AACE INTERNATIONAL RECOMMENDED PRACTICE

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COST RISK ANALYSIS AND CONTINGENCY DETERMINATION USING ESTIMATE RANGING FOR INHERENT RISKS WITH MONTE CARLO SIMULATION

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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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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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1. INTRODUCTION

1.1. Scope

This recommended practice (RP) of AACE International (AACE) defines general practices and considerations for inherent cost risk analysis and estimating contingency using a cost estimate ranging analysis with the Monte Carlo simulation (MCS) method. The method is only recommended for quantifying inherent cost uncertainty when the project scope is well-defined (i.e., Class 3 or better) and when the project has no new technology[1] and minimal complexity[2]. In all cases, the method is not to be used alone when there are significant project-specific risks (e.g., contingent risks or events). The method is applicable to two situations:

- As the sole method for cost contingency determination (e.g., a small project for an owner or a contractor bid estimate for a simple project when the owner retains responsibility for most scope and event risks).
- As part of a hybrid approach that uses this RP for inherent cost uncertainty and the expected value method (e.g., with RP 44R-08, *Risk Analysis and Contingency Determination Using Expected Value* [1]) to quantify project-specific cost risks (i.e., contingent risks or risk events). RP 113R-22, *Integrated Cost and Schedule Risk Analysis and Contingency Determination Using Estimate Ranging with Expected Value and Monte Carlo Simulation* [2] describes this hybrid approach.

A key principle for recommended quantitative risk analysis (QRA)[3] methods per RP 40R-08, *Contingency Estimating – General Principles* is that they be risk-driven; i.e., clearly link the risk to the impacts [3]. Estimate ranging using subjective team inputs from those involved in the project design, planning, and estimating can be expected to reliably capture the inherent cost uncertainties [4].

Estimate ranging does not meet the risk-driven principle when systemic and project-specific risks are significant. In particular, it is not recommended when the project scope is not well-defined (i.e., Class 10, 5, or 4), or the project has technology uncertainty, or any significant level of physical and/or execution complexity. Additionally, when there are significant project-specific risks (the main source of schedule delays as well), estimate ranging cannot be said to clearly link these defined risks to their impacts. In both situations, as discussed in RP 41R-08, *Understanding Estimate Ranging*, estimate ranging tends to underestimate contingency, often by significant amounts [5]. Alternative methods for these situations of greater uncertainty and risks are described in Professional Guidance Document PGD-02, *Guide to Quantitative Risk Analysis* [6].

RP 41R-08 broadly describes the class of QRA methods called estimate ranging. In general, estimate ranging methods with MCS replace fixed values in a cost estimate with 3-point or uniform distributions, establish correlations between the distributions, and running MCS to obtain an overall cost outcome distribution. There are many variations possible within this general description. For example, the fixed values replaced could be for individual estimate item costs or for various estimate subtotals. The values replaced could also be at the estimate element level such as quantities, productivity, item pricing, and so on, rather than for estimate item totals. This RP describes typical estimate breakdown variations with specific consideration of the need to address MCS correlation which becomes more challenging as more distributions are assigned. In addition to the topic of correlation, the RP also discusses MCS considerations for distribution assignment and determination of 3-point values; however, this RP is not a detailed treatment of MCS.

[1] Level of technology: the use of new technology (may be truly novel, but also just new to the company, or a new integration of existing technologies) [22].
[2] Level of complexity: the physical complexity of the asset, but also its execution strategy (reflects size, number of major scope elements, number of parties involved and so on, but also the challenges of their physical and management interactions) [22].
[3] The acronym for qualitative risk analysis is identified as QLRA, while the acronym for quantitative risk analysis is identified as QRA.

This RP briefly describes methods and considerations for facilitating and conducting QRA workshops and/or interviews to obtain QRA inputs, particularly with respect to overcoming team bias (see RP 62R-11, *Risk Assessment: Identification and Qualitative Analysis* with respect to risk identification) [7]. It also discusses the uses of the QRA output for contingency determination or as an input to a hybrid QRA application with the expected value method for cost. Finally, it discusses capturing risk analysis information for historical databases.

1.2. Purpose

This RP is intended to provide guidelines, not a standard, for contingency estimating that most practitioners would consider to be good practices that can be relied on and that they would recommend for use where applicable. There is a range of useful risk analysis and contingency estimating methodologies; this RP, combined with other QRA RPs outlined in PGD-02, will help guide practitioners in developing or selecting appropriate methods for their situation.

AACE recommends that whenever the term risk is used, the term's meaning be clearly defined for the purpose of the practice. The estimate ranging method described herein quantifies the impact of inherent risk. The RP 10S-90, *Cost Engineering Terminology* definition of inherent risk is "A risk that exists (but may or may not be identified) due to the very nature of the asset, project, task, element, or situation being considered" [8]. A similar 10S-90 term that could be said to apply is background risks which is defined as "A set of non-event risks specific to the risk quantification method which cause variability for which probability of occurrence is 100%. When using a particular method, the limited specific uncertainty must be communicated." A third definition in 10S-90 for background variability may be most applicable. That definition states that background variability is uncertainty that is "distinct from the variation caused by identifiable risks, that is caused by at least three commonly-found factors in projects; (a) inherent variability of the work not caused by identified risks, (b) estimating error and error of prediction, and (c) bias in estimating or prediction." The one commonality is that these all exclude risks with probability of occurrence of less than 100% (i.e., risk events). Further, it excludes escalation risk.

To clarify the risks covered, the concept of systemic risks needs to be addressed. RP 10S-90 defines systemic risk as "uncertainties (threats or opportunities) that are an artifact of an industry, company or project system, culture, strategy, complexity, technology, or similar over-arching characteristics." This encompasses inherent risks, but is broader. It is used most often in respect to the empirically-based parametric QRA method defined in RP 42R-09, *Risk Analysis and Contingency Determination Using Parametric Estimating* [9]. The historical data analysis used for parametric modeling captures the impacts of a wide spectrum of uncertainties that extend to the overall project system's interaction with external systems, uncertainty causes such as the level of complexity and technology, but also the nominal impacts of minor, non-critical risk events which often fall off of the risk management radar. The Venn diagram in Figure 1 illustrates the concepts of inherent risks (within dashed circle) as covered by this RP versus systemic risk and project-specific risks (mostly events with probability < 100%) that are not covered by this RP.

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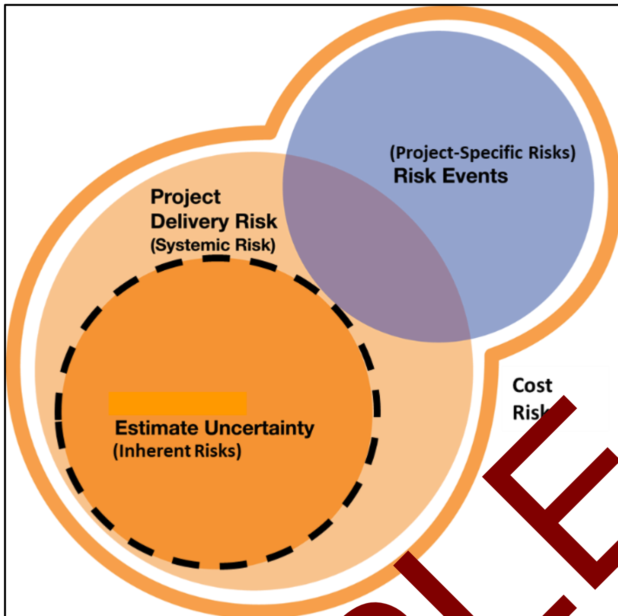

Figure 1 – Inherent Risk Versus Systemic Risks and Risk Events

1.3. Background

The first documented estimate ranging method in the AACE literature was *range estimating* introduced in the 1960s along with the introduction of MCS on mainframe computers (see RP 41R-08 for more history) [5]. Range estimating attempted to quantify the impact of all uncertainties and risks at a very high level; this approach is no longer recommended because it is not risk-driven. In the 1980s, MCS spreadsheet add-ons were introduced for personal computer applications. This put estimate ranging practice and model development within the reach of the average cost estimator. A variety of estimate ranging approaches can be found in the AACE literature from that time period. The method was often called the Monte Carlo method because there were few competing uses of MCS at the time (this name is not recommended because MCS is now a key aspect of other common QRA methods).

Estimate ranging with MCS lost its novelty as more advanced QRA methods such as integrated cost and schedule CPM-based analysis and empirically-based parametric modeling came to dominate QRA papers and articles through the 1990s and into the 2000s. While no longer a common topic of papers, estimate ranging with MCS in some form is still the most common QRA method given how accessible it is to the average cost estimator, particularly for small projects.

Common usage does not mean estimate ranging has been effective on all projects. In fact, a 2004 research study by a benchmarking firm found that estimate ranging (without identifying the variant) was a disaster in respect to project funding decisions when significant systemic risks were present [4]. In the same time frame, research was pointing out that optimism bias was not being properly addressed in major project cost forecasts (while that research did not address the QRA method, estimate ranging is known to be prevalent) [10]. Every empirical study reviewed shows estimate ranging has failed to realistically model actual cost growth for projects for which the level of scope definition is less than Class 3 and/or have any significant complexity [11]. The primary reasons for the method's underestimation bias are that estimate ranging is not risk-driven in respect to systemic and event risks and it does not employ empiricism. Therefore, this RP is limited to estimate ranging where these risks are not prevalent and where a team's personal or group experience can be expected to stand in for having an empirical basis (e.g., small,

