RISK-2555

Contingency Cage Match: Simultaneous Contingency Assessment Methods, A Case Study

Matthew Schoenhardt, P.Eng. and Vachel Pardais

Abstract— Of the four main methods of contingency assessments support by AACE, two offer reasonable sophistication and detail: recommended practice 41R-08 Range estimating (Monte Carlo simulation); and, 42R-08 Parametric estimating (systemic analysis). Both offer probabilistic results, risk register integration and leverage project team's knowledge and expertise. There are proponents within AACE of both methods who expound their favored approach (this Author being no exception). The ideal rapprochement is to use both methods simultaneously to offer two sets of "data points" on possible project cost outcomes. In the real world, budgets and project team availability, preclude this contingency Utopia.

In 2012, the Author had the opportunity to simultaneously complete both methods on a large, now substantially complete, project. This paper will review the project's post mortem implementation of the two contingency approaches; their predictive results against actual results; and, consultant and project team hours expended for each method.

Who will win this Contingency Cage Match? Will there be a clear winner? This paper will review the effort – accuracy relationship between the two approaches along with other time saving methods.

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Introduction

For Many risk management is a subset of project controls, and like any project control discipline, the purpose is to expend resources to avoid negative project cost, schedule or scope outcomes. If the efforts expended for project controls exceeds that of their reasonably anticipated benefits, one could deem them as a waste of resources. The costs of project controls are clearly visible; their initial expenditure early in the project and continues unabated throughout the project life cycle. Contrast to this is that the prime benefits conferred by project controls is the absence of project difficulty. The line between appropriate project controls and project outcomes can be tenuous. While literature has clearly shown the correlation between project controls and project outcomes in general [1] [2] [3] [4], no one can say with certainty that on any given project there is definitive causality. This perspective can drive many owner companies to try and spend as little as possible on project controls, in the misguided hopes of saving money, limiting the budget for risk and contingency assessments.

Contingency estimating on capital projects is perhaps the single largest line item in any capital estimate potentially coupled with the least effort and rigor in its development. There are four main families of contingency estimating supported by AACE: expert opinion, predetermined guidelines, range estimating and parametric [5] [6] [7] [8]. Of these, only the last two required significant effort, use of a risk register and provide probabilistic estimates. Typically, owner companies either have a preference or budget limitations and only use one method or the other. This paper will look at the application of these two sophisticated methods that were applied on the same project at the same time. This type of case study is rare, and while not in complete agreement with the scientific method, will provide useful insight into the relative effort-accuracy relationship between the range and parametric estimating methods.

This paper will first define what contingency is, what is covers and how it can be assessed. It will then describe the case study project, identify complications, and the two methodologies used to complete the contingency assessment. The efforts required, both consultant hours and project team hours, for each method will be compared followed by actual project outcomes. The paper will conclude with a critique of the methodology, identifying the potential for future work and a final conclusion. Unless otherwise stated all funds are in Canadian 2013 dollars.

What is Contingency?

This paper will only examine cost contingency and will use the AACE definition as follows [9]:

> "An amount added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs. … Contingency usually excludes:
>
> 1) Major scope changes such as changes in end product specification, capacities, building sizes, and location of the asset or project;
> 2) Extraordinary events such as major strikes and natural disasters;

> 3) Management reserves; and
> 4) Escalation and currency effects.
>
> Some of the items, conditions, or events for which the state, occurrence, and/or effect is uncertain include, but are not limited to, planning and estimating errors and omissions, minor price fluctuations (other than general escalation), design developments and changes within the scope, and variations in market and environmental conditions."

Contingency Methods

The main to biases to assess capital project contingency are opinion and empirical. Each of these can be applied with either a simple or sophisticated methodology. These four methods, shown in Figure 1, can be used independently or in combination. The four methods are:

1. Opinion
   a. Expert
   b. Range Estimating
2. Empirical
   a. Predetermined guidelines
   b. Parametric.

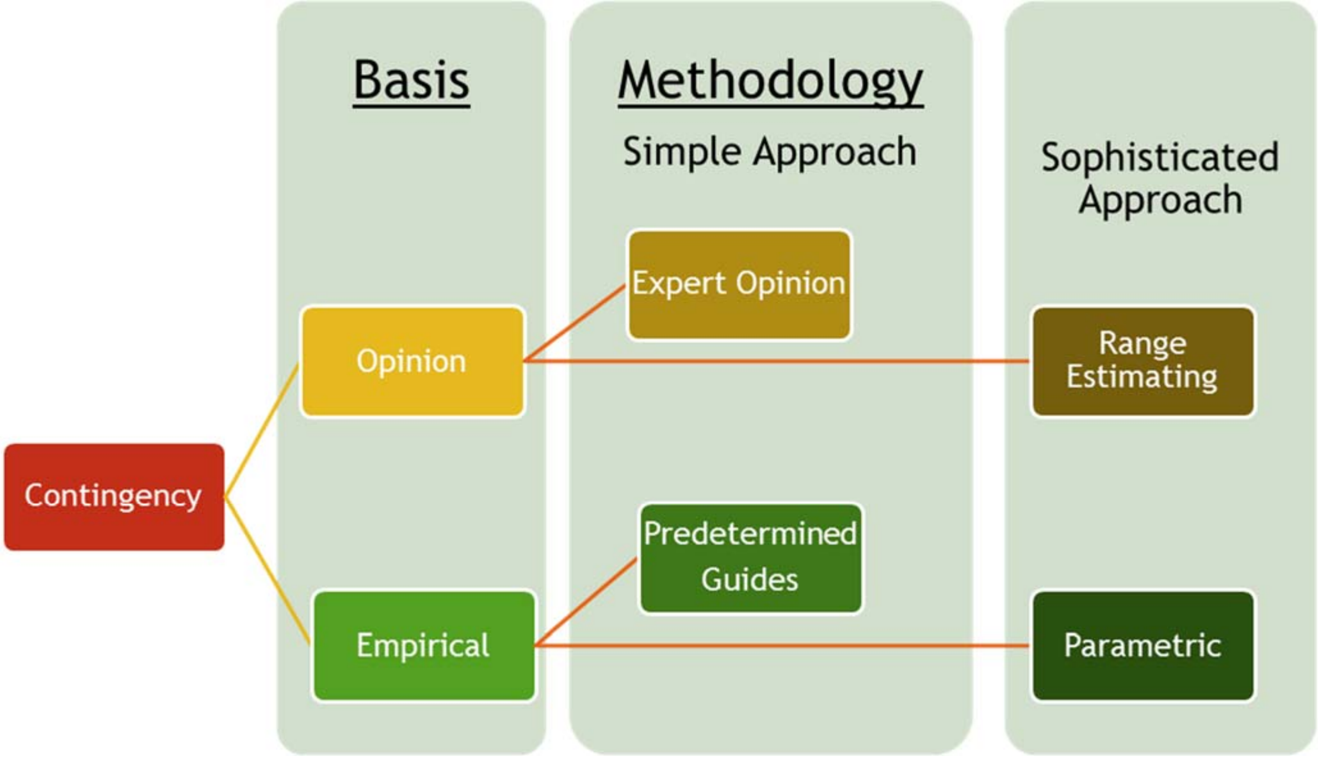


Figure 1: Contingency Assessment Approach Families [10]

AACE has nine principles for risk estimation that outline expectations for any given method [5].

1. Meets client objectives
2. Part of risk management process
3. Fit-for-use
4. Identifies risk drivers
5. Links risks to cost outcomes
6. Avoids iatrogenic (self-inflicted) risk
7. Employs empiricism
8. Employs competency / experience
9. Provides probabilistic results that supports decision making

Key to these principles is fit-for-use and meeting client objectives. As each of the four methods offer different cost and benefit relationships, the right method depends on the application, the possible consequences of project failure and the risk tolerance of the organization.

Opinion Basis: Expert Opinion

The most straightforward method of risk assessment is Expert Opinion. One simply asks a subject matter expert(s), presumably the project manager, how much contingency is required. This expedited method implicitly accounts for project risks (principles 4, 5, 7, and 8) but can fall short on principle #9: self-inflicted risk. This approach has both agency issues and is prone to heuristic bias – both optimistic and pessimistic. Too often these iatrogenic risks result in contingency assessments that are not repeatable in time on a single project, nor comparable between different projects. Some of the iatrogenic risk can be mitigated by increasing the number of experts, possibly through the Delphi technique [11], but this increases the complexity of the process undermining its key strength of speed.

Opinion Basis: Range Estimating

Range Estimating is a Monte Carlo approach illustrated by AACE recommended practice 41R-08. This approach takes the work or cost breakdown structure (WBS or CBS) and develops possible cost and quantity outcome distributions for each line item. This can be done either in a group setting or individually with project team members. Augmenting these range estimates is the risk register whose individual risks are quantitatively estimated for probability and impact. This information is fed into a Monte Carlo simulator that provides a probabilistic cost distribution curve. This process meets AACE's principles for contingency estimating, notably hitting #9 very well.

Where range estimating falls short in practice is principle #7: empiricism [12] [13] [14]. In theory, the developed ranges are based historic data, but all too often this data either does not exist or is too expensive to obtain forcing its substitution with expert opinion. This data breach creates the real possibility that the basis of a typical range estimated contingency is identical to that of expert opinion: a best guess. This reliance certainly is in keeping with principle #8, expertise, however the complex math disguises the fact that too often range estimating is, at its heart, expert opinion writ large.

Other draw backs of range estimating include:

1. It is labor intensive. A range estimated contingency may take over 24 hours of the project team's time.
2. Identified risks must quantify the unknown.
3. Evaluation of "black swan events" is inherently underestimated. [15]
4. Central limit theorem: increasing the number of independent variables decreases the possible range of outcomes.

Similar quantitative approaches include Expected Value, Event Modelling and Fault Tree Analysis [5]. These methods can have strong niche applications, but fundamentally share the strengths and weaknesses of range estimating.

Empirical Basis: Predetermined Guidelines

The second family of contingency methods draws its basis on historical data and has two main methods: predetermined guidelines and parametric. Both methods attempt to correlate the project's current level of project definition to an explicit or implicit historical data set.

The most common, and most maligned, industry method of determining contingency is described by AACE Cost Estimate Classification Systems 17R-97 [16] [8]. Predetermined guides rely on the concept that as a project becomes more defined, so too does its estimate become more accurate and precise. While these guides stand the test of time, they are often abused and misused by industry as a shorthand for detailed work. It is too easy for engineers to state that an estimate is an AACE class III without ensuring that it meets the criteria of a class III estimate. Estimate accuracy is the outcome of project deliverables, not an objective in and of itself.

Empirical Basis: Parametric

Like predetermined guidelines, Parametric or Systemic Contingency correlates the assessed project's current development with historical reference data, but a more granular level. Rather than simply stating that this project is a class III estimate in its entirety, it reviews the level of project development of individual project deliverables. This granularity is augmented by the inclusion of project specific risks and provide probabilistic results.

It is the author's supposition that the parametric approach is faster, cheaper and more accurate than a typical range estimate, but it is not without its faults. While the reliance on data reduces iatrogenic risk, the approach can be handicapped by database availability, relevancy, accuracy and project life cycle stage.

Comparison of Contingency Methods

Prior to this case study, the author's opinion on the relative insight, accuracy and effort of the four main contingency methods is shown in Figure 2 [17]. This opinion was based on observation and theory but had yet to be personally tested by the scientific method.

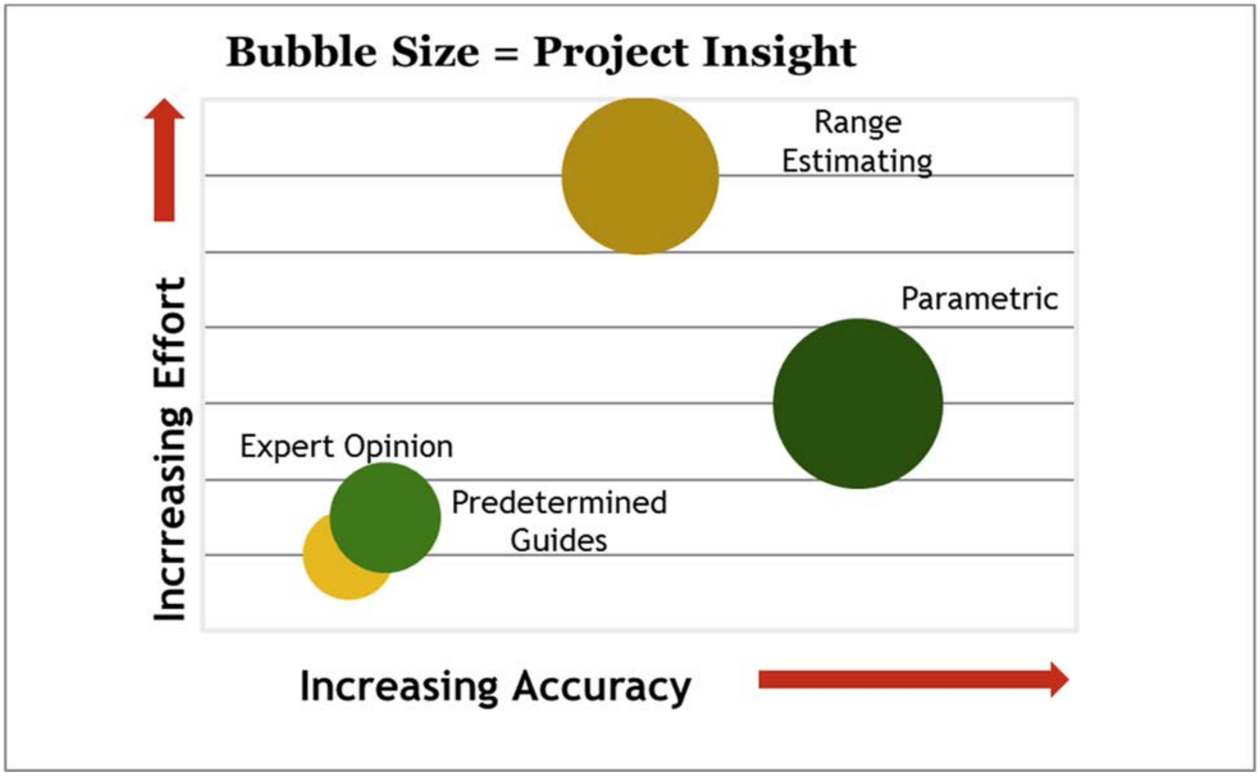


Figure 2: Comparison of Contingency Assessment Methods [10]

Project Description

The project owner was a Canadian midstream oil and gas company. The work occurred in Alberta Canada and was planned in two phases. As the project's actual results could be considered by some not to be exclamation point for project success the company wishes to remain anonymous. Luckily for the field of cost engineering, the outcomes were not the P50 cost estimates and provided insights into what can occur when cost adversity arises.

Phase 1 scope included increasing storage capacity, truck loading, manifolds, pumps and metering for a 2013 estimated cost of construction of $131 MM Canadian. These costs excluded interest during construction, and escalation. The work breakdown structure had 4 subprojects for this phase.

Phase 2 scope included debottlenecking of existing NGL system, expansion of that system, restarting inactive equipment, modified storage, firewater system, earthwork, initial rail loading and rail loop with a base estimate of $157MM. These costs excluded project management, field management, interest during construction, and escalation. The work breakdown structure had 8 subprojects for this phase.

The simplified work break down structure (WBS) for the project is shown in Figure 3 with each of the subprojects having an independent WBS after level 3.

1. Project
    1.1. Sub Project (8)
        1.1.1. Direct Construction
            1.1.1.1. Material & Equipment
            1.1.1.2. Labor
        1.1.2. Indirects
            1.1.2.1. Construction Management
            1.1.2.2. Labor Indirects
            1.1.2.3. Material Indirects
        1.1.3. Engineering
        1.1.4. Owners Costs

Figure 3: Work Breakdown Structure

Complications

Like all projects, this program has its own set of complications.

a) Each portion of the two-phase program were not in the same stages of development but shared project team members. This caused some blending of opinions on how mature each phase was with some degree of interphase rivalry.
b) The program utilized 6 different design firms. One of these design firms was specialized, while the other 5 all competed with each other in the market place and rivalry was an issue.
c) Ultimate integration of these six estimates was the responsibility of a third-party project management firm. This firm was new to the host company and during the assessment sessions there were apparent agency issues between the company and the project management firm [18]. The project management firm was later dismissed from the program.
d) The overall business scope was not fully complete and its allocation between the two phases was not firm resulting in fluid project scope. The general assumption was that anything phase 1 could not accomplish would be pushed into phase 2. In this respect phase 2 work was entirely dependent on phase 1. Despite this, the company was insistent that the two phases were independent and required distinct contingency values.
e) The results of the Phase 2 contingency assessment identified some material errors that were corrected in a major cost re-forecast that occurred one month later which added $18.2MM (12%) to the base estimate.
f) Finally, as phase 2 progressed it was divided into two separate projects with one focused on processing and the other focused on rail. With this understanding it is unlikely that

any contingency assessment method would have correctly predicted the cost outcomes of phase 2.

Methodology

Common Tasks

The approach used for the two contingency estimating methods had common process steps. In particular, they shared a common risk register. When modelling risks for either method the probability and cost impact were independently modelled. Correlations were independently allowed between probability (both risks are more/less likely to occur at the same time) and impact (in one risk has its largest impact, the other will also have its largest impact).

The original proposal for services had the requested traditional risk identification workshop and discussion / group method of developing range estimates. The divergence between the project management firm's view and the owner's perspective on the efficacy and value of each method led to the requirement of compromise through budget reduction. At the author's suggestion risk identification was completed through the more cost effective interview approach while range estimating was completed through anonymous voting using I>clicker technology [19].

The risk register was created by interviewing project team members in a one-on-one setting. This approach provides team member anonymity as the risk originator was not shared with the team. In the interview the project team member volunteered risks and commented on possible risks identified by the author; after which the facilitator asked probing questions based on the current project deliverables and the team member's area of expertise. Risks where then jointly qualitatively evaluated for impact (cost, schedule, scope) and probability using predefined a 1-5 scale bound by verbal anchors and numerical ranges. This allowed screening of key risks that were then reviewed, quantitively evaluated and responded to in a whole project team facilitated session. Attending the facilitated session included:

1. Owner's company six persons including: project director, procurement, regulatory and stakeholder engagement, project controls, construction, procurement, business development and engineering.
2. Project Management Firm: project manager, project controls, expeditor.
3. Engineering Firm(s): project manager, cost estimator, specialists.

For the purpose of this paper identified risks will be broadly broken into two separate categories: systemic risks and project specific risks. The definitions of these risk agree with AACE's recommended practice 10S-90. "Project-specific risks are uncertainties (threats or opportunities) related to events, actions, and other conditions that are specific to the scope of a project …The impacts of project-specific risks are more or less unique to a project." [9] "Systemic risks are uncertainties (threats or opportunities) that are an artifact of an industry, company or project system, culture, strategy, complexity, technology, or similar over-arching characteristics." [9]

Systemic Risks	Project Specific Risks
Addressed by progressive stage-gate development: • Uncertainty on soil conditions before field bore hole testing	Assumptions in contradiction of data, logic or industry best practices: • Zero, or less than average weather delay days • Typical productivity in areas with active operations • Fast tracked / shorter than typical regulatory approval
General fears common to all projects or those that lack a "credible threat": • Late drawings, equipment • Project team turnover • Low productivity	Ignoring credible threats, assuming negative trends or conditions will cease: • Not adjusting forecasts when demonstrated low cost or schedule performance indices
Risks whose response is typical / improved project controls or "do better": • Incorrect drawings • Safety events	Constraints • Seasonal construction • Board approval dates
Cannot easily estimate the risk's probability and impact.	Can reasonably estimate a risk's probability and impact.

Table 1: Contrasting Project Specific and Systemic Risks

Phase 1 identified 409 risks, of which 236 were considered unique including systemic, project specific, and opportunities. Phase 2 has 139 risks, of which 69 were considered unique including systemic, project specific, and opportunities. Only those risks that were considered "project specific" were explicitly modelled in the parametric approach while all risks, both systemic and specific, were incorporated only into the range estimating model.

Range Estimating Contingency Methodology

Range estimating methodology can be completed in a variety of ways with increasing detail resulting in increasing costs. A detailed Monte Carlo on this project could have taken several days of the team's time. Given limited resources and that a systemic assessment was being completed on this project a more cursory approach to the Monte Carlo was taken. Range estimates were obtained on all meaningful tasks which were coupled with the risk register items not addressed by the range estimate. The overall logic flow the range estimating process is shown in Figure 4 and each step will be discussed subsequently.

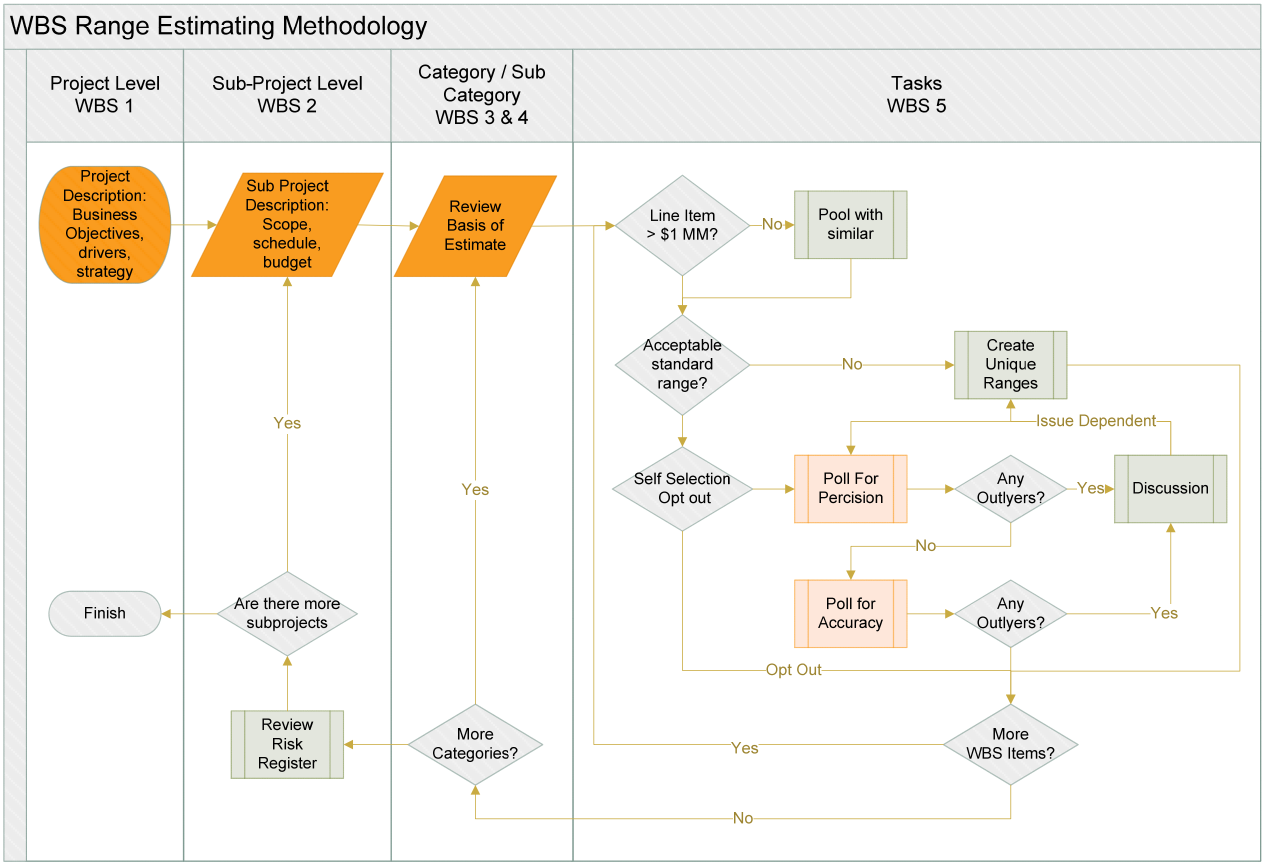


Figure 4: Range Estimating Methodology

The session began with an overall review of the methodology and trails of the equipment. Then the project director reviewed the overall project in its entirety (WBS level 1) with a focus on business objectives, corporate and client needs, organizational structure, high level project expectations, connections and boundary/battery limits for each subproject. A key risk that arose during this was that the business scope, especially for the second phase, was not considered frozen.

After this introduction, each of the four or eight subprojects (WBS level 2) was described by the project manager or functional lead with a focus on business scope, technical scope, schedule and budget. Once each subproject was described the relevant project controls team member described the basis of estimate (BOE) for category or subcategory.

All line items at a WBS level 4 with a cost over $1 MM were directly assessed. Remaining costs in each level 4 area were combined into similar buckets until a value of at least $1 MM was reached.

Prior to anonymous accuracy and precision polling, an open question was asked by the facilitator to the group if there was any reason for this WBS line item to be outside the prescribed ranges for accuracy and precision. If anyone thought it was, a separate discussion was had to either independently assess the line item, break it down into further components or to ensure appropriate understanding. Individuals where then encouraged to anonymously opt-out of the polling if they believed that they did not have sufficient expertise to provide.

Due to time and resource constraints rather than each item be uniquely assessed for best-base-worse case ranges, a Delphi technique was employed [11]. The project team was anonymously canvassed for their opinion on the line items' "precision" and "accuracy" through a live 1 to 5 voting system using the "I>clicker®" shown in Figure 5.

Figure 5: Image of hand held voting device – I>clicker [19]

The anonymous voting prevented group-think, individuals carrying undue influence, persuasive discussion, or compliance to unstated expectations (such as this is a class III estimate so no value should be greater than +/- 10%!) [20]. If an individual felt that they had no insight into a line item, they self-excused themselves from voting. After voting the results for the single line item were displayed on screen, and if they differed widely (see atypical polling in figure below), a discussion was had to ensure proper understanding followed by re-polling. The values from this second poll were always retained. If the votes were clustered, or something approximating a smooth or normal distribution ("typical poll"), the average score was retained and used to extrapolate the accuracy and precision values to support the Monte Carlo. If the values were not smooth after the second polling (an "atypical poll"), a custom representative bi- or multimodal distribution s were used. These two possible polling scenarios are shown in Figure 6 and Figure 7.

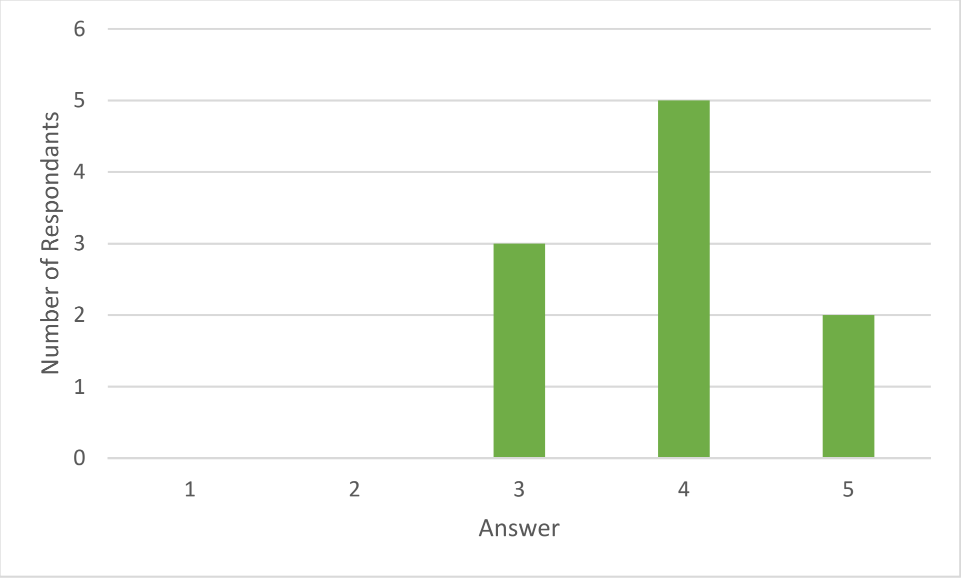


Figure 6: Typical Poll Response

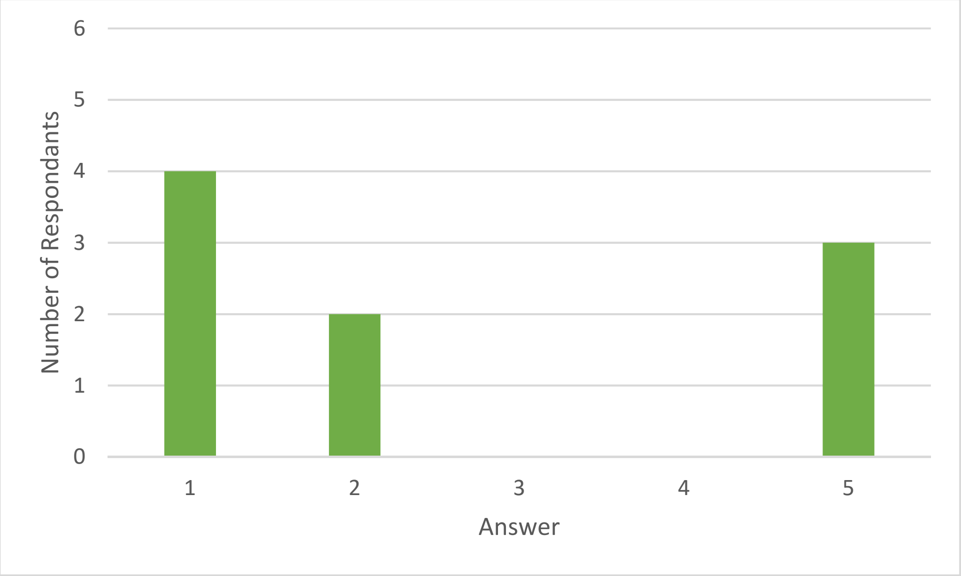
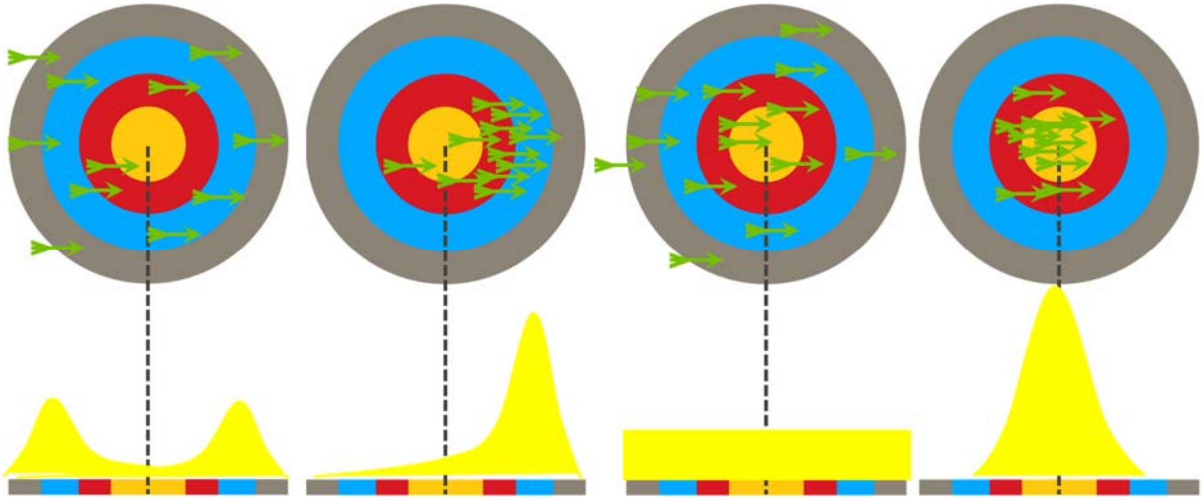


Figure 7: Atypical Poll Results

Accuracy and precision mean two different things. Figure 8is a graphical illustration of the differences. The illustration imagines arrows shot at a target. Accuracy reflects how close to the target the arrow is, while precision reflects how repeatable the results are. Beneath the targets are the resulting probability distribution.



Low accuracy
Low precision

Low accuracy
High precision

Fair accuracy
Low precision

High accuracy
High precision.

Figure 8: Graphical Representation of Accuracy and Precision

Each WBS items was polled for accuracy and precision. Precision answers the question, "How well do we know this number?" on a five-point scale. The higher the score, the wider the resulting range. A score of "1" meant that we know this number perfectly, while a score of "5" meant we know this number +/-30%.

Accuracy answers the question, "Is the estimate high, low or, about right?" on a five-point scale. The higher the score, the higher we thought the base estimate was and there for had to lower the mean in the Monte Carlo. A score of "3" indicated that the current estimate was about right. Numerical ranges for accuracy and precision scores are shown in Table 2.

I>clicker Score	Accuracy %	Precision (Range) %
5	25%	30%
4	10%	20%
3	0%	10%
2	-10%	5%
1	-25%	0%

Table 2: Accuracy and Precision Values for Range Estimating

Figure 9 graphically shows the 25 different combinations of precision and accuracy scores with the green line showing the estimated base value.

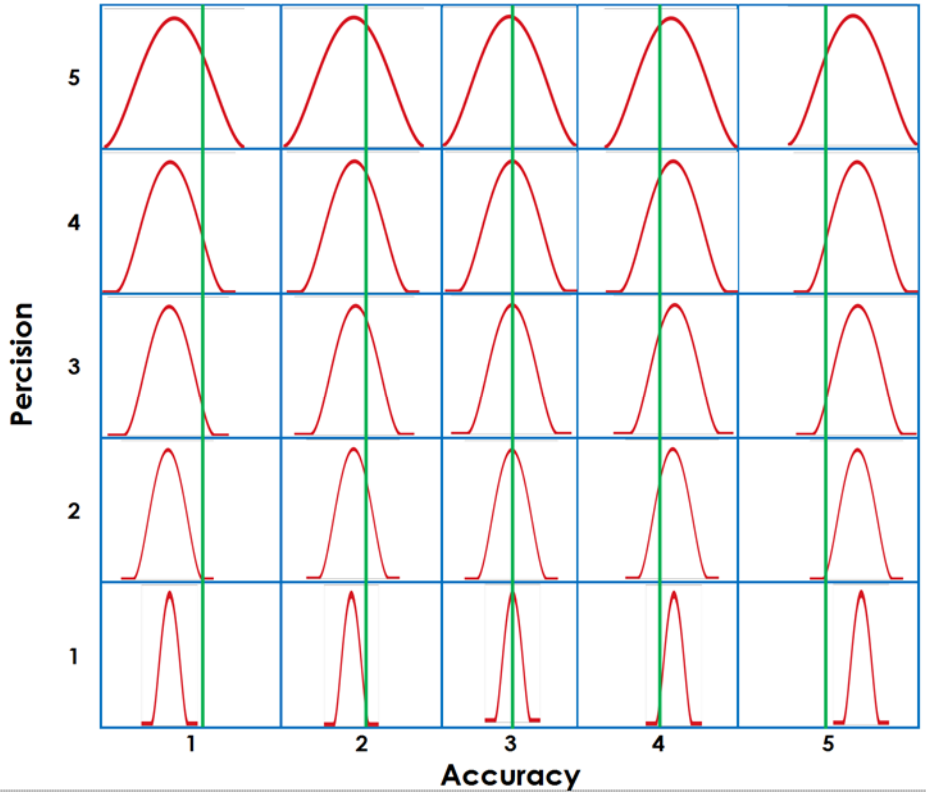


Figure 9: Visualization of Prescribed Accuracy and Precision Options

Once the votes were polled for each line item, if the distribution was "typical" the average value on the scale 1-5 was linearly calculated. If it was "atypical" a unique distribution was created. For the example in Figure 6 there are three poll response of "3", five of "4" and two of "5" the calculated accuracy value would be:

$$\frac{(3 \times 0) + (4 \times 10\%) + (2 \times 25\%)}{10} = +10\%$$

Equation 1: Sample Mean Calculation

The Monte Carlo then used a "pert" distribution using the voted-interpolated mean (accuracy) and range (precision). For "precision", the voted range was assumed to be 1 sigma, that is 2/3rds of the time the random value would be within the range. A perfectly voted "3" for precision with a mean of 100% with a full range from a low of 75% to a high of 125% while 2/3rd of the time the value would range between 90% and 110%.

The "accuracy" vote indicated the mean value for the distribution. This mean was then randomly shifted up and down in a pert distribution by the range indicated by the precision. Thus a 3-3 precision and accuracy vote would have a mean somewhere between 90% and 110%, while a 3-5 precision and accuracy vote would have a mean between 65% and 85%.

Correlations were created between alike line items (i.e. all labor items) at the nominal value of 0.5 for labor and materials and 0.75 for indirects. A correlation value of 0.0 means the two variables are completely independent, while a value of +1 means the values are perfectly correlated: that is, they move perfectly together (when the highest value for item #1 occurs the highest value for item #2 also occurs). A correlation value of -1 indicates the two values move perfectly in opposite directions (the highest value for item #1 always results in the lowest value for item #2). A value of 0.5 can be interpreted as that when line item #1 hits a high value, line item #2 hits a high value 50% of the time. Of the over 2000 possible relationships between range variables in both phase 1 and phase 2, over half had opinion-based correlations.

Each project specific risk was explicitly modelled with a unique, user-defined bi-nominal beta distribution for probability and a unique, user-defined triangular 3-point distribution for impact. These parameters were retained and used in the parametric methodology to ensure consistency. Systemic risks were taken from the risk register and mapped to cost impacts based on their qualitative evaluations. The list of systemic risks was "scrubbed" to remove duplicate items, schedule only impacts, and similarly themed risks and impacts may have been reduced to reflect cost impact of risks only.

Parametric Estimating Contingency Methodology

The parametric approach used was a hybrid combining a systemic assessment with the risk register. This approach is shown in Figure 10.

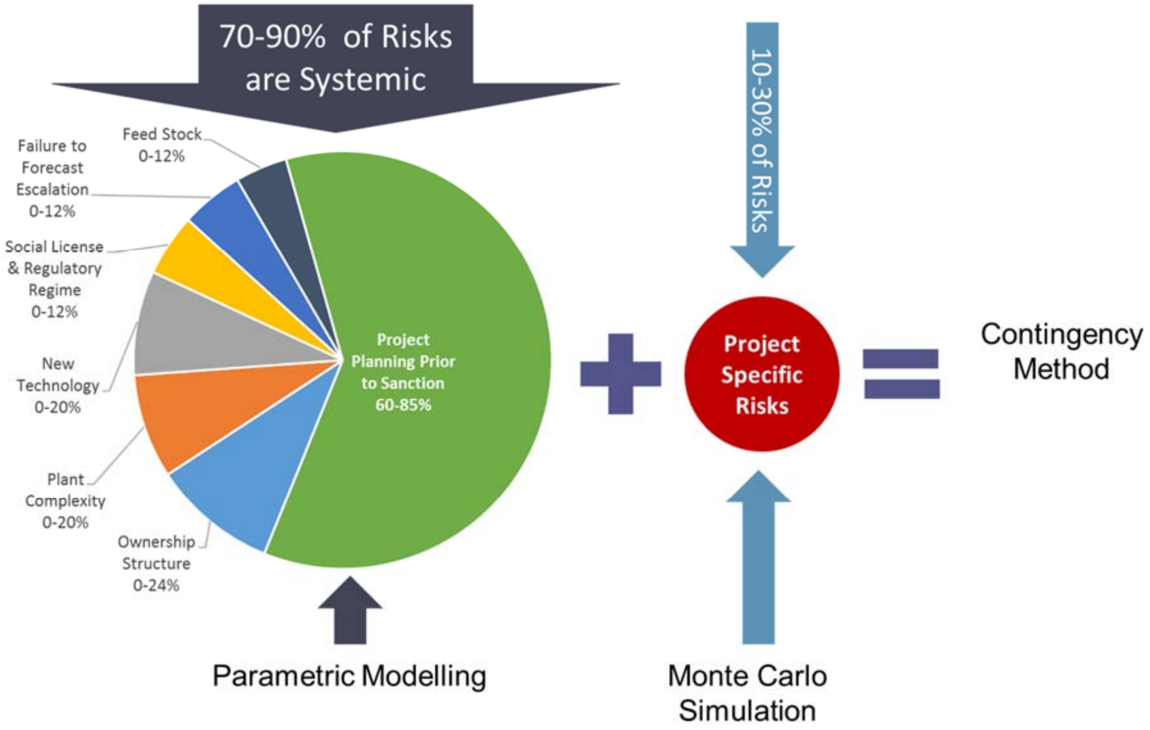


Figure 10: Parametric Contingency Method Used [18] [2] [4] [29] [26] [24]

The systemic tool was developed by the author and traces its roots back to the original Rand and Hackney models heavily augmented by subsequent research, AACE definitions, the Construction Industry Institute's project readiness index and the author's own experience on over $100B of project risk assessments [7] [21] [22] [23] [3] [24] [25] [26] [4] [27] [16] [8]. The assessment consists of 52 multiple-choice questions with answers ranging from not applicable through five steps of progressive development each described by verbal anchors that roughly followed from an unclassified estimate to something better than an AACE class III estimate. The topic areas and number of questions are as follows in Table 3:

Topic	Number of Questions	Types of Questions
Business Fundamentals	3	Commercial terms, business scope, business case
Scope Definition	2	Scope, mass and energy balances
Planning	11	Project Execution plan, regulatory, environmental social license, land contracting strategy, work breakdown structure, method of cost and schedule development
Design	11	Equipment list, reliability, control philosophy, utilities, inside and outside battery limits
Engineering	6	Process flow and instrumentation diagrams, geotechnical, design information
Project Team Disposition	8	Owner, design consultant, contractor, team size, work flows, aggressiveness
Reviews	6	Operations, construction, safety, bench marking
Risk modifiers	5	Technical complexity, new technology, feed stock, ownership

Table 3: Parametric Evaluation Topics

The weighting of each question is unique and the values to responses are not always linear. For instance, the importance of a single review question has more importance than a single planning question. The tool uses 52 questions with up to six different answers purposefully so that no single answer unduly skews the results and allows for a more holistic approach. In the author's experience on large projects it is not a single event or deliverable that endangers the project but the interaction of several deliverables or events. The range of the questions also tends to preclude a "legalistic" approach to reading the verbal anchors by participants. These discussions are inevitably connected to image protection and system gaming. The verbal anchors are consciously decoupled from explicit single AACE terms. For instance, in the cost estimating anchors there is no "class III" answer for the engineering firm to select, after all that is what their contract said they would deliver. Prior to the assessment session, all current as-is project deliverables are provided to the assessor to review and evaluate. This allows the assessor a degree of insight into where the project is actually at and provide better facilitation if the team is overly optimistic or pessimistic.

The assessment usually takes 2-4 hours to complete and requires the participation of the key members of the project team including members such as project manager, project controls, construction, operations, business development, regulatory, social license, engineering and construction. The assessor reads the question and allows the project team to discuss their project and decide which answer best reflects their current project progress. Often this discussion is of and in itself valuable to the team; acting as its own mini-project review. In one memorable pipeline project when the question on water arose, the team realized they had not planned on obtaining hydrotest water! Once the discussion is over, typically an expert led consensus occurs. The assessor, having reviewed the project deliverables and having insight into expected responses, gently challenges answers that are either too low or too high based on what they have seen demonstrated. The approach by the author is that of helpful facilitator rather than auditor: no one knows the project better than the project team and if the team wants to purposely mislead the assessor they will be fully capable of doing so. Finally, if there is any debate about a response the practice is to be conservative and select the lower developed answer. This is to accommodate the built-in conspiracy of optimism that seems to infect many project teams early in the life of a project.

Resource Requirements

The assessments for Phase 1 and Phase 2 were completed simultaneously. The hours required by the consultants was estimated at 277 hours and completed in 263 with total costs being approximately 15% less than estimated due to judicious use of junior staff. Consumed hours by task are shown in Table 4.

Task	Estimated Hours
Project Initiation	5
Risk Management Plan	3
Attendance of Project Team meeting(s)	6
Risk Identification Interviews	36
Risk Response Planning	15
Risk Response Review Session	25
Systemic Contingency Assessment	15
Range Estimate Assessment	85
Report Out	25
Travel	40
Extra	8
PROJECT TOTAL	**263**

Table 4: Consumed Consultant Hours

Figure 11out lines the consultant time requirements for each of the two methods, jointly as they were completed and in hypothesized standalone sessions (but still based on actual project hours). The left-hand side of the graphs indicates approximately half of the time was equally shared between the two contingency methods - including tasks like project set up, risk management plan, document review, risk register creation and travel - with 40% dedicated to range estimating, and the remaining 10% dedicated to the parametric approach. The conclusion that range estimating takes four times the consultant hours as parametric is misleading. The right-hand side of the graph separates the hours required to have independently completed a standalone range estimate and a standalone parametric assessment. With this lens, parametric assessments require approximately half the consulting effort of range estimating. When both methods are completed at the same time the synergy is significant, resulting in the incremental effort to complete a parametric assessment in addition to a range estimate being only 10%.

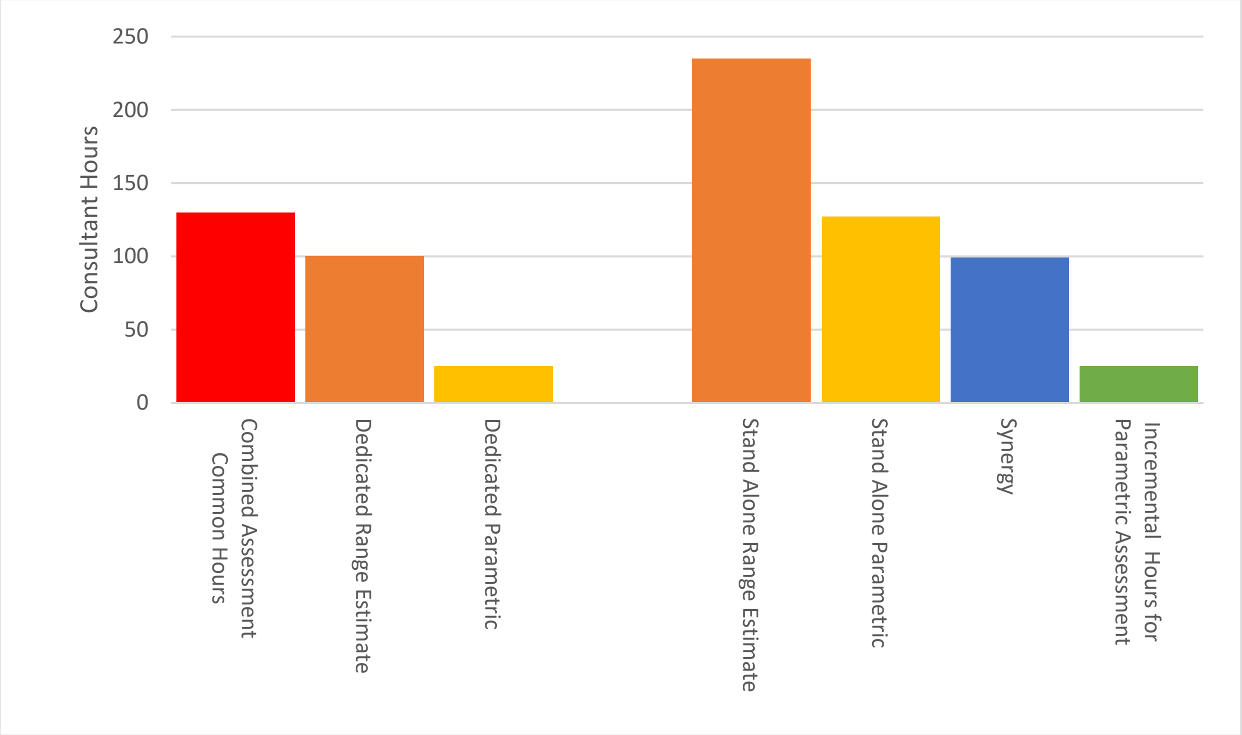


Figure 11: Break Down of Consultant Hours

Consultant hours are only a fraction of the total costs of completing any contingency assessment. For every consultant hour expended on this project, roughly a project team member hour was consumed, typically in meetings. Key to containing costs in a contingency assessment is the effective use of project team time and meeting efficiency. For this project, the risk register was developed by consultant interview of team functional leads rather than a whole team risk identification meeting. In the author's experience the interview approach generates a suitable risk register consuming roughly the same consulting hours but at 60-90% reduction in project team hours[1]. Similarly, the use of I>clickers, as discussed in the methodology, cut project team evaluation time in half. Figure 12shows consumption of project team hours. The complete

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[1] One project team hour, is one hour of every functional leads' time on the project team. The project team comprised of roughly 10 members excluding the risk consultant. Project team hours cost ~$1500/hr.

contingency assessment consumed 24 project team hours. If the two assessment approaches were used independently, range estimating would have consumed 21 project team hours while the parametric estimate would have consumed 9. Even using the I>clicker time-compression methodology, range estimating consumed over twice as much project team time as the parametric approach. Without the use of I>clickers it could easily have been three times as much. Completing both assessments methods at the same time provides significant project team time synergy (25%), but when viewing the parametric approach as an add-on the range estimating the incremental time requirements are under 15%.

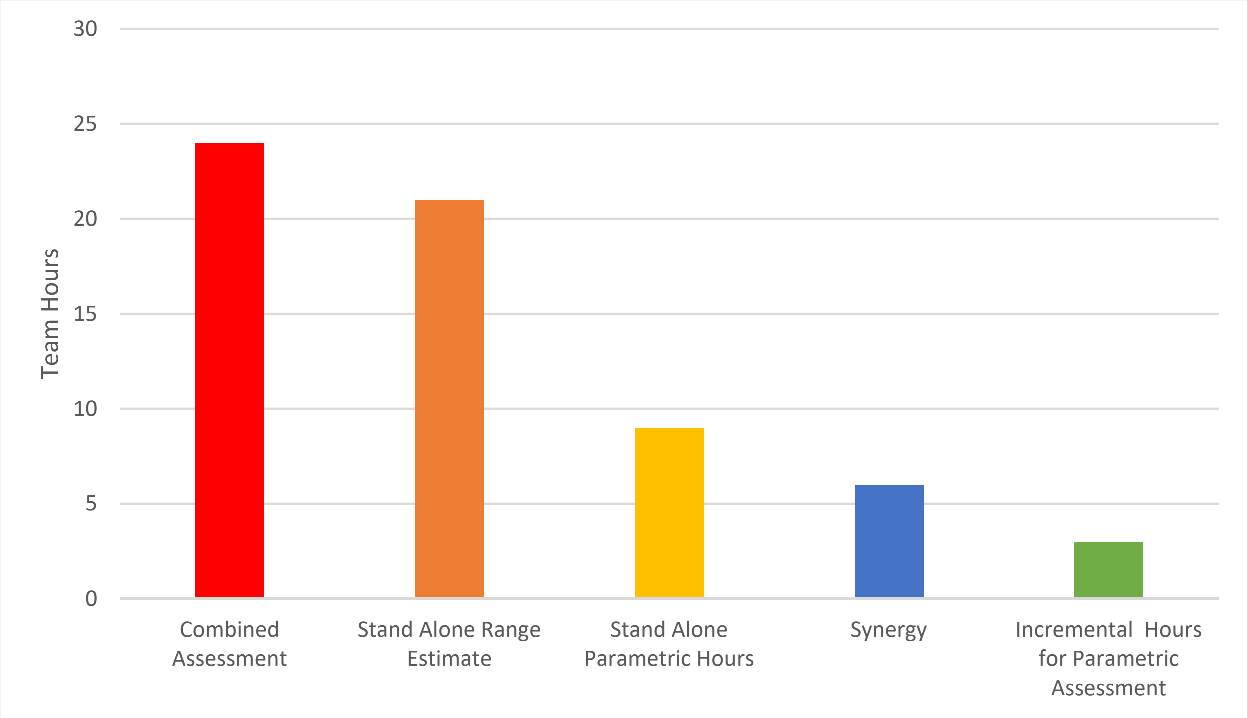

Figure 12: Consumed Project Team Hours

Contingency Estimating Results

The contingency assessment results are graphically shown in Figure 13 and Figure 14. Conceptually, that two approaches match what is predicted by theory and prior papers: the P50 costs are similar, however the range of possible cost outcomes predicted by the parametric approach is significantly wider. In both cases the parametric method predicts cost ranges that are much wider, over twice as wide at the range estimate in phase 2, and these ranges extend beyond both the upper and lower P10 and P90 bounds of the range estimates for both phases.

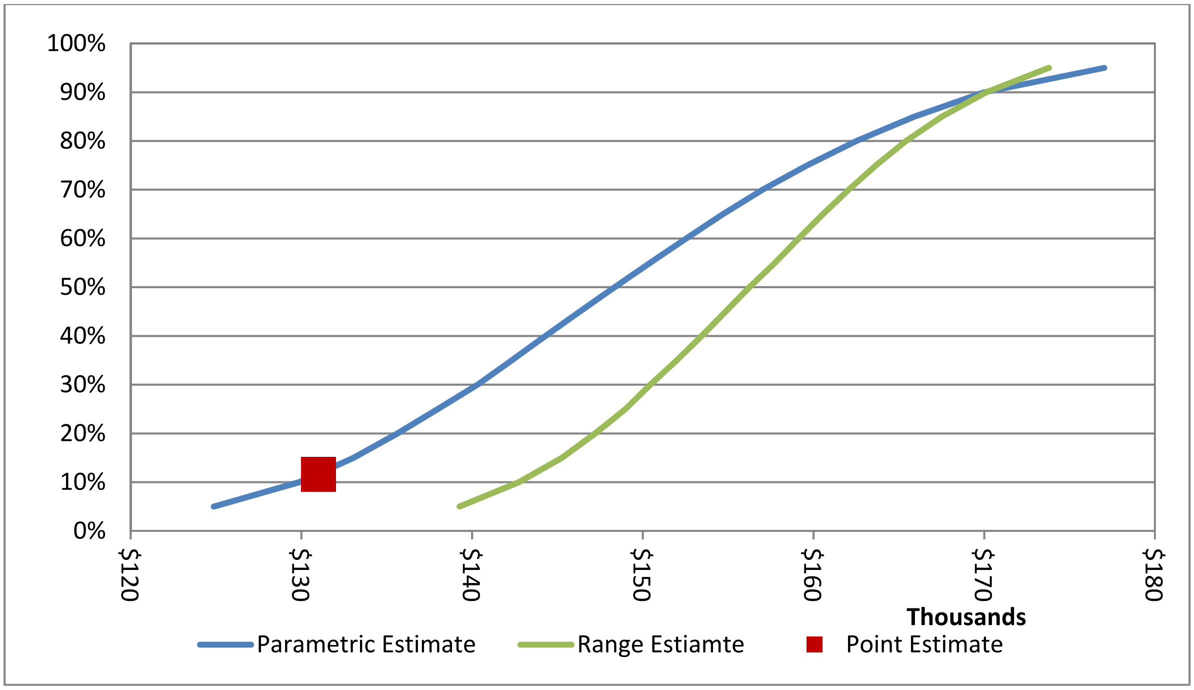

Figure 13: Phase 1 CFD Range and Parametric Estimates

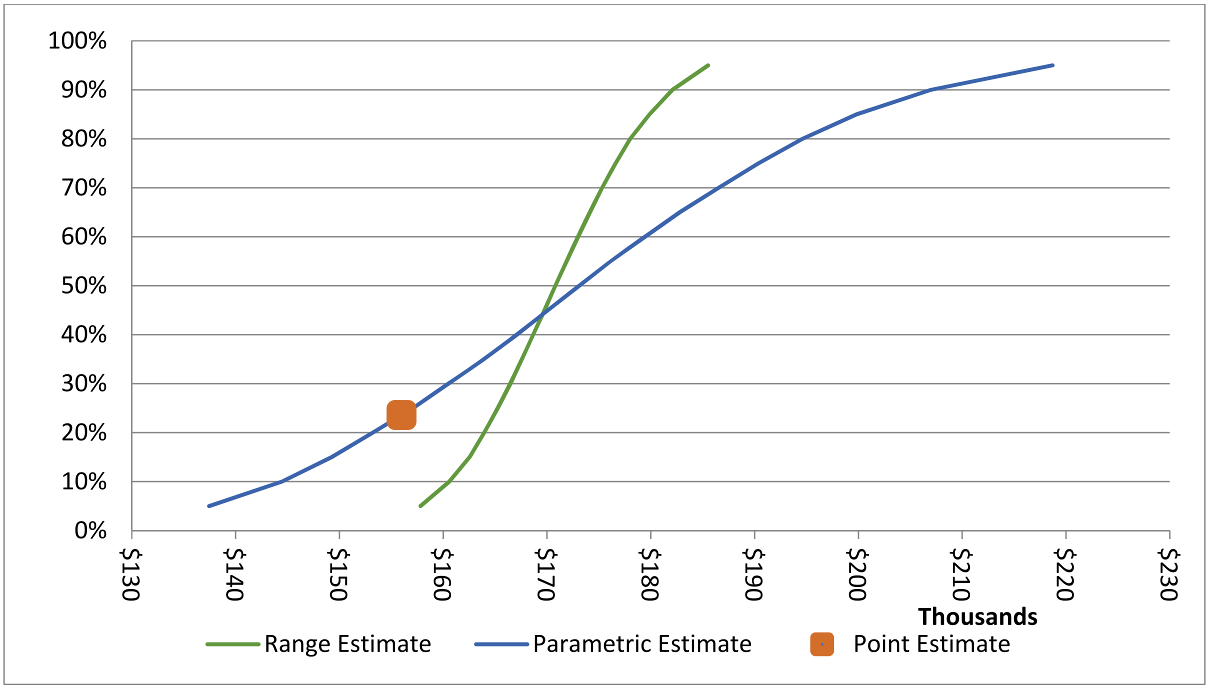

Figure 14: Phase 2 CFD Range and Parametric Estimates

The phase 1 range estimate does not immediately align with theory: its mean cost prediction is considerably greater than the parametric approach. The source of this variance is illustrated in Table 5 and Table 6that show the base estimate, the contingency driven by the range estimate, the contingency drive by systemic risk (either through parametric assessment or estimated risk register items from the range estimate approach) plus the common project specific risks. To make the two methods comparable in results, the "systemic" risk is evaluated by the parametric model are comparable to the sum of the risk register identified "systemic" risks plus the range estimating from the range model. It should be noted that the relative high degree of project specific risk for both projects is abnormal and is a result of the risk-decision making process. Certain items were considered "risks" during the session when in fact they could be considered as identified omissions. For example, the Phase 2 rail base estimate excluded a shunting engine, when one was required with the current operations plan, and neglected to capitalize the cost of plant shutdowns to enable tie-ins. In all, Phase 1 had four "almost certain" project-specific risks with a total expected value of $4.6MM and Phase 2 had six risks with an expected cost of $3.2MM.

Line Item	Range Estimate Expected Value ($MM)	Parametric Expected Value ($MM)	Variance ($MM)
Base Estimate	$130.9	$130.9	$0.0
Range Estimate Risk	$7.5	$0.0	$7.5
Systemic Risk	$14.9	$8.1	$6.8
Project Specific Risk	$10.3	$10.3	$0.0
Total	$163.6	$149.3	$14.3

Table 5: Phase 1 Breakdown of Contingency

Line Item	Range Estimate Expected Value ($MM)	Parametric Expected Value ($MM)	Variance ($MM)
Base Estimate	$156.0	$156.0	$0.0
Range Estimate Risk	$1.4	$0.0	$1.4
Systemic Risk	$4.7	$11.4	-$6.7
Project Specific Risk	$9.0	$9.0	$0.0
Total	$171.1	$176.4	-$5.3

Table 6: Phase 2 Breakdown of Contingency

Actual Project Results

At the time of the writing of the paper the much-delayed project review is underway. It is hoped that prior to final submission actual project costs will be known. While Phase 1 over ran this P50 estimates, current values on Phase 2 are much higher than expected – over $200 MM, well past the P50s of both methods and out of the P95 value for range estimating.

Like many major projects, bad things happened. Subsequent to the completion of phase 1, three major events occurred. First, the assumptions on civil earthworks cut and fill will incorrect for a variety of reasons and an additional 1 m of site fill was required costing tens of millions of dollars.

Secondly, the project management firm was removed from the project. While this risk was identified in the risk register as one with serious consequences – its expected value was twice that of the second largest risk - it was carried in both the range and parametric estimates weighted by its probability. Since the risk occurred it cost more than its expected value funded by contingency. Finally, the business scope of the debottlenecking and expansion increased by 50% significantly changing phase 2 project costs. While the first two events could be possibly parsed out and tracked back into the estimates, the change of phase 2 business scope is extremely difficult to break out and was not attempted by the host company.

Critique of Case Study Methodology

The main criticisms of the approaches used are:

1. Bias,
2. Lack of group risk identification, and
3. Limitations imposed by standard ranges.

Going into the analysis the author was biased towards the parametric approach, believing it to be better, faster, cheaper. In doing this the range estimating approach may have been unduly penalized both subconsciously and by their greater expertise with the parametric approach.

Risk identification is traditionally completed in a group setting with a focus on divergent thinking and facilitated brain-storming [11] [20] [28]. This approach allows for a better inter-play between functional experts and, the longer duration, facilitated, structured format does create larger, more potentially complete, risk registers. The interview approach used still allows for team discussion, but only of key risks. This discussion and quantification provides an opportunity for team interaction and synergy but on a more focused level. The larger question is, "Are the increased resources required for group risk identification sessions worth the increased results?" If so does this unfairly penalize either approach? It is the author's opinion that a well facilitated interview-based risk identification approach is great value for money, providing a risk register that is only 10-30% smaller than the group approach but still captures all the main risks.

Risk identification interviews in this application provided substantially the same amount of risk items as the risk workshop approach. While no two projects are identical, Figure 15is a sampling of risk registers completed by the author for projects in excess of $50MM showing the risk identification method, number total risks identified and number of unique risks. With this limited sampling, there is no obvious conclusions to be drawn as to the quality of risk identified, however both methods are clearly capable of generating the same volume of risks.

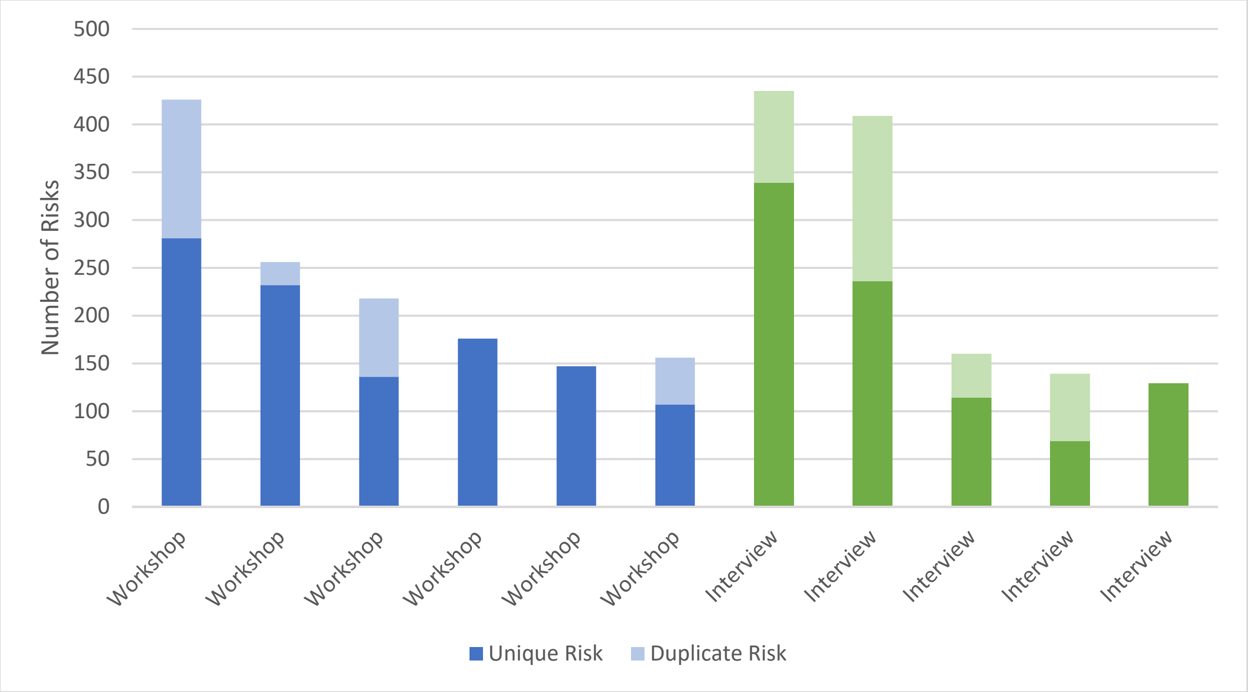

Figure 15: Risks Identified by Risk Identification Method

The use of I>clickers with standard accuracy and precision ranges may have in-appropriately narrowed team member's opinions on ranges. While there was an opportunity for team members to object to the pre-defined ranges, this did not typically occur. Possible reasons include [20]:

1. Group social norms - the desire to keep the meeting moving along and resentment for unnecessary delays – range estimating can be a tedious process at the best of times!
2. Fear of repercussions - as the I>clickers provided anonymity, making any infrequent objections more visible.
3. Fear of missing expectations – the group has externally-driven expectations as to the accuracy of the line items. Requesting a range outside of 25% can give the impression of incompetence or artificial inflation of values.

The actual variation in anonymous polling for accuracy and precision are shown in the heat-maps in Figure 16 and Figure 17. The darker the color the more frequent that combination of accuracy and precision was selected. It is evident that both phase 1 and phase 2 assessors were reluctant to identify WBS tasks with the worst possible accuracy and precision scores, and a general shying away from any extreme values: the central limit theorem at its best! Of interest is that the Phase 1 team was more willing to provide extreme values than the phase 2 team, yet it was Phase 2 that had the worse project cost outcomes. Of course, this is the critical point of view and it may be possible that Phase 2 just believed they had better estimating processes.

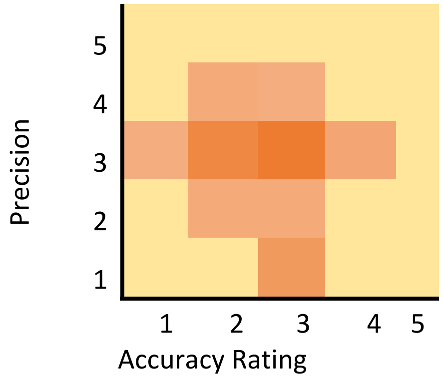

Figure 16: Phase 1 Heat Map of Accuracy and Precision

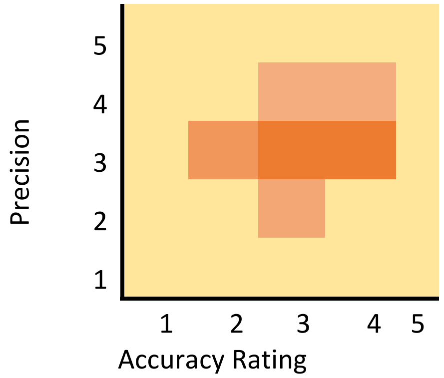

Figure 17: Phase 2 Heat Map of Accuracy and Precision

The I>clickers time savings may have not been worthwhile as it may have artificially truncated WBS task ranges. To test their hypothesis a range estimating workshop could be held, with the first half of task estimation being completed in a traditional workshop setting and the second set using I>clickers. An improvement to the I>clicker approach could also be to use ranges that are greater than 1-5, possibly 1-7 or 1-9 to provide emotional permission to select values at the further edges.

Alignment with AACE Risk Principles

AACE's recommended practice for contingency estimating consists of 10 principles outlined in Table 7 [5]. Both applications of the range and parametric estimating methods used in this case study substantially met all of these principles.

Principle	Range Estimate	Parametric
Meets client objectives	Yes	Yes
Part of risk management process	Yes	Yes
Fit-for-use	Yes	Yes
Identifies risk drivers	Yes	Yes
Links risks to cost outcomes	Yes	Yes
Avoids iatrogenic (self-inflicted) risk	Limited	Mostly Yes
Employs empiricism	Limited	Yes
Employs competency	Yes	Yes
Provides probabilistic results	Yes	Yes
Supports decision making	Yes	Yes

Table 7: Evaluation of AACE Principles of Risk Estimating

It is the author's opinion that of the two methods, in their application to this project, both suffered from iatrogenic (self-inflicted) risks. The heuristics required to complete a contingency assessment (in fact are one of the recommended principles; competency), intrinsically create iatrogenic risk and bias. If the best approach is to simply limit the impact of these shortcomings, the parametric approach is the better solution as it typically limits heuristic risk to project specific risks. Finally, in the range estimating method employed, empiricism was assumed to manifest in various expert's opinions while in the parametric methodology it was explicitly identified through the use of historic cost outcomes.

Conclusions

The conclusions of this single case study are:

1. Both range and parametric estimating provide probabilistic results.
2. Parametric estimating provides a wider range of possible cost outcomes.
3. Range estimating can preclude predicting worse case cost outcomes.
4. Range estimating can be more subjective and vulnerable to heuristic bias.
5. Parametric estimating requires less than half the consultant hours of range estimating.
6. Parametric estimating requires less than a third of the project team hours.
7. The incremental effort of completing a parametric estimate when a range estimate is being completed is negligible.
8. Use of I>clickers polling of predetermined accuracy and percussion ranges reduces the project team time requirements for range estimating.
9. Risk identification interviews are a cost-effective alternative to team sessions

Parametric and range contingency estimation methods both provide substantial insight into projects through the use of a risk register - partial quantified for parametric assessment and completely quantified for range estimates – and probabilistic results. As expected the total cost range predicted by the parametric approach is substantially wider than range estimating. In this case study, the parametric estimate provided a higher P90 value than range estimating, but was more interesting is that it also provided a lower P10 value. It would appear that the parametric approach not only provides increased cost pessimism, but also can provide some cost optimism. While it is a simple matter to run either model 1000 times independently, it is impossible to run the actual project that many times to assess which contingency method is truly more accurate. However, while both models for phase 2 provided similar expected values, the actual cost out come on phase 2 – a blow out by some opinions – was only approached by the parametric method. If this case study is representative of all projects, then the parametric contingency assessment method provides a more accurate range of possible cost outcomes.

In mapping the parametric estimate of systemic risk to the range estimate values and the risk register systemic risks, we can see notable differences in the project teams' outlook on phase 1 compared to the cost outlook on phase 2. While this subjectivity could be interpreted as project insight, it appears that this insight was askew and did not provide nearly enough contingency for phase 2.

The most startling observation in this case study is the significant difference in resource requirements for each contingency method. Assuming consultant hours are a reasonable proxy for an Owner's out of pocket expense, parametric estimating has a clear advantage: a cost of nearly half that of range estimating. With typical project team costs running north of $1500 per hour, Consultant hours comprise less than half of the total cost of a risk assessment. With this accounting the advantage of the parametric approach increased with almost 2/3rds less project team hours than range estimating. The true cost and time advantage of parametric over traditional range estimating is likely even larger as the use of I>clickers dramatically reduced the project team hours required to complete the range assessment. Without the I>clicker advantage, parametric assessments could easily require 75-80% less resources than a traditional range estimate.

If an owner is wed to range estimating, this case study clearly demonstrates that the addition of a parametric assessment to an existing range estimate only increases the total assessment cost and time requirements by a mere 10%. This additional project insight is worth 10% in the author's opinion.

Neglecting costs, the speed of parametric assessments offers its own advantages. Contingency assessments are often completed just prior to key project milestone dates such as project sanction. It is the author's experience that the two weeks before the AFE submission, next to commissioning, are some of the busiest times in the life of a project team. Owners must ask the question whether an extra day or two of time required by a range estimate during these critical windows is better spent in team-based constructability, operability, value engineering, cost or schedule reviews. It is the author's opinion that if it is only one or the other, the later activities will provide a better chance of project success than an extra few days of range estimating.

In conclusion, the parametric approach provides significant time, cost and accuracy advantages over a traditional range estimate solution.

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Matthew Schoenhardt, P.Eng. MBA, PMP, RMP
Principal, MS Consulting
mschoenh@telus.net

Vachel Pardais, RMP