Proceedings of the 2016 International Pipeline Conference
IPC2016
September 26-30, 2016, Calgary, Alberta, Canada

IPC2016-64015

PUT PAPER TITLE HERE

Matthew B Schoenhardt
MS Consulting
587.988.2305
mschoenh@telus.net
Edmonton, Alberta, Canada

ABSTRACT

ACCE recommended practice 43R-08 applies historical empirical data to estimate contingency. This Parametric contingency method has clear advantages over other 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" (less than $10MM) can eclipse the capital 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 regardless of the project's actual risk profile. Surely there must be a better way? A Canadian Midstream company thought so, and developed a pioneering solution: a small-project systemic contingency tool. This paper will review how the problem of small-project contingency assessments was solved using a parametric approach tailored to six different project categories.

Introduction

Significant effort and research has been expended understanding the cost behavior on large and mega-capital projects. These marque projects immutably change corporations and the careers of those involved. While even 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 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 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 semi-automated 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 saved exclusively for the marque 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:

- Review root causes of cost over runs on large and mega-projects;
- Describe and evaluate various contingency assessment methods;
- Understand the differences between large and small projects and how these differences influence their cost outcomes;
- Develop a problem definition;
- Detail the methodology used and implemented at a mid-sized Canadian midstream oil and gas company;
- Describe the solution;
- Discuss the need for cultural change management

and the impact of management policies; and,

- Outline areas of future work.

Common Risk Root Causes

The empirical data shows that there are seven primary drivers of cost variance. These root causes, shown below, are systemic and common almost all large capital projects [5] [6] [7] [8] [9] [10] [11]. These factors have been validated through numerous linear regressions over the past few decades and while the decimal points have changed, the underlying factors and their relative importance have not. The seven factors are:

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

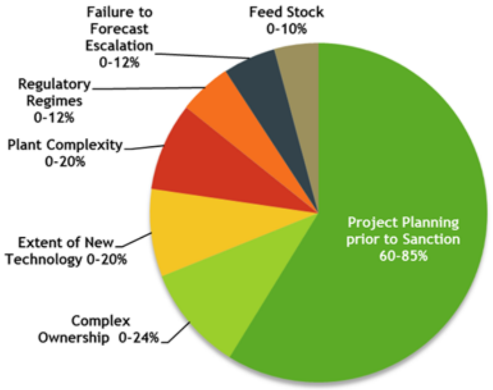

Figure 1: 7 Primary Drivers of Cost Variance

The single largest driver of large project cost outcomes is amount of effort prior to sanction. As project definition increases the lower the average and more narrowly distributed the cost overrun becomes [12].

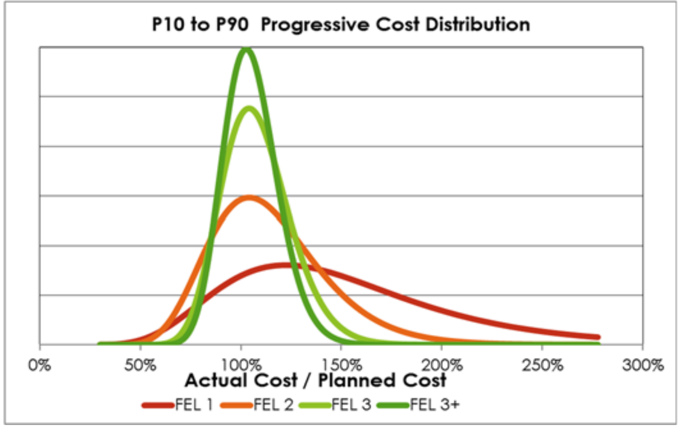

Figure 2: Impact of Increasing Project Definition on Cost Outcomes

As a result of an EEDC led study completed by Stantec, this systemic framework has anecdotally shown to correctly account for oil sands mega-projects in Alberta over the past 20 years [13] [14] [15] [16] [17] [18]. These factors do indeed cause cost overruns and, when avoided, can be correlated with significant cost underruns even in perceived high cost jurisdictions like Alberta [16].

Sample Manifestations of Root Causes

Seven common traits associated with increased project risk and their associated impacts to a project's risk profile are shown in below [7]. Each of these traits are not in and of themselves causes of project variance, rather they are symptoms of the seven underlying root causes previously earlier. When a project falls into these archetypes, project managers can expect a project with a higher risk profile with less predictable scope, schedule, and budget outcomes.

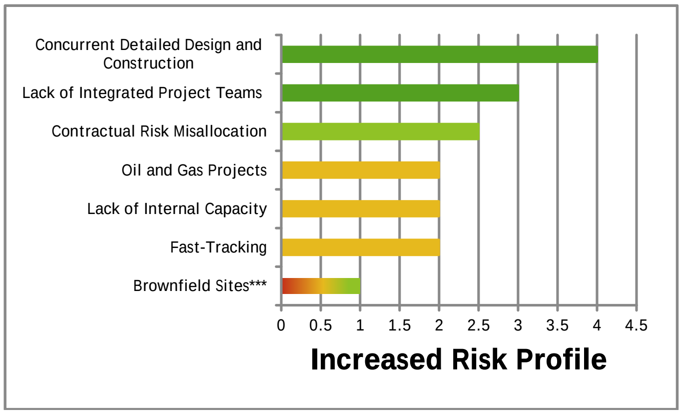

Figure 3: 7 Risk Factors (manifestations of root causes) [7]

Contingency Methods

There are two main approaches to assess how much contingency a capital project requires: opinion and empirical. Each of these two approaches can be assessed in either a simple or sophisticated manner. These four methods, shown in Figure 4, can be used independently or in combination. The four methods are [19] [20] [21] [22] [23] [24] [25] [26] [27] [28]:

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

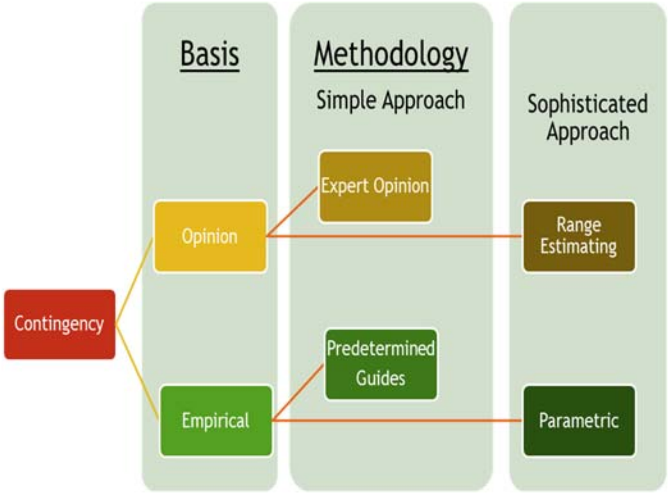

Figure 4: Contingency Assessment Approach Families

Each of the four methods have different levels of effort, benefits, and accuracy ranges. Risk and contingency management are a subset of project controls (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. In the expert opinion method the project team or similar subject matter expert(s) simply provide a contingency value or range [29] [20]. For instance all remediation projects carry 15% or in-line inspection has 8%. This method, while it is extremely cost-efficient and implicitly addresses project risks, is highly susceptible to bias and agency issues. As a further drawback, expert opinion tends not to be repeatable within, or between, projects. A method to address some of the heuristic bias is to employ the Delphi technique, polling several experts independently. While this may increase the accuracy of the estimate, it does increase the complexity of the process undermining one of the key strengths of this method of contingency assessment.

Opinion Basis: Range Estimating

Range Estimating and Simulation Analysis (or line-by- line 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 (both for cost and time). To these calculations project risks are added from the risk register with both probability and impact ranges (both cost and schedule). 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.

While this method provides a range of cost and schedule outcomes and can be augmented by a project-specific risk register it is has a number of short comings. Firstly, 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. Secondly, it requires the estimation of risks that are inherently 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. Thirdly the evaluation of "black swan events" is inherently underestimated [30]. Fourthly, range estimating is prone to the central limit theorem: as the number of independent variables increases, the resulting distribution becomes narrower [31]. Amateur modelers will add more and more detail to their models with the aim of improved accuracy, but end up making the model less accurate by neglecting the all-important correlation matrix. For instance the price of rebar is independent of labour 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 MS Project®[1] or Primavera® does not make one a scheduler, much less a planner, so too does the use of @risk guarantee an accurate contingency assessment. The key difference between an accurate range estimated contingency and an inaccurate one boasting only pretty graphics is found in a detailed correlation matrix. Finally, unless the simulation analysis is completely based on empirical data, it is more prone to iatrogenic risk (risk created by the risk analysis through faulty risk analysis practices) than other methods. All of these issues lead to simulation results that predict smaller cost outcomes than those that are actually incurred by real projects [32].

A complimentary concept to range estimating is Expected Value and its sister approaches of event modelling and fault tree analysis [22]. In these methods significant risks are identified and their possible impacts (scope, schedule, and budget) and their odds of occurrence (probability) are quantified. This data is put into a Monte Carlo simulation to create probabilistic cost and

---

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

schedule outcomes. This approach is very effective at evaluating specific event-driven risk, such as the risks of a particular HDD (horizontal directional drill); however, it is very poor at evaluating systemic project risks.

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. Both fundamentally attempt to evaluate the given projects' level of definition and correlate it to historical results from similar projects.

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] [29] [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 and layouts etc. and 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, not the other way around. In the authors' experience clients, owners, and engineers end up believing that the cost estimate accuracy range comes first, rather as an output of the estimating process grounded in what deliverables have been produced. 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 etc. and typically these deliverables if created are not always integrated with the engineering.

Empirical Basis: Parametric

Systemic Contingency, or parametric modeling, as defined by AACE RP 43R-08 [35] uses historic cost and schedule outcomes and correlates those with the degree of project development at time of sanction. This approach is grounded in the evidence that main sources of project cost variance on large and mega-projects are not unique, but rather common to all projects (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 etc. The parametric approach starts with comparable historic results and maps them to the project in question and then accounts for differences estimated from truly unique project-specific risks from the risk register. 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 [32] [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. Secondly, the development of a parametric process is reasonably complex, requires periodic calibration and, historical data that is hard to obtain or typically only available for large and mega-projects. Creating such a system for a single project would require more effort than possible benefit it could provide. Finally, once created the process implicitly requires the understanding that the project team is neither substantially more talented, nor their project significantly more difficult, than all the people and projects that have come before. A bitter pill for many proud professionals to swallow. While the objective, tools, schedules, and players in a project may be unique, the processes that drive capital projects to conclusion are common. This systemic contingency method, while not intuitive or simple, provides a low cost, risk-based, probabilistic contingency and when coupled with a risk register excellent project insight.

Comparison of Contingency Methods

In general the relative strengths and weaknesses of the four main contingency methods are graphically represented below [13] [36]. Given the level of effort required for more accurate range estimating and parametric approaches to contingency often small projects are forced into using expert opinion or predetermined guidelines.

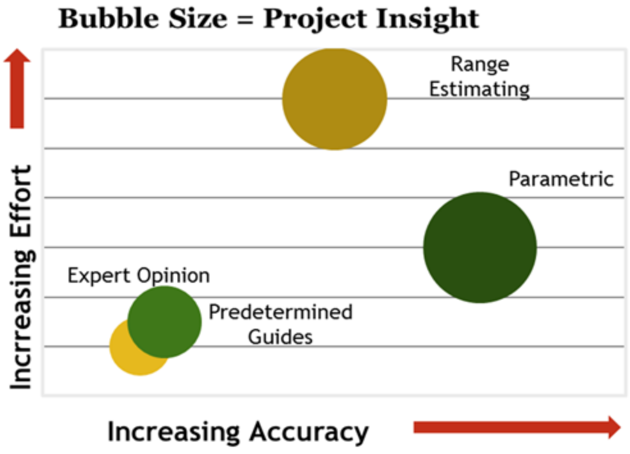

Figure 5 Comparison of Contingency Assessment Methods

Other than the application to schedule risk, cost range estimating on small projects does have one mitigating feature: instead of being 4-5 times the cost of a parametric assessment it is only 2-3 times as expensive. The reason is that small projects have few line items in their work breakdown structure (WBS) and the cost and complexity of a range estimate is arguably exponential. For instance an integrity repair dig or dig program may only have a dozen or so lines it is WBS. With only 12 variables the correlation matrix would only need to have at most 55 relationships. The maximum number of relationships required in a simplified correlation matrix is n(n-1)/2. Since each variable's relationship with itself is 1, the formula become (n-1)(n-2)/2). With this in mind the burden of creating a proper range estimate on a small project is merely arduous instead of herculean.

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 below [32]:

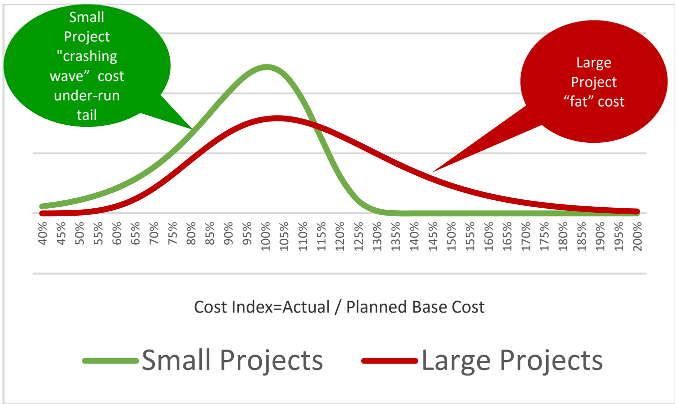

Figure 6: Cost Outcomes of Small and Large Projects

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).

Anecdotally these differences are easy to understand. The number of issues faced by a transcontinental pipeline project such as Energy East, Keystone XL, Northern Gateway or Transmountain are several orders of magnitude larger than those faced by a new storage tank. In above mentioned massive projects, each likely contains dozens of storage tanks.

The magnitude of large projects easily justify 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 may not be 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 this cost with possible savings from 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 consequences to the simple "10%" approach. First, it does not take into account the underlying risk of the specific project. Secondly, AACE guidelines of 10% contingency is 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. In this situation Agency theory would 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, maintain assets, or projects to incrementally enhance production or efficiency. Sample projects in the oil and gas midstream world may include: tank and pipeline inspections; laterals; remediation; integrity digs and repairs; maintenance projects; pump or manifold replacements and installations; civil earthworks or berms; and, replacement HDDs. 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 and 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 retained the author to develop a systemic contingency tool for 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 approved budget cost less approved contingency. This provided a cost index as show below with a below 1 indicating underspending and a value above 1 a project that requires contingency or possible over spending:

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

Figure 7: Cost Index Definition

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. As such these projects with AFE revisions 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 processes steps in revealed as man as a half dozen data entry errors.

The resulting before and after data is shown below, and despite its lumpiness it follows the general crashing wave pattern expected from small projects.

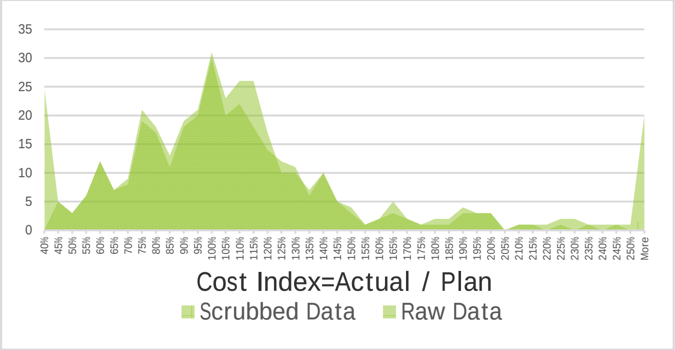

Figure 8: Cost Index before and after data scrub

Statistical Investigation

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. As expected valve replacements had lower cost outcomes than integrity repairs digs. In evaluating potential 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 below.

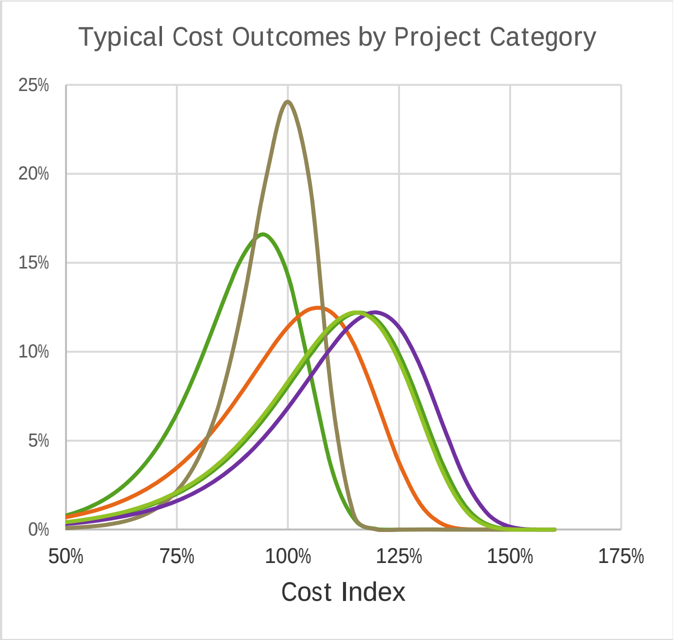

Figure 9: Cost Index Probability Distributions for Project Categories

On inspection of Figure 9 it would seem that two curves are almost identical while two others only differ by a higher or lower mean. Given the desire to simplify the tool it would seem logical to collapse two, if not four, of these curves into a single distribution. The following steps developed risk-based questions that are category specific making some risk questions irrelevant as each project categories can respond differently to data-driven risks. In the above figure the two seemingly identical curves are from the project categories vessel inspections and maintenance. For maintenance projects being "in-budget" compared to "emergency" or "special" work had significant correlation to cost outcomes whereas for inspections these traits had no statistical impact on cost outcomes whereas being part of a larger program of projects did. The project category with the tightest cost range was in-line inspections and the project category with the highest and widest cost outcomes was integrity repair digs.

Data Driven Major Risk Factors

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 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 size, year, geographic location, and project manager experience. To some surprise projects initiated by "business development" had no materially worse outcomes than other "engineering department" or field staff driven projects. Where possible it was attempt to track down "correlation" traits to root causes. For instance if a project manager's name was "James" the project was statistically four times as likely to go over budget. Obviously it is not the project manager's name the causes the overrun, rather as it turns out James extensively and exclusively worked on inherently high risk projects. When compared to similar risky projects by other managers, James results were no different. Conversely some variables that could not be immediately explained by their physical traits were discovered such as: harsher regulatory regimes resulted in lower cost indexes; projects starting in late summer have higher risk profiles; and, uncommon or "special" projects had lower cost indices. It is speculated policies and practices internal to the company lead to project management behaviours which in turn correlate to cost outcomes. 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.

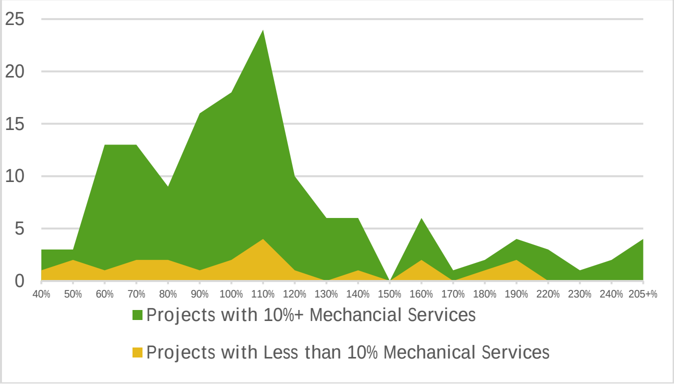

Figure 10: Sample of Statistical Difference between Projects with Different Percent Mechanical Services

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 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 differences in project definition, 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, line buildup, adequate flow rates, approval of required above ground markers, on-site inspection etc. As these minor risk factors were opinion based, they were given smaller impacts on the possible cost probability distribution (mean only) as a multiple of the base curves' variance (whereas data-driven risks impacted the curves mean and variation).

Tool creation

In keeping with the objective for a simple tool, the tool was created in MS Excel®[2], 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, with mini-paragraph verbal anchors, 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 reducing or eliminating the need for a project specific risk register. This allowed the tool to be used without a project manager developed 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 a follow up call was given to explain why it was not included.

Calibration

The project managers' "typical" responses were back fed 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. The figure below shows a specific project category's actual cost index results against the distribution for the best possible case, the worst possible case and the typical case.

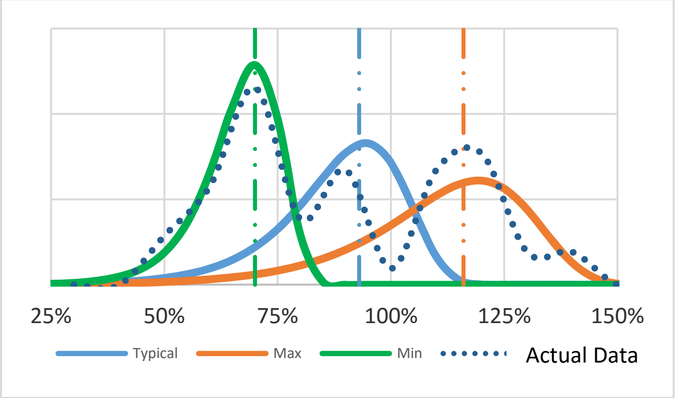

Figure 11: Calibration curves for sample project category

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). The two-page approach was used to 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

---

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

menus. Question responses are all verbally anchored – typically "Yes", "No", "Don't know" – and selected with a point-and-click interface. This single 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.

In all typical users are able to complete the tool in under 10 minutes. This is an insignificant incremental burden on already too-busy project managers given the significant benefits. This project control tool clearly passes any project managers 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 figure 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 many projects will underrun and recommends a *negative* contingency. In particular the average maintenance and in-line inspection projects have negative contingency: they are consistently over estimated. If the tool was 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 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 project 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 broadly established this minimum contingency can be reduced and the systemic reasons for cost over estimating can be addressed through other policies and practices.

An explicitly stated fear from project managers is that this tool could result in an increased number of supplemental / revised AFEs. No project manager desires to go to their boss and ask for more money. To address this a cumulative frequency diagram was created for each of the six project categories. The intent was to educate management on the consequences of policy decisions. Policy allowed projects to overrun over their approved AFE (including assigned contingency) by 10% without an AFE revision. The sample chart below shows the most volatile project category integrity repair digs: historical cost indices; 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 10% and 20% overruns; and, the highest possible tool assigned contingency. In reading the chart 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 at least 17% 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.

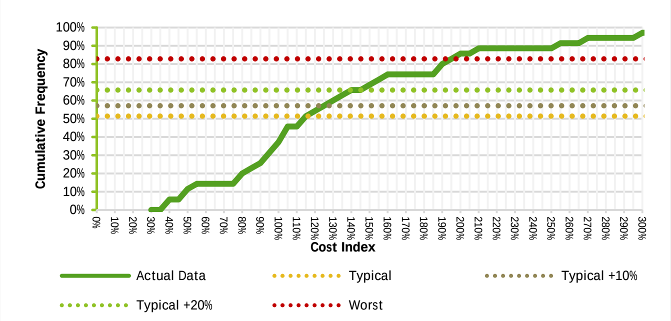

Figure 12: Tool Impact on AFE Revisions

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 the answers to all of the questions recorded more 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. 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: 7 Primary Drivers of Cost Variance

, 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 data-driven off of large and mega-project databases with fat right-hand cost overruns tails but small projects demonstrate a crashing wave pattern and a history of 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 favour 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.

REFERENCES

References

[1] Suncor, "Suncor Annouces 2013 Capital Spending Pland and Production Outlook," Suncor, Calgary, December 2012.

[2] Suncor, "Suncor Enberyg Annouces 2014 Capital Spending Plan and Production Outlook," Suncor, Calgary, November 2013.

[3] Suncor, "Suncor Engergy Annouces 2015 Capital Spending Pland and Production Outlook," Suncor, Calgary, November 2014.

[4] Suncor, "Suncor Energy Annouces 2016 Capital Spending Program and Production Outlook," Suncor, Calgary, November 2015.

[5] E. Merrow, "A Quantitative Assessment of R&D Requirement for Solids Processing Technology," Rand Corporation, 1986.

[6] E. Merrow, "Cost Growth in New Process Facilities," Rand Corporation, Santa Monica CA, 1983.

[7] E. Merrow, Industrial Megaprojects, New York: John Wiley & Sons, 2011.

[8] E. Merrow, "The relative Cost Factor: A method of comparing petrolum refinery investment," *Chemical Engineering,* 1987.

[9] E. Merrow, "Understanding Cost Growth and Performan Shortfalls in Pioneer Process Plants," Rand Corporation R2569 DOE, Santa Monica CA, 1981.

[10] C. Myers, "Understanding Process Plant Slippage and Startup Costs," Rand Corporation - R3215-PSSP, Santa Monica CA, 1986.

[11] C. Myers, "Industy Information Practices and the Failure to Remember," *Rand Corporation,* 1984.

[12] Independent Project Analysis, "IPA Home Page," 2012. [Online]. Available: www.ipaglobal.com/services/individual-capital-project-services.

[13] M. Schoenhardt, "Mega Project Costs in Alberta: Taking a Closer Look," Edmonton Economic Development, Edmonton, 2014.

[14] M. Schoenhardt, "Profitablity of Petrochemical Plants in Alberta Industrial Heartland Vs Gulf Cost," Edmonton Economic Development, Edmonton, 2013.

[15] M. Schoenhardt, "Why Projects Fail (And what can we do about it?), IPC2014-33515," in *International Pipeline Confrence*, Calgary , 2014.

[16] P. Fink, Interviewee, *Mega Projects In Alberta.* [Interview]. 2012.

[17] Alberta Finance and Enterprise, "Inventory of Major Alberta Projects 1999-2012," Government of Alberta, Edmonton, 2012.

[18] M. Schoenhardt, "Selling the Alberta Advantage," in *Economic Society of Northern Alberta*, Edmonton, 2014.

[19] AACE, "10S-90 Cost Engineering Terminology," 2012.

[20] AACE, "17R-97 Cost Estimate Classification System".

[21] AACE, "40R08 Contingency Estmating General Principles".

[22] J. Hollmann, "Recommended Practices for Risk Analysis and Cost Contingency Estimating," *AACE,* vol. RISK.01, 2009.

[23] J. Hackney, "Control and Mangement of Capital Projects," *AACE,* 2002.

[24] J. Hollmann, "The Monte-Carlo Challenge: A better approach," *AACE,* vol. Risk.03, 2007.

[25] E. Juntima, "Exploring Techniques for Contingency Setting," in *AACE Internation Transactions*, 2004.

[26] G. J. S Burroughts, "Exploring Techniques for Contingency Setting," *AACE,* no. EST.03.1.

[27] Project Management Insitute, Project Management Body of Knowledge 4th Ed, Newtown Square, PA: Project Management Insitute, 2008.

[28] AACE, "41R-08," Risk Analysis and Contingency Using Range Estimating.

[29] N. N. Taleb, The Black Swan: The Impact of the Highly Improbable, New York: Random House, 2007.

[30] C. Annis, "Statistical Engineering," 2016. [Online]. Available: www.statisticalengineering.com/central_limit_theorem.

[31] J. Hollmann, "Risk.1027 Estimate Accuracy: Delaing with Reality".

[32] AACE, "56R-08 Cost Estimate Calssification System As Applied for the Building and Geneeral Construction Industries".

[33] M. Banaitiene, Risk Management in Construction Projects, Intech, 20112.

[34] A. Ogilvie, "QuantifyingEstimate Accuracy and Percision fo rhte Process Industries: A revew of industry data," *AACE,* vol. RISK.1100, 2012.

[35] AACE, "42R-08 Risk Analysis and Contingency Determination USing Parametric Estimating".

[36] M. Schoenhardt, "Enbridge Cost and Schedule Contingency Assessments, IPC2012-90259," in *International Pipeline Confrence*, Calgary, 2012.

[37] P. M. Martin Gough, "Stability Model Method of Risk Management and Early Prediction of Project Performance," *The Revay Report,* 2006.

[38] K. Eisenhardt, "Agency Theory: An Assessment and Review," *Acadamy of Management Review,* vol. Vol 14, no. Issue 1, pp. 57-74, 1989.

[39] Deming, "Fourteen points," 2012. [Online]. Available: www.deming.org.