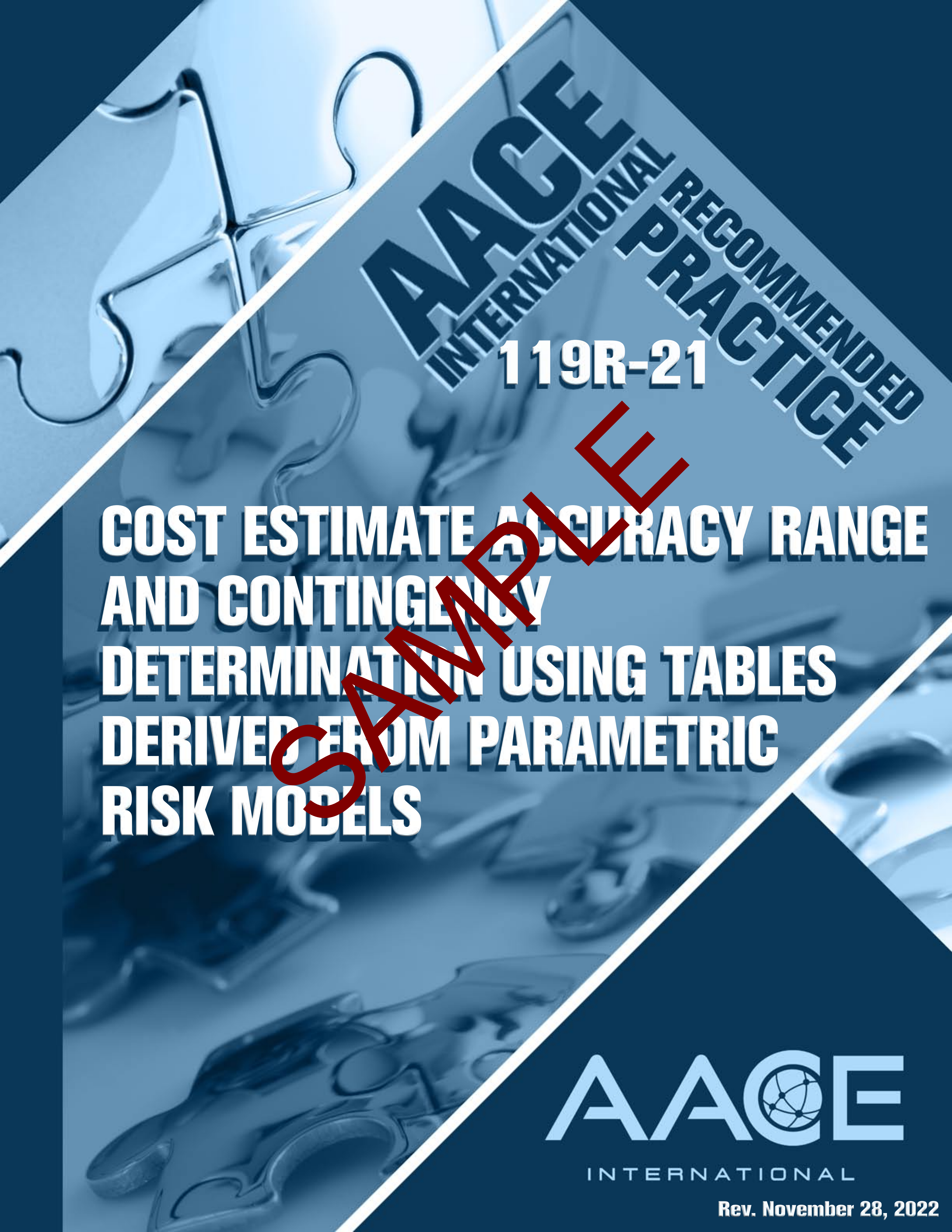

AACE INTERNATIONAL RECOMMENDED PRACTICE

119R-21

COST ESTIMATE ACCURACY RANGE AND CONTINGENCY DETERMINATION USING TABLES DERIVED FROM PARAMETRIC RISK MODELS

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TCM Framework: 7.6 – Risk Management

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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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1. INTRODUCTION

1.1 Scope

This recommended practice (RP) of AACE® International defines a tabular, risk-driven method for establishing predetermined cost estimate accuracy range and contingency values based on industry parametric risk quantification models. It uses the RAND Corporation (RAND)[1] parametric cost risk model from AACE RP 43R-08, *Risk Analysis and Contingency Determination Using Parametric Estimating – Example Models as Applied for the Process industries*, to illustrate the method and develop example tables [1]. However, the RP's tabular, risk-driven approach could be supported by other validated parametric models. In addition, the RP can be used as a base that users can adjust to align with their own empirical cost and risk experience (e.g., different estimating bias, unique risk profiles, etc.) The RP applies to the systemic risks for individual projects in any industry (not programs or portfolios) involving engineering and construction. The RP does not address schedule contingency. For more information about estimate accuracy ranges, refer to AACE RP 104R-19, *Communicating Expected Estimate Accuracy* [2].

The term predetermined means that an empirically-based, validated parametric model or equivalent empirical study has been pre-applied to generate accuracy ranges that reflect a range of known key risk drivers. A principle stated in all AACE estimate classification RPs is that the range must be determined through a quantitative risk analysis for each particular estimate. In that respect, this RP represents a minimum of analysis when more rigorous methods are not possible or reasonable such as early in the project development cycle or for lower capex projects. This RP is not to be used in place of more rigorous quantitative risk analysis methods if they are practical.

1.2 Purpose

The main objectives of this RP are to:

1. Enhance/support the range-of-range values in Table 1 of the various AACE International cost estimate classification system RPs by industry[2]. This is done by providing a set of risk-driven ranges that add insight to the otherwise ambiguous range-of-ranges.
2. Provide a quick, but risk-driven risk quantification method for project evaluation situations where more rigorous risk quantification methods are not justified or possible such as early in the project development cycle or for lower capex projects.
3. Provide a guideline for users to enhance their project system procedural documents; i.e., rather than reporting a fixed target range for each cost estimate class regardless of a project's risks, provide appropriate expectations for the level of technology and complexity of the project type.

1.3 Background

This RP covers an approach to generating contingency and range tables for systemic risks using an existing empirically-based parametric model to generate or "pre-determine" the table values. The definition of systemic risks as found in AACE RP 10S-90, *Cost Engineering Terminology* is "uncertainties (threats or opportunities) that are an artifact of an industry, company or project system, culture, strategy, complexity, technology, or similar over-arching characteristics" [3]. The RP describes this in more detail later.

AACE RP 40R-08, *Contingency Estimating-General Principles*, [4] identifies predetermined guidelines as a method for quantifying systemic risks. It states "A common approach is to establish a table of contingency values and ranges for each of AACE's estimate or schedule classes with alternate values and ranges provided for common risks such as the

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[1] See: www.rand.org
[2] Each of the estimate classification RPs has a Table 1 showing indicative range-of-ranges (this does not refer to Table 1 of this RP).

use of new technology". RP 40R-08 also states that "it cannot effectively address risks that are unique to a specific project, or risks that are common, but may have inordinate impacts on a given project". Hence, the parametric-based tabular method cannot be used alone except when systemic risks are dominant; i.e., for estimates classified as Class 5 or 10 in the AACE cost estimate classification approach [5]. In effect, the method presented in this RP can be considered an extension of RP 42R-08, *Risk Analysis and Contingency Determination Using Parametric Estimating* [6] in that it presents a mode of application only; tabular or graphical.

For Class 4 or better-defined estimates, it can be used in a hybrid approach that combines this RPs tables for systemic risks with a second method to address the project-specific risks. These hybrid methods are covered in RP 65R-11, *Integrated Cost and Schedule Risk Analysis and Contingency Determination Using Expected Value* [7] or 117R-21, *Integrated Cost and Schedule Risk Analysis and Contingency Determination Using a Hybrid Parametric and CPM Method* [8].

Another use of this RP within AACE International is to supplement the accuracy range-of-ranges for each estimate classification in the various AACE classification RPs as summarized in *Professional Guidance Document PGD-01, Guide to Cost Estimate Classification Systems* [5]. These wide ranges are intended to communicate that estimate accuracy is driven by a project's uncertainties and risks, and those uncertainties and risks can vary from widely from project to project. However, the ambiguity of a wide range-of-ranges is not conducive to clear communication in respect to any particular project scope. To avoid ambiguity, many, if not most, industry project process procedures (e.g., for phase-gate systems) express fixed range targets for each estimate classification.

An example project system guideline may state: "For Class 5, final actual costs should be within an 80 percent confidence interval range of +50/-30% around the project cost including contingency set at p50[3]." While clear, the specificity of a +50/-30% range for all projects is inappropriate. Unfortunately, a fixed +/- accuracy range pre-determines expected contingency. As was shown in a study that indicated that the standard deviation of typical cost growth distributions, for a base estimate of typical bias, is approximately equal to the contingency set at p50.[9] For example, the +50/-30 range around the amount including contingency would be associated with a contingency of approximately 25% (see the tables later in this RP. Further, research indicates that project risk analyses performed by teams have tended to replicate whatever fixed target range has been established by the organization [10]. Based on this, it is hoped that this RP will encourage improved risk-driven accuracy range guidelines. If a target range is going to influence risk analysis outcomes, it should be evidence-based and reflect actual uncertainty. Such guidelines can also provide reasonable range and contingency values for situations where a more rigorous quantitative risk analyses is not possible or reasonable. It should also be noted that the ranges suggested by this RP when technology and/or complexity are high may exceed the classification range-of-ranges; that is because the classification ranges are stated as being typical, not extremes (which indicates the need for a method such as this).

A caution in using this RP's contingency values is that, as stated above, they reflect a base estimate of typical bias. The RAND research was developed from large projects for which the capital objective is typically cost effectiveness. Large project base estimates tend to be biased lean (i.e., the base represents approximately a p10 to p20 level of confidence of underrunning the base). Small project systems tend to be focused more on predictability which results in less lean base estimating to the point that the final actual costs of many small projects will be less than the base estimate. Estimators using this RP need to be cognizant of their base estimating bias, and/or unusual risk profiles and adjust the RP range and p50 values accordingly.

The challenge then is to find evidence-based data to develop a risk-driven accuracy range and contingency guideline. Fortunately, there are industry parametric risk models available that can be used for this purpose. AACE RP 43R-08, *Risk Analysis and Contingency Determination Using Parametric Estimating –Example Models as Applied for the Process Industries*, provides a working Excel version of perhaps the best-known industry parametric risk model; i.e.,

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[3] While p50 as a basis for range determination is used in AACE estimate classification RPs, many suggest that the mean value is more appropriate because it is risk-weighted (i.e., better reflects skewed distributions.)

the RAND model [11]. The RAND model or variants thereof have been in continuous use since the 1980s for project risk analysis and contingency determination as well as for company project system benchmarking. It is a parametric risk model developed using multi-variable linear regression analysis of process industry project data. Its development is consistent with the practices covered by RP 42R-08, *Risk Analysis and Contingency Determination Using Parametric Estimating* [6]. The RAND model shows how cost growth (i.e., contingency usage) is driven by systemic risk drivers including the level of scope definition and the level of technology and complexity (as well as other drivers). Because the model inputs include ratings of technology and complexity, one study has shown that it is generically applicable to engineering and construction and similar projects in any industry [12].

Using the RAND model, it is a fairly simple matter to develop tables of accuracy range and contingency values that correspond to various risk drivers; i.e., the parameters of the model. The most significant risk driver is the level of scope definition; i.e., the AACE estimate classifications as covered in PGD-01 are used as its measure. The level of technology and complexity are the other main risk drivers; these attributes distinguish one asset type or industry from another. The recommended practice that follows better describes the RAND model, the risk drivers, the method of generating guideline tables, and recommended usages of those tables.

This RP is intended to provide guidelines (i.e., not a standard) to be used in establishing pre-determined reference accuracy range and contingency values in tabular or graphical format. The range values in this RP represent the outputs of the RAND model as provided in RP 43R-08. It is important that users of this RP be familiar with AACE PGD-01, RP 42R-08, and RP 104R-19. Users should assure that any tabular values used are consistent with their own projects and project system.

2. RECOMMENDED PRACTICE

2.1 Parametric Risk Analysis Models and Ranges

The use of this RP requires an understanding of parametric risk analysis models and their application as covered in RP 42R-08. That content is not repeated here. This RP assumes that the practitioner has a reliable, good quality parametric model available. This RP is focused on accuracy ranges and the method of deriving such a range from a parametric model. Note that some of the derivation discussion is of a somewhat abstract nature and experts will be prone to argue the details; practitioners should be asked to keep in mind the RP's ultimate purpose of simplification and to decide if the results are practical and reasonable.

Based on multi-variable regression analysis, a parametric model will generate the mean result value (i.e., as in regression to the mean). However, best practice for risk analysis and contingency estimating is to produce a distribution of possible outcomes so that management can decide how much risk they are willing to accept and therefore, how much contingency (and reserve if applicable) will be required. Industry research provides a relatively simple method to produce a distribution knowing only the mean value, if that value is roughly normally distributed. That method hinges on two research findings. The first is that cost overrun and schedule slip data expressed as the ratio of estimate/actual is approximately normally distributed [11] [13]. Because regression works best with normally distributed data, estimate/actual is the metric studied in the reference research and recommended by this RP for model development[4]. The second finding is that the overall project contingency as normally reported in industry (i.e., at p50 or mean confidence level) roughly equals the standard deviation of cost variation from a base estimate of typical bias (e.g., the base representing roughly a p15 confidence level) [9]. The following is an example, using the RAND model outcomes, of how a distribution can be derived; however, the method applies to any parametric model which includes the significant risk-drivers discussed in this RP.

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[4] Note that lognormal distribution is generally a good fit for cost growth as measured by the actual/estimate ratio; i.e., actual/estimate is normally distributed in log-space. However, the estimate/actual transformation to achieve normality is simpler to work with.

The RAND study of 104 estimates had a mean and standard deviation of the normalized[5] estimate/actual ratio of 0.78 and 0.19 respectively[6], with the metric being approximately normally distributed [11][7]. The NORMINV function in Microsoft Excel® can be used to recreate the full distribution (syntax is NORMINV (probability, mean, standard deviation) as shown on the left of Table 1. The "p" is the confidence level: i.e., the percent confidence that the value will be less than this value. Inverting the ratio to actual/estimate restores skewness and presents outcomes in the way needed for contingency determination. That inverse is shown on the right columns of Table 1.

The contingency to add to the base estimate is the fractional value after the 1; for example, 1.20 means 20% contingency. Note that for the estimate/actual ratio, the median (p50) and mean are equal, but for in the skewed actual/estimate values on the right, the mean will be greater than the p50. In this case, the mean value of the skewed actual/estimate distribution is approximately 37% (which happens to be about the p60 value). This is approximately the standard deviation of this distribution.

p	**Estimate/Actual** NORMINV (probability,0.78,0.19)	p	**Actual/Estimate** (Inverse of data to the left)
10%	0.54	90%	1.8[illegible]
20%	0.62	80%	1.61
30%	0.68	70%	1.47
40%	0.73	60%	1.37
50%	0.78	50%	1.28
60%	0.83	40%	1.20
70%	0.88	30%	1.14
80%	0.94	20%	1.06
90%	1.02	10%	0.98

Table 1 - Use of Estimate/Actual Dataset Mean and Standard Deviation to Develop a Distribution

2.2 Using the RAND Parametric Risk Model to Develop Range Tables

As an example of a parametric model, the working Excel version of the RAND model in RP 43R-08 was used to develop the values in this RP. That model includes an algorithm that takes various systemic risk ratings and calculates a single cost contingency output that is assumed to be approximately equivalent to the p50 value which is the confidence level reflected in AACE classification recommended practices[8]. The approach used in Table 1 of the AACE estimate classification RPs and in this RP is to report the range at an 80% confidence interval (i.e., the p10 and p90 range) around the total cost including contingency set at the p50 confidence level.

This RP repetitively applies the RAND model, each time using different parameter inputs, to generate matrices or tables of outputs for predicted cost growth from the base cost estimate for p10, p50 and p90 confidence levels. The "contingency as standard deviation" approach with an estimate/actual cost growth measure form is used to derive the p10 and p90 values. The range of parameters, and calculation of the cost growth values are described in the next sections.

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[5] Prior to calculating ratios, the impact of escalation and currency risks, major scope changes and critical risk events are removed from the actual costs. This is done using standard normalization practices. For specific details see [11].

[6] The inputs and results in this RP are reported to only two significant figures to best reflect the uncertain nature of the statistics.

[7] Note that the RAND study used the estimate/actual ratio in its regression model to approximate normality. Inverting estimate/actual model outcome to actual/estimate for reporting restores the skewness (e.g., lognormal) one would expect.

[8] Again, using the mean for contingency determination would be more conservative. The p50 value is most appropriate for a small project portfolio where highs and lows will balance. For large projects, it is not uncommon to fund a management reserve at a higher confidence level such as p70 to p90 given typical lower risk (overrun) tolerance for large investments.