RISK.01

Recommended Practices for Risk Analysis and Cost Contingency Estimating

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ABSTRACT—In 2008/09, AACE International's *Decision and Risk Management (DRM) Committee* published an exciting new series of Recommended Practices (RP) for analyzing risks and estimating cost contingency. The first RP establishes basic principles that any practice should consider. This is followed by RPs on three contingency estimating methods: Range Estimating, Parametric Estimating, and Expected Value. The Parametric Estimating RP is supported by Excel® working tools that apply methods published by John Hackney and the RAND Corporation. This paper starts by summarizing each of the RPs and the example tools. This is followed by a description of a hybrid method used by the author that combines Parametric and Expected Value methods in a way that leverages the advantages of both. Finally, there is a discussion of some methods that are not recommended and a challenge for industry to support more research. Note that while the paper borrows text liberally from the RPs (to avoid misrepresentation), it reflects the views of the author and not AACE or the DRM committee; users must refer to the RPs before judging, deciding or taking any action.

Keywords: Cost Contingency, estimating, risk analysis, and Total Cost Management

AACE Recommended Practices and Other Technical Products

AACE' International's Technical Board is responsible for establishing the technical foundation of the association's educational and certification products. This is done through three main products; the Total Cost Management Framework (TCM), Recommended Practices (RPs), and Professional Practice Guides (PPGs). The product contents are as follows:

TCM Framework: An Integrated Approach to Portfolio, Program and Project Management: This is AACE International's technical foundation text [1]. It shows how all the skills and knowledge of cost engineering are applied in an integrated process. It also provides an annotated outline of "what" cost engineers do, but it does not address "how-to" information.

How-Tos Are Included in AACE International's RPs.
RPs: These are AACE International's "how-to" documents. They are structured in accordance with the **TCM Framework**. They are typically developed by AACE International's Technical Committees and/or Special Interest Groups (SIGs), Sections, or other teams. They are developed in accordance with a documented procedure including extensive reviews. In some cases, AACE International may endorse existing products by others as a recommended practice. RPs cover practices that a "general" consensus of experts in the practice area consider reasonably reliable. AACE International works with organizations such as ANSI and ASTM to publish selected RPs as industry full consensus standards.

Professional Practice Guides (PPGs): These are edited compilations of the "best of" AACE International's technical papers, articles, and other references. They are often source material for RPs, but have not been subjected to the RP consensus review process.

Decision and Risk Management Recommended Practices
After publication of the **TCM Framework** in 2006, the AACE International Technical Board faced a challenge in developing RPs to cover the hundreds of process steps and practices outlined in the Framework. Each Technical Committee was charged with identifying and working on priority RPs. The Decision and Risk Management (DRM) committee (at writing, chaired by Mr. Michael Curran) believed that quantitative risk analysis and contingency estimating was a priority area not adequately covered in the literature. In fact, there was a general concern that industry was using contingency estimating practices that had been proven ineffective, if not downright dangerous.

In 2007, AACE International launched an effort to develop a Decision and Risk Management Professional (DRMP) Certification. This added more incentive to developing RPs regarding the subject. The products identified for priority action included the following:

- **TCM Framework**, *Risk Management Chapter 7.6*: Update [1].
- *RP 40R-08: Contingency Estimating: General Principles* [2].
- *RP 41R-08: Risk Analysis and Contingency Determination Using Range Estimating* [3].
- *RP 42R-08: Risk Analysis and Contingency Determination Using Parametric Estimating* [4].
- *RP 43R-08: Example Models As Applied in the Process Industries* [5]. And,
- *RP 44R-08: Risk Analysis and Contingency Determination Using Expected Value* [6].

The following describes the rationale behind the DRM committee putting a focus on these products:

TCM Chapter 7.6: There was a need to ensure that the AACE International process for risk management (in which contingency estimating is one step) was consistent with external industry standards (e.g., ISO 31000 [7])

Contingency Estimating Principles: With so many methods (and advocates thereof), it was challenging to find a way to select practices to "recommend." The most impartial approach was to first come to consensus on what the characteristics or "first principles" of a recommended practice would be. Then, candidate practices could be compared to how well they adhered to these principles.

Contingency Estimating RPs: The focus was on practices that were both tested in practice and/or research and aligned reasonably well with the first principles.

TCM Chapter 7.6 on Risk Management

The **TCM Framework** includes a series of integrated process maps. TCM chapter 7.6 covers the risk management process as shown in figure 1. It is important to note that the process includes contingency estimating as a distinct step or area of practice.

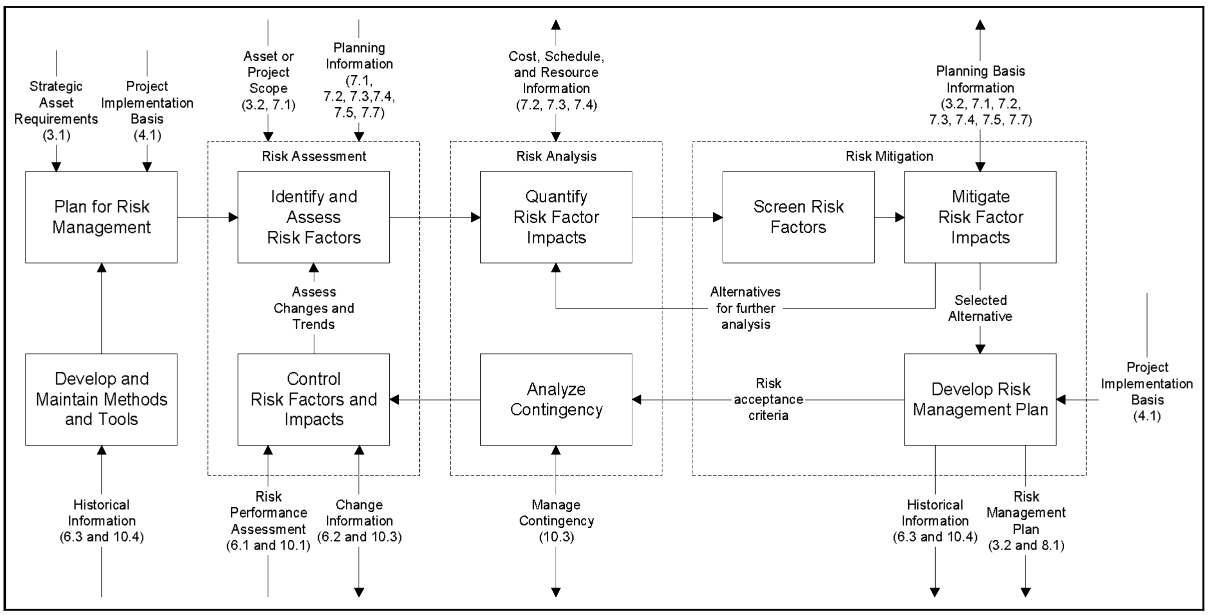

Figure 1—The Risk Management Process From TCM Framework Chapter 7.6

The DRMP task force reviewed this chapter for improvements and found the following:

- AACE International's process is generally consistent with the ISO 31000 standard. And,
- AACE International's process is the only one that highlights the place of contingency estimating.

The review found that while "quantification" of risks is a part of all industry risk management processes, most limit their scope to quantifying for ranking and screening purposes. Most risk management processes stop short of addressing the final quantification step that links risk management to project decisions, budgeting and change control (i.e., the contingency estimate). In makes sense that AACE International, being the premier association for both investment analysis and project control, had the only process that highlights this step.

RP 40R-08: Contingency Estimating: General Principles

This RP 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 using. It applies 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).

General Principles of Estimating Quantitative Risk Impact

The following are the general principles (copied directly from the RP), 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 respect the general principles above are not recommended for use. Both recommended and not recommended methods are described later in the paper.

General Categories and Characteristics of Methods in Practice

The RP describes four classes of methods used to estimate risk cost/time that can respect the basic principles. These include:

- Expert Judgment.
- Predetermined guidelines (with varying degrees of judgment and empiricism used).
- Simulation analysis (primarily expert judgment incorporated in a simulation).
    - range estimating; and,
    - expected value.
- Parametric modeling (empirically-based algorithm, usually derived through regression analysis, with varying degrees of judgment used).

Hybrid methods that combine several or all of the above classes are also common. Table 1 (copied directly from the RP) provides an overview of the primary classes of risk cost/time estimating methods and consideration for each in regards to the general principles.

Practitioners should refer to the AACE International RPs describing the principles and specific methods.

	Classes of Contingency Estimating Methods			
First Principles	**Expert Judgment**	**Predetermined Guidelines**	**Simulation Analysis**	**Parametric Modeling**
Meets client objectives, expectations and requirements	Whether a given method or combination of methods best meets the clients objectives, expectation or requirements must be determined prior each application			
Part of a risk and decision management process	Any method can potentially be incorporated in a process.			
Fit-for-use	Any method can potentially be made to address a variety of applications, but typically each method has strengths and weakness. Hybrid approaches can take advantage of the strengths of several methods.			
Starts with identifying risk drivers	Any method can potentially be made to start with identifying risk drivers.			
Links risk drivers and cost/schedule outcomes	Requires that expert(s) make and communicate the linkages	Linkages can be directly incorporated in the guidelines	Linkages are directly used in the *expected value* method	Linkage is inherent to this method
Avoids iatrogenic (self-inflicted) risks	Bias must be tempered, often through consensus	Care must be taken with risks not considered in the guidelines	Complexity of the method increases the need for disciplined approach	Care must be taken with risks not considered in the model
Employs empiricism	Generally requires the use of lessons learned, and/or validation or benchmarking using historical information (not an inherent feature of the method)			Explicitly addressed if regression based
Employs experience /competency	Expertise explicitly required	Expertise employed in development	Expertise employed in analysis	Expertise employed in development
Provides probabilistic estimating results	Can provide subjective ranges	Can provide predetermined ranges	Direct output of most simulations	Can be a direct output of algorithm

Table 1—Classes of Contingency Methods and General Principle Considerations

RP 41R-08: Risk Analysis and Contingency Determination Using Range Estimating

As quoted from this RP, it describes a methodology to determine the probability of a cost overrun (or profit underrun) for any level of cost estimate and to determine the required contingency needed in the estimate to achieve any desired level of confidence. The range estimating technique is equally applicable to both cost estimates and profitability analyses (e.g., return on investment, projected earnings, earnings per share). It is also applicable to schedule-risk applications provided that the ranges determined for the critical schedule tasks do not result in a change in the critical path.

The RP warns users that the principles in the RP must be rigorously followed in order to achieve the desired results. In that respect, it would be unwise to attempt to provide too many details of the method here. In short, range estimating combines Monte Carlo sampling, a focus on the few critical items, and heuristics to rank critical risks and opportunities. "Critical items" is a key concept in this RP. Michael Curran has demonstrated that project uncertainty is concentrated in a relatively small number of items [8]. Also, if you "range" the non-critical items, you introduce "iatrogenic" risks (i.e., self-inflicted) because the resultant output from the Monte Carlo simulation will be a too narrow (i.e., too low contingency at any level of confidence).

The basic process steps of the method described in the RP include:

- Identify the risks.
- Identify critical items.
- Determine the ranges.
- Determine the probability distribution functions (PDFs).
- Simulate using Monte Carlo. And,
- Determine contingency based on the outcome distribution.

Most of the RP content focuses on three topics: critical items, ranges, and PDFs. The RP provides cost and profitability thresholds for an item to be considered "critical". Only critical items are ranged; the remaining non-critical items will be point values in the simulation. To determine the criticality of each item, the project team predicts the possible extreme considering all risks, including compounding effects. The RP notes that the effort to gather reliable information on and assess critical items should not be minimized.

Once the critical items are determined, their range is assessed. The range is what you don't normally expect - the extremes, both positive and negative, which could happen, not what you expect to happen. If it can happen, it must be considered (although not to the point of absurdity). The team will also assess the probability of underrunning the estimated value. This range information is then used in selecting and specifying PDFs for the critical items. The RP recommends triangle or double-triangle PDFs, however, others such as log-normal or beta may be used if appropriate. The key is to use a PDF that appropriately reflects the implicit skew of the range information without being too difficult to define.

Many of the methods found in industry that are being called "range estimating" are not in accordance with this RP (see later discussion). Therefore, practitioners should always make sure that when someone uses the term, that they are talking about the same practice.

RP 42R-08: Risk Analysis and Contingency Determination Using Parametric Estimating
Parametric methods are commonly associated with estimating cost based on design parameters (e.g., capacity, weight, etc.). In this case, the method is used to estimate contingency based on risk parameters (e.g. level of scope definition, process complexity, etc.). The RP includes practices for developing the parametric methods and models (generally empirically-based). Future revisions of the RP are planned for scheduling applications.

This RP is the only one in the current series based on published empirical research findings. This research, first published by an AACE International founding member, John Hackney, demonstrated that *poor project scope definition* was often the greatest project cost and schedule risk driver and the impact of this objectively measurable risk was predictable [9]. This risk research ultimately led to the development of project scope development processes (e.g., phase-gate systems) and scope definition maturity matrices such as those included in AACE International's recommended practice for cost estimate classification [10].

To use this method, it is necessary to categorize each risk as one of two types: risks that have systematically predictable relationships to overall project cost growth outcome and those that don't. These categories have been labeled as "systemic" and "project-specific" risks (i.e., risk taxonomies or breakdowns for other purposes are not covered in this RP).

The term systemic implies that the risk is an artifact of the project "system," culture, business strategy, process system complexity, technology, and so on. Research has shown that the impacts of these risks are measurable and predictable. Measures of these risks are generally known even at the earliest stages of project definition, and furthermore, the impacts of these risks tend to be highly dominant for early estimates. Also, the link between systemic risks and cost impacts is stochastic in nature; this means it is very difficult for individuals or teams to understand and to directly estimate the impact of these risks on particular items or activities in a work breakdown structure (WBS). For example, the risks of process technology on something like site preparation may be dramatic, but is not readily apparent to any individual. The following are typical systemic risks dealt with using parametric methods:

Process Definition

- basic design;
- level of technology;
- process complexity; and,
- material impurities.

Project Definition

- site/soils requirements;
- engineering and design;
- health, safety, security, environmental; and,
- planning and schedule development.

Project Management and Estimating Process

- estimate inclusiveness;
- team experience/competency;
- cost information available; and,
- estimate bias.

The term *project-specific* implies that the risk is specific to the project. The impacts are not highly predictable between projects within a system or within an industry as a whole. For example, rain may have much more impact on one project than another depending on the project characteristics and circumstances. The impacts of these risks are not amenable to quantification using parametric methods (see expected value method).

There are two processes described in the RP; model development and tool use. These include the following steps:

Model/Tool Development

- establish requirements;
- obtain data and references; and,
- perform analysis and develop tool (including probabilistic outcomes).

Model/Tool Use

- identify the risks (inherent to the model);
- quantify or rate the risks (using model heuristics);
- coordinate with method for project-specific risks; and,
- determine contingency based on the outcome distribution.

Much of the RP is focused on model development because the method is dependent on analysis of actual experience and capturing it in the parametric model. Usage is straight-forward; simply rate the risk parameters according to defined heuristics and run the model. A challenge is that some systemic risks are politically-charged or otherwise subject to bias and therefore difficult to objectively rate. For example, stating that your company or team has poor project management and control competency or that your estimating data or process is uncompetitive or low quality often requires impartial analysis and evaluation from outside the team. Advantages of this method include explicitly addressing the dominant risks on projects at early phases and dovetailing with the scope development phase-gate systems most companies use today.

RP43R-08: Risk Analysis and Contingency Determination Using Parametric Estimating-As Applied in the Process Industries

This RP is an addendum to RP 42R-08 above. It documents (with permission) two working Microsoft Excel® examples of published, empirically-based process industry models of the type covered by 42R-08. The example models are intended as educational and developmental resources; users must first study the reference source documentation and calibrate and validate the models against their own experience. AACE International has posted these models along with the RPs in its website.

The two models include the "Hackney" model [9], and the later "RAND" model [11]. These are based on empirical study of causal relationships between cost growth (i.e., contingency usage) and various systemic risk drivers such as the levels of scope development and the level of process technology. While this RP summarizes the basis of the models, users must review the source documents before using the tools. Instructions for using the tools are included in the worksheets.

RP 44R-08: Risk Analysis and Contingency Determination Using Expected Value
The expected value method has been in common use for both decision and risk management for many decades. In fact, it is sometimes called the "standard risk model" in literature. Expected value in its most basic form can be expressed as follows:

Expected Value = Probability of Risk Occurring × Impact If It Occurs

This calculation has long been fundamental to decision tree analysis and risk screening or ranking. Its use is common because it is quantitative, simple to understand, simple to calculate, and it explicitly links risk drivers with their impacts so that the risks can be managed (i.e., a first principle of quantification). An advantage of the method is that the team can use the same quantification method at every step of the process from decision analysis, risk screening, to contingency estimating.

The method is recommended only for "project-specific" risks as defined for RP 42R-08. The following are examples of *project-specific* risks from the RP (not all inclusive):

- weather;
- site subsurface conditions;
- delivery delays;
- constructability;
- resource availability; and,
- quality issues (e.g., rework).

The link between project-specific risks and cost impacts is more deterministic than for systemic risks; i.e., project-specific risks are readily understandable by an individual or team and they can reasonably estimate the impact of these risks on particular items or activities (for example, the risks of excess rain on site preparation).

The method is applied at later phases of estimating (i.e., Class 4 or better) when measures of project-specific risks are identifiable and quantifiable. At Class 5, parametric methods are recommended because systemic risks are dominant at that phase. As discussed later, the expected value and parametric methods can be combined in a hybrid approach.

As with range estimating (RP 41R-08), the method uses Monte-Carlo simulation to obtain a probabilistic output. In the expected value method, PDFs are assigned and ranges determined by the project team for both the probability and the impact estimates. Correlation or dependency between risks (and between WBS items if impacts are estimated in more detail) must be addressed as well. The Monte-Carlo simulation is then run. The challenges of predicting extreme impact ranges and using appropriate PDFs that address skewness are the same as with range estimating. An additional challenge is assessing the correlations between risks.

Like all recommended methods, it results in a probabilistic output. However, unlike range estimating, this method results in a ranked lists of "root cause" risks rather than "critical items"; i.e., it explicitly links the causes of uncertainty with the ultimate outcomes. If the impacts were estimated by WBS, it can also provide a list ranked by the risks for each WBS item if desired.

A Hybrid Method

The following method is one used by the author in consulting with companies in the process industries. It is not directly covered by an RP, but it includes methods and approaches in the RPs described above.

The hybrid method used by the author combines parametric and expected value analysis. This can be done because both methods directly estimate the probable cost distribution of the impacts of each risk. To combine the methods, one simply includes the outcome of the parametric model (i.e., its outcome probability distribution) as the first risk in the expected value model. This covers the systemic risks. The project-specific risks are then quantified and added to the expected value model. The systemic and project-specific risks are generally independent of each other. Monte-Carlo simulation is then applied to the combined cost risk model to obtain a combined outcome probability distribution. Figure 2 illustrates the concept [15].

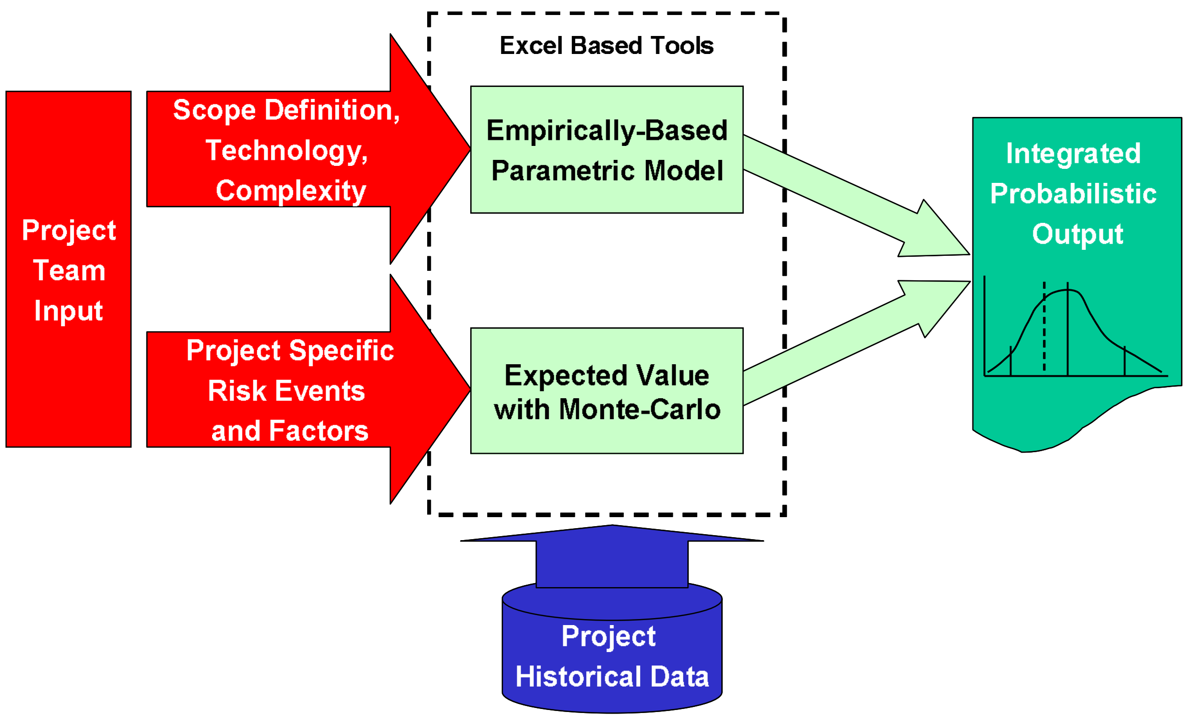

Figure 2—A Hybrid Approach to Contingency Estimating

It is important to ensure that risks are not double counted when combining methods. Each risk must be categorized as systemic or project-specific. Each risk is then quantified in their respective analyses and contingency estimates.

As RP 42R-08 points out, "for Class 5 estimates, parametric methods alone are generally adequate given the dominance of systemic risk impacts and lack of knowledge of project specifics. However, for Class 4 or better, other methods…should be used in combination with the parametric analysis." Figure 3 illustrates when each of the models may be used [15].

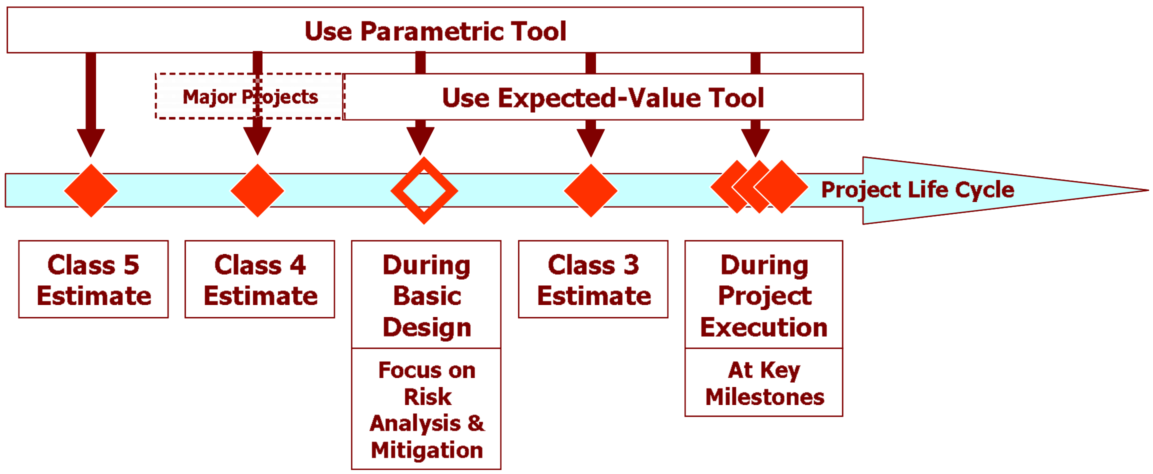

Figure 3—When to Use Methods in a Hybrid Approach

The Method Most Commonly Used Is Not Recommended

The following discussion in this paper is the opinion of the author, but is based on empirical research.

In years of reviewing the literature, I have found only one published empirical study of process industry contingency estimating methods. In 2004, Gob Juntima of Independent Project Analysis (IPA; a project system benchmarking and research company) presented a paper that quantitatively explored the historical performance of the various techniques in use [12]. Juntima found that, despite decades of discussion and development, "…contingency estimates are, on average, getting further from the actual contingency required." They further state that, "This result is especially surprising considering that the percentage of projects using more sophisticated approaches to contingency setting has been increasing." In particular, when they looked at projects for which the scope was poorly defined, they found that the more sophisticated techniques were "a disaster". Shockingly, the industry has largely ignored this clear indictment of its commonly used methods.

As seen from my consulting experience, the most common "sophisticated" method that Juntima referred to is Monte Carlo analysis of "line-item" ranges. In this method, the

Monte-Carlo model is simply a spreadsheet summary of the project estimate in which ALL the point estimates of the "line-items" (at some level of reporting detail that varies) are replaced by a PDF (usually triangular), for which a ranging exercise assigns low, most likely and high values. Typically, a Monte-Carlo simulation is run on this model without taking the necessary step of defining dependencies/correlation of all the line-items. This method differs from 41R-08 Range Estimating in its failure to define critical items, its lack of rigor and/or failure to seek extremes in ranging, the selection of invalid PDFs for skewed costs, and the failure to deal with dependencies. Dependencies are essentially impossible to establish for a model that does not define a line-item's link to the risks that in part create the dependency. It generally ignores systemic risks. In terms of first principles, it violates a number of those identified in 40R-08 and therefore is unlikely to be recommended by AACE International. As IPA found, the outcomes are a "disaster" for projects with poor scope definition at authorization (an all too common condition). Contingency is almost always significantly underestimated by this method--drastically so for early estimates. The industry's decades long experiment and infatuation with various poorly rationalized flavors of this method is a proven failure and its use must stop.

Using invalid methods is damaging the reputation of our profession. An example is the press received (a rare thing for a cost engineering topic) for a method called "Reference Class Forecasting" proposed by B. Flyvbjerg [13]. In essence, this method says that since the record of deceptive estimating for public mega-projects is so abysmal, owners should just give up on pretending to be disciplined and base project cost estimates on the past without regard as to why most past projects are often cost disasters. To be fair, this method indicts "lying" by public agencies and officials (a systemic risk) and not our risk management practices, but we must recognize that it is flawed methods such as line-item Monte-Carlo that permit these lies to pass unchallenged.

Unfortunately, while this paper focuses on cost contingency, the discussion above applies to the most common methods used to quantify schedule uncertainty (note that the IPA research did not cover schedule risk analysis methods because of their more limited use, and the fact that "cost is king" for the profitability of commodity process projects). The schedule risk analysis methods in question include PERT, applied to the critical path, and "activity ranging" applied in a critical path network (CPM) and running Monte-Carlo. These are corallaries to "line-item ranging" for costs. Like cost ranging, these methods fail to address systemic risk which research shows also drive schedule slip [14]. They also fail to link risks to impacts. Unfortunately, there is no empirical research to show, and little reason to believe on a first principles basis, that these ranging methods produce schedule risk or slip estimates that correlate with reality.

The IPA paper offered a partial remedy; namely that empirical, regression-based models "…can be a viable alternative or an excellent supplement to the traditionally used methods for contingency setting." This is particularly true when project scope is poorly defined.

The Industry Needs More Contingency Methods Research

In a broad survey of the existing literature on risk analysis, Lionel Galway of RAND found a dearth of critical literature and research to support much of what various parties espouse in our industry [15]. In regards to various risk analysis methods, Galway states, "The striking lack in the textbook literature is that there is little literature cited on the use of the techniques. That is, there are no pointers to a "critical literature" about the techniques such as when they are useful, or if there are any projects or project characteristics that would make it difficult to apply these methods. There are also few or no sets of case studies that would illustrate when the methods worked or failed."

Galway further states "This is clearly an area where research is needed. The lack of a body of empirical evidence, the often-cited reluctance of managers to use risk analysis techniques in project management, and the ambivalence of risk practitioners themselves over key issues such as applicability all call for a program of evaluation of these techniques and their application, especially in the area of complex, technologically advanced projects." Certainly, there has been considerable research on the relative importance of various risks; this research aids mitigation strategy, but it provides little practical help with quantification. While I cannot speak for AACE International, I believe the Association or any professional or academic would support such a research challenge.

Summary

This paper summarized an exciting new series of RPs that AACE International has published for analyzing risks and estimating cost contingency. AACE International has even created working Excel® tools that apply the methods published by leading experts. My hope is that by publishing this paper, these practices will get more attention and use.

The other hope expressed in the paper is that industry will sponsor more empirical research on risk analysis and contingency estimating. One of the only research studies existing shows that the methods many companies are using can be a "disaster" when scope definition is poor (as is common). Their indiscriminate use must be stopped. However, it is our duty to develop, demonstrate and communicate better ways to replace the failed approaches.

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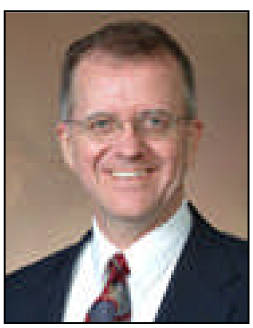

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