Abstract—From 2007 to 2013, the AACE® International Decision and Risk Management (DRM) Subcommittee produced several recommended practices (RPs) for risk analysis and contingency determination methods that aligned with principles documented in RP 40R-08. These included RP 42R-08 for the parametric estimating method for systemic risks and RP 65R-11 for the expected value method for project-specific risks. This paper describes how these two methods can be applied together in a way that is both realistic (i.e., yields empirically valid outcomes) and practical (i.e., can be applied on any project at any phase regardless of the project size or quality of base estimates and schedules.) The methods integrate cost and schedule risk analysis (i.e., outcomes can be presented with a joint confidence level chart) without reliance on critical path method (CPM) schedule models. Finally, the methods can be implemented using spreadsheets with a Monte Carlo simulation add-in (in fact, RP 43R-08 provides working parametric model spreadsheets.) The paper centers on a table summarizing how the methods best address the risk quantification principles in RP 40R-08.
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Introduction/Background

In support of an initiative by the AACE® International (AACE®) Decision and Risk Management (DRM) technical subcommittee to compare alternative integrated cost/schedule contingency estimating methods at the AACE® 2017 annual meeting, this paper presents the case for a hybrid parametric/expected-value approach (the hybrid) espoused by the author and covered by several AACE® Recommended Practices (RPs). It compares this approach against the agreed comparison initiative benchmark which is AACE® RP 40R-08 (Contingency Estimating; General Principles) [1].

Background

The DRM comparison initiative was proposed in part because a book published in 2016 titled “Project Risk Quantification” (PRQ) [2] challenged the use of several common methods; namely Line Item Ranging (LIR) and Critical Path Method (CPM) based approaches on the grounds that the former does not model cost growth realistically and the latter is impractical for most projects and only realistic if combined with the parametric method in a hybrid. This paper should be read alongside the peer papers of the methods comparison initiative.

Much of the information in this paper is an update and amalgam of past papers by the author. A 2007 paper initially challenge the LIR method and offered alternative approaches that research indicated were more realistic [3]. The 2007 paper referenced empirically-based industry research that found that “…contingency estimates are, on average, getting further from the actual contingency required.” The researchers called the LIR method “a disaster” for projects that were not well defined [4]. In summary, the LIR method centers on substituting probability distribution functions (PDFs) for cost estimate line item or summary values and applying Monte Carlo Simulation (MCS) to the resultant model. The method’s major shortcoming is that it does not explicitly link risk drivers (e.g., the level of scope definition) with outcomes.

In 2007 a DRM effort was initiated to develop a suite of risk management RPs and a DRM Professional certification program (DRMP). Given industry research findings, there is no RP for the LIR method. By 2010 the DRM/DRMP efforts had progressed and this author published a paper reviewing the integrated cost and schedule contingency estimation methods that were in RP development at that time; namely the cost loaded CPM-based approach and the hybrid parametric/expected-value approach [5]. The 2010 paper also assessed these methods against the first principles of contingency estimating in RP 40R-08. This 2017 paper updates the 2010 paper with information regarding Joint Confidence Level (JCL) determinations, but excludes the CPM-based method discussion (covered by others as part of the 2017 comparison initiative).

The paper assumes that readers have an intermediate level of knowledge of project risk quantification (PRQ) processes, Monte-Carlo Simulation (MCS), probabilistic methods, and basic expected value and parametric estimating concepts. It also expects readers who are...
considering the implementation of new methods to have reviewed the referenced AACE® RPs – these are only briefly summarized here.

**Parametric/Expected-Value with MCS Hybrid Method**

The integrated, hybrid cost and schedule risk quantification methods covered by this paper includes parametric modeling of systemic risks (parametric) and expected value with MCS modeling of project-specific risks (EV w/MCS). Two methods are combined because no single method is optimal for quantifying the different risk types (i.e., systemic and project-specific). This hybrid approach was first published in 2010 [5] and was further elaborated upon in the PRQ book in 2016 [2]. Figure 1, from the PRQ book, summarizes the author’s overall integrated approach to PRQ with the parametric and EV w/MCS methods shown as the first steps in the PRQ process.

![Figure 1 – Integrated Project Risk Quantification Flow Chart](image)

Figure 1 – Integrated Project Risk Quantification Flow Chart [2] (with permission)
As discussed in the 2010 paper, to understand the need for a hybrid method, the user must first understand the differences between the systemic and project-specific risk types. These terms are defined in RP 10S-90 [6]. Systemic risks are those that have systematically predictable relationships to overall project cost and schedule growth outcomes. The term systemic implies that the risk is an artifact of the project system, culture, business strategy, process system complexity, technology, and so on. Systemic risks are dominant for poorly defined projects, and their nature, behavior and impacts are not reasonably quantifiable using traditional brainstorming workshop input. Systemic risk impacts can only be modeled based on empirical research of past projects; i.e., multiple linear regression analysis of historical data on risks and their cost and schedule outcomes. Project-specific risks are those that do not have predictable, systematic relationships with outcomes; i.e., they are specific to the project. These are commonly risk events or conditions. Project-specific risk assessment is amenable to traditional brainstorming workshops and can be realistically modeled using time-honored EV methods (i.e., probability times impact with MCS). Empirical research indicates that no single contingency estimating or modeling method is optimal for both of these risk types. Therefore, this author believes a hybrid approach is not only realistic, but necessary for valid risk quantification. An impediment to wider industry usage has been that systemic risks themselves are not widely recognized or understood by industry and even many risk experts.

The parametric method for systemic risks is covered in RP 42R-08 [7]. The EV w/MCS method for project-specific risks is covered in RP 65R-11 [8]. These RPs are summarized as follows:

**Parametric (RP 42R-08):** This method starts with collecting historical data on project system attributes, quantified measures of systemic risks (e.g., level of project scope definition, complexity, etc.), and cost growth and schedule slip outcomes for projects. Using multiple linear regression analysis, parametric model equations are developed that show the relationship of cost growth or schedule slip (outcomes) and the systemic risks (parameters). The model results in a mean predicted value; however, methods are described to translate the mean to a full distribution. Unfortunately, few companies have in-house data and/or skills for modeling. However, this is not a major problem because systemic risks and their behavior are fairly industry-generic and there is over 50 years of research and model development in the public domain that anyone can apply and build upon. Working Excel® parametric models are even included as attachments to RP 43R-08 [9]. The PRQ book provides a further working model example [2].

**EV w/MCS (RP 65R-11):** This method starts where qualitative risk assessment leaves off; i.e., with the risk matrix ratings from the risk register. Expected value (EV) is simply the product of the percent probability of the risk occurring (an event, condition or uncertainty) multiplied by estimates of the risk’s cost and schedule (duration) impact. The sum of each risk’s EV is the project’s EV; this sum is the mean outcome for project-specific risks. No MCS is required to obtain this mean outcome; however, by quantifying the impacts as PDFs based on team input, MCS can be applied to obtain probabilistic results. Cost and schedule are inherently integrated because the cost and schedule impact estimates are based on a planned risk response. The method directly links the risks and their impacts.
The two RPs described above do not cover how to apply the two methods in a hybrid combination. However, the combined approach was summarized in some detail in the 2010 paper as follows [5]:

1. Assess and rate or quantify the systemic risks and enter them in an empirically-based parametric cost and schedule contingency estimating model (re: RP 42R-08).
   a. If the estimate and schedule are AACE® Class 5, the analysis is complete, determine the cost and schedule contingency based on management’s risk tolerance and the parametric model’s probabilistic output.
   b. If the estimate and schedule are AACE® Class 4 or better (project-specific risks are knowable), continue to the EV w/MCS method in step 2.
2. Screen the risk register and develop a list of critical project-specific risks; the definition of critical risks is included in RP 65R-11 (they are usually highlighted as red in a risk matrix). Note that escalation risks are not covered in this paper.
3. Assess and input the percent probability of occurrence for each critical risk. This can be treated as a distribution depending on the team’s confidence in their assessment (i.e., one can treat the probability as an uncertainty).
4. Determine and document the assumed risk response (or range of responses) to be taken if the risk occurs (e.g., let things ride, take some defined corrective action, etc.).
5. Assess and input ranges for the cost and schedule impacts of each risk (typically 3-point estimates) for the risk response(s) anticipated.
   a. For schedule, the duration impact entered is to the completion milestone (analyst’s knowledge of what is on the critical and near critical paths and the network’s general behavior is needed).
   b. For cost, the impact is a combination of time-dependent (i.e., burn rate) costs for schedule delays and direct costs for the risk response assumed, if any.
6. Set up a calculation of the EV of the cost and schedule impact of each risk (probability times impact).
7. To integrate the parametric and EV w/MCS model results (hybridization), include the parametric model output distributions (re: step 1) as the first critical risk in the EV w/MCS tool (i.e., systemic risks in aggregate become risk #1 in the EV model).
   a. The systemic risk is given a probability of occurring of 100 percent (it is a fact or attribute of the project system; i.e., the overall system uncertainty).
   b. The parametric model cost and schedule outcomes are defined as custom PDFs and a correlation coefficient (e.g., 0.5) between them is estimated.
8. Run the MCS and determine the overall cost and schedule contingency (and reserves if appropriate) based on management’s risk tolerance.
   a. Because the parametric model output is an input to the EV w/MCS model, the hybrid integrates all contingency risks in a single cost and schedule output.
   b. Because project specific risk impacts are based on assumed risk responses, their cost and schedule results are also integrated.
Joint Confidence Level (JCL) Determination

In 2009, the National Aeronautics and Space Administration (NASA) instituted a policy that certain project budgets were to be based on a “joint cost and schedule probabilistic analysis” with budgets to reflect a “70 percent probability that the project will be completed at or lower than the estimated amount AND at or before the projected schedule.” [10] NASA calls this the “Joint Confidence Level” or JCL [11]. In NASA practice, the JCL is based on the cost-loaded CPM-based risk analysis method. Unfortunately, some in industry have mistakenly come to equate the cost-loaded CPM approach with JCL. In fact, CPM modeling is not required for JCL; the hybrid parametric and EV w/MCS method also supports JCL determinations.

Figure 3 is an example cost and schedule MCS output scatterplot (in this case using Palisade @Risk software) from the hybrid method. The scatterplot includes separate 50 percent confidence level lines (p50) for cost and for duration (the vertical and horizontal lines near the center.) In the lower left corner of the Figure, it shows that 38.5 percent of the MCS outcomes were in that quadrant that is less than the p50 cost AND less than the p50 schedule levels. In other words, the separate 50 percent cost and schedule levels equate to a JCL of 38.5 percent. If NASA used this method, to meet their p70 JCL policy criterion, they would shift the separate cost and schedule target lines to higher confidence levels until the lower left quadrant contained 70 percent of the MCS outcomes.
Comparison of the Hybrid Method to RP 40R-08 Principles

RP 40R-08 provides an objective basis or yardstick (i.e., principles) against which one can assess the suitability of any contingency estimating method. The DRM committee developed RP 40R-08 specifically to guide determinations as to which PRQ practices should be recommended. For example, the LIR method does not meet the important “clearly link risk drivers and cost/schedule outcomes” principle. The following are the RP’s general principles that any methodology developed or selected for quantifying risk impact should address:

- Meet client objectives, expectations and requirements
- Part of and facilitates an effective decision or risk management process (e.g., TCM)
- Fit-for-use
- Starts with identifying the risk drivers with input from all appropriate parties
- Methods clearly link risk drivers and cost/schedule outcomes
- Avoids iatrogenic (self-inflicted) risks
- Employs empiricism
- Employs experience/competency
- Provides probabilistic estimating results in a way the supports effective decision making and risk management

Table 1, the main product of this paper, summarizes how the hybrid method performs in respect to the AACE® RP 40R-08 principles.
First Principles | Hybrid Parametric and EV w/MCS Method Characteristics
--- | ---
Meets client objectives and requirements | Realistic and practical for estimates and schedules of ANY quality, at ANY project phase, and of ANY size. It is highly customizable and is calibrated to the client’s project system. 50+ years of industry empirical research adds credibility.
Part of a risk and decision management process | Explicitly aligns with industry phase-gate scope development and decision making processes. Emphasizes the often ignored risk that the project system process itself is uncertain. The EV method is an elaboration of the risk matrix (no discontinuity between qualitative and quantitative assessment).
Fit-for-use | Can be used on any estimate or schedule and can be applied by in-house staff using software that is usually already available in-house (i.e., spreadsheets with MCS add-on). Can be customized.
Starts with identifying risk drivers | Risk categorization (e.g., systemic and project-specific) is an attribute of the method and it considers risk response as well.
Links risk drivers and cost/schedule outcomes | Driver-to-outcome linkages are explicit for all risk types. The EV method focuses on risk response planning to generate more realistic outcomes. Supports JCL.
Avoids iatrogenic (self-inflicted) risks | The flexibility of not requiring CPM comes at the price of not driving strong planning discipline. However, explicit quantification of bias (a systemic risk) sets the method apart.
Employs empiricism | Parametric modeling is explicitly based on historical experience (multiple linear regression analysis) and is readily calibrated.
Employs experience/competency | As with all methods, requires strong facilitation. Expertise is required to develop and maintain parametric model. In lieu of a CPM basis, requires strong planner/scheduler input.
Provides probabilistic estimating results | All integrated methods covered by AACE® RPs produce probabilistic outcomes. Supports JCL evaluations.

**Table 1 – Hybrid Method versus RP 40R-08 General Principles**

Table 2 provides a strength/weakness evaluation of the hybrid method.

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Explicit risk-impact linkage</td>
<td>• No commercial software/few users</td>
</tr>
<tr>
<td>• Empirical basis (realistic)</td>
<td>• Without CPM basis requires more skilled/intuitive assessment</td>
</tr>
<tr>
<td>• Universal applicability (any quality of input, any Class, any project size or type (practical)</td>
<td>• Cost/schedule integration for time dependent costs less explicit than CPM</td>
</tr>
<tr>
<td>• Repeatable</td>
<td>• Does not encourage use of quality planning and schedule methods</td>
</tr>
<tr>
<td>• Addresses bias directly</td>
<td></td>
</tr>
<tr>
<td>• Addresses risk response scenarios</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2 – Hybrid Method Strengths and Weaknesses**
Parametric/Cost-Loaded CPM Hybrid Method

It was stated in the introduction that it is this author’s opinion that the CPM-based method is impractical for most projects and is only realistic if combined with the parametric approach in its own hybrid. Being impractical day-to-day does not mean it should not be considered for projects where appropriate CPM expertise and discipline can be brought to bear. However, it would still necessary to explicitly consider systemic risks in order to produce realistic outcomes. Because no other paper in the 2017 DRM comparison initiative is expected to cover a hybrid parametric/CPM approach, the following short summary is provided (the method is covered in detail in the PRQ book [2].)

The hybrid approach starts with the cost-loaded, risk-driven, CPM method addressed in AACE® RP 57R-09 [12]. The following modifications are made to that RP’s approach:

1. Eliminate all subjective “uncertainty risks” (these risks are what the parametric model will quantify).
2. Add a Systemic Risk activity to the schedule that starts with the as-is completion milestone and finishes with a new total completion milestone.
3. Assign a duration and non-time dependent cost to the systemic contingency activity equal to the mean of the systemic risk parametric model outputs.
4. Convert the parametric model’s distributions of absolute duration and cost impact values to factors relative to the mean, and apply those factors as custom impact multiplier distributions to the new Systemic Risk activity (note: negative values can be replaced with zero on the low end to preclude negative durations). These have 100% probability of occurring.

Figure 4 illustrates the RP 57R-09 example schedule model with the new Systemic Risk activity included in it. When the MCS is run on this CPM model, the parametrically-based systemic risk uncertainty will now be incorporated in the overall cost and schedule outcomes.

<table>
<thead>
<tr>
<th>ID</th>
<th>Description</th>
<th>Remaining Duration</th>
<th>Start</th>
<th>Finish</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>0050</td>
<td>Commissioning</td>
<td>100</td>
<td>20-Jan-13</td>
<td>29-Apr-13</td>
<td>$16,500</td>
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<tr>
<td>0060</td>
<td>Project Turnover</td>
<td>0</td>
<td></td>
<td>29-Apr-13</td>
<td>$0</td>
</tr>
<tr>
<td>0070</td>
<td>Systemic Risk</td>
<td>30</td>
<td>29-Apr-13</td>
<td>29-May-13</td>
<td>$3,000</td>
</tr>
<tr>
<td>0080</td>
<td>Final Completion</td>
<td>0</td>
<td>29-May-13</td>
<td></td>
<td>$0</td>
</tr>
</tbody>
</table>

Figure 4 – RP 57R-09 Example Schedule with Systemic Risk Added [2] (with permission)
Conclusions

It is hoped that this paper provides the reader with a general understanding of why the author recommends that companies implement and apply a hybrid parametric and EV w/MCS approach as standard base practice. The method effectively addresses all of the key RP 40R-08 principles. In particular, the parametric method is the only one that “employs empiricism” explicitly and can be demonstrated to be realistic. The hybrid is also the most practical approach (“fit-for-use” and “meets objectives”) because it can be used on any project, of any size, at any phase, regardless of the quality or bias of base plans (particularly CPM schedules which are notorious for having poor quality, if one is available at all). Further, it can be applied by in-house staff using standard software that most companies already have (i.e., spreadsheets with an MCS add-on). Beyond that, functional parametric models are provided by AACE® in RP 43R-08 and in the author’s book. A challenge with considering alternate methods such as these is assuring stakeholders of their reliability and credibility; the hybrid method is well covered by references for that purpose.

For large, turnaround, and other projects that can muster high quality planning and scheduling, cost-loaded CPM approaches can also be considered, but only when combined in a hybrid approach using a parametric method to quantify systemic risks.

References


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