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Parametric Contingency Estimating on Small Projects

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Abstract

Recommended practice 43R-08, Risk Analysis and Contingency Determination using Parametric Estimating applies historical empirical data to estimate contingency. This Parametric contingency method has clear advantages over other AACE recommended practices for mega-projects including speed, accuracy and cost effectiveness. While mega-projects capture the attention of executives, shareholders, media and researchers, the sheer quantity of many companies' "small projects" can eclipse the capital spend of a single mega-project. For most companies, small projects are the foundation of sustained and incremental profitability. The size of "small projects" often precludes detailed contingency assessments by project managers while their puny stature renders them unattractive to academic research. As a result many firms solve this problem by simply applying 10% contingency across the board to small projects, regardless of the project's actual risk profile. This paper outlines a pioneering solution: a small-project systemic contingency tool. This paper will review how a Canadian midstream oil and gas company solved the problem of small-project contingency assessments using a parametric approach using in-house data.

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Introduction

Significant effort and research has been expended understanding the cost behavior on large and mega-capital projects. These marque projects immutably change careers and corporations. While landmark projects create step-wise change for corporations, it is the small, sustaining capital and incremental productivity projects that underwrite a corporation's long-term financial promises and prospects. While these large projects can easily justify the funds to develop and implement a detailed risk management and contingency assessment processes - the consequences of failure are simply too large - no small project individually can afford to spend the funds required to complete a comparable level of assessment. A simple range-estimate session can easily cost over $25,000 between consultants, engineers, contractors and the project team. While no single small project will likely change the course of a large corporation, their aggregate impact is unquestionable. Between 2013 and 2016 Suncor spent 45% to 55% of its annual capital program on sustaining capital ($3.2B to $4.5B respectively in absolute spending on sustaining capital) [1] [2] [3] [4]. With so many small projects the natural solution is to develop a process. Many corporations do have an automated process for contingency on small projects: blindly apply 10%. Is this the correct amount? Is there a better way? These questions are seemingly exclusively saved for the marquee projects. This paper will demonstrate how a Canadian mid-sized midstream oil and gas company developed and implemented a parametric contingency method on small projects.

This paper will provide background to the situation by: reviewing the root causes of cost over runs on large and mega-projects; describing and evaluating various contingency assessment methods; illustrate the differences between large and small projects; and, how these differences influence their cost outcomes. The paper will then: develop a problem definition; detail the methodology used to resolve the problem at a mid-sized Canadian midstream oil and gas company; and, describe the solution. Finally, the paper will discuss the need for cultural change management, the impact of management policies and outline areas of future work.

Common Risk Root Causes

Beginning with the original RAND studies and subsequent demonstrate that there are seven primary drivers for cost variance on large projects. These root causes, shown below, are systemic and common almost all large capital projects [5] [6] [7] [8] [9] [10] [11]. The seven factors and their relative importance are listed below and illustrated in Figure 1:

1. Project planning prior to project sanction
2. Ownership structure
3. New technology
4. Plant complexity
5. Regulatory regime
6. Failure to forecast escalation
7. Feedstock

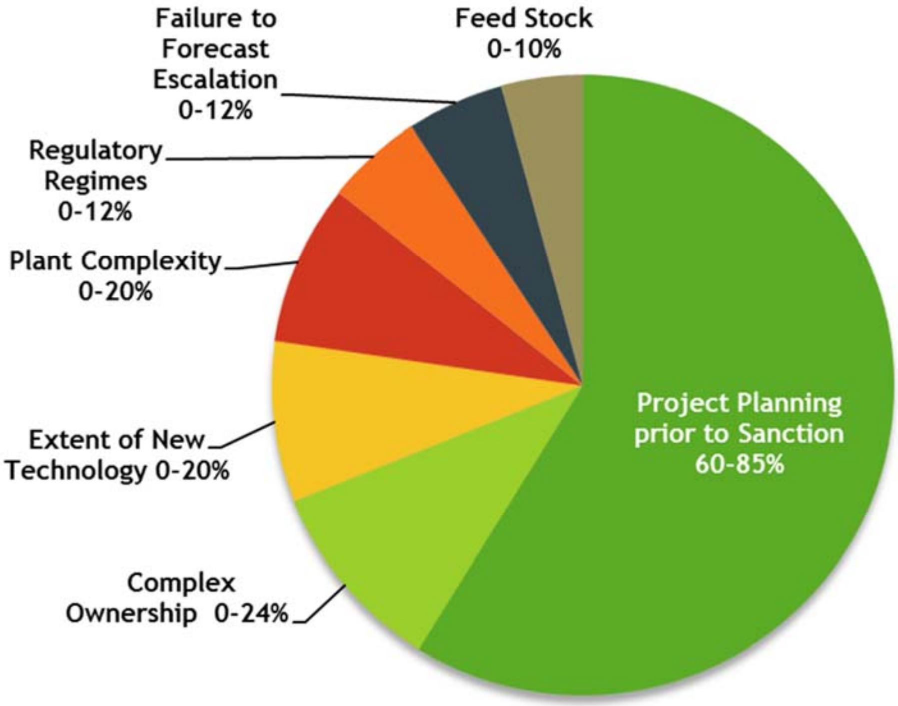

Figure 1: Seven Primary Drivers of Cost Variance on Large Projects

As Figure 1 indicates, the single largest driver of large project cost outcomes is amount of effort prior to sanction. As project definition increases the lower the average cost overrun and the more narrowly distributed the cost overrun becomes as shown in Figure 2 [12].

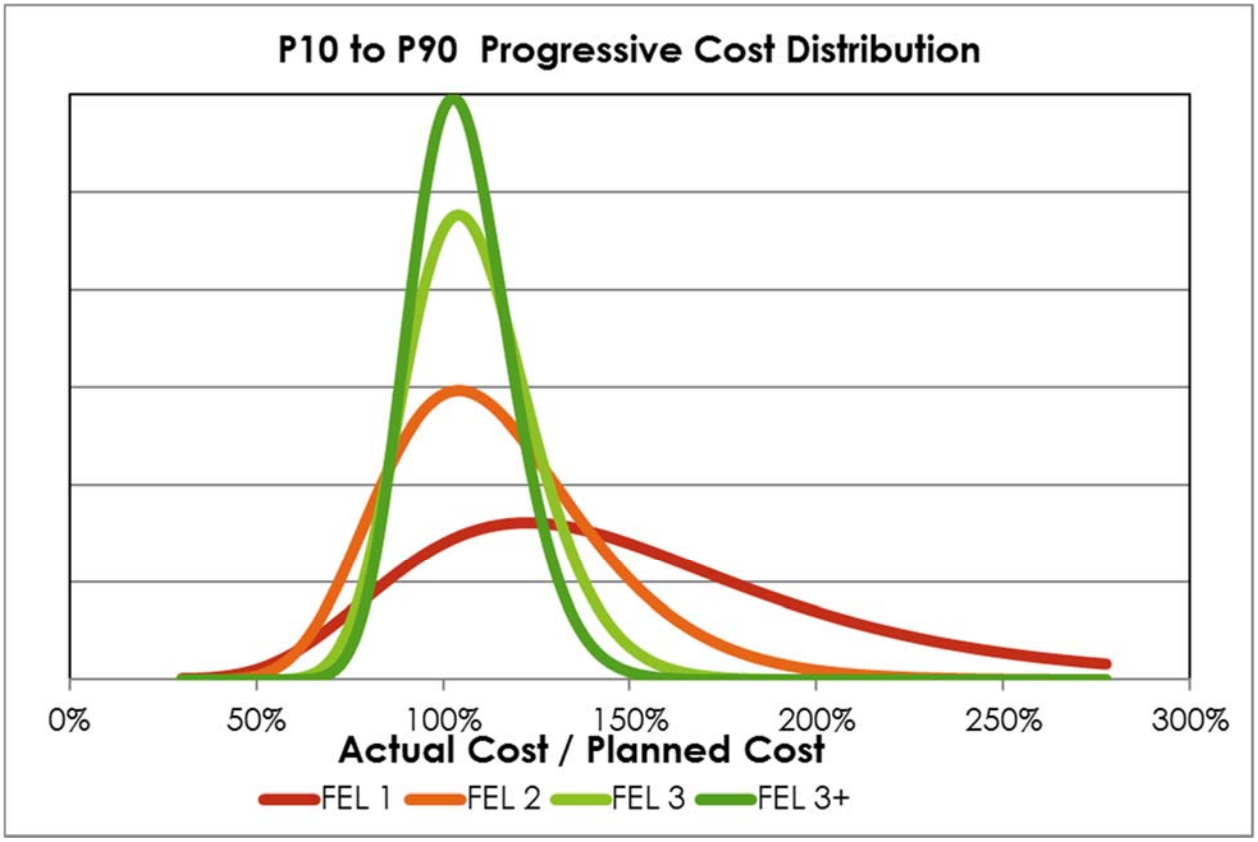

Figure 2: Cost by Level of Project Definition

This framework explaining root causes for cost variance has been qualitatively applied to 20 years of Alberta's oil sands mega projects [13] [14] [15] [16] [17] [18]. As expected the massive cost overruns encountered are supported or even predicted by these methods. This study [13] of a petro-chemical plant in Alberta during this time frame also showed that geography is not destiny. The reference mega-project qualitatively avoided the common root causes and embraced industry best practices and came 15% under budget [16].

Contingency Methods

There are two main basis to assess how much contingency a capital project requires: opinion and empirical. Each of these two basis can be applied with either a simple or sophisticated methodology. These four methods, shown in Figure 3, can be used independently or in combination. The four methods are [19] [20] [21] [22] [23] [24] [25] [26] [27]:

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

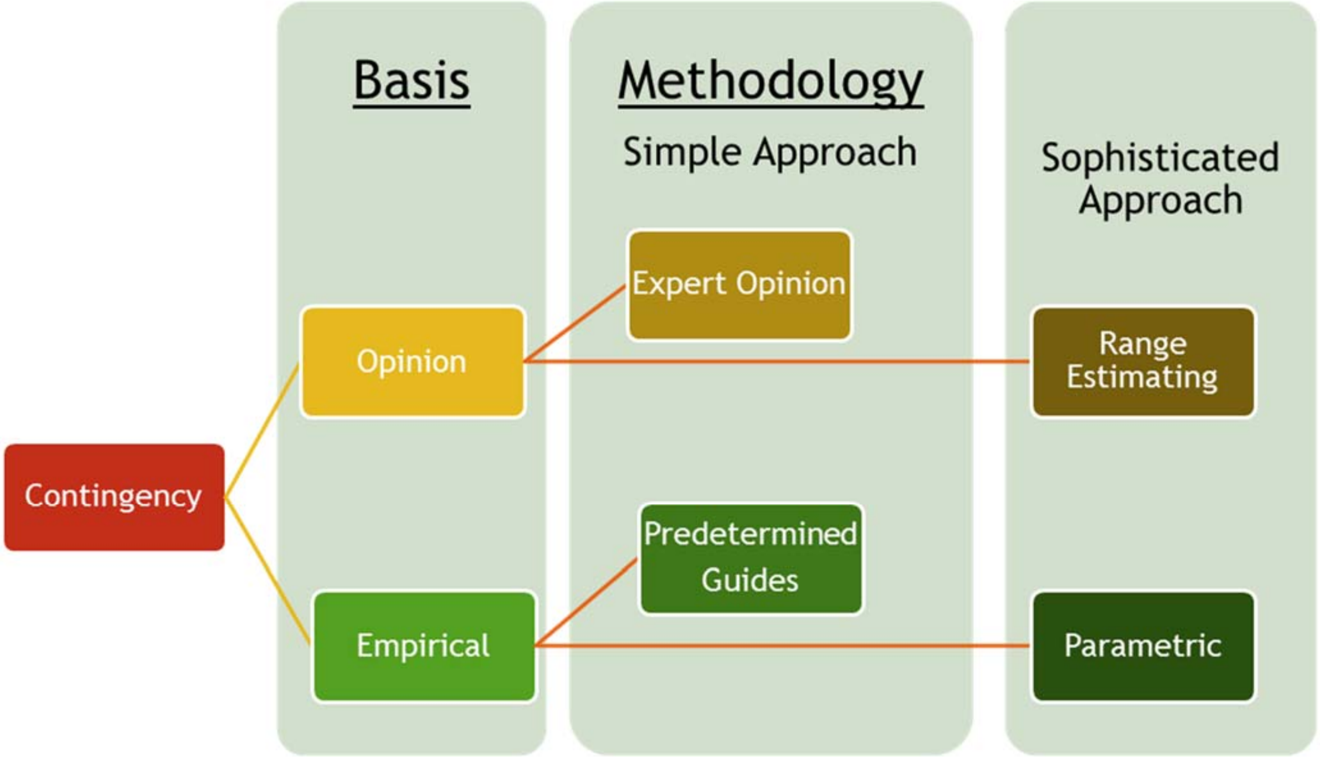

Figure 3: Contingency Assessment Approach Families

Each of the four methods offer different cost and benefit relationship. Risk and contingency management are a subset of project controls and, in many respects, project controls is the front line of risk mitigation methods. As such the "right" degree of project controls is wholly dependent on the scope of the project, the consequences of project failure and the risk tolerance of the organization [27].

Opinion Basis: Expert Opinion

The simplest, lowest cost and quickest method of risk assessment is Expert Opinion. To obtain the "expert" opinion contingency, one simply asks a subject matter expert(s) suitably familiar with the project [21]. While speedy and implicitly accounting for project risks, this approach has both agency issues and prone to heuristic bias – both optimistic and pessimistic. As a result, Expert Opinion contingency assessments are not repeatable in time on a single project, nor comparable between different projects. A method to address some of the heuristic bias is to employ the Delphi technique, polling several experts independently. This may increase the accuracy of the estimate, it also increases the complexity of the process undermining its key strength.

Opinion Basis: Range Estimating

Range Estimating is a Monte Carlo approach illustrated by AACE recommended practice 41R-08 [28]. In this approach the work break down structure (WBS) is reviewed in detail with ranges or distributions created for each line item's quantities and unit rates costs and durations. To these calculations project risks are added from the risk register with quantitatively defined probability and both cost and schedule impact ranges. A Monte Carlo simulation is then applied that provides an apparently very mathematical distribution curve. This appearance is misleading.

Ideally the variables ranges in a Monte Carlo simulation are data-based. In practice this is almost never the case. Typically variable ranges are ultimately drawn from the project team's tacit and Expert Opinions. This data source means the foundation of a typical Range Estimated contingency is identical to Expert Opinion: someone's best guess, albeit disguised with excessive math. Rather than asking subject matter experts' for a range or value for the total installed cost of a project, Range Estimating instead asks for a range on many different line items and adds them up.

Even when bolstered by project-specific risk register, Range Estimating has a number of short comings. First, it is labor intensive. A Range Estimated contingency can easily take several days of the project team's time when it is least available – days after the cost estimate is complete and days before AFE approval. Second, for the ranges of risks to be accurate, the user must estimate risks that are by definition both unknown and unquantifiable. For example in order to correctly model the risk of late engineering drawings, a subject matter expert must give a probability and impact distribution. That this is impossible almost self-evident: if an SME knew which drawings would be late and the consequence of lateness, they would take corrective action. Third, the evaluation of "black swan events" is inherently underestimated [29]. Fourth, simulations are bound by the central limit theorem: increasing the number of independent variables decreases the possible range of outcomes [30]. Too often inexperienced modelers will increase the level of model details expecting to improve their model's accuracy but with the counter-intuitive result of making the model less accurate. This can be partially corrected by a robust correlation matrix. For instance, the price of rebar is independent of labor rates but is strongly correlated to the price of structural steel, pipe and conduit. As the ease of the software has increased over time, the abundance of "amateur" individuals performing Monte Carlos has increased. Just as owning Microsoft® Project[1] or Oracle® Primavera P6™ does not make one a scheduler, much less a planner, so too the use of Palisade @Risk® does not guarantee an accurate contingency assessment. The key difference between an accurate Range Estimated contingency and an inaccurate estimate boasting pretty graphics is found in a detailed correlation matrix. Finally, without exclusive reliance on real data Range Estimating is has more iatrogenic risk (risk created by the process through faulty practices) than other three methods. All of these issues lead to simulation results that predict smaller cost outcomes than those that are actually incurred by real projects [31].

In the same vein of quantitative approaches to risk analysis are Expected Value, Event Modelling and Fault Tree Analysis [21]. Like Range Estimating, these approaches are mathematical in approach but focus on explicit events, risks or competing scenarios. The resulting analysis may be static such as traditional expected value, or probabilistic as the result of a Monte Carlo simulation. These techniques are excellent for evaluating discrete events and those with mutually exclusive outcomes. Like Range Estimating, these approaches tend to do a poor job at evaluating systemic project risks that have been shown to drive the majority of large project's cost variance.

Empirical Basis: Predetermined Guidelines

The second family of contingency methods eschews opinion and focuses on empirical data. The two siblings of data-based approaches are predetermined guidelines and Parametric. At their heart both techniques correlate the project's level of definition with historical or typical cost outcomes.

Predetermined guidelines are the most common industry method of determining an estimate's accuracy as described by AACE Cost Estimate Classification Systems 17R-97 [21] [32] [33]. Why these guidelines are accurate, or where the source data came from, maybe lost to time. The approach relies on the concept that the more defined a project is, the more accurate the cost and schedule estimates are. This correlation is both well documented and stands the test of time [5] [6] [7] [8] [9] [10] [11] [34]. A class III estimate typically has a cost accuracy range of +30 to -20% [20]. This tends to be true assuming and that the engineering and other deliverables have been created as a class III estimate requires completed P&IDs, single line diagrams, finalize plot plans, layouts and more. Herein lies this approach's key failing in application. It is the method of creating the estimate - the level of effort and detail in project deliverables - that creates an accuracy range. Too often owners and engineers alike treat estimate accuracy as the first deliverable, rather than an outcome of deliverables. The class of estimate is determined by its estimating method, not its accuracy. For instance, one can use a class V estimating methodology (analogous or referential estimating using key parameters – number of bedrooms, bathrooms, size, property type and location) to provide ± 10% accuracy for purchasing a resale home simply by using Multiple Lister Service (MLS) [42]. The second main source of error in this approach is that a Class III estimate requires not only engineering deliverables, but also deliverables for environmental, regulatory, stakeholder engagement, procurement, operations, finance, marketing, human resources to name a few and typically these deliverables, if created and suitably detailed, are not integrated with engineering.

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[1] Microsoft® Excel® are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries

Empirical Basis: Parametric

Systemic Contingency, or Parametric modeling, as defined by AACE RP 43R-08 [35] compares the current project's level of development with historical reference project's cost and schedule outcomes. Grounded in the concept that projects are not unique in their behavior, cost or schedule outcomes, this approach assumes they all share the same main sources of systemic risk (as previously discussed in Common Risk Root Causes). Unsurprisingly, all projects suffer from systemic risks: weak project controls, staff turnover, incorrect or missing drawings, weather delays, late equipment as a partial listing. The Parametric approach relies on a database of historic project results that includes their level of project definition prior to sanction, its final cost and schedule outcomes, and some accounting for realized project specific risks. The project in question is then compared to the database to give possible cost and schedule outcomes. To this range of outcomes project specific risks can be added. In the author's experience on hundreds of projects totaling over $100B, less than 10% of identified risks are truly unique and can be considered project specific risks. Project- specific risks often are created by the project's constraints and assumptions.

The Parametric approach is faster, cheaper and more accurate than a typical Monte Carlo assessment [31] [36], however it does have some draw backs. First, Parametric contingency estimates lose accuracy after the detailed design stage is complete and do not seem to be accurate for short-term schedule estimating. This could be addressed by larger databases that include project definition levels post sanction. Second, the development of a Parametric process is reasonably complex, requires periodic calibration, and historical data that is hard to obtain or only available for large and mega-projects. Creating such a system for a single project would require more effort than possible benefit. Finally, the approach is rooted in the notion that projects are not unique, nor are we better at managing projects than our predecessors. While a project's objective is unique, the processes that drive capital projects to conclusion are seemingly unchanging. Systemic contingency, when coupled with a detailed risk register detailing its project specific risks, provides a fast, risk-based, probabilistic contingency assessments.

Comparison of Contingency Methods

Figure 4 below provides the author's comparative opinion on the four main methods of contingency assessments. [13] [36] While Range Estimating and Systemic provide the highest level of insight, the speed and improved accuracy of the systemic method makes it preferable. The author once had an unbelieving project manager who insisted on completing both the Parametric and Range Estimating approaches at the same time on the same project. The results were exactly as literature would suggest: Range Estimating took triple the amount of the team's time, cost three times as much and provided similar mean contingency values as the Parametric approach but a much narrower range of possible outcomes.

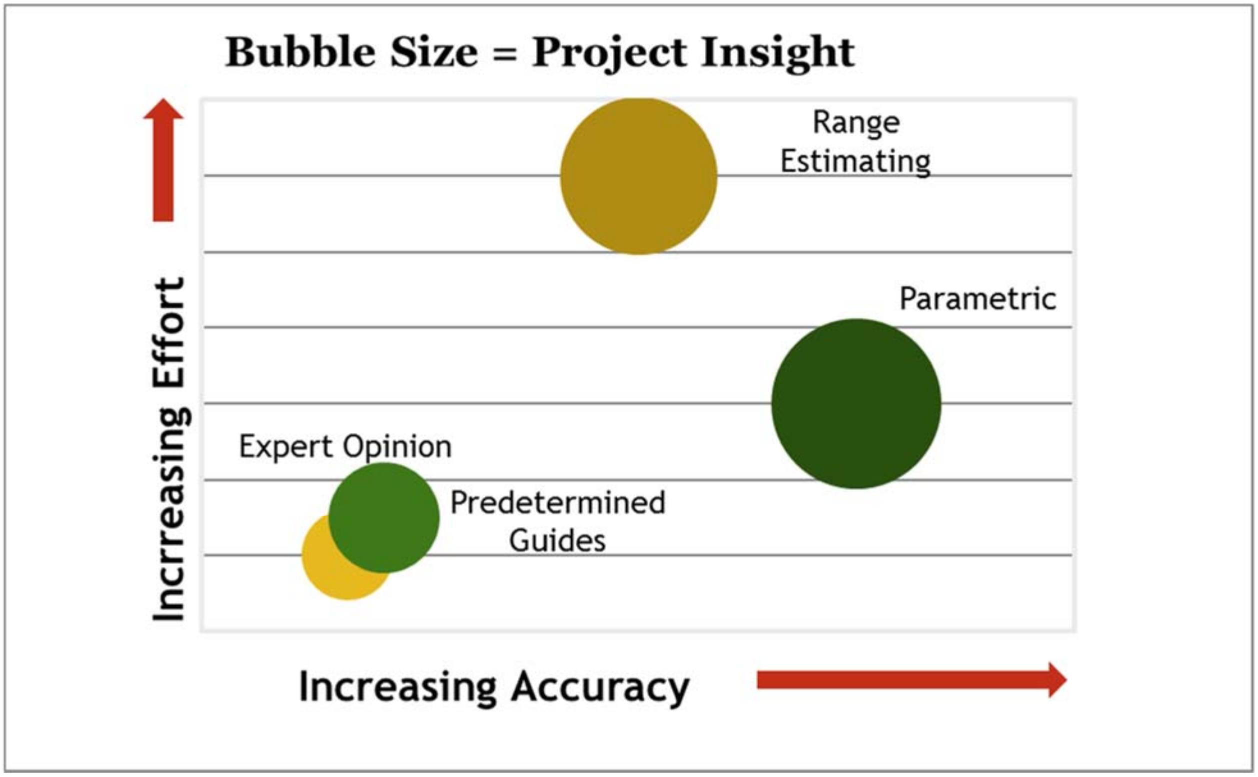

Figure 4 Comparison of Contingency Assessment Methods

Contrast of Large and Small Capital Projects

Large and mega-projects capture the attention of media, executives, investors and academics. They provide step-wise change to an organization's assets and performance. With project teams of over 100 staff, large projects have all the organizational complexity of a small to medium enterprise. Spending hundreds of millions, even billions of dollars, over several years, these herculean undertakings will have staff turnover, changes in direction, varying market and weather conditions. Contrasting this, are small capital projects. Often with a capital spend in the millions (or less), durations measured in months (if not weeks) and a project "team" consisting of a single person. While some attempts have been made at classifying projects and providing a distinction between large and small [37] a good general statement is:

- Large projects' problems cascade causing secondary, tertiary or future hidden problems due to their complexity, whereas
- Small projects' problems can be contained and isolated.

This definition supports empirical evidence when it comes to the cost outcomes of large and small projects illustrated in Figure 5 below [17] [31]:

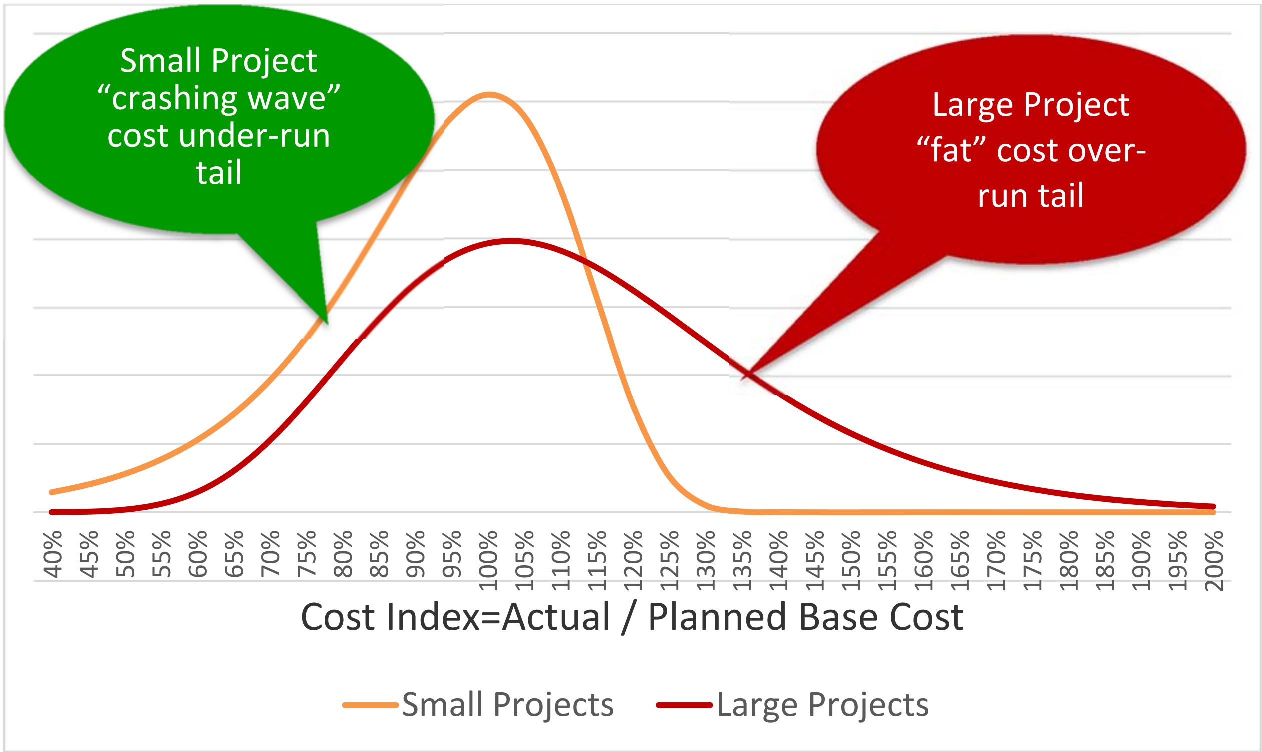

Figure 5: Cost Outcomes of Small and Large Projects

The cascading issues of large projects are a possible explanation of their "fat" right hand (overrun) tail. When cost overruns occur, the can extend dramatically so that the median outcome (most likely P50) is lower than the mean outcome (arithmetic average). When large projects fail, they fail dramatically. In contrast, small projects have a "crashing wave" shape or a "fat" left hand (underrun) tail. The typical small projects tend to cost underrun (barring agency issues between project managers and management).

The magnitude of large projects easily justifies more extensive project controls and risk management. It is fairly easy for $200,000 of risk management effort to pay for itself many times over on a $100 MM project. On small projects, this is not the case. Even a scaled down Parametric or Range Estimating exercise for a small project can cost over $10,000 making it hard to offset with possible savings on a $500,000 project. It is intuitive that these project management funds are better spent on some other form of project controls, or, not spent at all and simply "saved". As a result many organizations simply apply a 10% contingency to all of these small projects [33].

There are some negative consequences to the simple "10%" approach. First, it does not take into account the underlying risk of the specific project. Second, AACE guidelines for 10% contingency are associated with a class 3 or better project definition, whereas often small projects barely meet a class IV definition [33]. These factors can create the situation when a small project simply does not have enough contingency. Many organizations allow up to a 10% cost overrun on small projects without a supplemental or revised AFE (Authorization for Expenditure). In some organizations a project manager's consequences for going over this amount can be significant. Agency theory would encourage project managers in this situation to "pad" or inflate their cost estimates so that they can be on the conservative side. This unintended behavior can be compounded by organizations that reward project managers for cost underruns. These two factors maybe one explanation of why small projects underrun. Conversely, some organizations penalize project managers for underruns. Agency theory would then incentivize them to allow scope creep and unnecessary spending [38]. A better solution is providing projects with contingency that is tailored to the risk of the project.

Problem Definition

Small projects tend to be either sustaining capital projects, required to comply with changing regulation and asset maintain, or to incrementally enhance production or efficiency. Taken in aggregate these small projects can equal or even eclipse the spending of any single large project at a company [1] [2] [3] [4]. Over allocation of capital on these projects can hurt a company's bottom line by tying up constrained capital and precluding other worthwhile projects. Each project cannot afford a full risk-based contingency assessment. The sheer volume of these projects merits a process solution funded at the program level. This problem calls for a systemic answer: a parametric contingency assessment tool for small projects. The ideal solution is:

1. Data based,
2. Simple to use,
3. Does not require a risk register, and
4. Project specific.

Given the limitations of the Parametric approach for estimating schedule contingency coupled with small projects' relatively short duration, schedule contingency is not required. If a small project has a sensitive schedule, such as a maintenance turnaround, a Monte Carlo of the schedule or other schedule risk solutions could be implemented.

Methodology

A mid-sized, Canadian midstream oil and gas company previously retained the author to develop a systemic contingency tool for large projects and has been successfully using the tool for almost three years. For small projects they were using a standard 10% contingency and were dissatisfied with the results. The company retained the author to develop a systemic contingency tool for their small projects using an in-house database of over 400 projects spanning over 2 years. While these projects varied in scope, geography, routine and special maintenance, they all had common traits:

- Under $10 MM Cdn;
- Schedule less than 1 year;
- Compact or simple scope; and,
- More or less "routine" projects (none of them would attract executive, media or investor attention).

The methodology followed the following steps:

1. Data scrub.
2. Statistical investigation.
3. Key risk drivers.
4. Project Manager interviews.
5. Tool creation.
6. Calibration.
7. Beta-test.
8. Rollout.

Data Scrub

The data was reviewed comparing the actual project cost divided by its AFE budget cost less approved contingency. This provided a cost index, shown below in Equation 1, so that a value below 1 indicates underspending while a value above 1 was a project that required contingency or had possible over spending:

$$Cost\ Index = \frac{Actual\ Spent}{Approved\ AFE\ Budget - Approve\ Contingency}$$

Equation 1

Many of the projects had supplemental / revised AFEs. Projects with amended AFEs were reviewed to determine if the extra spending was the result of a change in business scope or simply a cost overrun. Changes in business scope included increases to capacity/volume, different connectivity requirements etc [36]. Such changes were treated as "new" project definitions and not cost overruns. Unsurprisingly most AFE revisions were cleverly disguised excuses or realized risks that were beyond a project manager's control – weather, quotes coming in higher etc –as few project managers would revise an AFE with reasoning "I was wrong". By definition many of these risks are systemic and would occur regardless of a project manager's skill. Projects with AFE revisions without changes in business scope were treated as cost overruns.

All projects with a cost index of 30% or less were removed from the data set with the assumption that they were likely undocumented reductions in business scope. All projects with a cost index below 50% and above 200% were individually reviewed for validity with project managers. This review supported later process steps and revealed over a half dozen data entry errors. Figure 6 shows the original data and the scrubbed data. Despite its lumpiness, Figure 6 follows the general crashing wave pattern expected from small projects. [17]

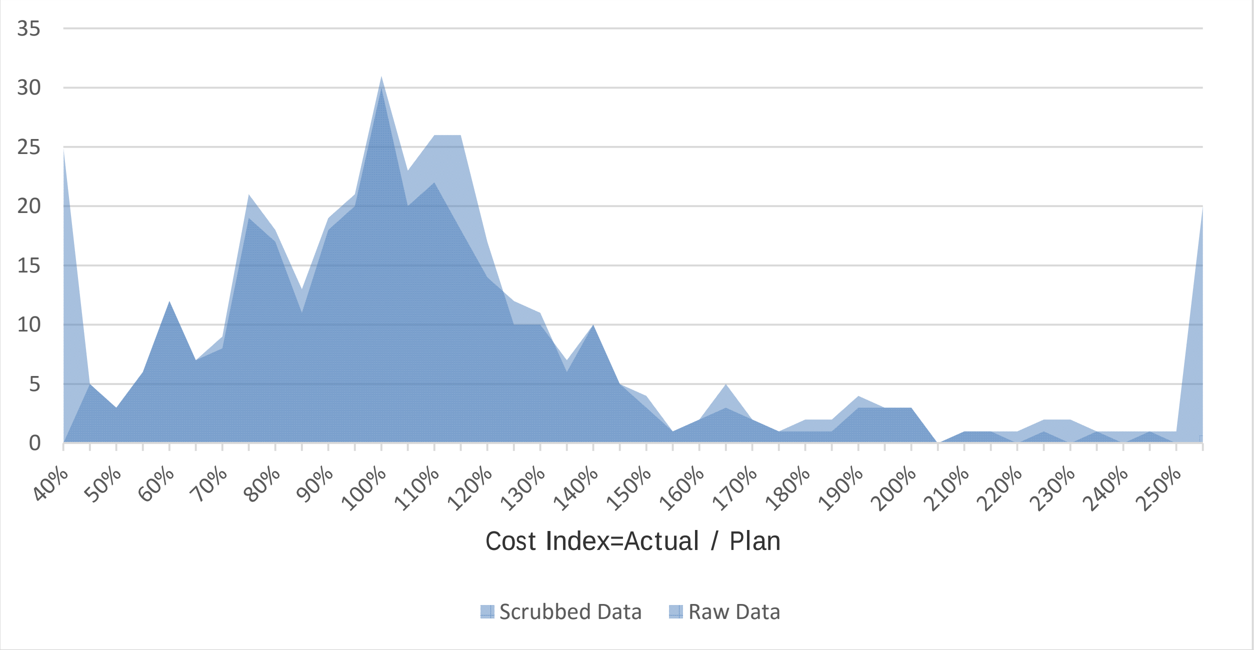

Figure 6: Cost Index before and after data scrub

<u>Statistical Investigation</u>

The data was parsed by a variety of over 30 standard factors defined on the AFE forms including:

- Project Type
- Asset class
- AFE originator business unit
- Year
- Start Quarter
- Location
- Budget status
- Regulatory regime
- Program or standalone project
- Ownership structure
- Spend allocation on standard WBS
- Project Manager
- Project Manager experience
- Project Cost

Through this analysis it was possible to determine that some projects categories had statistically different cost indexes than others. In evaluating potential differentiating criteria a bias was included to attempt to minimize the number of variables so that the final tool would be easier to use. This resulted in some project categories being merged with others, reducing the number of relevant project categories from over 20 down to six common project cost outcome distributions. Each project category was tested to determine the curve basic shape (normal, lognormal, uniform, triangular etc.). Interestingly each project category had the same common curve-type (within statistical tolerance) albeit with different variables. Results are shown in Figure 7 below.

Figure 7: Project Categories Cost Index Probability Distributions

Figure 7 indicates that several of these six project curves are very similar: two curves are almost identical while two others seem to differ by their means. The simplicity design objective drove consolidation of multiple curves into a single distribution indicating it may have been possible to further compress the number of categories. This was not done for two reasons. First, subsequent development steps defined category-specific risk-based questions that are irrelevant to various project categories (e.g. right of way access on a scrubber replacement project). Second, some of the project categories responded differently to data driven risks requiring multiple project categories and their associated curves as discussed below.

<u>Data Driven Major Risk Factors</u>

Within these six project categories, individual AFE defined traits were evaluated to determine if they were statistically different from the rest of the data. As illustrated in Figure 8 below, projects with less than 10% AFE spending on mechanical services behaved differently than projects with greater than 10%. Interestingly some of the pre-supposed risk factors had no statistical impact, or insufficient impact including: capital cost, year, location, and project manager experience. Conversely some variables that could not be immediately explained were discovered such as: harsher regulatory regimes resulted in lower cost indexes; seasonality impacts other than winter; and, uncommon or "special" projects had lower cost indices. A second screen was used to determine if a given variable was shared across project categories or unique. The results of these screens reduced the number of possible risk factors from over 80 down to 7. These seven data-driven risk factors resulted in standard shifts to cost probability distribution (both mean and variance) for each project category. These seven data-driven risks are company / project specific and are not those discussed in Common Risk Root Causes. The 7 Common Root Causes by pure coincidence match the number data-driven risk factors.

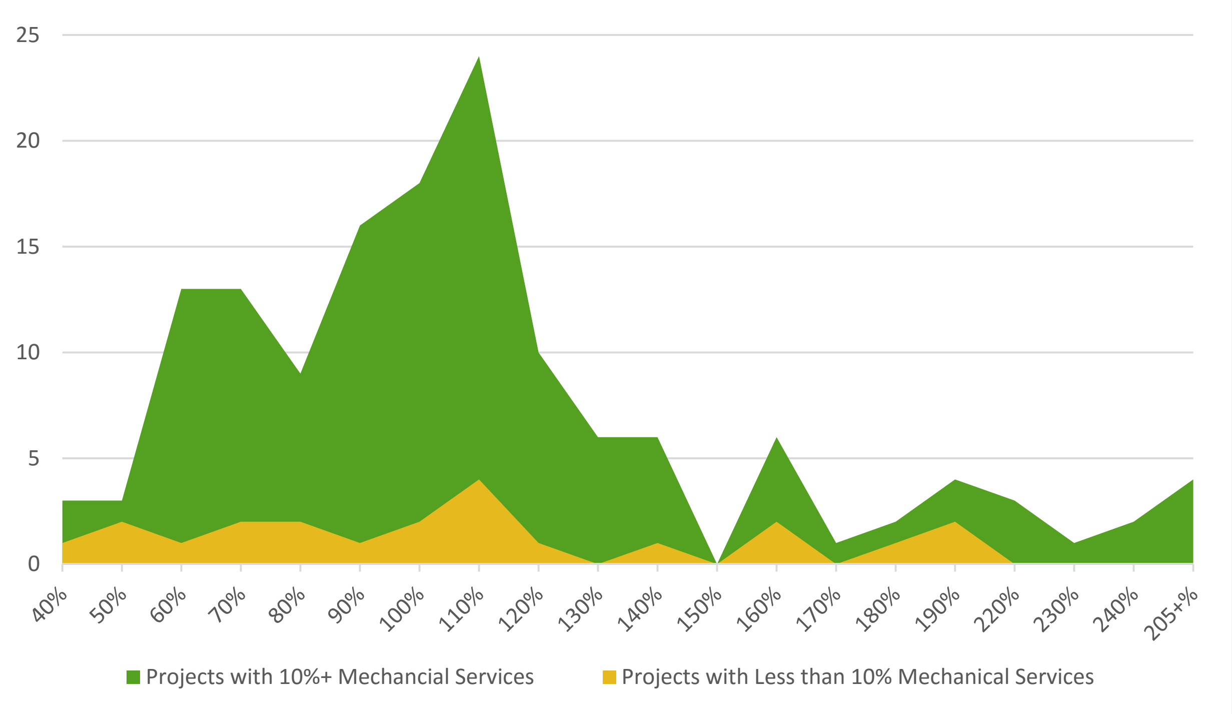

Figure 8: Sample of Statistical Difference between Projects with Different Percent Mechanical Services

Project Manager Interviews

Once the initial data was collected and analyzed it was shared in one-on-one interviews with a subset of seasoned category-specific project managers. During these sessions the following was reviewed:

1. Did the preliminary findings make sense?
    a. Are the six project categories sufficient?
    b. Are the 7 major data driven risk factors real?
2. Discuss the level of effort normally completed for an AFE.
    a. How often was more or less effort completed?
3. Discuss specific project outliers
    a. On their projects that went over, what happened?
    b. On their projects that went under, what happened?

From these questions several things were determined. First, the level of project definition prior to sanction was common within a project category and between project categories. This permitted the assumption that any variation within a project category was not due to project definition (like large projects in Figure 2), but due to some other risk factors. It also allowed for simplification of the final tool as rather than trying to assess the level of project definition, the tool only had to review relevant risk factors.

From outlier discussions common cause risks for cost over and underruns were identified. These traits became estimate-based category-specific risk factors as direct causality could not be proven due to limited data sample size.

These "estimated" minor risk traits included items such as: known environmental sensitivities; spill history; site access; contracting strategy; operations confirmation of assumptions etc. As these minor risk factors were opinion based, they were given smaller impacts on the cost probability distribution (mean only) as a multiple of the base curves' variance.

Tool creation

In keeping with the objective for a simple tool, the tool was created in Excel®, with various pull down menus and error checking. A master list of 33 questions was created from the major data-driven risk factors and the minor estimated risk factors. Questions' responses were "point and click" answers that best describe the response. Unlike large parametric tools, the answers were very specific and limited. Often "Yes", "No" or "Don't know". No project category required responses to each of the 33 master questions. The fewest number of questions in a category was 11 while the largest was 25. This question list acts as a "defacto" risk register. Reviewing all the major and minor common risk factors significantly reduces or eliminates the need for a project specific risk register. This allowed the tool to be used without a custom risk register, passing another requirement of the tool.

Beta-test

The trial tool was emailed out to the previously interviewed project managers who were asked to complete the tool for a "typical" project in their given project category. Other than a few lines in the body of the email no formal training was given. Only one of the project managers called for clarification (a phone call that lasted one minute) and all could finish the tool in under 10 minutes. Clearly the tool passed the ease-of-use and speed requirements. The project manager's provided feedback on: ease of use; question and answer phrasing; tool layout; and, general reception. This feedback was incorporated back into the tool, or if not, a follow up call was given to explain its exclusion. These selected project managers would become advocates and ambassadors for the new process.

Calibration

The project managers' "typical" responses were feed into the tool to determine if it tool would give cost index predictions in line with average actual cost outcomes. The tool was then run with the worst possible questions' responses and the best possible questions' responses to verify that the tool could provide cost outcome ranges that reflected reality. In an iterative process the weights of the various questions for each project category were adjusted accordingly: mixture of science and art. Figure 9 shows a specific project category's actual cost index results against the distribution for the best possible case ("min" or minimum contingency), the worst possible case ("max" or maximum contingency) and the typical response contingency curve. Curves for all project categories used comparable graphs to support calibration.

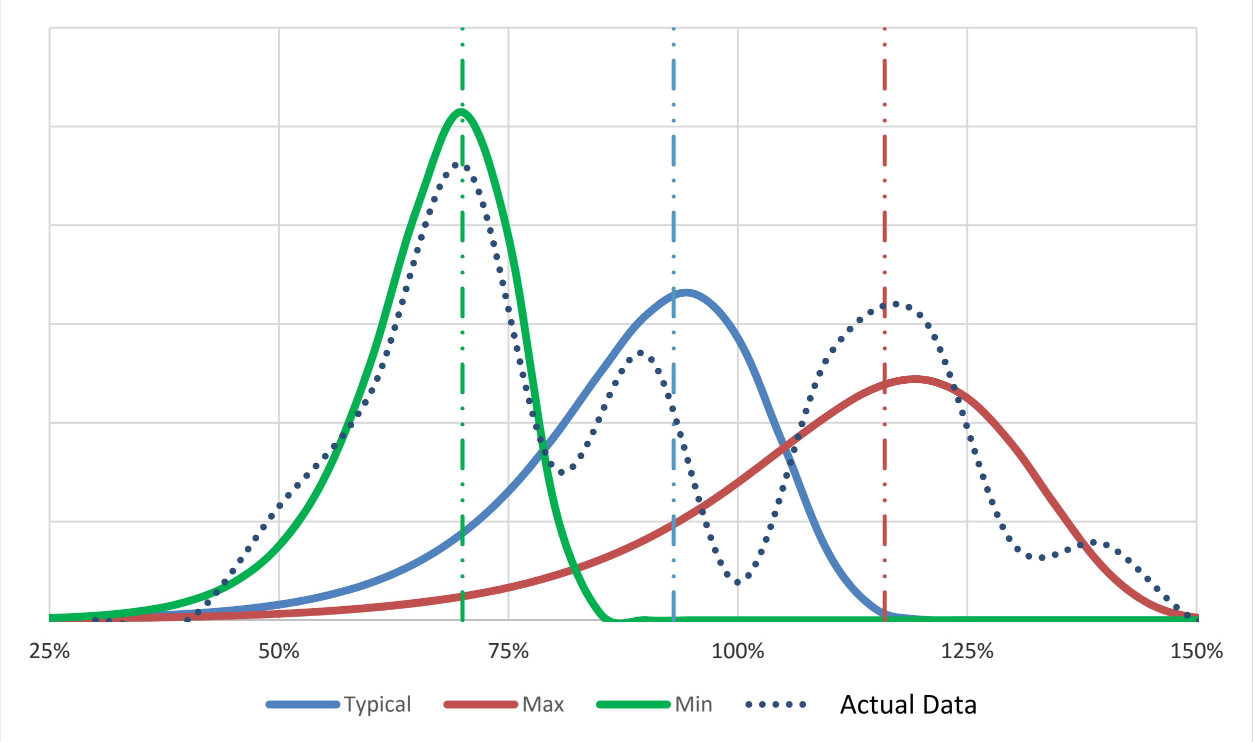

Figure 9: Calibration curves for sample project category

Solution Description

The final product for use by project managers is a two-tab Excel® file: one tab for inputs and question responses; and a second for results. Calculation and calibration tabs were locked and hidden within the tool to prevent damage or unintended use. The two-page approach make it more difficult for project managers to game the system. The input page has a header requiring basic project parameters project category, start date, estimated cost etc. that are pulled from the AFE submission supported by pull down menus. Question responses are all verbally anchored – typically "Yes", "No", "Don't know" – and selected with a point-and-click interface. This front tab (page) will be included with AFE submissions as a high-level risk-based project review alleviating the requirement of a project specific risk register. The output tab provides a table showing the P10, P50, Mean and P90 costs along with a single recommended contingency, a probability distribution curve and a cumulative frequency diagram specific to the project.

All trained users are able to complete the tool in under 10 minutes. This time requirement is an insignificant incremental burden on already too-busy project managers given the significant benefits. This project control tool clearly passes any project manager's cost-benefit evaluation. The tool meets all the design criteria:

1. Data based,
2. Simple to use,
3. Does not require a risk register, and
4. Project specific.

Cultural Change

From its inception this project required change management: cultural buy-in was critical to the tool's success and integration. With that in mind experienced project managers were involved early and often. For the most part project managers were very excited to abandon the tyranny of 10% contingency and the prospect of a contingency value more in line with the project's risks. Roll out sessions explaining what was done, the results, how to use the tool, and interaction to address specific concerns were conducted for all departments and users.

One of the consequences of the "crashing wave" small project curve is that it accurately predicts reality: small projects tend to underrun their cost estimate. In the data set just under half of the projects had a cost index below 100% and over 2/3rds did not use their full assigned contingency. Grounded in data, the tool predicts most projects will underrun and recommends a *negative* contingency. If blindly followed this could lead into a fear-fueled vicious cycle: fears of not enough contingency leads project managers to artificially inflate cost estimates and subsequent periodic recalibration then recommends even greater negative contingencies. Fear must be removed from the system for optimal performance [39] so a minimum contingency policy was created: all projects would receive at least 10% contingency. The tool still accurately indicates the likelihood of a cost underrun, but overrides the recommended mean contingency with 10%, while flagging the user that a minimum contingency has been assigned. As the tool is used and confidence more broadly established this minimum contingency can be reduced and the systemic reasons for cost over estimating can be addressed through other policies and practices.

Company policy allowed project cost overruns of up to 10% over their approved AFE (including assigned contingency) without an AFE revision. Project managers indicated that AFE revisions are considered "four letter words" by management and explicitly stated fears that this tool could result in an increased number of supplemental / revised AFEs. To address this a cumulative frequency diagram was created for each of the six project categories with the intent of educating management on the consequences of policy decisions. Figure 10 is for the most volatile project category and includes:

- Historical cumulative cost index;
- The tool's typical contingency assignment (using the "typical" responses as defined by project managers in section Project Manager Interviews);
- A typical assessment with a policy allowing a 10% cost overrun;
- A typical assessment with a theoretical policy of allowing 20% overruns; and,
- The highest possible tool assigned contingency ("worst").

In reading Figure 10 a typical project contingency would result in at most a little over half the projects having sufficient funds. The application of the 10% policy results in drop to a maximum of 45% AFE revisions while a 20% policy reduces this to a mere 25%. Using the logic that the projects most likely to encounter significant overruns are those with the highest risks, the tool identifies these risks and assigns the maximum contingency possible. As a result management should expect between 17% and 45% of all projects in this category to require AFE revisions. For some project categories these policies result in a minimum AFE revision frequency of 1% or less. With this information Management can make an informed business decision that balances financial oversight and fiscal authority with increased work effort and paper work.

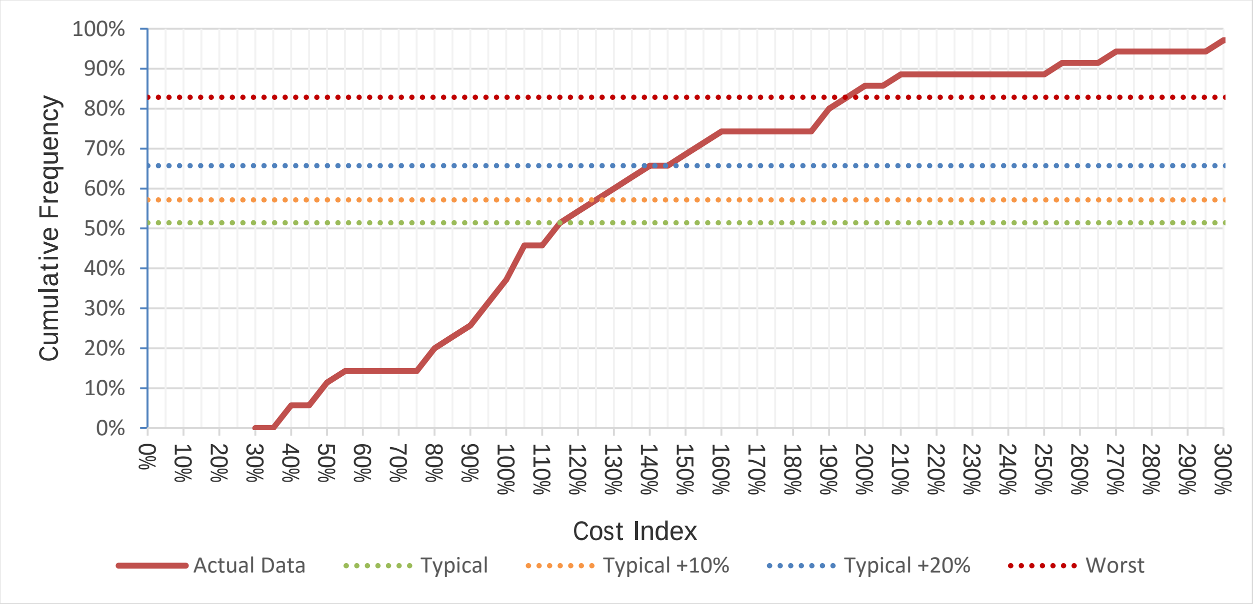

Figure 10: Tool Impact on AFE Revisions

Additional Work

Recalibration

Cost outcomes are directly related to project management practices and management policies. These are not always stable over time. While backwards application demonstrates the tool's accuracy, it still has its vocal and silent doubters. In two years' time recalibration will be completed using historic projects that utilized the tool. As each small project must complete the assessment it will allow the calibration of predicted with actual results. With recorded responses to all of the questions, some of the "estimated" minor risk traits can be transformed into "data driven" major risk traits. This will allow the removal or revision of some questions – further stream lining the process – or the addition of new "estimated" risk traits.

An example of this process was revealed during calibration with the "safety assessment" question. Every single project manager indicated they completed an informal safety assessment prior to AFE submission. None indicated that a safety assessment was skipped and all indicated a full assessment would be completed during the project. This is not a surprise in our safety-conscious environment: it is a bold project manager who admits that they were not concerned with safety on their project. Given the tool's objective of speed, if project managers only have one answer to this question, why ask it at all? Here the policy of paramount safety trumped other objectives and data: the safety question stayed in the tool.

Fractal Patterns

In completing this work an extremely interesting phenomena was found: curves, within curves, within curves. While the overall data complied with the expected small project "crashing wave" probability distribution, within that master data were project categories that shared the same "crashing wave" probability distribution but with statistically different means and variations. Within each project category – without fail - there were multi-modal probability curves as shown in Figure 8. Given each project within a category has a common amount of project work prior to sanction (i.e. all were sanction from the same class of estimate, roughly a class IV) the variation within the project category could not be attributed the main root risk cause for large projects, "planning prior to sanction" as shown in Figure 1, but was due to some other variable(s). It is speculated that these underlying "crashing wave" curves arise from the interaction between "data-driven" risks and "estimated" risk traits discussed above. Going forward data will be collected on the "estimated" minor risk traits to tie them back to the lowest level of curve possibly showing a fourth level that further increases the tool's precision.

Conclusion

This paper demonstrated that an easy-to-use parametric contingency estimating tool can be developed and successfully implemented for small capital projects. The tool allows tailored contingencies for individual projects permitting project managers security knowing they will have sufficient contingency while avoiding tying up excess capital.

The parametric approach works as 60-90% of cost overruns are driven by seven root causes. Small projects carry limited budgets for project controls that preclude the cost of the more sophisticated contingency assessment methods, such as Range Estimating. Conversely common Parametric tools are driven off of large and mega-project databases with fat right-hand cost overruns tails unlike actually small projects crashing wave pattern and a tendency to cost underruns. The foundational knowledge from large project parametric processes can be applied to small projects. The large volume of small projects leads to a processes-based solution and the extent of in-house data precludes the need for external project databases.

The required solution had to be accurate, data-driven, easy-to-use, repeatable, project specific and most importantly fast. While the tool meets all these criteria, it had to be deployed in a manner that acknowledges the change in a corporate culture. If the process is used as a method to reduce contingency it can increase the agency issues between management and project managers. The tool's unintended benefit was the insight management gained on impact policies have on work effort and paper work.

While the tool was backward tested, it remains to be seen if the predicted results match the actual results. A recalibration in two years will undoubtedly provide better insight and what learnings will need to be re-incorporated into the tool. In particular the concept of fractal probability distribution curves within curves within curves is mesmerizing: rather than viewing cost outcomes area random point in a probability curve, do certain traits "load the dice" in favor of one end of the curve or another? While large and mega-projects capture the industries collective attention, small projects offer something enticing – potentially large databases and relatively fast feedback loops. Ongoing work on this tool may reveal why certain projects tend to cost overrun more than others. Knowing this the industry might better put resources in the correct places to consistently avoid the "fat" end of the cost index tail.

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