-1011. I have been employed by Southern California Gas Company since 2013 and had previously worked for the company from 2002 to 2007. I have held various positions at SoCalGas in the Engineering, Operations and the PSEP Organizations. These roles included working as the Region Associate Engineer, Pipeline Design Engineer, and as the Portfolio Manager for PSEP projects in the Northwest Distribution Region. I have also worked for two Engineering, Procurement and Construction (EPC) contracting firms from 2007 until 2013 where I supported and managed several large capital projects in the oil and gas industries.

I am currently employed as the Manager of Construction Estimating and Engineering. My principal responsibility is managing all Southern California Gas Company Construction estimates and ensuring that all engineering deliverables and activities are accurately provided.

I received a Bachelor’s Degree in Mechanical Engineering from the University of Arizona, and I am a Registered Mechanical Engineer in the State of California. I have previously testified before the Commission in 2018.

Attachment 1

AACE International

Recommended Practice No. 18R-97

AACE INTERNATIONAL RECOMMENDED PRACTICE

18R-97

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

AACE INTERNATIONAL

AACE International Recommended Practice No. 18R-97

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

TCM Framework: 7.3 – Cost Estimating and Budgeting

Rev. March 6, 2019

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

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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Disclaimer: The content provided by the contributors to this recommended practice is their own and does not necessarily reflect that of their employers, unless otherwise stated.

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

TCM Framework: 7.3 – Cost Estimating and Budgeting

March 6, 2019

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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 process industries. It supplements the generic cost estimate classification RP 17R-97[1] by providing:

- A section that further defines classification concepts as they apply to the process industries.
- A chart that maps the extent and maturity of estimate input information (project definition deliverables) against the class of estimate.

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

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

This document is intended to provide a guideline, not a standard. It is understood that each enterprise may have its own project and estimating processes, terminology, and may classify estimates in other ways. This guideline provides a generic and generally acceptable classification system for the process 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.

INTRODUCTION

For the purposes of this document, the term *process industries* is assumed to include firms involved with the manufacturing and production of chemicals, petrochemicals, and hydrocarbon processing. The common thread among these industries (for the purpose of estimate classification) is their reliance on process flow diagrams (PFDs), piping and instrument diagrams (P&IDs), and electrical one-line drawings as primary scope defining documents. These documents are key deliverables in determining the degree of project definition, and thus the extent and maturity of estimate input information. 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.

Estimates for process facilities center on mechanical and chemical process equipment, and they have significant amounts of piping, instrumentation, and process controls involved. As such, this recommended practice may apply to portions of other industries, such as pharmaceutical, utility, water treatment, metallurgical, converting, and similar industries.

Most plants also have significant electrical power equipment (e.g., transformers, switchgear, etc.) associated with them. As such, this RP also applies to electrical substation projects, either associated with the process plant, as part of power transmission or distribution infrastructure, or supporting the power needs of other facilities. This RP excludes power generating facilities and high-voltage transmission.

This RP specifically does not address cost estimate classification in non-process industries such as commercial building construction, environmental remediation, transportation infrastructure, hydropower, “dry” processes such as assembly and manufacturing, “soft asset” production such as software development, and similar industries. It also does not specifically address estimates for the exploration, production, or transportation of mining or hydrocarbon materials, although it may apply to some of the intermediate processing steps in these systems.

The cost estimates covered by this RP are for engineering, procurement, and construction (EPC) work only. It does not cover estimates for the products manufactured by the process facilities, or for research and development work in support of the process industries. This guideline does not cover the significant building construction that may be a part of process plants.

This guideline reflects generally-accepted cost engineering practices. This recommended practice was based upon the practices of a wide range of companies in the process industries from around the world, as well as published references and standards. Company and public standards were solicited and reviewed, and the practices were found to have significant commonalities. [4,5,6,7] These classifications are also supported by empirical process industry research of systemic risks and their correlation with cost growth and schedule slip [8].

COST ESTIMATE CLASSIFICATION MATRIX FOR THE PROCESS INDUSTRIES

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

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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 but 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%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Table 1 – Cost Estimate Classification Matrix for Process Industries

This matrix and guideline outline an estimate classification system that is specific to the process industries. Refer to Recommended Practice 17R-97 [1] 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.* [16]

Table 1 illustrates typical ranges of accuracy ranges that are associated with the process 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 into 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. [17]

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 composition of the input and output process streams.

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

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 process 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. [18]

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. [19]

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.

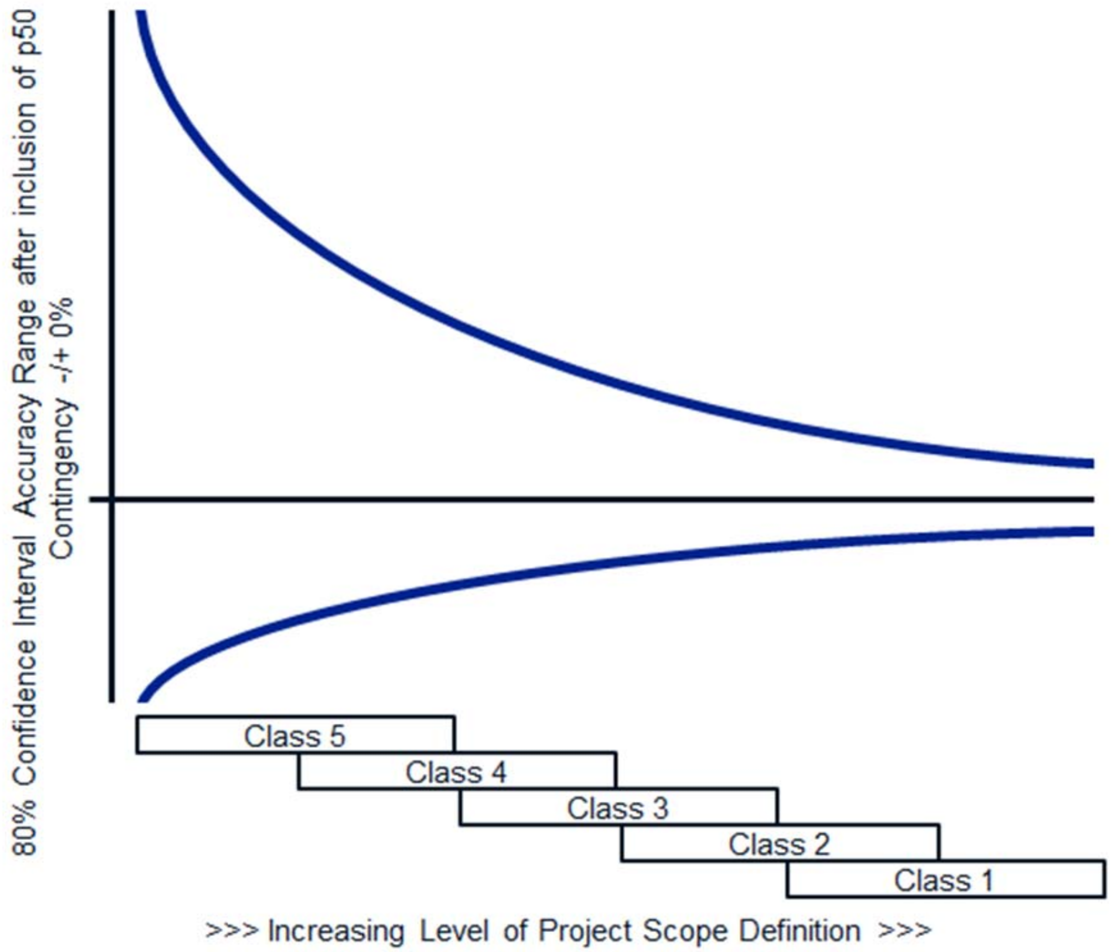

Figure 1 – Illustration of the Variability in Accuracy Ranges for Process Industry Estimates

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.

CHARACTERISTICS OF THE ESTIMATE CLASSES

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

For each table, the following information is provided:

- **Description:** A short description of the class of estimate, including a brief listing of the expected estimate inputs based on the maturity level of project definition deliverables**.**

- **Maturity Level of Project Definition Deliverables (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.

<table>
<tr><th colspan="2">CLASS 5 ESTIMATE</th></tr>
<tr><td>Description:
Class 5 estimates are generally prepared based on very limited information, and subsequently have wide accuracy ranges. As such, some companies and organizations have elected to determine that due to the inherent inaccuracies, such estimates cannot be classified in a conventional and systematic manner. Class 5 estimates, due to the requirements of end use, may be prepared within a very limited amount of time and with little effort expended—sometimes requiring less than an hour to prepare. Often, little more than proposed plant type, location, and capacity are known at the time of estimate preparation.

Maturity Level of Project Definition Deliverables:
Key deliverable and target status: Block flow diagram agreed by key stakeholders. List of key design basis assumptions. 0% to 2% of full project definition.

End Usage:
Class 5 estimates are prepared for any number of strategic business planning purposes, such as but not limited to market studies, assessment of initial viability, evaluation of alternate schemes, project screening, project location studies, evaluation of resource needs and budgeting, long-range capital planning, etc.</td><td>Estimating Methodology:
Class 5 estimates generally use stochastic estimating methods such as cost/capacity curves and factors, scale of operations factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, and other parametric and modeling techniques.

Expected Accuracy Range:
Typical accuracy ranges for Class 5 estimates are
-20% to -50% on the low side, and +30% to +100% on the high side, depending on the technological complexity of the project, appropriate reference information and other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks.

Alternate Estimate Names, Terms, Expressions, Synonyms:
Ratio, ballpark, blue sky, seat-of-pants, ROM, idea study, prospect estimate, concession license estimate, guesstimate, rule-of-thumb.</td></tr>
</table>

Table 2a – Class 5 Estimate

CLASS 4 ESTIMATE	
Description: Class 4 estimates are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Typically, engineering is from 1% to 15% complete, and would comprise at a minimum the following: plant capacity, block schematics, indicated layout, process flow diagrams (PFDs) for main process systems, and preliminary engineered process and utility equipment lists. **Maturity Level of Project Definition Deliverables:** Key deliverable and target status: Process flow diagrams (PFDs) issued for design. 1% to 15% of full project definition. **End Usage:** Class 4 estimates are prepared for a number of purposes, such as but not limited to, detailed strategic planning, business development, project screening at more developed stages, alternative scheme analysis, confirmation of economic and/or technical feasibility, and preliminary budget approval or approval to proceed to next stage.	**Estimating Methodology:** Class 4 estimates generally use factored estimating methods such as equipment factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, the Miller method, gross unit costs/ratios, and other parametric and modeling techniques. **Expected Accuracy Range:** Typical accuracy ranges for Class 4 estimates are -15% to -30% on the low side, and +20% to +50% on the high side, depending on the technological complexity of the project, appropriate reference information, and other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks. **Alternate Estimate Names, Terms, Expressions, Synonyms:** Screening, top-down, feasibility (pre-feasibility for metals processes), authorization, factored, pre-design, pre-study.

Table 2b – Class 4 Estimate

CLASS 3 ESTIMATE	
Description: Class 3 estimates are generally prepared to form the basis for budget authorization, appropriation, and/or funding. As such, they typically form the initial control estimate against which all actual costs and resources will be monitored. Typically, engineering is from 10% to 40% complete, and would comprise at a minimum the following: process flow diagrams, utility flow diagrams, preliminary piping and instrument diagrams, plot plan, developed layout drawings, and essentially complete engineered process and utility equipment lists. Remedial action plan resulting from HAZOPs is identified. **Maturity Level of Project Definition Deliverables:** Key deliverable and target status: Piping and instrumentation diagrams (P&IDs) issued for design. 10% to 40% of full project definition. **End Usage:** Class 3 estimates are typically prepared to support full project funding requests, and become the first of the project phase control estimates against which all actual costs and resources will be monitored for variations to the budget. They are used as the project budget until replaced by more detailed estimates. In many owner organizations, a Class 3 estimate is often the last estimate required and could very well form the only basis for cost/schedule control.	**Estimating Methodology:** Class 3 estimates generally involve more deterministic estimating methods than conceptual methods. They usually involve predominant use of unit cost line items, although these may be at an assembly level of detail rather than individual components. Factoring methods may be used to estimate less-significant areas of the project. **Expected Accuracy Range:** Typical accuracy ranges for Class 3 estimates are -10% to -20% on the low side, and +10% to +30% on the high side, depending on the technological complexity of the project, appropriate reference information, and other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks. **Alternate Estimate Names, Terms, Expressions, Synonyms:** Budget, scope, sanction, semi-detailed, authorization, preliminary control, concept study, feasibility (for metals processes) development, basic engineering phase estimate, target estimate.

Table 2c – Class 3 Estimate

<table>
<tr><th colspan="2">CLASS 2 ESTIMATE</th></tr>
<tr><td>Description:
Class 2 estimates are generally prepared to form a detailed contractor control baseline (and update the owner control baseline) against which all project work is monitored in terms of cost and progress control. For contractors, this class of estimate is often used as the bid estimate to establish contract value. Typically, engineering is from 30% to 75% complete, and would comprise at a minimum the following: process flow diagrams, utility flow diagrams, piping and instrument diagrams, heat and material balances, final plot plan, final layout drawings, complete engineered process and utility equipment lists, single line diagrams for electrical, electrical equipment and motor schedules, vendor quotations, detailed project execution plans, resourcing and work force plans, etc.

Maturity Level of Project Definition Deliverables:
Key deliverable and target status: All specifications and datasheets complete including for instrumentation. 30% to 75% of full project definition.

End Usage:
Class 2 estimates are typically prepared as the detailed contractor control baseline (and update to the owner control baseline) against which all actual costs and resources will now be monitored for variations to the budget, and form a part of the change management program. Some organizations may choose to make funding decisions based on a Class 2 estimate.</td><td>Estimating Methodology:
Class 2 estimates generally involve a high degree of deterministic estimating methods. Class 2 estimates are prepared in great detail, and often involve tens of thousands of unit cost line items. For those areas of the project still undefined, an assumed level of detail takeoff (forced detail) may be developed to use as line items in the estimate instead of relying on factoring methods.

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

Alternate Estimate Names, Terms, Expressions, Synonyms:
Detailed control, forced detail, execution phase, master control, engineering, bid, tender, change order estimate.</td></tr>
</table>

Table 2d – Class 2 Estimate

CLASS 1 ESTIMATE

Description:
Class 1 estimates are generally prepared for discrete parts or sections of the total project rather than generating this level of detail for the entire project. The parts of the project estimated at this level of detail will typically be used by subcontractors for bids, or by owners for check estimates. The updated estimate is often referred to as the current control estimate and becomes the new baseline for cost/schedule control of the project. Class 1 estimates may be prepared for parts of the project to comprise a fair price estimate or bid check estimate to compare against a contractor's bid estimate, or to evaluate/dispute claims. Typically, overall engineering is from 65% to 100% complete (some parts or packages may be complete and others not), and would comprise virtually all engineering and design documentation of the project, and complete project execution and commissioning plans.

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

End Usage:
Generally, owners and EPC contractors use Class 1 estimates to support their change management process. They may be used to evaluate bid checking, to support vendor/contractor negotiations, or for claim evaluations and dispute resolution.

Construction contractors may prepare Class 1 estimates to support their bidding and to act as their final control baseline against which all actual costs and resources will now be monitored for variations to their bid. During construction, Class 1 estimates may be prepared to support change management.

Estimating Methodology:
Class 1 estimates generally involve the highest degree of deterministic estimating methods, and require a great amount of effort. Class 1 estimates are prepared in great detail, and thus are usually performed on only the most important or critical areas of the project. All items in the estimate are usually unit cost line items based on actual design quantities.

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

Alternate Estimate Names, Terms, Expressions, Synonyms:
Full detail, release, fall-out, tender, firm price, bottoms-up, final, detailed control, forced detail, execution phase, master control, fair price, definitive, change order estimate.

Table 2e – Class 1 Estimate

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ESTIMATE INPUT CHECKLIST AND MATURITY MATRIX

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

General Project Data:

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

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.

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

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

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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 [12].

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 [13] for the process industry and IR115-2 [14] for the building industry. Similar systems have been developed by the US Department of Energy [15].

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Attachment 2

AACE International

Risk.08 - Defining Risk and Contingency for Pipeline Projects

RISK.08

Defining Risk and Contingency for Pipeline Projects

F. Cristina Figueiredo, P.Eng. and Brent Kitson, P.Eng.

ABSTRACT— Pipeline projects are linear projects that often stretch over several communities, states, provinces or even countries. Local economic conditions will impact the cost of the project and can vary by location. Pipeline projects will be impacted by economic volatility. Alberta is an example of an economy that has experienced an unprecedented rate of escalation in the labor market in recent years. Large pipeline projects are impacted by global economic conditions. Components such as steel for pipe and pipe fabrication are impacted by the global market. The scoping and execution of pipeline projects require the input and coordination of numerous internal stakeholders, customers, regulatory bodies, resources and public bodies. Identifying risk and determining an appropriate amount of contingency is a challenge that must be addressed to ensure accurate information is available to base critical financial decisions upon. This paper will address processes to define risk and contingency for pipeline projects. Some of the typical risks associated with pipeline projects will be discussed.

Keywords: Contingency, cost, financial, labor, pipeline projects, risk and scope

The planning and execution phases of a pipeline project require the involvement and coordination of numerous internal stakeholders, and external stakeholders including customers, public and private regulatory bodies, and resources. The identification of the risks involved in such projects is essential to ensure accurate information is available to base critical financial decisions as well as to minimize exposure to potential adverse impacts. During the pipeline project lifecycle, risk shall be managed in a continuous, consistent, structured and standardized approach.

Risk is the exposure to the potential impacts of a possible event. The potential impact may be positive or negative. A possible event causing negative effects is a "threat", while a possible event causing positive effects is an "opportunity."

The possibility of occurrence of an event depends on how likely it is to happen. Risk level is described by the mathematical product of the probability for an event to occur, multiplied by the expected magnitude of impacts caused by the event. The conceptual formula to assess risk level is: RL = P x I, where, RL = Risk Level, P = Probability and I = Impact. When impact is evaluated in financial terms, impact is equal the estimated monetary value of the damages (threat), or the estimated monetary value of the benefits (opportunity). Risk can be mitigated by reducing or eliminating either the probability of occurrence or the impact if the event occurs.

In pipeline projects, risk impacts are evaluated in the five following main areas: cost, duration, scope, health, safety and environment.

This paper will present the risk management (RM) process that has been developed by a pipeline company committed to an ongoing process improvement to align with best practice industry standards and recommended practices.

Risk Management Overview

Risk management is an integral component of good management and decision-making at all levels. As per definition, risk management is a systematic approach to setting the best course of action under uncertainty by identifying, assessing, understanding, acting on and communicating risk issues, i.e., risk management (RM) is a process that addresses uncertainty [5, 6].

A successful risk management (RM) system is comprised of the risk policy, the company ownership of the process, the integration of the company values to manage risk, the risk management process and the risk management standard framework.

For instance, a RM process used by a pipeline company presents five core interdependent sub-processes:

- **Planning:** How to implement and practice the RM process and framework elements.
- **Identification**: Procedures and methods to identify, describe, and document risk.
- **Assessment:** Qualitative or quantitative risk level assessment and prioritization.
- **Response:** Create and execute mitigation actions, or monitoring and control strategies. And,
- **Monitoring and Control**: Monitor current risk, new risk, evaluate RM effectiveness, follow up on response plan status, check control points, identify and close gaps.

The risk management process map in figure 1 shows further details of a RM standard framework of a pipeline company.

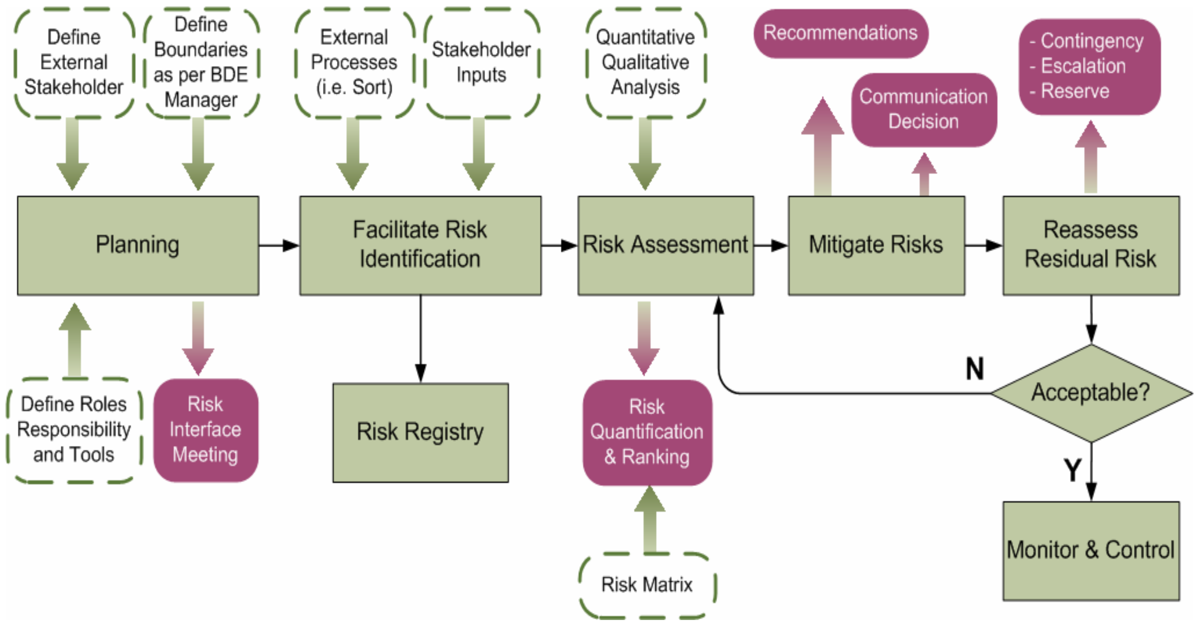

Figure 1—Risk Management Process of a Pipeline Company

Risk Implementation Plan

The risk implementation plan defines how to implement and practice the RM process and framework elements. It documents how a specific project team is to strategically implement and practice the risk management framework.

The risk implementation plan will start defining a boundary of control (i.e., the risk management roles and responsibilities of project members), indentifying and engaging stakeholders, functional leads, risk owners, subject-matter experts and communicating of the methodology, boundary and focus area for risk identification. It is important to be aware of the relevant risk areas of the project that needs to be discussed versus the irrelevant ones. Also, the risk implementation plan shall identify and engage a suitable facilitator to run risk identification sessions.

The main output of the "risk implementation plan" is the risk interface meeting which reviews the risk implementation plan inputs described above.

Table 1 shows some specific examples of pipeline project risk areas:

RISK AREAS	EXTENDED DESCRIPTION
COMMERCIAL	Commercial contracts,
COMMISSIONING	Commissioning, start up, equipment set up, FAT
COMMUNITY	Community, aboriginal affairs, local communities, associations
COMPLIANCE	Compliance, regulations
CONSTRUCTION	Construction, construction strategy, logistics
CORPORATE	Corporate, AFE, stake-holders, company approvals
ENGINEERING	Engineering, design, scope, process engineering, reliability, equipment performance envelop, maintainability, safety requirements
ENVIRONMENTAL	External environment, snow, seasons, weather, flora, wild Life, lakes, rivers, above ground level risk.
ESTIMATING	Base cost estimation, indirect and direct cost, assumed productivity base
FINANCIAL	Foreign exchange, discounted cash flow, ROE (Return on Equity)
GEOLOGY	Soil, terrain characteristics, geology, topography, below ground level risk
LEGAL	Legal, contracts, litigation,
MARKET	Price indices, currency, inflation, market competition
OPERATIONS	Operations interface, transfer to operations
PERMITS	Environmental permits, other official agencies permits
PM	Project management, gates, deliverables, scope definition, schedule, risk plans, practices and standards, training, etc
PROCUREMENT	Procurement, procurement strategy, lead time, shipping, delivery,
RESOURCES	Resources, labor, trades, skilled resources, contracts
RIGHT OF WAY	Right of way, access, condemnation, acquisitions
UTILITIES	Power, utilities infrastructure

Table 1—Risk Areas

Risk Identification

The risk identification process starts with a clear definition of the core project objectives. Core project objectives can be outlined as scope, schedule, cost, safety and environment. It is important to identify the project components that are more relevant or influential to the core project objectives i.e. to focus on project critical components (criticality assessment).

The risk identification process benefits from inputs (tools) like brainstorming sessions, checklists, review of historical records for other similar projects, stakeholders discussions (i.e., gathering all stakeholder inputs in relevant areas), collecting other risk analysis completed (i.e. system operability review, HAZOP), strengths, weaknesses, opportunities, and threats (SWOT) analysis, collecting historical information available (i.e., risk incident root cause reports), cold eyes reviews, project execution plan, and execution strategies repot.

The main output of the risk identification process is a "risk register." The risk register is the central repository for risk information of the project. It supports most of the phases of the RM standard framework. The risk register contains the risk ID, probabilities, estimated cost impacts (low, likely, high), and its categorization (systemic, project specific, escalation and others). Figure 2 shows an example of a simplified risk register.

Risk ID	Description of Risk	Probability ((VL,L,M,H,VH))	Description of Impact		Cost Impact	Schedule Impact	Mitigation Strategy
1	Construction delayed due to permits not yet approved.	L	Affect construction schedule	Low:	$ 13,000.00	Yes	Enough lead time has been allowed for in the schedule to ensure permits are in place. Off site fabrication could begin if permits are delayed. Cost impact should be low due to construction cannot actually start before permits are obtained. These costs are therefore more project extension delays.
				Likely:	$ 13,000.00		
				High:	$ 48,000.00		

Figure 2 – Example of a Simplified Risk Register

Identifying Systemic and Project Specific Risks

Risk management practices define systemic and project specific risks as different categories of risks. To identify systemic risks, it is important to understand their stochastic nature. It is known that the level of uncertainties in a project is inversely correlated to the level of definition of project scope, schedule and cost estimate. Even when scope is completely defined, uncertainties in cost and schedule will always exist considering the fact that the project may be impacted by factors that may not be predicted precisely such as, weather, trade skill levels, contractor project management effectiveness, price indexes, inflation, labor conflicts, community interaction, etc. Systemic risks can be identified as the drivers of project uncertainty that affects the generality of the project (i.e., they can be analyzed statistically but not predicted precisely (stochastic in nature)).

Project specific risks are driven by events or cause conditions that upon being realized in a project, produce a significant impact in a specific project activity, or resource or project component. Project-specific risk drivers result in cost impacts that are more deterministic in nature, meaning the impact to a given schedule task or cost account is more readily identifiable. Table 2 shows some examples of systemic and project specific risks of a pipeline project.

Systemic Risk Drivers	Project Specific Risk Drivers
Commercial Project Scope Project Planning /Execution Plan Overall Scope Definition Engineering Deliverables	Heater scope change due to Hazop fidings Underestimated permit processing time Facilities engineering packages late Solvent system requires vapor recovery system
Estimate Inclusiveness Estimating Data Quality Estimate Competitiveness Percent Fixed Price Prject Management Effectiveness Poor definition of rules and responsibilities	Water from hydro testing requires cleaning before disposal Incentives program missed / difficulty finding enough labor force Inexperienced project manager Underestimated steel proce
New Technology Material Properties Facility Complexity Project Execution Complexity	HDD takes longer due to geotechnical problems Critical path commiioning materials late Site congestion at pinch points Equipment failure during commisssioning, no spares available

Table 2—Systemic vs. Project Specific Risks

Risk Assessment

Once risk has been identified, the following step in the RM process is the assessment of its risk level, determination of acceptability, prioritization and definition of a target date to respond to it. The risk assessment process analyses the quantitative and qualitative information of the risk description, probabilities and impacts (low, likely, high).

Best practice historical data shows that projects that use no risk assessment experience an increase in variable cost growth, the execution schedule can become longer, they may experience start up problems, and technical problems are more likely to arise.

Risk level assessment starts with the quantification and ranking of probability and potential impacts that a risk event may originate. Probability is assessed based on information of the cause and conditions that may trigger events that originate risk drivers. Qualitative evaluation of probability or impact is based on experience and requires engagement of subject matter experts. In qualitative analysis, probability and impact are estimated within a range, the probability and impact range are related to the risk tolerance criteria managed by the company. For instance, the pipeline company cited in this paper uses probability and impact table containing 5 ranges: very low (VL), low (L), medium (M), high (H) and very high (VH).

Impact is estimated independently for each of the five main areas (cost, duration, scope, health, safety and environment). During risk-analysis sessions, estimation of impacts is not practical and may not result in a precise figure. While some impacts can be estimated without difficulty in units of cost, others, such as safety and environment, are better estimated in terms of the qualitative magnitudes of the impact. The principal of using thresholds in the impact categories is to rank them on the basis of their impact on project objectives. Schedule in and of itself has no commonality between projects in terms of its relative importance or rank. All schedule impacts should be translated to cost impact as the primary ranking criteria. There are a few exceptions, such as when it is a distinct objective set by business or an agreement with client regardless of costs. For instance, if the project slips 3 months or more, company members would be fired by board, project would be terminated by the client, or the company's reputation may be tarnished in the public eye. In all other cases, schedule shall be converted to costs, using case specific estimation. The team must first establish the project specific criteria, i.e. what the "show stopper" criteria is for the project in terms of duration (e.g., 3 months slip means project fails to meet objective). So, it can be easily converted to percent of total duration.

Table 3 shows a risk Probability – impact table, one of the most popular risk management tools. A risk assessed as highly likely to happen and as having a high impact on the project will need closer attention than a risk that is low in terms of both probability and impact. Each risk can be allocated to one of the cells in table 3.

Risk Probability and Impact			
	Low Impact	**Medium Impact**	**High Impact**
High Probability			
Medium Probability			
Low Probability			

Table 3—Risk Probability – Impact Table

Contingency Determination Process

Contingency is a cost element of an estimate to cover the probability of unforeseeable events to occur and that if they occur, they will likely result in additional costs within the defined project scope [1].

Estimating contingency is one part of the risk management process. Many methods and techniques have been proposed in the literature for estimate contingency. They are mainly risk analysis techniques. The best contingency estimating method depends on the type of risk.

Systemic risks are driven by risks that all projects face and the risk impact on most projects for a given company "system" are relatively consistent and predictable. The recommended practice to estimate a systemic risk is to use a parametric modeling [3].

The pipeline company herein cited has developed a systemic and a project specific risk tool to calculate contingency. The systemic tool uses a parametric model. It is basically a questionnaire where the team rates the status of the risk drivers in 5 categories: Level of project scope definition (i.e., scope content, planning basis, design detail, site definition, etc); Estimate basis (quality of database, conservativeness, inclusiveness, extent of fixed costs and equipment, etc); Process technology/complexity (use of new technology, qualities of feedstocks, number of process steps, etc.);Project complexity (use of new organization or execution strategies, etc.);Project management (level of management and control discipline).

The systemic risk tool is typically used alone to calculate contingency for class 5 estimates. In the early stages of the project lifecycle (i.e. screening and planning stages), scope definition, technology, and complexity risks dominate the cost outcome. The systemic risk tool will translate quantified risks into a cost distribution with the main purpose of estimating the overall capital cost of a project within a probabilistic expectation of finishing the project within a target cost (usually the P50-P55).

Project specific risks are those that are unique to a particular project's scope, strategies, attributes, and so on. The nature of these risks and extent of their impact are not consistent between projects in a given company. For these risks, risk impact must be defined and estimated uniquely. Thus, to estimate project specific risks, the recommended practice is to use "expected value model" [4]. The pipeline company herein cited has developed a project specific risk tool that together with the systemic risk tool calculates contingency for class 4 and 3 estimates. The project specific tool uses an "expected value" model, i.e., cost impact of each risk driver is explicit in an expected-value cost model. This tool requires that Monte-Carlo simulation be run to obtain the final cost distribution. The contingency determination process used by the pipeline company herein cited is shown in figure 3.

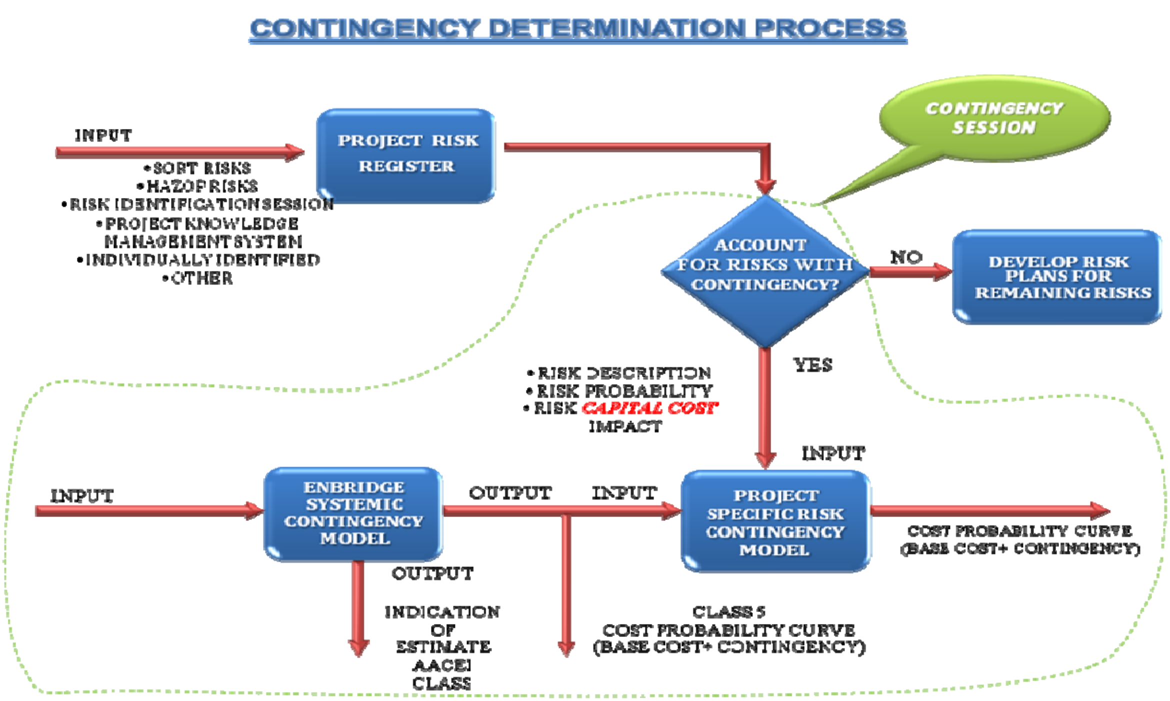

Figure 3—Contingency Determination Process

During the detailed design and procurement stages, the project increases the level of scope, schedule and estimate definition and so increases the need to detail contingency as the main purpose of manage (control) contingency during execution. Contingency is expected to be expended and it is controlled like any other "control account" in the budget contingency management during project execution shall align best practices in risk management in order to monitor and control risk responses.

Risk Response/Mitigate Risks

Once risks are identified and assessed, the next step is to mitigate the risks. To mitigate the risks, risk drivers shall be clearly understood. Options for risk response are identified and evaluated. The options can be defined by six categories: Avoidance (total elimination of the risk); Mitigation (apply methods to eliminate or reduce probability or impact of the risk); Acceptance (accept the risk, assign contingency budget or recovery plan to respond to the cost impact of the accepted risk); Research (accurate assessment of risk level through research activities, surveys or studies); Transfer (transfer of risk ownership, i.e., contracting out portion of scope execution or acquiring risk insurance); Monitoring (i.e., to decide not to take immediate response to a risk, but to track, follow up on conditions, trends or behavior of risk drivers over time). To sustain the risk response plan, it is essential to provide updates to the Risk Register by updating the assignment of a person as risk owner, and recording the specific risk mitigation or action plans linked to the risk item.

Monitoring and Control

One of the main objectives of monitoring and control risks is to assure an ongoing risk identification, assessment and response. Some best practices requirements to monitor and control risks include: periodically review the status of the identified risks in the risk register; review the effectiveness of the risk response used; identify, assess and develop risk responses for any new risks that may arise and were not included in the previously risk response plan; maintain updated tracking on contingency usage and risk drivers of contingency.

A RM process used in a pipeline company has been outlined. A RM process shall create value for the company and be an integral part of an organizational process. It should be structured, transparent and inclusive. Also it should be able of continuing improvement.

There are innumerous benefits that a structured RM process can provide to a project. It provides a structured framework for more effective strategic planning, maximizing opportunities and minimizing losses; promotes greater openness in decision making and improves communication; provides senior management with a concise summary of the major risks affecting the project; provides a framework for ensuring that risks are adequately managed; provides an effective approach which enables management to focus on areas of risk in their operations.

When a RM process is first implemented in a company, it is important to understand that it will not be perfect. Only through practice, experience, and actual loss results, the company will improve the RM process and gather contribute information to allow possible different decisions to be made in dealing with the risks being faced.

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Attachment 3

AACE International

EST.03 – Exploring Techniques for Contingency Setting

EST.03

Exploring Techniques for Contingency Setting

Scott E. Burroughs and Gob Juntima

One of the primary areas of concern for a company's project system is the assignment of reliable contingency allowances in project cost estimates. Over the years, various contingency-setting techniques have been developed in an ongoing search for reliable approaches. These techniques vary from simple to extremely complex in their development and use, but all have the objective of improving the accuracy of project estimates. Unfortunately, very little data have been published on how successful industry contingency-setting techniques have been in improving project estimate accuracy. The goal of this paper is to objectively and quantitatively explore the historical performance of the various techniques. In addition, we will also describe a technique successfully used by Independent Project Analysis, Inc. (IPA), but little used in industry, and see how its performance compares with the common industry approaches.

CONTINGENCY VERSUS THE BASE ESTIMATE

Conflicting views exist about what contingency is. For the purpose of this paper, contingency is defined as the amount of money that experience has demonstrated must be added to the base estimate to provide for uncertainties related to (a) project definition and (b) technological uncertainty. Contingency is money that is expected to be spent. The contingency account is not intended to provide for changes in the defined scope of a project (e.g., change in capacity or product slate) or for unforeseeable circumstances beyond management's control (e.g., 100-year storms or strikes against equipment vendors). Contingency should not be viewed as a reserve or slush fund that the project team cannot spend without upper management approval. Likewise, management should not have the expectation that, if a project team does its job well, contingency will not be spent. A competitive approach is to set contingency at an amount that achieves a 50 percent probability of overrun. At a 50 percent probability, the project system, on average, is expected to spend all of its contingency.

The previous discussion assumes that the base estimate is a realistic and competitive estimate of the known scope and also assumes typical site and market conditions. A competitive base estimate is free of excessive allowances and markups for general unknowns. Allowances to cover specific, but uncertain, items are expected within a base estimate. The competitiveness of the base estimate is a key factor to consider in contingency setting.

THE TECHNIQUES

The vast majority of projects set their contingencies using techniques that can be grouped into one of three categories: predetermined percentage, expert's judgment, and risk analysis. We will also explore a fourth technique called regression analysis, or ordinary least squares regression, that IPA and a few others use. The first three categories will be the focus of our historical analysis. Because numerous publications describe the three most common contingency-setting techniques, we will only discuss those methods briefly.

Predetermined Percentage

Many company or site project systems use predetermined or mandated percentages of the base estimate as the project's contingency. We found that many project systems mandate that all projects will include contingency of either 5 or 10 percent of the base estimate. Although the basis for the percentage may seem arbitrary, 5 to 10 percent is a reasonable average for contingency use in the process industries.

The advantages of this technique are its ease of use and consistency. Using a consistent percentage removes subjectivity from the process. Because of the ease with which it is implemented, a fixed contingency percentage is often the technique applied to smaller projects. The disadvantage of the technique is the fact that it removes specificity and subjectivity from the process; it is inflexible to potentially important risk drivers, such as process complexity, use of new technologies, and level of project definition. Because of this, the method tends to underestimate contingency needs for complex and poorly defined projects and to overestimate for simple or well-defined projects. By failing to take project risk drivers into account, the predetermined percentage method produces large variations in the probability of overrun or underrun from project to project.

Expert's Judgment

A more advanced and flexible methodology for determining contingency is to use the educated judgment of experts to assist in setting a contingency level. In this technique, skilled estimators and project team members use their experience and expertise to assign a level of contingency that they believe is appropriate for the project at hand. Unlike the predetermined percentage technique, expert judgment considers specific risk factors and base estimate competitiveness.

The degree of structure to this contingency-setting process varies widely. Typically, the experts must consider bounds or norms (formal or informal) for contingency outcomes. These bounds may be expressed by using an expanded version of the predetermined contingency approach whereby the experts must select from contingencies that are predetermined for discrete risk levels (e.g., 15 percent for high risk, 10 for average, and 5 for low risk). If the process is more highly structured than this, it tends to be classified as a risk analysis approach, which is discussed in the next section.

By using specificity and subjectivity in setting each project's contingency level, a project system is more likely to have more accurate estimates. However, subjectivity is also the main disadvantage of this method in that the skill, knowledge, and motivations of the experts may vary widely. Typically, only a few experts are available whose understanding of project cost risk and estimate competitiveness can be relied on. This expertise is not easily transferable, which makes turnovers a primary concern.

Risk Analysis

Risk analysis techniques examine risk factors in a more structured way than expert judgment and apply specific quantitative methods of translating the assessed risks into contingency values. The quantitative methods are usually probabilistic in nature and allow the statistical confidence level of cost outcomes to be considered.

The most commonly used form of risk analysis employs Monte Carlo simulation as the quantitative method. In this technique, a probability distribution is assigned to each estimate line item or subtotal, and the simulation tool (typically a spreadsheet add-on) randomly selects a possible outcome from each item's distribution and aggregates the item outcomes into a total expected project cost outcome. This process is repeated many times (e.g., 1,000 iterations) to obtain an average total cost. The distribution of the iterative outcomes can then be used to select a contingency value that provides the level of statistical confidence desired. Using Monte Carlo analysis or similar risk analysis techniques allows estimators to examine the risk of individual project cost elements in a highly structured way.

The main advantage of risk analysis techniques is that they are probabilistic in nature. They allow confidence levels to be explicitly considered, and they are also very flexible. Monte Carlo analysis can be applied to any estimate or cost analysis that can be totaled or modeled in a spreadsheet; the spreadsheet model can be as simple or complex as desired. For any given model, the estimator then has almost infinite flexibility in assigning probability distributions to estimate elements

Risk analysis techniques have another advantage if the risk assessment step is done in a group setting wherein the project team reviews the entire estimate from a risk perspective. This is often the only team review of the estimate, and the outcome of the review is almost always an improved base estimate, as well as a probabilistic-based contingency value.

A major disadvantage of risk analysis techniques as typically applied is that the estimate items for which probable outcome distributions are being assigned are not, in themselves, risk drivers. The distributions assigned, therefore, tend to be somewhat meaningless. For example, the typical cost model is a spreadsheet tabulation of estimate elements, such as piping and electrical line items. The estimator is expected to assign a probability distribution (e.g., triangular distribution with +50/-30 percent high-low range) to "piping." However, if the major risk driver is level of project definition, few, if any, estimators will have a really good idea of how project definition (or weather or labor markets, etc.) will affect any particular line item.

Risk analysis also requires more time and resources to implement compared with predetermined percentages or an expert's judgment. The Monte Carlo technique is also deceptively complex. For example, it requires that dependencies be established between elements of the cost model, which is almost always skipped by users because few understand cost item dependencies (e.g., if the electrical cost outcome is on the high end of its range, what is the probability that the piping cost outcome will also be on the high side). The complexity also allows outcomes to be easily manipulated, so the results are often inconsistent. The time and complexity of risk analysis techniques often mean that they are reserved primarily for larger projects or projects of increased business importance.

Regression Analysis

Regression analysis is a statistical technique for estimating the equation that best fits sets of observations of a response variable and multiple explanatory variables in order to make the best estimate of the true underlying relationships between these variables. IPA uses regression analysis to establish contingency requirements. This technique was formulated by collecting detailed histories of projects and identifying key factors that drive differences between project estimates and actual cost outcomes. As with risk analysis techniques, regression analysis is based on quantitative modeling. However, the explanatory variables in the regression model are quantified risk drivers, not estimate line items or subtotals. Regression analysis is empirical and objective, and regression models produce consistent results no matter who applies them.

Similar to risk analysis techniques, regression models are probabilistic in nature and allow the statistical confidence level of cost outcomes to be considered. However, unlike risk analysis techniques, regression analysis is based on actual data, not assumed probability distributions and risk driver-cost outcome relationships. Because regression models are based on historical data, they bring expert knowledge to contingency setting without the need for a skilled expert on every project.

Through regression analysis, we have found several project risk drivers, both controllable and uncontrollable, to be the strongest drivers of project cost deviation or the amount of contingency used. The following is a list of these risk drivers.

Project Definition Level—The objective of project definition or Front-End Loading (FEL) is to gain a detailed understanding of the project and to minimize the number of execution uncertainties. Project definition level is an important driver that can have a direct effect on the level of contingency used by a project. It is one of the most important elements in our model.

Use of New Technology—Projects involving new technology—that is, technology that has no commercial history either within the owner company or elsewhere—have been historically proven to require more contingency. New technology may involve the use of new chemistry, first-of-a-kind major equipment, or existing equipment performing a new service. New technologies are associated with more risk than proven technologies because Industry has little or no experience with a new technology. As a result, the use of new technology increases the amount of contingency required.

Process Complexity—Complexity can be measured in many ways. We define complexity as the number of continuously linked process steps, counted on a block basis, in a facility. Parallel trains are counted only once, and the control system and off-sites are not included. As project complexity increases, the need for increased contingency also increases.

Contracting and Execution Strategy—Projects executed using lump-sum contracts typically require less explicit contingency than other contracting strategies because they move much of a project's risk from the owner to the contractor. Execution strategy affects contingency use because, if a project is cost driven, it is less likely to take actions and make changes that will put cost at risk. If a project is schedule driven (i.e., the project team is willing to spend money to achieve its schedule objective), more risk may be acceptable, and costly changes may be tolerated.

Equipment Percentage—Because the majority of major equipment estimates are based on firm quotes, equipment cost experiences the least cost growth. Even for early estimates using historical data or budget quotes, equipment cost estimates tend to be more accurate than the estimates for other cost accounts. Therefore, projects that have a high equipment percentage typically require less contingency.

Other inputs that should be considered when creating a regression model are company cost culture, estimate inclusiveness, process impurity problems, project management practices, project scope characteristics, and estimate quality.

HISTORICAL PERFORMANCE

The objective of this section is to present the results of our historical analysis of the process industry's contingency data over the last 10 years. Before we discuss our methodology and findings, we need to introduce our dataset of projects.

The Database

The dataset used for this research is a subset of the IPA Downstream Project Evaluation System (PES®) Database. The PES database currently consists of more than 8,000 projects, each with more than 2,000 pieces of information. These data points capture detailed project-specific information, including project definition, technology, project management, cost, schedule, operating performance, and safety. The database contains projects in a wide range of industrial facilities that were executed by more than 200 companies around the world. From this database, we selected a subset of 1,500 projects on which we have detailed information regarding cost, scope, contingency level, and contingency-setting technique. Because we are primarily interested in more recent projects, about half of the selected projects in our dataset were completed after January 2000. Including a wide spectrum of project costs was also important. To that end, projects in the dataset range in size from less than $100,000 to greater than US$1.5 billion. All costs are adjusted to 2002 United States (U.S.) dollars, which allows us to compare projects executed in different years.

Historical Measure of Contingency

In order to quantitatively evaluate the accuracy of each project's contingency, we needed to create some type of measurement, which we called the Contingency Performance Indicator (CPI). The CPI is defined as the absolute value of percent of contingency used minus the percent of contingency estimated. For example, Project A has a base estimate of $8 and a contingency of $4. The actual cost of the project is $10. In this example, the CPI = absolute[(10-8)/8 - (4/8)] = 25 percent. For this project, the estimated contingency (50 percent) is different from the contingency used (25 percent) by 25 percent.

The perfect CPI of 0 percent is a result of the estimated contingency exactly predicting the actual amount used. Because the CPI is an absolute measure, any deviation from the estimated contingency, whether it is an overrun or an underrun, is treated in the same way and results in a positive score. For the purposes of this study, we are concerned only with the accuracy of the predicted contingency, not the direction of deviation.

EVOLUTION OF CONTINGENCY TECHNIQUES

When we examined whether the industry was improving in contingency estimation over the last 10 years, we found that the CPI has, on average, been increasing. Figure 1 indicates that contingency estimates are, on average, getting further from the actual contingency required. This decline in performance is driven by dramatically worse performance for smaller projects. The CPI for large projects has been largely constant over the last 10 years, with a median of about 7 percent. During the same time period, small projects have gotten dramatically worse in contingency estimation, with the CPI measure going from a median of about 6 percent in 1994 to 1995 to a median of about 10 percent in 2002 to 2003. In essence, the average difference between estimated contingency and the actual contingency required on small projects has almost doubled in the last 10 years.

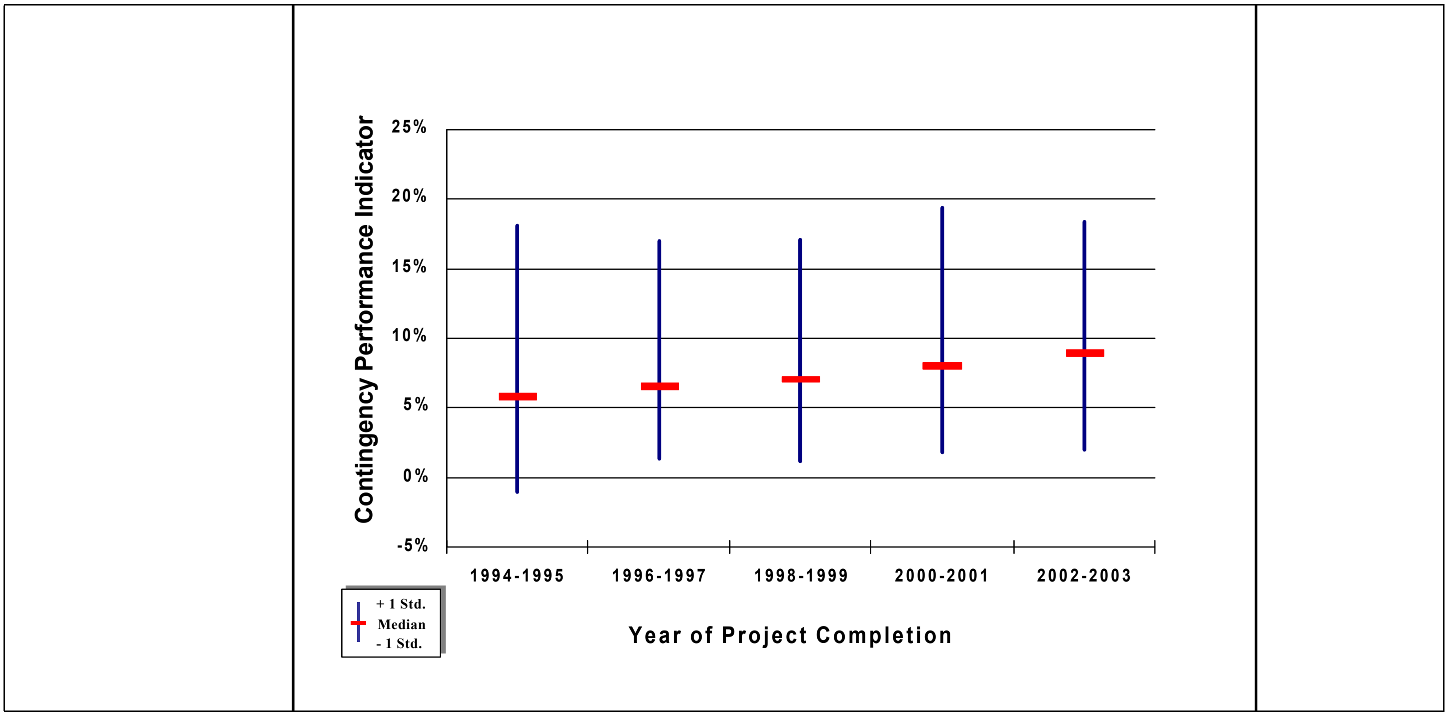

Figure 1—Contingency Performance Over the Last Ten Years

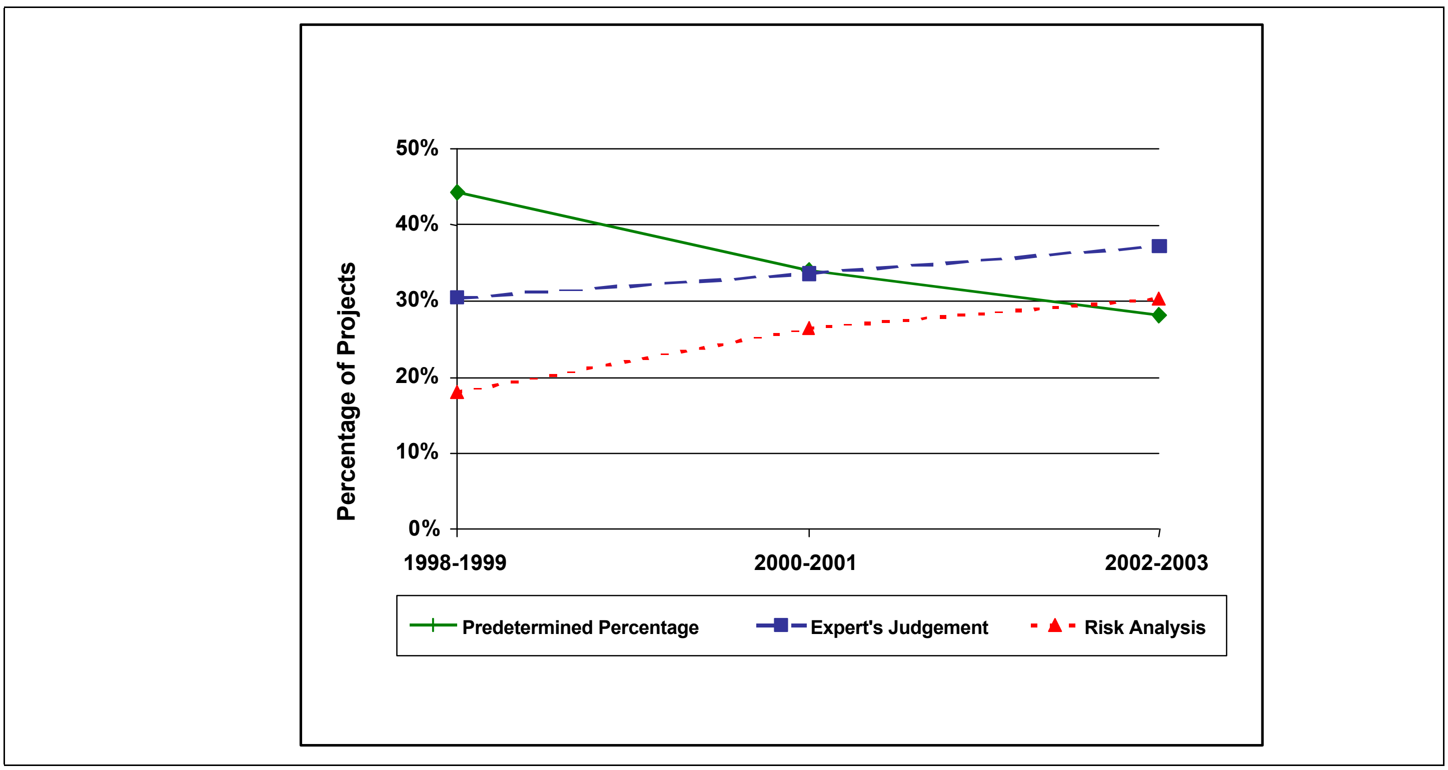

Figure 2—Use of Contingency Techniques

This result is especially surprising considering that the percentage of projects using more sophisticated approaches to contingency setting has been increasing. As shown in Figure 2, about 20 percent of projects used risk analysis techniques prior to the year 2000. In the post-2000 period, project teams' use of risk analysis has increased to more than 30 percent. During the same period, the use of predetermined percentages has dropped from almost 50 percent to 30 percent.

COMPARING THE TECHNIQUES

To better understand the decline in contingency-estimating performance, we evaluated projects executed using the three commonly used estimating methods. The industry belief has been that projects that use a risk analysis technique to estimate contingency will achieve better accuracy (i.e., lower CPI). In fact, all three of the techniques produce results that are essentially the

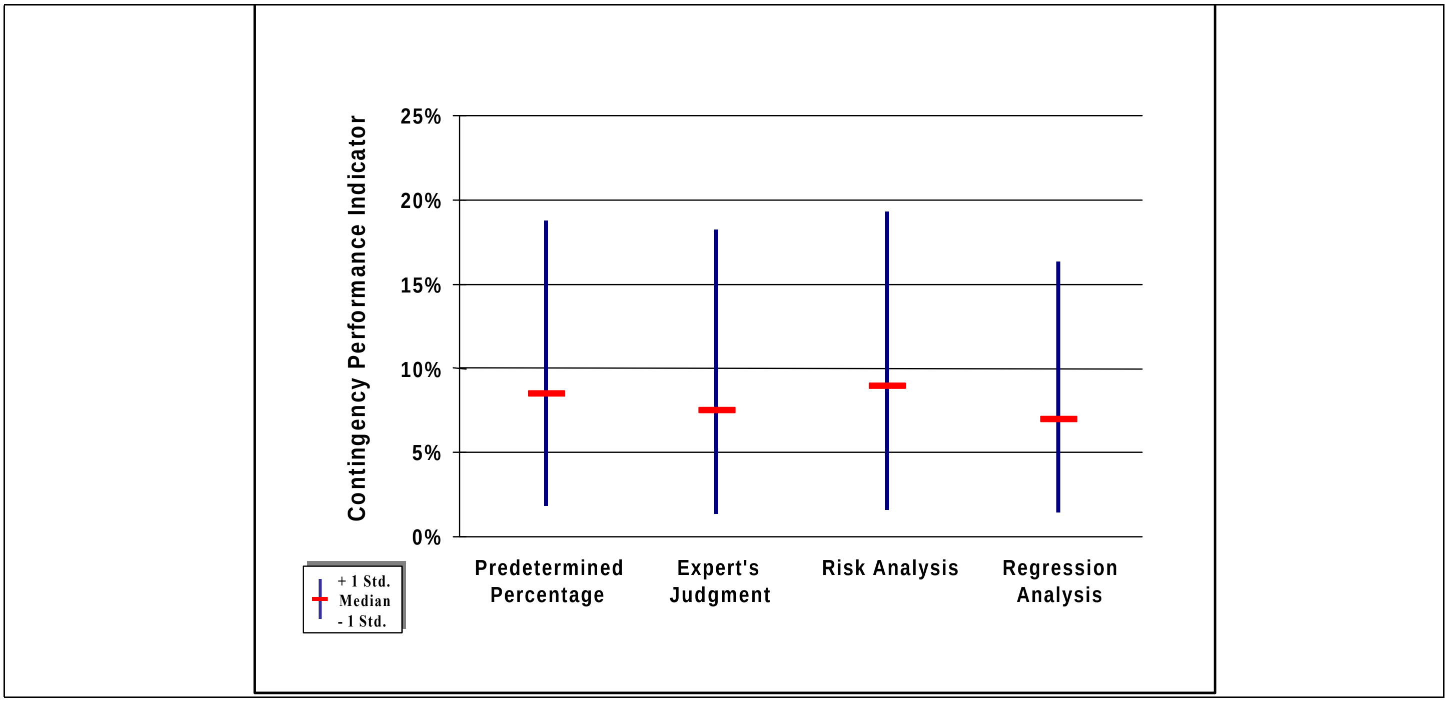

Figure 3—CPI for the Three Contingency Setting Techniques

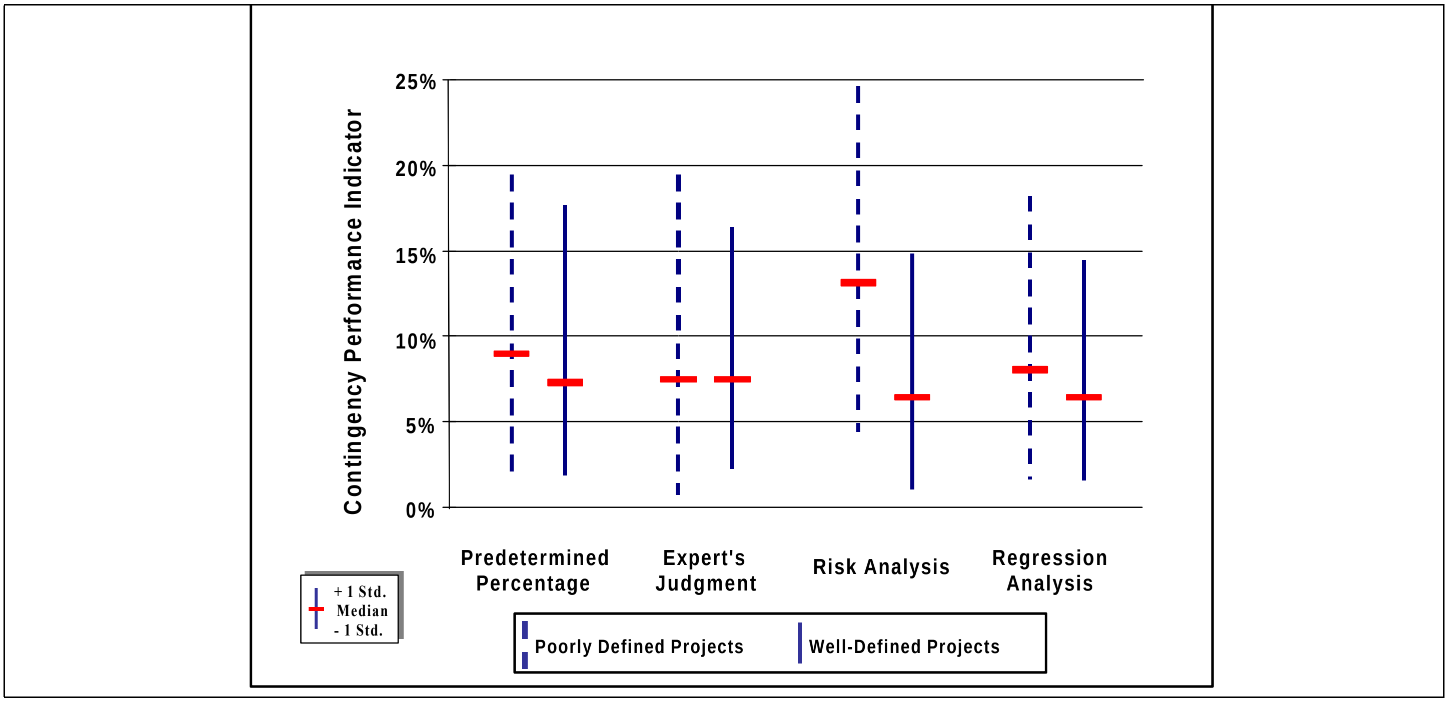

Figure 4—CPI for Well-Defined Projects vs. Poorly Defined Projects

same, as shown in Figure 3. No statistically significant difference exists between the three techniques. This is true for both new technology and off-the-shelf projects and is independent of project size and complexity. As previously stated, Monte Carlo analysis as typically applied, does not explicitly address how risk drivers link to cost outcomes; therefore, there is no reason to believe it would yield better results than the other techniques. As a means of comparison, IPA's regression model produces a median CPI of 7 percent for the same group of projects.

The most important risk driver is the level of project definition at the time of authorization. When we examined CPI by project definition level and contingency estimation technique, the results were dramatic. Figure 4 shows CPI medians for projects, split by level of project definition. For well-defined projects that used either a predetermined percentage or an expert's judgment, the median difference between estimated contingency and actual contingency requirements is almost 7.5 percent. However, when the project team used risk analysis techniques, the median difference is reduced to less than 6.5 percent. When we looked at projects that were poorly defined, using a risk analysis technique is a disaster. The median CPI for risk analysis balloons to 13 percent when used on poorly defined projects. In addition, the variance of CPI results also increases by 50 percent, indicating that risk analysis is inconsistent and unpredictable for these projects. Projects that used either a predetermined percentage or an expert's judgment are indifferent to project definition level, with the median CPI still below 9 percent. We believe that the risk analysis results reflect the fact that teams are attempting to address both the poor quality of the base estimate, as well as other risk factors, and they are overly optimistic. When a technique does not explicitly address risk drivers, too much flexibility does not yield improved contingency setting performance.

Regression analysis yields a similar CPI regardless of the level of project definition. This is due to the fact that regression analysis uses the level of project definition as an explicit factor when estimating contingency requirements.

As we have seen, assigning contingency to capital projects is one of the greatest challenges faced by project teams and estimators. Although the various techniques that are used to assist in that decision are similar, each has strengths and weaknesses. Through our historical analysis, we have found that certain techniques are more reliable under certain project risk conditions. Using an expert's judgment as the basis for setting contingency levels invariably outperforms the use of predetermined percentages. This is true regardless of project size, definition level, or complexity. Both of these techniques are stable enough, however, that they can be used on any type of project without the worry of drastically reduced performance for a given set of risk factors. This is not necessarily true for risk analysis techniques. This research has shown that risk analysis techniques can deliver slightly better contingency accuracy for projects that have good levels of definition prior to authorization. The use of risk analysis techniques on projects that are not well defined produces considerably worse results than other methods. For these projects, using a different contingency estimating method is preferable. Because the difference in performance is so drastic, choosing what technique to use, given differing project risk factors, is an extremely important decision.

Another technique discussed was regression analysis. Regression analysis directly addresses the factors that drive project risk, and these are the factors that drive the consumption of contingency. In order to use this technique, detailed project data, including cost and project drivers, must be collected. These data, taken from actual projects with quantifiable results, form the foundation for regression analysis. Although this technique takes time to develop, the finished product is easy to use and produces consistent and accurate results. This technique, if implemented correctly, can be a viable alternative or an excellent supplement to the traditionally used methods for contingency setting.

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