AACE INTERNATIONAL RECOMMENDED PRACTICE

# 117R-21

# INTEGRATED COST AND SCHEDULE RISK ANALYSIS AND CONTINGENCY DETERMINATION USING COMBINED PARAMETRIC MODELLING AND MONTE CARLO SIMULATION OF A CPM MODEL



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TCM Framework: 7.6 – Risk Management



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**Contributors:**

*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.*

Colin H. Cropley (Primary Contributor)
James E. Arrow, DRMP
Francisco Cruz Moreno, PE
John K. Hollmann, PE CCP CEP DRMP FAACE Hon. Life
Dr. David T. Hulett, FAACE

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August 15, 2022

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## 1. INTRODUCTION

### 1.1. Scope

This recommended practice (RP) of AACE International defines the general practices and considerations for combining parametric and CPM-based methods for risk analysis and contingency assessment in construction-based projects. These integrated cost and schedule risk analysis (ICSRA) methods can be combined provided steps are taken to avoid double-counting sources of risk.

The RP defines the combination of the two methodologies to avoid double-counting of risk, not the source methodologies themselves. For those, refer to AACE RP 42R-08 [1] and to AACE RP 57R-09 [2].

### 1.2. Purpose

This document is not intended to be a standard. This document is intended to provide a guideline for combining parametric and CPM-based ICSRA methods that most practitioners would consider to be good practices that can be relied on and that they would recommend be considered for use where applicable.

### 1.3. Background – Source of ICSRA Methodologies

The starting point is a comparison of the methodologies that have been brought together in this RP. Reference is made to RP 40R-08, *Contingency Estimating – General Principles* [3]

#### *1.3.1. Parametric + Expected Value (P+EV)*

RP 113R-20, *Integrated Cost and Schedule Risk Analysis and Contingency Determination using Combined Parametric and Expected Value* [4] describes this hybrid ICSRA methodology. It combines the quantification of systemic risk, usually the major source of risk in a project, assessed by parametric modelling, with the other source of risk, the critical project-specific risks normally found in the project risk register. Both are combined by use of Monte Carlo simulation (MCS) using the technique known as expected value. Once the parametric model is developed [1, 4], implementing this hybrid methodology is relatively straightforward. It meets one of the key general principles for contingency estimating in that it explicitly references past project performance [3].

On the other hand, P+EV only quantifies overall cost and schedule contingencies. It does not quantify subproject cost contingencies nor schedule contingencies of intermediate milestones. Furthermore, the methodology is unable to optimize risk, it simply assesses it. In addition, the success of the methodology depends on two equally important requirements:

- The parametric model represents the various major drivers of uncertainty realistically so that assessments of, for example, scope definition or strengths and weaknesses of the project team produce valid changes to cost and schedule uncertainty.
- The assessments of the various major drivers of uncertainty are as objective as possible, with minimal introduction of biases by the participants in the assessments.

The vulnerability of the P+EV methodology to failure to fully achieve each of these requirements can be considered disadvantages.

*1.3.2. CPM-Based ICSRA Assessment of Cost and Schedule Contingencies*

This class of contingency assessment methodologies includes the CPM-based ICSRA risk drivers method described in RP 57R-09, *Integrated Cost and Schedule Risk Analysis Using Risk Drivers and Monte Carlo Simulation of a CPM Model* [2] and its near-variant the risk factors method (in which the identified risk drivers are not necessarily based on root-cause analysis and may require correlation between related factors).

These methods include analysis of risk events which may be identified during risk workshops or confidential one-on-one risk interviews and are compiled in the project risk register.

The methodology involves comprehensive MCS analysis of the full project scope enabling reporting on all cost and schedule aspects. It also enables optimizing schedule risk (and thus time-dependent cost) through identifying and ranking the highest schedule drivers and subsequently documenting changes to the schedule to progressively reduce schedule risk.

Disadvantages include the time and effort required for this full analysis and the fact that the methodology does not explicitly include past project performance. More definitively, the absence of reference to past project performance means that the methodology relies almost completely on subjective assessments of probabilities and impact distributions. This allows for reference to productivity data for some schedule and cost impact distributions and to data on the frequency of occurrence of some contingent risk events. In these project model cases, most input distributions and probabilities are likely to be subjective. This typically results in output probability impact distributions that underestimate the pessimistic "tail" of the distribution, usually substantially. The output probability impact distributions are also likely to underestimate the optimistic end, compared with real project outcomes data.



*1.3.3. Similarities and Differences Between P+EV ICSRA and CPM-Based ICSRA*

Both methodologies start with 100% probability impact uncertainty and add in <100% probability discrete risks or risk events. Both methodologies refer to the project risk register.

Parametric modelling assesses a particular kind of uncertainty, driven by the system in which the project is being delivered. The discrete risks incorporated in the P+EV methodology are also of a particular kind, identified as project-specific and relating to project execution, which usually comprise a subset of the risks in the risk register.

To take this comparison to a more useful point, it is helpful to step back and compare the different ways in which risk is classified using the two methodologies.

**1.4. Background – Alternative Classifications of Risk**

CPM-based ICSRA divides project cost and schedule impact risk according to:

- Whether the risk is always present (100% probability), also described as *inherent risk*, or
- Whether the risk may or may not be present (<100% probability), also described as *contingent risk* (because the effect of the risk is contingent on the risk's occurring).

P+EV ICSRA divides risk according to the way in which it is assessed:

- Risk originating from the project delivery system – so-called *systemic risk* (as described in section 1.3 of [4]) and
- Project-specific risk events assessed as large enough to be designated *critical*, where this term is defined in

 

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RP 65R-11 [5] for AACE Estimate Classes 3, 4 & 5 as causing cost variances > 0.5% of project capital expenditure (capex) or >5% of project profit (a more difficult metric to apply in contingency assessments). For detailed Estimate Classes 1 & 2, the capex threshold is > 0.2%.

The P+EV methodology uses these critical risk cutoffs on the basis that any project to be included in a parametric modelling database would be normalized for inclusion by removing such project-specific risks which would otherwise distort the data. Thus, such risks must be added back in when assessing overall project risk.

These alternative classifications of risk overlap with each other. Understanding how this overlap occurs is key to combining the two methodologies. A Venn diagram for this purpose is shown in Figure 1.

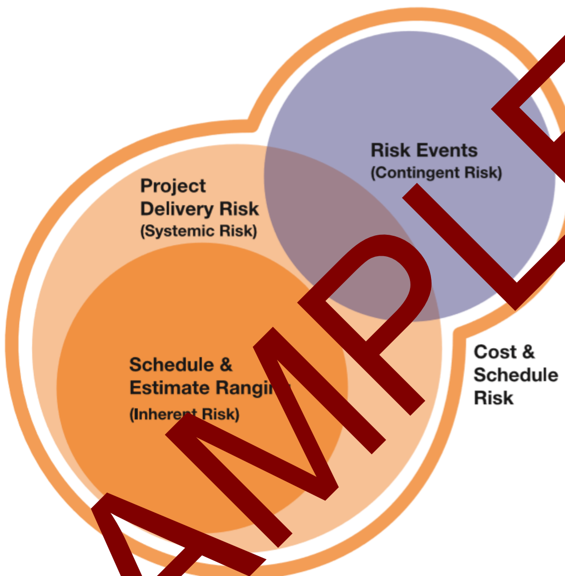




**Figure 1 – Venn Diagram Comparing Risk Classifications**

The two classes of risk used in CPM-based ICSRA are shown as the darker discs:

- Inherent Risk - duration and cost uncertainty
- Contingent Risk – risk events

The types of risk expressed in P+EV ICSRA, based on the way they are quantified are shown in Figure 1 as follows:

- Systemic Risk – as expressed in project delivery risk (measured by parametric modelling) usually encompasses all inherent risk covered by cost estimate and schedule duration uncertainties, plus some of the risk events in the risk register (namely general or systemic risks and less-than-critical project-specific risks).
- Critical-scale project-specific risk events are represented by the risk events not overlapped by the project delivery risk disc in the Venn diagram. Under the P+EV methodology, these critical risk events represent the risk responses developed by the risk team attending the expected value workshop as part of the P+EV process.

This RP describes how the net systemic risk not overlapping the inherent risk is quantified and how the risk events not covered by systemic risk are identified and added into the parametric + CPM-based ICSRA model.

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## 2. RECOMMENDED PRACTICE

### 2.1. Combine Parametric and CPM-Based ICSRA Methodologies

The combination of parametric and CPM-based ICSRA methodologies described by this RP, for convenient reference is abbreviated to P+IRA. A flowchart is provided in Figure 2 to visualize the complete sequence of events. Note that escalation and currency risks are not covered in this RP. These could be substantial risks in the large and complex projects for which this methodology is recommended (see RP 58R-10, *Escalation Estimating Principle and Methods Using Indices* [10]; or RP 68R-11, *Escalation Estimating using Indices and Monte Carlo Simulation* [11]).

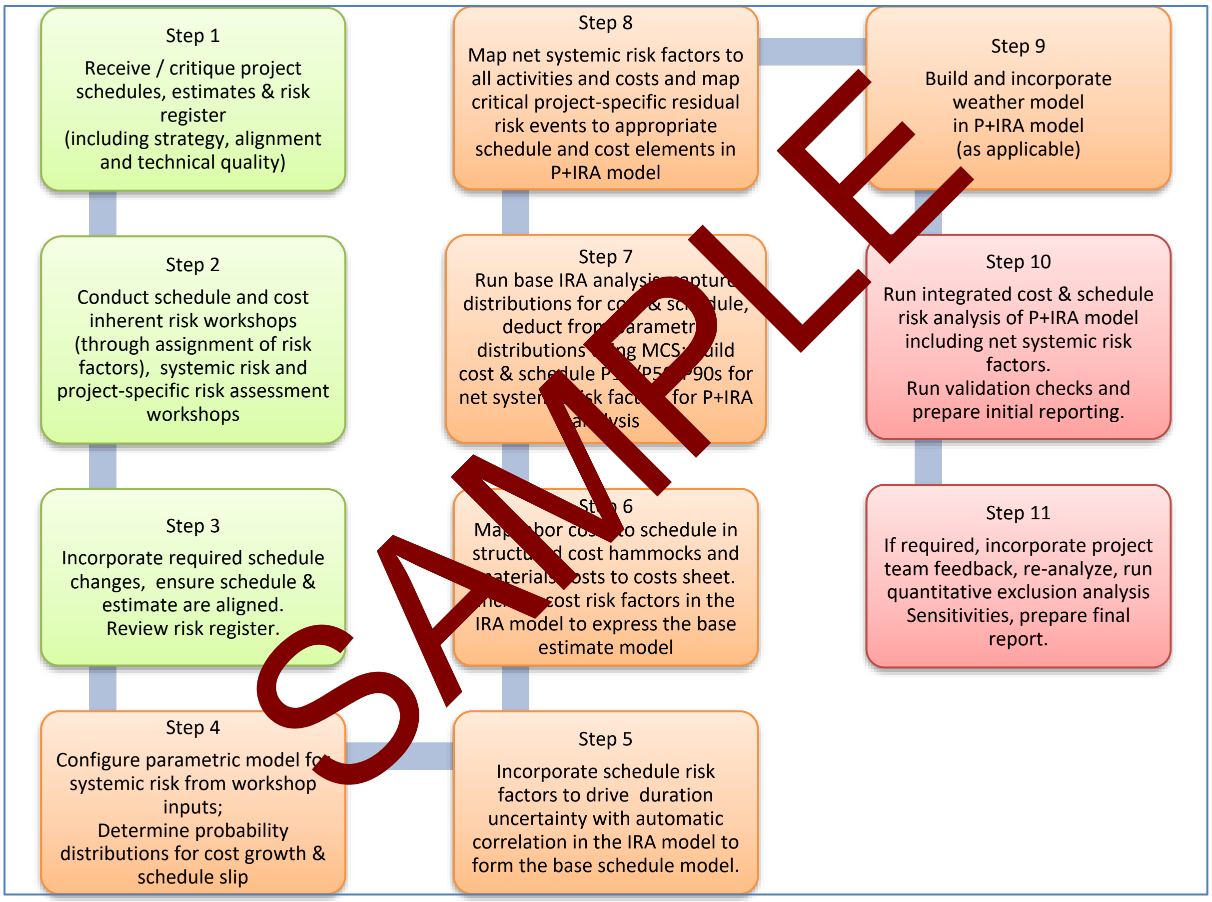



**Figure 2 – Methodology Flowchart for Parametric + CPM-Based ICSRA (P+IRA) using Risk Factors**

Much of the content of Figure 2 is covered in other RPs [1] [2]. Most of the focus of this RP is on Step 7. This is described in more detail in the logic diagram shown in Figure 3. The methodology was first published in a paper presented to the 2019 AACE Conference and Expo [6].

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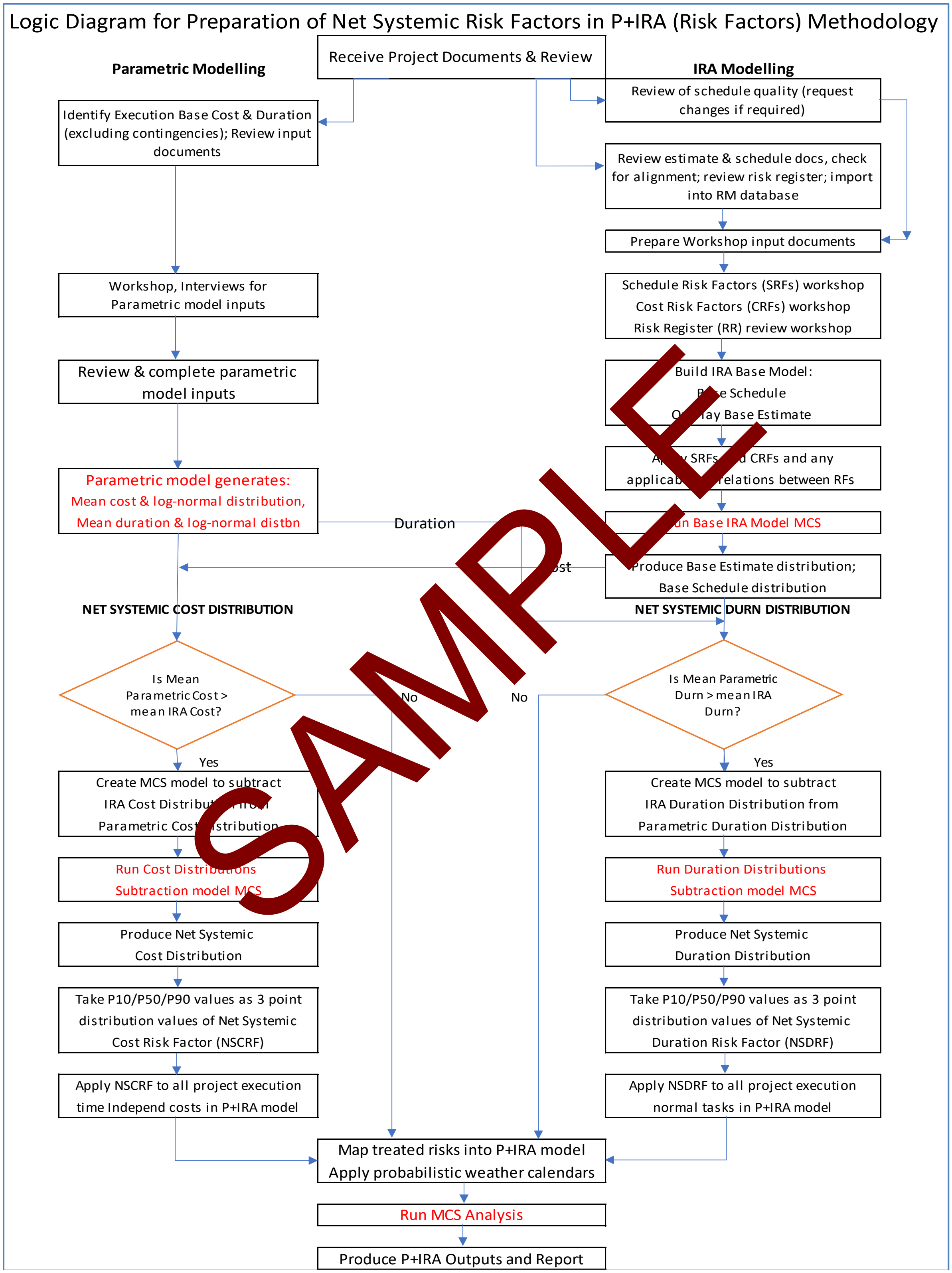



**Figure 3 – Logic Flow Diagram for Preparation and Use of Net Systemic Risk Factors**

The upper part of the logic diagram shows the parallel development of the parametric and CPM-based cost and schedule models. The lower part describes the calculations for the net systemic distributions and risk factors for cost and schedule. It allows for the possibility that one or both of the cost and schedule parametric model mean values may not exceed the corresponding CPM-based model mean values. Because the CPM-based models are mainly or exclusively built on subjectively assessed distributions, it is possible for them to produce larger mean values than the parametric model if the workshop assessment teams or interview subject matter experts are more pessimistic than the parametric model. Practical experience has shown that this can happen. It can be argued that even if the mean parametric cost or schedule duration does not exceed the corresponding CPM-based mean value, the net systemic risk factors should still be determined and applied because the distribution spread effects will still be important. As noted in section 1.3.2, it would be unusual for the CPM-based distribution to be broader than the parametric distribution, especially at the pessimistic end.

#### *2.1.1. Point at Which Methodologies are Combined*

Workshop sessions have been held for systemic risk and for reviewing the risk register to identify the critical project-specific risk events (including assessment of responses to the occurrence of the risks) which are to be included in the analysis. All required information to complete the parametric model has been obtained and the systemic cost growth and schedule slip distributions have been generated by the parametric model.

Under the CPM-based IRA methodology, workshop sessions have also been held to identify and scale the risk factors driving the project schedule activity durations and the project cost line items. During these risk factor workshop sessions, further potentially critical project-specific risk events may be identified to add to the risk register.

The base estimate has been overlaid on the base schedule and the 100% probability duration and cost risk factors identified in the workshop sessions applied to enable the base schedule distribution and base estimate distribution to be produced.

### 2.2. Assess Net Systemic Cost & Schedule Risk Factors using Monte Carlo Simulation (MCS)

To illustrate the methodology and provide essential details for understanding and using the methodology, an example project using the risk factors method is described.

Please refer to the Appendix for a detailed set of instructions on quantifying the net systemic cost risk factor and the net systemic duration risk factor for a project and mapping those risk factors into the project P+IRA model.

### 2.3. Map Critical Project-Specific Risk Events to Appropriate Schedule and Cost Elements

As per Step 8 of the flowchart in Figure 2, the project-specific critical risk events are then mapped into the P+IRA model to the activities to which they apply (for duration impacts) or to the time-independent cost elements (for cost impacts) of treated risks or risk responses agreed to be applied in the event of the risk occurring.

Note that due to the inclusion of net systemic risk impacts, in accordance with the Venn diagram in Figure 1, any systemic (general) risk events in the risk register are already covered by the net systemic risk factors. The net systemic risk factors also cover sub-critical scale project-specific risk events.