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ENBRIDGE COST AND SCHEDULE CONTINGENCY ASSESSMENTS

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ABSTRACT

All capital projects have an element of risk and uncertainty. In today's business environment this requires more than just simply adding 10 percent contingency to the cost estimate to cover off project unknowns. Before sanctioning a project for hundreds of millions of dollars, Board of Directors need to know what possible cost and schedule outcomes exist in order to safe-guard shareholders' investments. Contingency assessments must be:

- Risk-based
- Project Specific
- Repeatable
- Defendable
- Cost effective

Six years ago, Enbridge grappled with these issues and realized it needed to adopt a new method of assessing both cost and schedule contingencies. After evaluating options, Enbridge set upon developing an in-house parametric modeling solution for its contingency assessment needs.

This paper will:

- Identify various options for assessing contingency
- Review the Enbridge process
- Demonstrate the value of a simplified risk register
- Identify required data inputs
- Illustrate calibration and accuracy of assessments
- Discuss business advantages of parametric modelling

INTRODUCTION

Definition of Contingency

According to the Association for the Advancement of Cost Engineering International (AACEI) contingency is defined as:

"An amount added to an estimate (of cost, time or other planned resource) … to allow for items, conditions or event(s) for which the state, occurrence and or effect is uncertain and that experience shows will likely result, in aggregate, in additional cost" (AACEI 10S-90).

Common Problems in Assessing Contingency

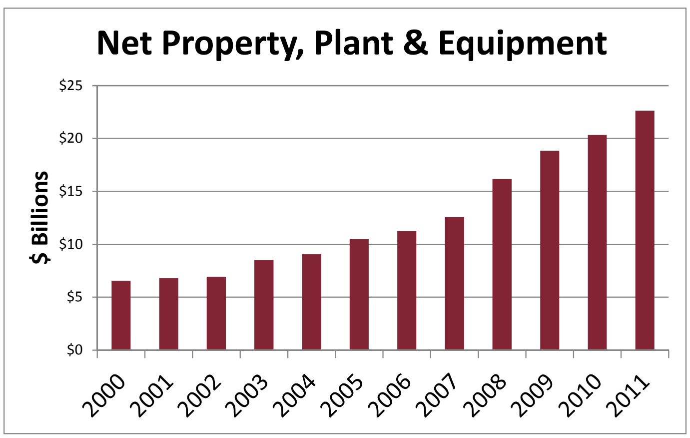
In the absence of hidden or unknown padding, projects without both cost and schedule contingencies are projects that are likely to go over budget and/or miss their in-service date. While the need for contingency appears to be a fact of life, the process of developing contingency is fraught with issues. Project Managers, acting in self-interest, have an incentive to implicitly or explicitly hide contingency within the estimate. In dealing with the Project Manager, Executive Management is at a disadvantage when determining the appropriate amount of contingency due to asymmetric project information. Compounding this, is the Agency issues. Project Managers typically have an incentive to increase contingency in order to make their job easier (Agency theory is how to align the interests of owners and people, "agents" who are paid to act on behalf of those owners to objectively further the owners interests regardless of their own). The inverse effect is also known to occur, in that Project Managers tend to be an optimistic population taking pride in their ability to overcome adversity and have a natural inclination to underestimate the consequence of risk and hence lower contingency. On the other side of the Agency issue is Project Managers that go over budget are penalized, while coming under-budget are rewarded, regardless of how reasonable the budget was. Project Managers who continually come in under budget can be accused of "sand-bagging" and have their budgets arbitrarily reduced. The formal and unbiased creation of contingency allows Management and Project Managers to openly discuss the real potential ranges of cost and schedule outcomes of a project.

Background to Contingency at Enbridge

Motivation

Enbridge, like most of the North American pipeline industry is undergoing a renaissance as the traditional sources of energy generation and geographic consumption has changed. Evidence of this is the fact that Enbridge's net plant, property, and equipment (PPE) 5-year annual compound annual growth rate is 15 percent (Figure 1). This significant departure from historical investment levels required a change in project management execution methodologies. One of these changes was Enbridge's approach to contingency evaluation and management.

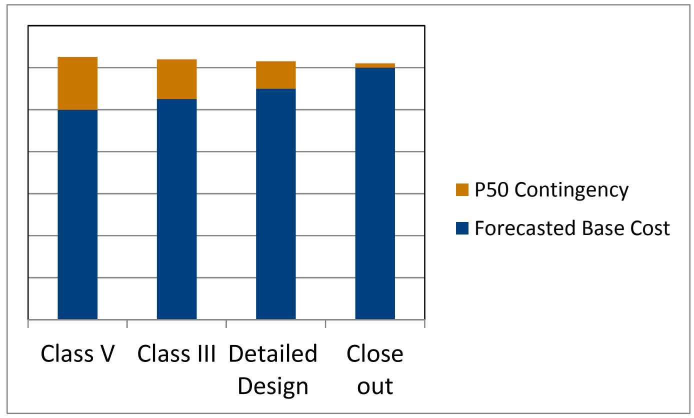
FIGURE 1: ENBRIDGE PPE GROWTH



Enbridge Contingency Philosophy

Enbridge expects projects to consume contingency to cover off anticipated, but unplanned, growth (Figure 2). Contingency covers project scope development, refinement, and errors and omissions. Contingency cannot be used for changes to Business Scope or Escalation.

FIGURE 2: PROJECT CONTINGENCY DRAWDOWN



Escalation is the notion that capital projects today will be more expensive in the future as input costs, from labour to steel, increase and general inflation decreases purchasing power. Escalation is to capital projects as inflation and the consumer price index is to running a household. At Enbridge, economic escalation is calculated separately from contingency by a dedicate team whose approach would be another paper altogether. Whereas contingency can be viewed as scope-cost uncertainty in today's dollars, escalation can be viewed as cost uncertainty in time over the duration of the project. Contingency addressed the variability in Project Scope in today's dollars while Escalation, calculated separately, addresses how much today's costs will be at some point in the future.

Business scope is a description of the business, money making needs of a client or the business. Business scope performance requirements are met by the physical assets identified by the Project Scope. Project Scope is the technical means to archive the business scope objective. An example of the contrast between business scope and project scope are as follows:

Business Scope: 400 kbbl/d between Fort McMurray and Hardisty, with a certain system reliability, meeting current safety and operational requirements, etc.

Project Scope: 36" pipe line with a certain MAOP, along a given route with four pump stations located at A,B,C, and D each with two-5000 hp pumps, VFD and a live spare, 4 x 300 kbbl tanks, block values at all major river crossings, etc.

Methods of Estimating Contingency

There are four general methods to assess contingency:

1. Expert Opinion
2. Predetermined Guidelines
3. Range Estimating and Simulation Analysis
4. Parametric Modeling

Expert opinion is where the project team or similar subject matter expert is simply asked for a contingency value. This method, while extremely cost-efficient and addresses project uniqueness, is highly susceptible to bias and agency issues. As further drawback expert opinion tends not to be repeatable within a given project or between projects.

Predetermined guidelines are the most common in industry and reflect Front End Loading, Independent Project Analysis or Association for the Advancement of Cost Engineering (AACEI) rules of thumb where the project's contingency is based roughly on the work completed. This method is also cost effective and provides repeatability, but does not allow for uniqueness in projects, requires risk management or provides a range of possible outcomes.

Range Estimating and Simulation Analysis (or line-by-line estimating) is a Monte Carlo approach where every cost and schedule activity in the work breakdown structure (WBS) is assessed for uncertainty and probabilistic ranges. This method is risk focused and provides ranges of possible outcomes, but is labour intensive and requires the estimation of risks that are inherently unknown. One of the areas where simulation analysis is extremely usefully is for short- to medium-term schedules as it fully embraces the concept of multiple critical paths and critical chains.

Parametric modeling uses historic cost and schedule outcomes and correlates that with the degree of project development at sanction. Historical data is then adjusted for the presence of a realized Project Specific risks. This approach is illustrated in the Rand Studies and AACEI's recommended practices for parametric estimating. The Rand studies looked at over 50 major industrial process plants built in the United States by over 40 different companies over a 50 year period and then related the degree of advancement of various variables to the actual cost and schedule outcomes against the sanctioned plan. This method, while not intuitive or simple, provides a low cost, risk-based, probabilistic contingency.

The author's opinion of the relative strengths and weaknesses of each of the four options are listed in the below. Using a red-yellow-green for poor-moderate-good and check marks and X's for good and poor respectively. NA indicates this process typically does not use or considers this factor.

FIGURE 3 STRENGTHS AND WEAKNESS OF MAJOR CONTINGENCY ASSESSMENT METHODS

Method	Speed /Cost Per assessment	Simplicity / Cost to develop / Maintain	Repeatability / Susceptibility to Bias	Project Specific Focus	Risk Based	Probabilistic Results	Risk Register Simplicity
Expert Opinion	✓ (green)	✓ (green)	X (red)	✓ (green)	X (yellow)	X (green)	NA (red)
Predetermined guidelines	✓ (green)	✓ (green)	X (red)	X (red)	X (red)	X (red)	NA (red)
Range Estimating	X (red)	X (yellow)	✓ (green)	✓ (green)	✓ (green)	✓ (green)	X (yellow)
Parametric Modeling	✓ (green)	X (red)	✓ (green)	X (yellow)	✓ (green)	✓ (green)	✓ (green)

Enbridge Contingency Process

Enbridge uses the parametric contingency estimating approach. By providing all of the benefits of the more sophisticated contingency analysis methods with few drawbacks, this approach to contingency gives reliable project cost and schedule outcomes with minimal effort. Enbridge's large portfolio of projects and project proposals easily offsets the fixed cost of creating and maintaining this process. The level of efficiency of this method is highlighted in that over an 24 month time period, one contingency assessor was able to complete over 100 unique project assessments totaling more than C$24B of capital. Projects ranged in size from a few million dollars to several billion. A typical assessment takes as little as 5-40 man hours. In order to maintain an unbiased view, Enbridge's contingency assessors are not associated with any one team or project. This independence allows for an objective assessment, one not unduly influenced by the project team. Independent assessors provide Executive Leadership with a clear understanding of project, program, and portfolio ranges of cost and schedule outcomes.

Enbridge limits its contingency process to risks that have a direct impact on the project's capital cost and schedule. Risks outside these bounds are noted, but do not have an impact on cost or schedule contingency.

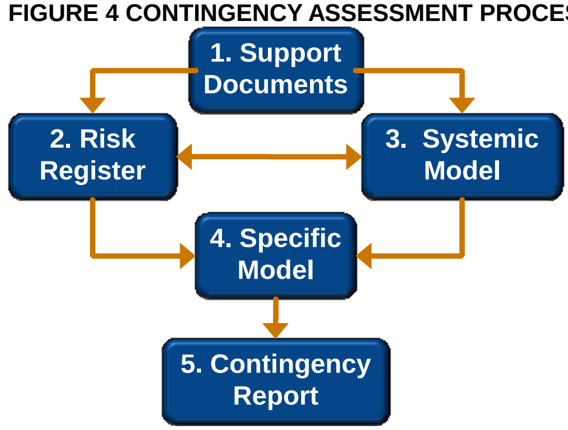
Contingency assessments occur:

- Each time a project proposal changes classifications
- Every quarter for projects in execution
- Upon request

The Assessment Process

An overview of the process is show in the figure below:

FIGURE 4 CONTINGENCY ASSESSMENT PROCESS



The following sections, 1-5, will address each of these process steps in turn.

1: Support Documents

Typically a request for an assessment is made by the Project Controls Manager or Risk Manager for active projects or the Project Development Lead for proposals. Prior to the two-hour contingency session with the team, the Assessor obtains and reviews:

- Project Scope documents (DOUs, PFDs, DBM. BOE, BOS, status reports)
- Cost data (approved, expended, incurred, and forecast at completion)
- Schedule (baseline, base, project float, and critical milestones)
- Risk Register
- Organizational Chart

Should there be any questions or clarifications these are resolved prior to the meeting. The initial base cost estimate is to be risk-free, contingency-free, and escalation-free cost of completing the project in today's dollars. It is essential that this Base Estimate preclude cost contingency, or the assessment will suffer due to contingency on contingency syndrome and have exorbitantly high cost that precludes sanction. Pre-existing schedule contingency is allowed so long as it is clearly identified—as total project float—and is tracked. The difference between the Base Line schedule and the Base Schedule is the total project float. The Baseline Schedule may be one year, but the base schedule would typically be of a shorter duration due to the presence of project float.

2: Risk Register

Enbridge has a standard risk register maintained and published by its Project Management Office (PMO). For the purposes of a contingency session the following data is required:

- Risk description and root cause
- Probability, three-point cost and schedule impacts (see figure 5 below)
- Schedule criticality (relationship between delay caused by the risk to a given task(s) and the anticipated delay in the in-service date)
- Correlations and dependencies
- Risk response plan, plan funding, and residual risk
- Risk status

Enbridge uses a three-point estimation—Worst, Best, and Most Likely—of a risk's impact for both cost and schedule. The worst, best, and most likely scenarios are typically easy for a Subject Mater Expert (SME) to provide and the distribution does not presuppose a level of knowledge that may not exist. Similarly the probability of occurrence allows the use of fuzzy logic for a range of probabilities rather than an exact number. For schedule impacts an added factor is applied, 'criticality'. Criticality relates the delay to the risk-affected task to the delay in the in-service date. A visual representation of the expected value of a schedule risk is shown below.

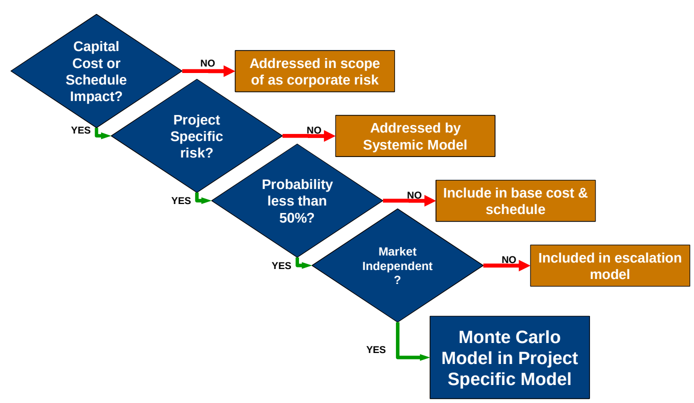
Enbridge risk guidelines follow that of AACEI in that the risk must have an expected impact greater than 0.5 percent of the total installed cost. This criteria typically excludes "black swan" or Force Majeure events that have enormous impacts, but extremely low probabilities such as earth quakes, terrorism, acts of war, and strikes.

FIGURE 5 GRAPHICAL REPRESENTATION OF A RISK

As shown in Figure 6, risks are included in the contingency and modeled as a Monte Carlo event if it passes the following criteria:

a. Capital cost or schedule impact
b. Project Specific risk
c. Less 50% probability
d. Market Independent

FIGURE 6 TREATMENT OF RISKS IN THE RISK REGISTER



Project Specific versus Systemic Risks

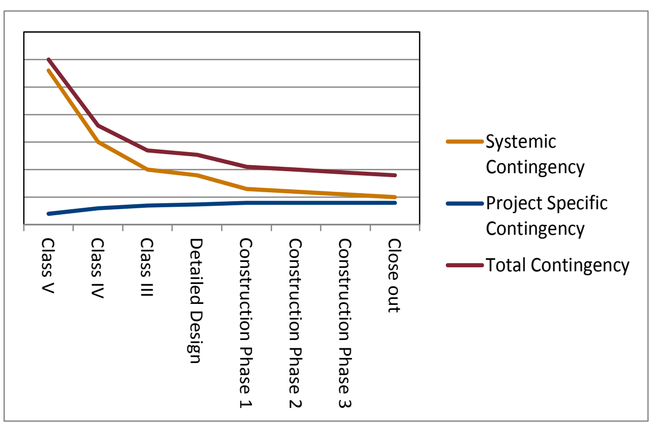
Paraphrased from AACEI, Systemic Risks are those risks that are inherent to the project development and execution process and could occur on any project. Systemic risks are initially high and decrease in magnitude as the project matures in execution. Examples of Systemic risk include:

- Communication difficulties between parties
- Late delivery of drawings or equipment
- Low productivity

Contrasting Systemic risks are Project Specific risks. A Project Specific risk needs to be a "credible threat", not just a fear or concern of a remote possibility. Project Specific risks are unique to the project and tend to arise due to the project's triple constraints: scope, schedule, and budget. As these three constraints are further defined and increased, Systemic Risk will decrease and Project Specific risks will increase. As the project's definition is refined, Systemic Risks can turn into Project Specific risks or new Project Specific risks can be revealed. At the early stages of a project typically only 5-15 percent of the risks in the risk register are truly Project Specific. On most active projects it is not common to have less than a dozen Project Specific risks. This is one of the benefits of Enbridge's approach as this greatly simplifies the risk register and risk management. Figure 7 illustrates an idealized relationship between contingency due to Systemic and Project Specific risks as a project progresses. This figure does reflect any specific project and should not be interpreted as real data. The contingency due to project specific risks increases as a percentage of the overall contingency, but does not dramatically increase as a percentage of total non-fixed cost. The reason for this is unlike systemic risk, project specific risks tend to be time-sensitive and as the schedule progresses project specific risks either expire—and are removed from the risk register and contingency—or are triggered and then incorporated into the base cost forecast or fixed costs. As project specific risks are removed from the risk register due to realization or expiration, they tend to be replaced by new risks that are constantly being added to the risk register. Thus while the blue project-specific contingency line looks constant, in practice, its underlying drivers are usually in constant flux.

If it is difficult to accurately estimate the probability and impact of a risk it is usually an indication that it is a Systemic risk. While it is possible to develop risk response plans to a Project Specific risk, the ability to respond to a risk does not automatically make the risk Project Specific.

FIGURE 7 SOURCES OF COST CONTINGENCY IN RELATION TO REMAINING NON-FIXED COSTS



3: Systemic Model

The Systemic model reviews:

- How well is the project understood?
- What work and deliverables have been completed?
- How detailed and aggressive is the execution plan?

Project responses are evaluated objectively by the Assessor. In this entire review there are no right or wrong answers and while progress is assessed, no attempt is made to identify if it is sufficient given the time and resources expended. Contingency assessments are not project audits. The project team presents data, which is accepted at face value. The contingency Assessor reviews and appropriately challenges items to ensure an appropriate level of understanding, but this is not intended as an audit, quality control or quality assurance, rather it can be viewed as a seasoned set of second eyes. In this review, the assessor will share risks that other projects have realized or identified in order to improve risk management across the entire portfolio.

The System Model is divided into three basic sections:

1. Multiple choice verbally-anchored questions that best describe the work completed in three areas:
    a. Scope definition (7 questions)
    b. Project planning (5 questions)
    c. Engineering deliverables (7 questions)
2. Basis of cost and schedule estimate
    a. Inclusiveness, quality and competitiveness of the estimate
    b. Percent of fixed cost and schedule (remaining work)
    c. Project management effectiveness
3. Project complexity
    a. New technology
    b. Transported material concerns
    c. Technical and execution complexity

The System Model outputs project cost and schedule outcomes on a probabilistic basis to reflect the project's Systemic cost and schedule risk. Fixed costs are deemed to be those costs that have zero uncertainty about them and typically include all incurred costs and fixed price material purchases. Signed lump sum contracts for construction services are not typically deemed as fixed costs, but result in higher scores for project definition and basis of the cost and schedule estimate (sections 2 and 3 listed above).

Interaction between Project Specific Risks, Risk Register, Systemic Model, and Forecast

It is important that project issues, trends or project change orders be identified in one, and only one, of the risk register, cost forecast or the systemic model. Failure to do so will result in either a double counting of issues—unnecessarily increasing contingency—or neglecting to address issues—and underfunding projects. Enbridge's practice is that if a risk is more than likely to occur – has a probability greater than 50 percent—it is assumed to occur and be included in the execution strategy, base cost, and schedule. The residual risk or opportunity of non-occurrence can then be further modeled as a project specific risk as appropriate. Ensuring issues are captured in only one location can become complicated when trends are beginning to form on projects, but are not yet full-blown project change orders.

The contingency assessor must ensure consistency within the project and between projects for the determination of Systemic versus Project Specific risks. At a low level of definition an item in the risk register could be considered Systemic whereas later in the project the same risk is Project Specific. For instance one of the questions in the system model concerns geotechnical work completed. At the lowest level of Systemic model's soils and terrain question, it is impossible to determine the odds of success of any single given horizontal Direction Drill (HDD) and thus failure of a standard HDD is a Systemic risk. The highest level of Systemic model's soils and terrain question, all the geotechnical work such as bore holes are complete and estimations for HDD failure are possible. At the highest level of project definition, the possibility of HDD failures can to be identified as Project Specific risks.

Possible examples of systemic risk include:

- Bad weather
- Communication issues
- Underperforming project management
- Low labour productivity
- Rework
- Late delivery of material
- Incomplete or erroneous engineering drawings
- Random strikes and lock outs

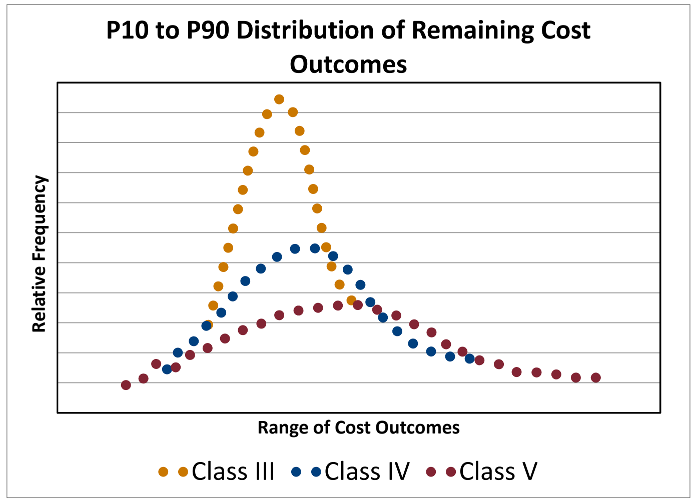
Systemic risks often have the theme of the day-to-day project management headaches and hurdles that must be solve. While examples of project specific risks are difficult to generalize as they evolve from the triple-constraints of the project, some possible examples include:

- Known inclusion of off spec-material
- Hurricanes in the gulf coast
- Crossing nature preserves or difficult topography
- Regulated or limited construction windows
- Repurposing or re-using equipment
- Accessing unique resources

4: Project Specific Model

The Project Specific model integrates the Project Specific risks from the risk register with the results of the Systemic model. The resulting cost and schedule ranges can be shown as either a cumulative frequency diagram or a traditional "bell" curve. Enbridge's typical practice is for projects to carry the 50th percentile (P50) cost and schedule contingency in their budget. This allows effective distribution of contingency across a portfolio of projects while providing sufficient incentive for Project Team execution diligence. The P50 is not the expected final cost of a project, rather it is the midpoint—half the projects will exceed this value and half will under run. P50s are analogous to the mean or median value. The P50 gives no indication of the range of possible outcomes as measured by a confidence interval or standard deviation. With this understanding, not all P50s are equal. While the P50 contingency is the typical practice, some projects will carry more or less depending on the analysis, risk profile, schedule constraints, and management discretion. Enbridge uses a four level classification system that is not identical to all industry's norms. It ranges from an unclassified, Class V, Class IV, and Class III. Enbridge's contingency system is not validated nor is used for unclassified estimates. Potential results for Enbridge's P50 cost contingency by Class are shown in Figure 8. It is easy to see that the distribution of a Class V estimate is more than twice as wide as the distribution of a Class III estimate and that the Class III's P50 value is almost three times as likely to occur.

FIGURE 8: POTENTIAL COST DISTRIBUTIONS OF ENBRIDGE PROJECTS



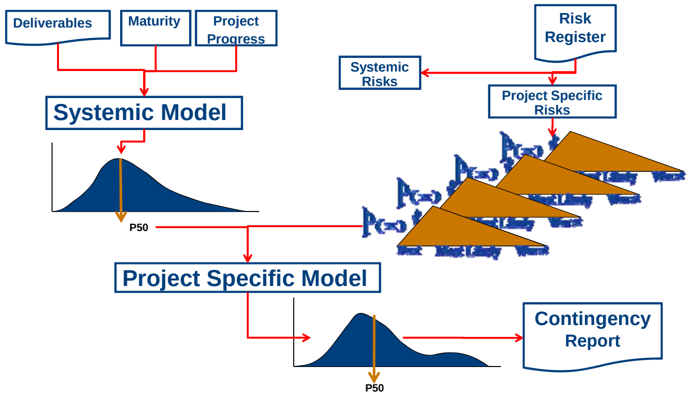
5: Contingency Report

Once the contingency session is complete, the assessor runs the various models and generates a standard contingency report. This report:

- Shows the cost and schedule contingencies as both standalone curves and in relation to other projects
- Analyzes and interprets results
- Makes observations and recommendations to improve the odds of project success
- Identifies overwhelming risks, that should they occur, would likely make the P50 cost or schedule contingency insufficient

A visual summary of the process is illustrated in Figure 9:

PAFIGURE 9: SUMMARY OF CONTINGENCY ASSESSMENT PROCESS



RESULTS

Preliminary results of calibration are show in the figures below, first with each project being given equal weight, and second with each project weighted by its average cost. The data shown is not the complete data set—values were randomly removed to preclude confidential information—but, it is representative. Here, with only limited data we see the theoretical predicted distribution of an infinite number of projects in the red line with actual projects shown by the blue bars.

Each actual data point represents a single multi-million dollar project, usually in excess of $100 MM, with a project start date after January 2007. While Enbridge successfully executes billions of dollars of projects every year, 6–16 projects a year, data points will never be sufficient to fill in the entire curve. Ideally each project was sanctioned after a Class III estimate; however, some smaller projects are sanctioned at Class IV or V level estimate. It is both expected in theory and reflected in practice the higher the level of estimate, the broader the range of possible outcomes.

FIGURE 10: PREDICTED VS ACTUAL RESULTS BY PROJECT COUNT

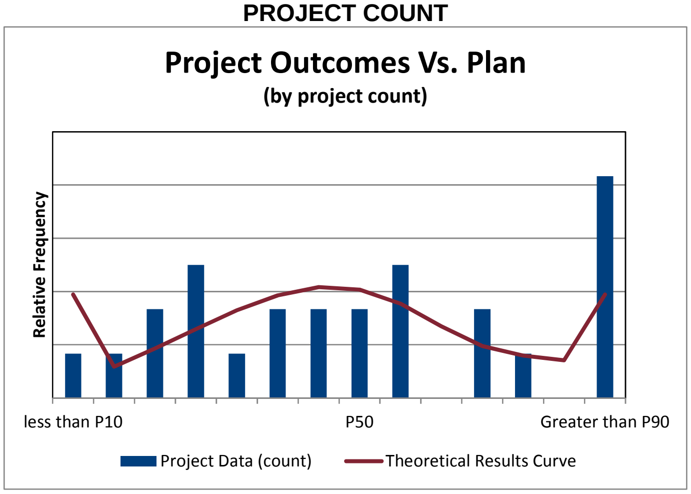
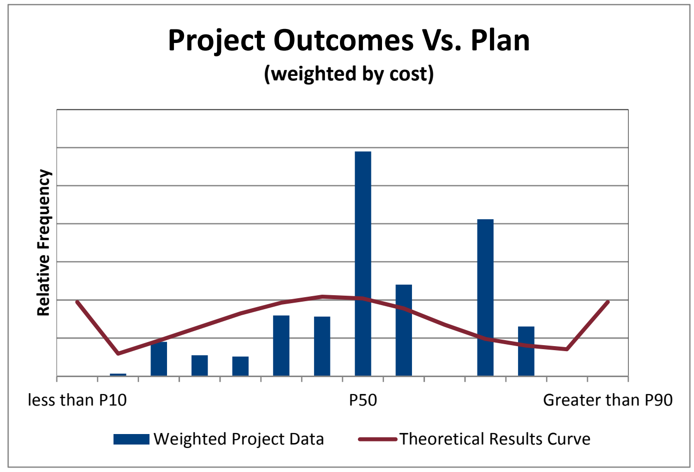


FIGURE 11: PREDICTED VS ACTUAL RESULTS WEIGHTED BY PROJECT COST



The head and tail ends of the red theory line indicate the 10th and 90th percentile as a single histogram bucket that captures all project outliers that extend beyond these values. The noticeably spike in Figure 10 of actual projects resulting in costs exceeding the P90 cost could be concerning. Contrasting this is when the projects are weighted by cost this spike is no longer apparent as all of these P90-projects either tended to be inconsequential in terms of total portfolio spend of sanctioned prior to the Class III estimate. By weighting the curve by project cost the goodness of fit noticeably improves and would indicate that Enbridge obtains improved forecast to actual results for larger projects, a noticeable rarity in the mega-projects game.

While escalation was considered in the calibration it was assumed the actual versus forecast escalation was perfect. While this escalation assumption may require a leap of faith, Enbridge's approach to escalation, while not perfect, is sophisticated and correctly identifies emerging trends several years out. Anecdotally errors in escalation tend to be "noise" for the purpose of contingency calibration. Justification of this assumption is perhaps another IPC paper.

Another critical assumption was that the underlying project management process is both consistent and uniformly applied: statistically the process is "in-control". In reality Enbridge's Project Management processes undergo and constant continuous improvement, which should tighten the distribution curve and reduce outliers. To partially address this issue, projects that were sanctioned prior to 2007 (introduction of Enbridge's Major Projects group and contingency process) were not included in the data set. A time-series graph was attempted (figure not shown), and while not statistically significant due to insufficient numbers, generally supports the validity of this hypothesis.

The calibration results have the data-based mean within 1 percent of the theoretical mean, while the current R^2 of the model, or goodness of fit, is approximately 0.5. This indicates that approximately half of the results show can be predicted by the theoretical curve. Given the assumptions built into the model limitations (consistent process, perfect escalation forecasts) and limited observations (less than 30 data points result in some histogram buckets having zero observations) this is a very good fit.

FUTURE WORK

Going forward Enbridge will continue to refine its model through regular calibration efforts. One of the issues presenting itself is that calibration is based on historical data that is representative of where Enbridge was when projects where sanctioned—two to four years ago— and do not reflect the continuous improvement in project delivery that Enbridge is demonstrating today. Even a company as large and successful as Enbridge may only bring into service a handful of projects a year. This is one of the inherent weaknesses of parametric estimating: one is trying to estimate a moving target that is related to the organizational capacity of an organization and attempt to quantify the changes to determine if they are materially sufficient to change the model. All of this is done with a relatively small data-base of values.

The contingency process was designed for Enbridge Major Projects. While Enbridge completes only a handful of Major Projects each year, it completes scores of smaller projects in the $1 MM to $10 MM plus range. In recent years, these smaller projects have increased the frequency of using this process. It is possible that modifications to this model are desirable to improve the accuracy and cost effectiveness on smaller projects. Given the data availability of these projects is an order of magnitude greater than major projects calibration could be completed. Should the outcomes of these smaller projects not be sufficiently statistically different from that of the major projects, they could provide a wealth of data points to speed up data calibration.

CONCLUSION

Parametric estimating is a quick, cost effective and accurate method at estimating cost and schedule contingency on large projects. With minimal effort this process can be formalized and centralized providing not only a solution to potential agency issues, but allowing objective inter-project and program comparisons. The role of the Contingency Assessor brings not only their unbiased view and repeatability to the process, but creates an effective method of sharing lessons learned and improving portfolio wide risk management. The authors of this paper can identify several occurrences of the early identification of risks on certain projects that were realized on other projects. Also the authors have been able to identify of portfolio risks after seeing several projects that on single project would identify or could address.

The speed and ease of this process allows contingency, and hence contingency draw down, to be monitored cost effectively on a quarterly basis. This monitoring acts as an alternative avenue for early identification of projects in distress allowing for timely intervention to avoid project failure. Conversely contingency draw down allows effective financial management across a portfolio, reallocation contingency between projects when needed and removing surplus contingency from the project pool, freeing up capital to sanction new profit making projects.

Enbridge views their contingency assessment process, as part of their larger project management process, to be a competitive advantage that allows them to bring projects to fruition faster, at a lower total installed cost with less cost and schedule variability.

ACKNOWLEDGMENTS

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