AACE International Recommended Practice No. 44R-08

RISK ANALYSIS AND CONTINGENCY DETERMINATION USING EXPECTED VALUE

TCM Framework: 7.6 – Risk Management

Acknowledgments:
John K. Hollmann, PE CCE CEP (Author)
Ricardo Accioly
Rodney B. Adams CCE
Dr. Said Boukendour
Dr. Ovidiu Cretu, PE
Michael Portigal
John G. Zhao

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INTRODUCTION

Scope

This recommended practice (RP) of AACE International (AACE) defines general practices and considerations for risk analysis and estimating cost contingency using expected value methods. This RP applies specifically to using the expected value method for contingency estimating in the risk management "control" step (i.e., after the risk mitigation step), not in the earlier risk assessment step where it is used in a somewhat different manner for risk screening.

Purpose

This RP is intended to provide guidelines (i.e., not a standard) for contingency estimating that most practitioners would consider to be good practices that can be relied on and that they would recommend be considered for use where applicable. There is a range of useful contingency estimating methodologies; this RP will help guide practitioners in developing or selecting appropriate methods for their situation. This RP is limited to estimating cost contingency.

Background

This RP is new. However, it is based on a method that has been in common use for both decision and risk management for many decades. Expected value in its most basic form can be expressed as follows:

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

The figure below shows a more specific example of the concept; in this case, $1,000 would be included in contingency for this particular risk[6]:

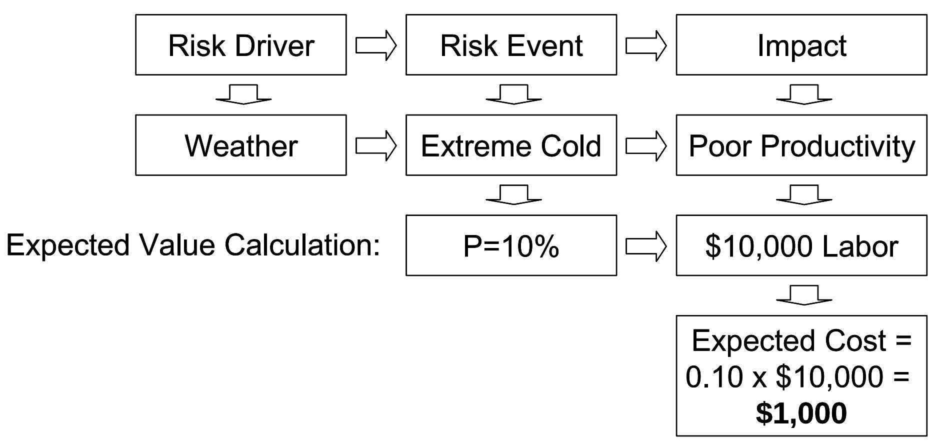

Figure 1. Example of Expected Value Calculation

This calculation has long been a fundamental method used in decision tree analysis and risk screening [3,4,5]. 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. However, its use for contingency estimating has not been as common. References by Dey[4], Hollmann[6], and Mak *et al.*[7] report on applications employing expected value concepts.

While it is advantageous for risk management to use methods that explicitly link risk drivers with their impacts, the effort involved in expected value methods for contingency estimating can be seen as a challenge. At screening, minimal cost competency is needed (i.e., risk impacts are often addressed as high/low or major/minor or other loosely quantified measures) so expected value usage is common. However, for contingency estimating, expected value requires cost estimating competency (particularly conceptual estimating) to explicitly scope and estimate the risk impacts. Range estimating on the other hand[2] does not require the preparation of explicit impact estimates; this can be seen as either an advantage or disadvantage.

Expected value has two other significant advantages; it does not require that the team change its basic risk quantification methods between decision analysis, risk screening and control, and it can provide a contingency estimate without using Monte-Carlo (however, its use is recommended).

It is AACE's recommended practice that whenever the term *risk* is used, that the term's meaning be clearly defined for the purposes at hand. In expected value practice as described in this RP, *risk* means "*an undesirable potential outcome and/or its probability of occurrence*", i.e. "*downside uncertainty (a.k.a. threats)*." *Opportunity,* on the other hand is *"a desirable potential outcome and/or its probability of occurrence",* i.e, "*upside uncertainty."* The expected value process for risk analysis quantifies the impact of *uncertainty*, i.e. "*risks + opportunities*".

Background-Risk Types

Because the expected value method of contingency estimating explicitly links risk drivers with their impacts, it requires more explicit understanding and treatment of the risk types than less explicit methods such as range estimating. In respect to expected value, as with parametric contingency estimating methods[1], risk types fall into one of two categories; 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 for contingency estimating purposes (i.e., there will be other ways to categorize risk types for other purposes.)[6]. To use the method properly, it is important to understand the distinctions of these types.

The term *systemic* implies that the risk is an artifact of the project "system", culture, politics, business strategy, process system complexity, technology, and so on. A challenge for contingency estimating, is that 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 (for example, the risks of process technology on something like site preparation or concrete foundations may be dramatic, but is not readily apparent). For this reason, the use of expected value methods, which rely on more *deterministic* estimating practice, should be limited to *project-specific* risks.

The term *project-specific* implies that the risk is, as it says, specific to the project; for example, the amount of rain that might fall on a specific project site. The link between *project-specific* risks and cost impacts is fairly deterministic in nature; i.e., these risks are amenable to individual understanding and to estimating the impact on particular items or activities (for example, the cost impacts, allowing for accuracy range, of excess rain on site preparation work can be estimated).

Another risk taxonomy distinction of value to understanding this method is fixed (or discrete) versus variable (or continuous) risk *impacts*[7]. There are two uncertainties in the expected value equation; probability and impact. If the impact is "fixed" or discrete in nature (and estimable), then most of the uncertainty is in the probability of its occurrence. If the impact is variable, then there are two levels of uncertainty; probability of occurrence, and scope and cost of the impact. Understanding this can help the user in planning how difficult the implementation will be, and may suggest alternate approaches to how to deal with the uncertainty.

The RP will explain how parametric and expected value contingency estimating methods can be used together in a way that best addresses both systemic and project-specific risks.

RECOMMENDED PRACTICE

The following steps assume that a formal risk management process is being followed and that risks have already been mitigated in the project plans to some extent. This recommended practice then addresses the residual risks that need to be controlled and managed. Often, constrained for time, teams will skip the mitigation effort and jump right to contingency estimating which defeats much of the value-adding purpose of risk management.

RISK IDENTIFICATION

Identify Residual Project-Specific Risks

This is not an RP about risk identification. However, the expected value method requires that risks that are to be “accepted” to some extent (i.e., will remain part of the project scope and plan after mitigation) be explicitly identified. To use expected value, the risk identification step must distinguish between systemic and project-specific risks. This is facilitated when parametric methods are used because the systemic risks are generally known and addressed directly in the parametric model. The remaining risks are then usually project-specific.

Typically, risk identification for contingency estimating is a separate step from risk identification for screening. Most risk management models do not make it clear that after risks have been identified, screened as to significance, and addressed in revised plans (i.e., by transferring, accepting, reducing, etc.), the team must then take a fresh look at the residual risks that may be of a somewhat different nature. This includes the possible introduction of iatrogenic risks (i.e., the mitigating action may create a new risk). Also, new risks may have come up in the time between the earlier mitigation and planning modifications and the final contingency estimating step.

Risk identification to support contingency estimating also tends to be more definitive in nature as to specifying risk events in a way that the impact can be clearly understood and estimated. Otherwise, the identification process is similar, starting with a diverse and knowledgeable team using elicitation methods such as brainstorming, then recording the risks[3]. The risks will be screened for significance during the quantification steps that follow.

QUANTIFICATION/CONTINGENCY ESTIMATING

The risk identification step will result in a list of significant risks and opportunities for which probability of occurrence and impacts need to be estimated.

Estimating the Probability of Occurrence

As with any estimating or forecasting process, experience is the best foundation. The risk analysis team should include representatives of any entity that is likely to have some control of and/or be significantly impacted by potential risks. This usually means lead individuals from business, operations, design, procurement and other functional areas of the project team. The more and broader the experience in the room, the better the analysis will be. In any case, the risk analysis participants should be familiar with the project plans and cost estimate.

For the expected value method, it is required that cost estimating expertise be part of the process and that the estimating representative be familiar with the basis and content of the estimate for the subject project and others like it. Further, the estimator should be well versed in (or know where to find) historical experience and lessons learned with cost risks and their impacts for comparable projects.

The team, usually in a workshop setting, reviews each risk and identifies the probability of each risk's occurrence. This can be a direct estimate from 0 to 100 percent probability; however, probabilities are usually given names (e.g., very high, high, etc.) with preset values to assist in getting consensus because specific values are difficult to agree on.

If Monte-Carlo is to be used later (which is recommended), then the team must also identify the degree to which the risks are dependent, and if so, the extent and nature of the correlation. For example, there may be an interaction between the risk of rain and the risk of poor slope stability (e.g., if it rains a lot, the soil slope stability is likely to be worse). Using Monte-Carlo software, the users must quantify the correlation (e.g., the slope stability and rain have a 0.5 correlation coefficient) . In addition, the Monte-Carlo model can be made to address the team's confidence (i.e., the degree of consensus) in the probability rating. This is done by treating the probability of occurrence as a distribution (e.g., triangular is common) which will have wider ranges when there is less consensus in the rating.

Estimating the Impact if the Risk Occurs and Screening

Having clearly identified the risk or opportunity, the team must agree on the scope of the impact and quantify it at a conceptual level of definition (e.g., AACE Class 5). For example, if the risk was a 100 year rain event, the team may agree that the primary impact would be a flooded site that requires pumping, excavation rework, and delay with a period of poor productivity. The estimator(s) on the team then provides a quick conceptual estimate of this impact using conceptual metrics such as the typical cost of a day's delay assuming a certain manloading and so on. The estimating knowledge required for this method is not trivial.

This initial estimate is for screening. If a quick calculation of the probability times impact yields a value that is not significant to costs or profitability, then it is dropped from consideration (but kept in the register) and is not used in the contingency calculation. Significance can be judged using the same criticality criteria cited in AACE's range estimating RP 41R-08[2] as shown in the table below:

Bottom Line Critical Variances		
Bottom Line (Cost or Profit)	Conceptual Estimates (AACE Classes 3, 4, 5)	Detailed Estimates (AACE Classes 1, 2)
Cost Δ	± 0.5%	± 0.2%
Profit Δ	± 5.0%	± 2.0%

For the remaining critical items, the estimator will then typically refine the scope and cost of the impact after the risk analysis session. The estimate is usually developed to a Class 5 summary level of detail (e.g., a breakdown such as engineering, equipment, bulk materials, labor, and so on). While the need to prepare estimates may seem onerous, there should usually be less than 15 or so risks that pass screening, and their impacts are usually limited to a few estimate items. The level of effort is not significant for a skilled estimator.

Assessing Ranges of Impact

If Monte-Carlo is to be used later (which is recommended), then the team will revisit both the scope and quantification of the impact and its costs to estimate the range for each risk or opportunity that passes the screening. Unlike range estimating for which the team must consider *all* risks that may affect a given critical item (making it difficult to see how broad the range can be without expert facilitation), expected value only needs to deal with one risk and the ranging tends to be fairly straightforward. Still, the leader of the risk analysis must strive to ensure that the worst case outcomes have been considered.

Again, the estimator will then typically refine the range estimate of the impact after the risk analysis session. For Monte-Carlo, they will also need to choose a distribution with triangle, double triangle, or beta being typical with the understanding that triangular distributions can be inappropriate for highly biased distributions (refer to reference [2] regarding distributions).

To improve communication as to the nature of the impact estimate, some have found it useful to categorize each risk as either “fixed” or “variable” in terms of its impact (i.e., a similar concept is “discrete” or “binary” risks versus “continuous” risks). The impact of a fixed or binary risks has limited range (e.g., the risk is a flood that may overtop a dike, and the impact is to bring in a second pump at a known costs). A variable or continuous risk has an extent and impact with a wider possible range (e.g. the risk is severe rain with an intensity that can vary, and an impact that depends on the status of work at the time). The nature of the impact is also a consideration when evaluating contingency versus reserve funding (e.g., major fixed or binary risks are less amenable to funding with contingency; see later discussion).

Coordinate with Contingency Estimates for Systemic Risks

Parametric and expected value analysis can be easily combined because expected value models work by directly estimating the probable cost distribution of the impacts of each risk[1]. In that case, the results of the parametric model (i.e., its outcome probability distribution) are included in the expected value model as the first risk. Then other project-specific risks (e.g., heavy rain) are quantified and added to the model. Monte-Carlo simulation can then be applied to the entire combined cost risk model to obtain a combined probability distribution.

For Class 5 estimates (i.e., based on minimal scope definition[8]), parametric methods alone are generally adequate for contingency estimating, given the dominance of systemic risk impacts and lack of knowledge of project specifics. For Class 4 or better, the methods should be used in combination. The most important consideration in combining methods and outcomes is to ensure that risks are not double counted. After risks are identified in a risk analysis session, each risk must be categorized as systemic or project-specific. Each risk is then quantified in their respective analyses and contingency estimates.

Assessing Overall Outcome using Monte-Carlo

Having quantified and defined distributions to the probabilities and cost impacts, and having established dependencies between the risks (and between summary cost accounts as used in the risk impact estimates) , the cost risk model can be run through a Monte-Carlo simulation using one of the many commercial software packages available.

The cost risk model input includes the base estimate plus the parametric model outcome distribution (e.g., systemic risk impact) plus the products of the distribution of probability times the distribution of the cost impact for each project-specific risk.

An advantage of the expected value method is that the cost impact of each risk is quantified. While it is recommended that there be only one contingency account in a project cost budget, it can useful for later risk management and contingency drawdown to have the potential impact of each risk explicitly quantified (i.e., if the risk does not occur, it provides an indication of the potential contingency, pending ongoing risk analysis, that could be returned to the business).

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Estimating Contingency

The Monte-Carlo output is a distribution of possible cost outcomes at different levels of confidence in underrun. Contingency is then the difference between the base estimate cost and the cost at whatever level of confidence of underrun management desires depending on their risk appetite, acceptance or tolerance level. For example, if they desire to fund the project at a 70 percent probability of underrun, then the contingency value would be the p70 value from the outcome cost distribution less that base estimate value. Management typically sets a standard level of risk tolerance as a company policy.

Note that this method can provide a cost output distribution for each risk (including the input distribution for the systemic risks). While mean outputs (expected values) can be summed for each risk to arrive at an overall mean outcome or expected value, you cannot sum the other ranges (e.g. p90).

P50 vs. Expected Value

When using the expected value method, it is important to keep in mind that the p50 value of a Monte-Carlo simulation is not equal to the expected value (mean) for asymmetric distributions. If you sum the probability weighted expected value outcomes for each individual risk, the total will exceed the p50 value of the simulation if most distributions are skewed to the high side as is most often the case. The difference may or may not be trivial depending on the skewness. As discussed in the previous section, it is management's responsibility to decide on their level of risk tolerance; the expected value sum is then another possible value to consider. For those who prefer to fund contingency at a p50 level of confidence, but still recognize that expected value is in fact "expected" to be spent, the difference may be funded as a reserve.

Evaluating Contingency (Versus Reserves or Other Treatment)

Because the expected value method provides an estimate of the full cost impact of each risk if it occurs, the method allows users to further assess the adequacy of the contingency funds. Contingency is only useful for funding risk impacts that represent a limited portion of the overall contingency funding (usually variable or continuous in nature). High impact/low probability risks (usually fixed or binary in nature) often cannot be effectively funded with contingency because, if the risk occurs, especially at its maximum impact, it may consume all of the contingency and much more. You can never put enough in the contingency account to cover such a risk, and if you do, you will likely kill the project economics even though the risk has a low probability of occurring. Also, if you fund even a portion of this risk, it will likely be spent if project management is not disciplined (the team will know the money is unlikely to be needed, and inadequate in any case, so it is free for the taking). Therefore, these high impact/low probability risks that swamp contingency should be removed from the contingency analysis, and their assessment and treatment dealt with separately as appropriate (e.g., through reserve funding on a portfolio basis, additional mitigation, etc.).

SUMMARY

It is hoped that enough information is provided in this RP to help guide practitioners in developing or selecting appropriate methods for their situation. Users are encouraged to study the reference materials including the RPs for alternate methods. Future revisions of the RP are expected to cover scheduling applications.

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CONTRIBUTORS

John K. Hollmann PE CCE CEP (Author)
Ricardo Accioly
Rodney B. Adams CCE
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