RISK.01

Alternate Methods for Integrated Cost & Schedule Contingency Estimating

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ABSTRACT—Schedule contingency estimating is not widely used in project planning. Even less commonly used are methods that integrate cost and schedule contingency estimating. Only one integrated method is well covered in the literature; i.e., range simulation applied to a cost-loaded CPM schedule. However, this method, as typically practiced, is poorly aligned with some of AACE International's established principles for good contingency estimating practice. This paper presents the most commonly used Critical Path Method (CPM) model-based methods, as well as an alternate hybrid parametric model/expected-value method that does not rely on the CPM model and is designed to better align with principles of good contingency estimating practice while being practical to use on all projects. Pros and cons of the alt paper also explains why cost and schedule risk analysis must be do e contingency estimating method used.

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Introduction/Background

Having consulted on capital project benchmarking and practice improvement for many years, I have had the opportunity to observe the cost and schedule risk analysis and contingency estimating practices used, and results obtained, by many global owner companies in the process related industries. On the positive side, recognition of the need for better risk management processes and methods is growing. However, the following are some cost/schedule risk analysis problems or gaps observed:

- Few are doing *schedule* risk analysis or contingency estimating (further, many firms lack any significant in-house planning and scheduling competency).
- Cost and schedule risk analysis and contingency estimating are *rarely integrated.*
- There is *little awareness of AACE Recommended Practices* or the landmark industry research behind them.
- Project cost and schedule predictability seem to be *getting worse* (while the stakes are becoming greater all the time).

Some of these gaps result from basic lacking in capital management leadership and/or cost engineering competency (particularly scheduling) in the owner companies. However, some of the gaps result from the industry as a whole having few effective, broadly applicable and practical tools for integrated cost/schedule contingency estimating to chose from. As AACE International develops its Decision and Risk Management Professional (DRMP) specialty certification, these and other gaps in the literature and technology have become apparent to AACE International. The AACE International Technical committees are working to close these gaps by defining recommended practices. In that light, I hope that this paper will serve as a potential catalyst for a new AACE International Recommended Practice (RP).

The paper reviews the most common integrated cost/schedule contingency estimating method (CPM-based activity ranging with cost loading), presents an alternative new practice (parametric/expected-value hybrid), and compares them. These two methods are then compared against AACE International's first principles yardstick for evaluating contingency estimating practices [1].

Assumptions Regarding This Paper's Scope

This paper is intended for those considering which integrated cost/schedule contingency estimating method to use on their projects. The paper further assumes that these readers already have an intermediate level of knowledge of risk management processes, Monte-Carlo modeling, parametric estimating, and estimating contingency based on probabilistic estimating outputs (i.e., the types of things covered by AACE International Recommended Practices).

The scope of the methods described in the paper assumes that contingency estimating will be applied in a risk management process. For example, such a process is described in AACE International's **Total Cost Management (TCM) Framework** *Section 7.6* [2]. In the TCM process, *contingency estimating* is a distinct step. Readers should note that the TCM process is the only industry risk management process model that highlights contingency estimating. Most, as exemplified in the ISO risk management process [3], do not effectively integrate risk quantification with project control planning. The TCM process, like all risk management processes, starts with identifying risks and assessing and screening them for the purpose of treating them (e.g., mitigate, transfer, etc). This paper does not focus on these initial steps; it is focused on estimating contingency (i.e., time and costs allowances for uncertainty in project plans) for the "residual" risks that remain after risk treatment. It also does not focus on the risk workshop/analysis aspect of the contingency estimating process; workshop performance tends to be similar for all the methods described here.

In summary, the paper is focused solely on the contingency quantification step.

CPM-Based Activity Ranging With Cost Loading Method

The purpose of the "Cost Loaded Critical Path Method (CPM)" class of methods is to leverage the ability of modern scheduling tools to support resource-loading and Monte-Carlo modeling. The CPM-based class of methods (which are the most commonly used although still not widely) is better described in other papers and an AACE RP in draft at time of writing. [4,5,6]. However, in summary (and at the risk of over simplification), the "Cost Loaded CPM" methods have the following steps:

1. Develop the "base" (contingency-free) project estimate and schedule. Optimally, these are integrated using a common work breakdown structure (WBS). The schedule must be a high quality CPM schedule model.
2. Resource load the schedule with all cost information. The costs include the entire project budget, generally at a summary level (note that this is not resource-leveling; that cost/schedule integration step should have been already done if it is a "quality" schedule). Resources that are time-dependent (e.g., labor or equipment with a daily rate) are distinguished from those that are not (e.g., materials).
3. Assess and enter the risk information in the schedule model (the schedule tool must support Monte-Carlo modeling). There are several alternate methods for doing this:
    a. Activity Ranging: Replace the cost-loaded activity duration with a probability distribution (typically triangular or 3-point; low, most-likely, high) based on project team assessment of the range (risks are not *explicitly* identified or linked to impacts in the model). Impacts on non-time dependent costs are considered through traditional cost ranging.
    b. Risk Driver: Starting with a list of residual risks (plus a general "background" risk), link the risk to activity-by-activity time multipliers (factors) and also cost factors for non-time dependent costs. Then, assess and input the probability of occurrence (e.g., 50%) of each risk, and assess and input ranges on the activity and cost multiplier factors (again, typically triangular or 3-point; e.g., 0.8, 1.0, 1.2).
4. Run the Monte-Carlo model and determine the cost and schedule contingency based on management's tolerance for risk and the model's probabilistic output.

There are a number of potential variations from the typical approach described above. These options include (but are not limited to):

- Risk Driver (option 3b above): The use of this method is increasing since commercial tools to support it were introduced circa 2005.

- Conditional Branching: What if a risk event happens which would cause the team to change the schedule logic? To address this common situation, conditional branching (conditioned by occurrence of the risk), could be incorporated in the schedule model. However, the author has never seen or read of this being done in regular practice (i.e., “static logic”, unaffected by risk events, is almost always assumed).
- Parametric Modeling: the typical method requires the team to directly input impact distributions (e.g., 3-point). However, these distributions could be based on parametric models that tie project attributes with cost and schedule impacts. This is particularly relevant for the concept of “background” or systemic risks. Again, the author has never seen or read of this being integrated with the Cost-Loaded CPM method.

Anyone wanting to implement any of the method variations described above should refer to the paper references for “how-to” information. Hopefully, the brief summary above will be sufficient to support the alternate method comparison that is a purpose of this paper.

Parametric/Expected-Value Hybrid Method

This class of methods integrates separate contingency estimating practices that have been documented in the literature elsewhere [7]. The purpose of a hybrid method is to leverage the strengths of each component method, including parametric estimating [8] and expected value [9]. It does not directly use the CPM schedule; this is both a strength and a weakness as will be discussed later. This paper is the first published description of the hybrid approach.

To understand the driver and need for this method, the user must understand the concept of risk breakdown and the difference between “systemic” and “project-specific” risk types. 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 impact is not readily quantifiable by traditional risk analysis. Project-Specific risks are those that do not have predictable, systematic relationships with outcomes; i.e., they are specific to the project [8]. These risks are amenable to traditional risk analysis. There is no single contingency estimating method that works well with both of these risk types.

The hybrid parametric/expected value method has the following steps:

1. Develop the “base” (contingency-free) project estimate and schedule. The estimate and schedule can be of any level of detail and quality (the plan detail and quality attributes are in fact systemic risks specifically addressed by the method). A CPM schedule model is not required.
2. Assess and rate/quantify the systemic risks and enter them in an empirically-based parametric cost and schedule contingency estimating model.
    a. If the estimate and schedule are AACE International Class 5 [10], the analysis is complete--determine the cost and schedule contingency based on management’s tolerance for risk and the parametric model’s probabilistic output. No Monte-Carlo is required.
    b. If the estimate and schedule are AACE International Class 4 or better, continue to the project-specific method in the next step

3. Develop a list of significant residual project-specific risks (i.e., excluding systemic risks as addressed in your parametric model).
4. Assess and input the probability of occurrence (e.g., 50 percent) of each risk
   a. This can be treated as a distribution depending on the team's confidence in their assessment (i.e., treat the probability as uncertain).
5. Determine and document the assumed risk response (or range of responses) most likely to be taken if the risk occurs (e.g., let things ride, take some defined corrective action, etc.).
6. Assess and input ranges on the cost and on the schedule impacts (typically triangular or 3-point) for the risk response(s) anticipated.
   a. For schedule, identify the activity or group of activities impacted. The criticality of these activities, and the extent that they are parallel with activities impacted by other risks must be approximately rated (analyst's knowledge is relied on if there is no CPM schedule).
7. Calculate the "expected value" of the cost and schedule impact of each risk (probability times impact). If the result is unacceptable (e.g., client will not allow any schedule slip), return to step 6 and consider revised risk responses (e.g., take corrective actions to avoid any schedule impact, but with increased cost impact).
8. To integrate the systemic and project-specific model results, enter the cost and schedule probabilistic outputs of the Parametric model as the first risk in the expected value tool. The parametric tool will have provided cost and schedule distributions that can be used as pre-defined or custom distributions (with probability of 100 percent) in the expected value tool.
9. Run the Monte-Carlo model and determine the overall cost and schedule contingency based on management's tolerance for risk and the model's probabilistic output.
   a. Because the parametric model output is an input to the expected value model, the model integrates all contingency risks in a single cost and schedule output.
   b. Use the assumed risk responses for risk management during execution (i.e., when a risk occurs during execution, you will have already noted your expected response).

Method Comparison

Based on Principles of Practice

AACE International RP 40R-08 (*"Contingency Estimating: General Principles")* [1] provides an objective basis or yardstick (i.e., principles) against which you can assess the suitability of any contingency estimating method that you are considering. The principles apply to methods for estimating any kind of risk funds or allowances including contingency, reserves, or schedule allowances. The RP also provides a categorization framework or taxonomy for describing various methods (the methods themselves are covered by other AACE International RPs). The following are the 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. And,
- Provides probabilistic estimating results in a way the supports effective decision making and risk management.

Methods that do not broadly respect the general principles above are not to be recommended for use. Table 1 summarizes how the methods covered in this paper perform in consideration of the AACE contingency estimating principles.

	Integrated Cost/Schedule Contingency Estimating Methods		
First Principles	**Cost Loaded CPM-Activity Ranging**	**Cost Loaded CPM-Risk Driver**	**Hybrid Parametric/ Expected-Value**
Meets client objectives and requirements	Whether a given method best meets objectives, expectations or requirements must be determined prior to each application.		
	If an objective is to be applicable for all estimates and schedules, CPM methods are generally not applicable		Can be used on any estimate or schedule
Part of a risk and decision management process	Process does not address risk response (e.g., does not address changing logic in response to risk; i.e. no risk to plan logic)		Considers ways that risk could impact plan logic
Fit-for-use	Requires a quality, fully cost-loaded CPM schedule. Not applicable to Class 5.		Can be used on any estimate or schedule
Starts with identifying risk drivers	Systemic and dynamic (logic impact) risks are not identified		Risk categorization is part of method, and can deal with alternate logic
Links risk drivers and cost/schedule outcomes	*No* explicit linkage	Linkages are explicit except for systemic (background) risks	Linkages are explicit for all risk types
Avoids iatrogenic (self-inflicted) risks	No clarity that it addresses *any* given risk (understates risks when scope definition is poor)	No clarity that it addresses systemic risks (understate risks when scope definition is poor)	Schedule assessment is more subjective and may encourage sloppiness. Requires strong facilitation.
Employs empiricism	Generally requires the use of lessons learned, and/or validation or benchmarking using historical information (not explicit)		Explicitly addressed in parametric model
Employs experience /competency	All methods require facilitator expertise		Additional expertise required to develop parametric model
Provides probabilistic estimating results	All produce probabilistic outcomes		

Table 1—Integrated C/S Contingency Methods vs. General Principles

Based on Strengths/Weaknesses

A comparison of the methods on a strengths versus weaknesses basis is shown in table 2.

Method	Strengths	Weaknesses
Cost Loaded CPM with Activity Ranging	• Explicit cost/schedule integration for time dependent costs • Encourages use of quality planning and schedule methods • Commercial software/many users	• No explicit risk-impact linkage • No empirical basis • Requires quality CPM, cost-loaded schedule & competent scheduler • Not applicable to Class 5 • Static logic/risk response assumed • Weak for systemic risks
Cost Loaded CPM with Risk Driver	• Explicit risk-impact linkage (but not for systemic risks) • Explicit cost/schedule integration for time dependent costs • Encourages use of quality planning and schedule methods • Commercial software/some users	• No empirical basis • Requires quality CPM, cost-loaded schedule/competent scheduler • Not applicable to Class 5 • Static logic assumed • Weak for systemic risks
Hybrid Parametric/ Expected-Value	• Explicit risk-impact linkage • Empirical basis • Applicable to schedules of any quality • Applicable to all Class of plans • Address logic/risk response scenarios	• No commercial software/few users • Non-CPM schedule requires more intuitive assessment • Cost/schedule integration for time dependent costs not explicit • Does not encourage use of quality planning and schedule methods

Table 2—Integrated C/S Contingency Methods Strengths vs. Weaknesses

Comparison Summary

As a consultant, I recommend that companies implement and apply the “Hybrid” approach for their standard practice. It is most broadly consistent with first-principles (risk-impact linkage, empiricism, fit-for-use, etc.) and it is applicable on every project without exception (it is also inexpensive). For large, turnaround, and other projects where significant team resources can be brought to bear for upfront planning and scheduling, I recommend that teams apply the cost-loaded CPM with risk drivers method (and test with hybrid); however, instead of an intuitive allowance for “background” risk, I would apply an explicit parametric analysis of “systemic” risk to derive the background distribution (i.e., make it a hybrid method).

Because the cost-loaded CPM with risk drivers method requires a high level of quality in planning and CPM scheduling, it is simply not practical for day-to-day use at most companies. Unfortunately, the quality of project schedules is very poor at the time that contingency is estimated. A research study by IPA, Inc. of 494 project schedules from major global companies at the time of project authorization showed that only 13 percent had CPM schedules with resource loading [11]. While a complex schedule model is strength for project control, it is very difficult to use it for analyzing the risk of dynamic logic/alternate risk responses. It also does not apply to Class 5 planning. Finally, it only addresses systemic risk to the extent that it is made a hybrid with parametric methods. Therefore, I do not recommend cost-loaded CPM with risk drivers as a basis for standard practice.

The usage of Cost-Loaded CPM with activity ranging (not risk driven) is difficult to defend in any respect. Along with impracticality, it violates a vital first principle of risk management which is to start with identifying the risk and using that risk knowledge. A paper by the author in 2007 reviews why cost or schedule "ranging" that is not linked to risk drivers is a dangerous practice [7]. I cannot think of any reason to recommend this approach (which is unfortunately the most common integrated cost/schedule method in use today).

Why Cost and Schedule Risk Analysis Must Be Performed Together

Cost/schedule <u>integration</u> in contingency estimating is important because:

- most risks impact schedule (e.g., delays).
- many costs are time dependent (e.g., idle labor during a delay). And,
- risk response, and therefore impact, depends on the project's cost and schedule objective (e.g., need to assess cost/schedule trade-offs of alternate risk responses).

Few would argue the point that most risk drivers affect both cost and schedule, and because of that, cost and schedule risk analysis should be integrated. However, in my consulting I find very few projects that assess cost and schedule risk at the same contingency estimating workshop, at the same time, by the same team. There are many reasons for this behavior including tool differences, staff and consultant specialization differences, different estimate and schedule progress, limited time for meetings, etc. However, the result of separate sessions is always poor quality contingency estimates and risk management in general.

The reason that cost and schedule risk must be evaluated together is that cost and schedule risk are not independent, cost and schedule impacts depend on the assumed risk response, and there is a cost/schedule trade-off in determining which response will best meet management objectives (hopefully, management told the team whether the objective is cost or schedule driven—most often they have not). For example, if the risk event being evaluated is a major rainstorm with flooding, the risk response could be to a) slow down work and let the site dry out which means a long delay but with minimal costs (stretched out indirects), or b) initiate a massive, costly pumping and dry out recovery effort with little schedule impact (remember, this is a "residual" risk because we presumably decided earlier not to mitigate through design). We can see that the team is going to have to analyze the cost/schedule tradeoffs of these and other potential responses; this simply cannot be done effectively in separate sessions.

Further, defining the cost and schedule impact for any particular risk requires an iterative process because the team and management must come to consensus on whether cost or schedule is most important in each risk instance. The typical iterative sequence of integrated cost/schedule risk analysis is:

1. Assume a risk response.
2. Estimate cost impact based on the assumed risk response.
3. Estimate time impact based on the assumed risk response.
4. Determine if Management finds the cost and time impacts to be acceptable (most often one or the other is not).
5. Re-assess the response and cost/schedule impacts (repeat from step 1). And,
6. Record response assumed in planning for use in later risk management during execution.

In short, it is nearly impossible to address alternate risk responses and cost/schedule tradeoff when cost and schedule risks are analyzed in separate sessions, particularly with separate teams. It should also be obvious that for effective risk analysis that considers alternate risk responses, both project and business management representation must be in the room.

Conclusions

It is hoped that the reader has a clear understanding of why I recommend that companies implement and apply a hybrid Parametric/Expected-Value approach as their standard practice. For large, turnaround, and other projects that can muster high quality planning and scheduling, Cost-Loaded CPM with Risk Drivers should be considered, but only when combined in a hybrid approach using a parametric method for systemic or background risks. Further, cost and schedule risks must be evaluated considering alternate risk responses and cost/schedule tradeoffs and that should take place in one integrated risk analysis workshop supporting the contingency estimating process. This is a robust approach as most likely to contribute to overall project system success.

My apologies to those that found the method descriptions to be overly simplified; I encourage everyone to study the References for more specific “how-to” information.

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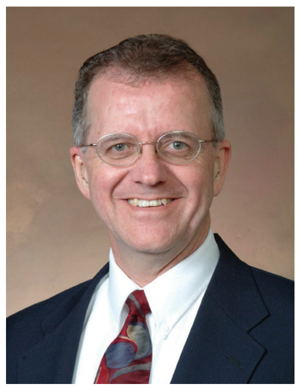

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