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WHY PROJECTS FAIL (AND WHAT WE CAN DO ABOUT IT)

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ABSTRACT
Over two-thirds of all mega projects result in failure, meaning they significantly exceed budget, miss schedule targets, or fail to achieve production close to design capacity. The reasons for project failure have been well documented over the past fifty years. Despite this large body of empirical evidence, many executive and project leadership teams continue to repeat the mistakes made on past projects. This can be partially attributed to project teams believing that their projects are somehow different from past projects and that others' project mistakes are not relevant to their project. This paper is a literature review that considers the seven common root causes of project failure and how these root causes relate to the pipeline industry. No new primary data will be presented. The seven common root causes for project failure and their approximate impact on budget variance are:

1. Failure to complete front end loading = 60–85%
2. escalation = Up to 12%
3. Regulatory regimes = Up to 12%
4. Plant complexity = Up to 20%
5. New technology = Up to 20%
6. Solid feedstock = Up to 10%
7. Complex ownership = Up to 24%

This paper will also review and discuss seven common project traits closely associated with project failure, although not direct root causes. These traits are:

1. Concurrent detailed design and construction = up to four times greater risk profile
2. Non-integrated project team = up to three times greater risk
3. Contractual risk misallocation = up to two and a half times greater risk
4. Fast-tracking projects = up to two times greater risk
5. Lack of internal capacity = up to two times greater risk
6. Oil and Gas industry = up to two times greater risk
7. Brownfield vs. greenfield site = no direct impact

With these root causes and traits identified, several methods of risk and contingency analysis will be examined. An evaluation of each method's ability to increase the success rate of capital projects will be discussed; ultimately, resulting in a recommendation on the optimal risk and contingency framework for improving project success rates. The paper will conclude with a summary of how Stantec's risk and contingency framework is being implemented on pipeline projects.

Key Words: risk, risk management, contingency, contingency drawdown, project controls, project management, project planning.

INTRODUCTION

"A (capital) project is a temporary endeavor undertaken to create a unique result." [1]

By this definition, people have been doing capital projects for millennia - from the Pyramids and Stonehenge, to the Great Wall of China and the Parthenon. While technology, methods, labor, and construction duration may have changed, our underlying ability to conceive, develop, and manage projects have not. Wherever humans and our monuments go, hubris and failure are not far to follow. In the 1970s The US Department of Energy in conjunction with the Rand Corporation began a study to understand why projects fail so that lessons could be learned and the frequency of failure could be reduced [2-6]. Out of these studies, Ed Merrow formed Independent Project Analysis (IPA) as a private corporation to continue the work of the Rand Corporation [7].

The empirical data has identified that projects, despite their "unique outcomes," are incredibly similar in how they behave. Many project managers seem to believe they are smarter and better able to execute projects than their predecessors or that their project is somehow different or special. Data suggests that nothing could be further than the truth. In fact, as an industry, our ability to predict project cost and schedule outcomes has actually declined over the past 30 years [8], despite significant advancements to technology and training programs. These improvements, while successfully decreasing the execution duration of projects, have not been able to improve our ability to forecast project outcomes.

In Figure 1 the initial data sources from the Rand Study [2-6] are shown. While the first data set contained approximately fifty projects, the data base has expanded over the years and now numbers in the thousands. The decimal points have changed, but the overall picture remains the same.

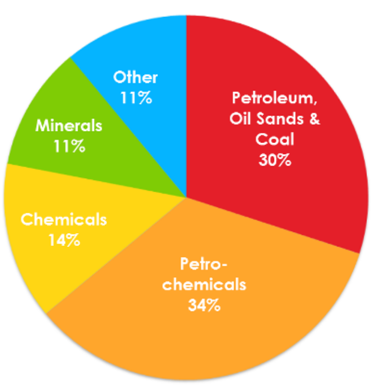

FIGURE 1 DATA SOURCES

Definition of Failure

<u>Industrial Mega Projects</u> [8] defines project failure as:

1. 25% cost overrun sanction cost
2. 25% schedule slippage from planned in-service date
3. Sanction cost and schedule are 50% greater than comparable projects
4. Substantial difference between planned capacity and actual capacity

Using this definition, over 65% of mega projects ($1 billion+) result in failure–an outrageous number considering the funds spent in developing and executing these projects. If we are to reverse the trend and break the bonds of history, we must understand that our projects are not a unique endeavor, stop making excuses as to why our project is different, and embrace lessons learned from the past.

SEVEN ROOT CAUSES OF RISK

The empirical data shows that there are seven primary drivers of cost variance. These root causes [2-6, 9, 10], shown in Figure 2, are systemic to almost all capital projects. 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.

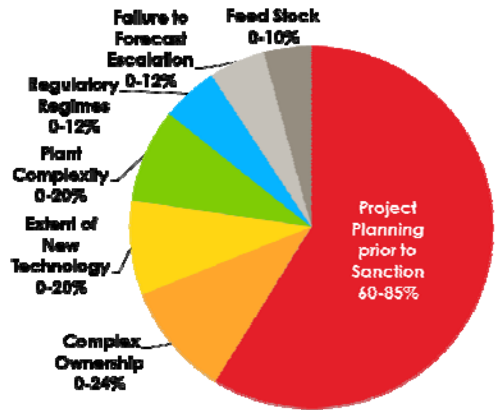

FIGURE 2 PRIMARY DRIVERS OF COST VARIANCE

As a result of an EEDC led study completed by Stantec [19-24], this framework has anecdotally shown to correctly account for mega-projects in Alberta over the past 20 years. These factors do indeed cause cost overruns and when avoided can be correlated with significant cost underruns!

Extent of Front End Loading

This trait is the single largest source of project variance, from planned to actual spend, accounting for approximately two-thirds of all project variance. The relationship between proper planning and accurate prediction of outcomes is both well documented and consistently observed over time. For a project's cost estimate design companies deliver a "class III" estimate as is contractually required. In many cases owners do not have the time or resources to validate the class of estimate produced. Furthermore, a true AACE "class III" is not just a set of P&ID drawings but also includes regulatory, land, environmental, execution plans, fully programed schedule, and an integrated business case [15]. Many of these deliverables are outside the scope or capability of traditional engineering firms. Taking a project to FEL 3 or a class III estimate will take up to 5% of the final project cost and can take over two years to complete for large projects [9]. If the project does not proceed into execution, these costs are expensed as a loss. This discourages management from making the necessary large upfront investment to produce proper quality estimates. While it is desirable to sanction after FEL 3 is complete, it is not always possible and early sanction may be required for valid business reasons. In these situations executives need to understand the consequences of early sanction in order to properly examine the tradeoff between the variability of project outcomes and business needs.

To address these issues the establishment of stage-gate project development and capital approval processes ensure that project deliverables are both developed in sync with the overall project, and meet the required level of detail.

Complex Ownership

The second largest driver is complex ownership structures. Many in private industry are quick to point out the waste inherent in public projects, and hold themselves as paragons of resource efficiency. While the data supports the private sector claim of public largesse, in fact the worst ownership structures for efficiency are complex partnerships: joint ventures of private-private partnerships and public-private partnerships (P3s) [9]. The more complex the ownership structure the more likely there will be:

- Divergent interests
- Conflicting approval and authority requirements
- Excessive oversight
- Mismatched leadership based on ownership rather than expertise
- Delayed decision making and funding releases
- Conflicting corporate cultures

While joint ownership may diversify financial risk, it increases the project's aggregate risk. Partnerships need to have clear decision making lines established prior to execution. In formulating ownership structures for capital projects, the simpler it is the better.

New Technology

The third largest risk associated with capital projects is new technology–it is called the "bleeding edge" for a reason. By definition no one truly knows how commercially unproven technology will behave despite promises from the proprietors of the technology. While typical pipeline projects tend not to include truly new technology, owners must honestly evaluate how substantially different their technology will be. Potential attributes of new technology may include:

- Commercially unproven
- New or modified block process steps
- Novel integration of proven technology
- Untried methods or approaches
- Inexperienced owner, design firm, or contractor

Project risk can be reduced by reviewing all technology for proven commercial viability, ascertaining the pure technology requirements, and determining if existing alternatives can be used instead of the "bleeding edge" technology.

Plant Complexity

While all projects contain similar underlying processes, some projects are more technically complex than others and result in greater cost variance. The original Rand studies define project complexity as "the number of continuously linked process steps or blocks" [3-6]. More process steps equate to a more complex project, as this is simply a manifestation of the theory of constraints [18]. Figure 3 contrasts five similar production processes with a desired output of 100%:

1. A single step process with ±10% production variance
2. 5-Step sequential linked process with each step having a with ±10% production variance
3. 10-Step sequential linked process with each step having a with ±10% production variance
4. Identical to process #2 (5-Step sequential process) with each step having 105% of required capacity and a ±10% production variance
5. Identical to process #2 (5-Step process) with sufficient inventory buffers between steps to effectively de-link the entire process

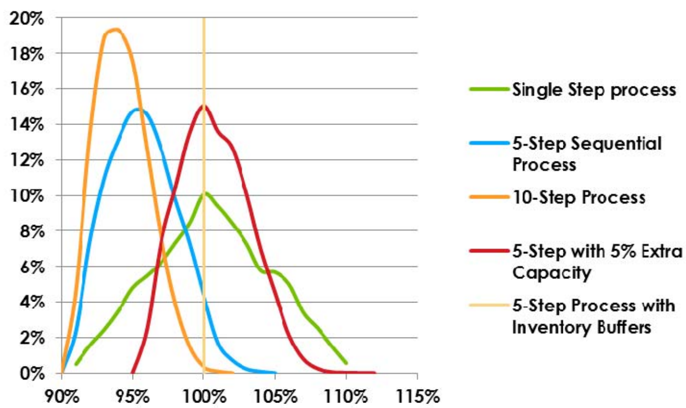

FIGURE 3 IMPACT OF LINKED PROCESS BLOCKS

As depicted as the number of process steps increase, the total effective production decreases (green-blue-orange line). To correct the decline in production, additional capacity can be added (red line) or 10% inventory buffers can be created, effectively delinking the process. However, both of these corrective actions have costs and illustrate how complexity leads to cost variability.

Plant complexity risk can be mitigated by: understanding and modeling process block dependencies; reviewing the economics of intentional surplus capacity design in each process step capacity; and breaking the sequential processes limitations by the introduction of capacity buffers. It is not uncommon for design companies to "overbuild" the capacity of the system in fear of penalty clauses and "must meet" requirements. In order to address hidden superfluous capacity and its associated cost implications, contract documents need to remove the fear from the system [27].

Failure to Forecast Escalation

A seemingly immutable fact of life is that things usually cost more tomorrow than they do today. Nowhere is this more true than in construction. While inflation (the cost of a basket of consumer goods) may only be increasing at ~2% a year, escalation (the cost of construction) can easily double or triple this figure [24, 25, 28]. Escalation will cause cost variation but does not automatically mean cost overruns. For instance, in the 1970s oil crisis, escalation of capital projects in North America tended to overestimate escalation which supported potential cost underruns and consequently improperly allocated capital funds. While predictions of the future will always be somewhat wrong, data purchased from companies that generate bottom-up forecasts usually get the direction and approximate magnitude right even if they get the decimal places wrong. The empirical evidence of this primary driver indicates that it is not simply a matter of failing to achieve accuracy to the first or second decimal point. Rather projects fail to treat this cost item with the due diligence it requires. It is not uncommon on a pipeline project to put considerable effort and resources into understanding and designing crossings while only a fraction of that is put into understanding escalation even though cost escalation alone can easily add up to double the cost of all the crossings. Additionally, cost components vary across projects (more steel, less labor) and escalation affects each item differently. These discrepancies need to be accounted for when calculating overall project escalation.

Project proponents also need to consider what impact their project will have on the overall market place. While a small lateral may not change the market price of specialized labor, massive projects will create their own escalation [20-24]. One can see this today in the pipeline industry as mainline contractors and pump manufacturers are reaching capacity making it possible for two projects within the same company to compete with each other for resources.

This root cause of risk can be mitigated by applying appropriate data-based due-diligence to the escalation rather than opinion.

Regulatory Regimes

Clarity around regulatory regimes and changing regimes, and a thorough understanding of the current and possible changes to regulatory regimes, are in the third tier of root causes for cost variance. For pipeline projects the single largest portion of the schedule is likely centered on obtaining regulatory approval. While the traditional definition of regulatory regimes included only the legal requirements, it is anecdotally fair to include social license. The current major attempts to export oil from Canada – Northern Gateway, Energy East, and Keystone XL – all have a firm grasp on the legal requirements, but politics driven by social license are trumping what would otherwise be routine matters. More and more frequently proponents of major projects are realizing too late that status quo community engagement is no longer acceptable.

Feedstock

The original Rand studies identified a clear split between projects' whose feedstock was solid compared to those who had liquid or gas feedstocks [2-6]. This may be a surprise to some when they consider the volatility of compressed natural gas. While solids tend to be less volatile, their physical properties are more difficult to determine when compared to liquids and gases. One of the reasons for this is most solid feedstocks are extracted directly from the earth whereas most liquid and gaseous feedstocks are produced. The variability in feedstock properties drives variability in process and project outcomes as shown in Figure 4 [9].

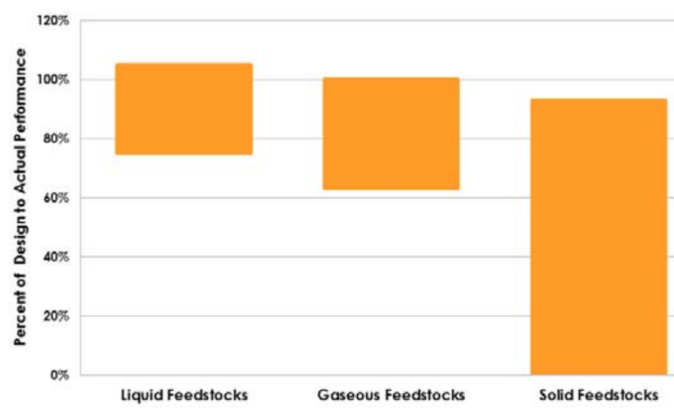

FIGURE 4 ACTUAL PERFORMANCE TO PLAN BY FEEDSTOCK

This understanding has led to increased data collection in the past 30 years, which has determined that the intrinsic variability and physical properties of the underlying feedstock are the culprit. Fully understanding the physical and chemical properties of a project's feedstock are key to controlling scope, schedule, and budget variability. Spending resources to know the properties of a project's feedstock will reduce a prime root cause of project variability and decrease a project's risk profile.

Seven Traits Associated with Risk

Seven common traits associated with increased project risk and their associated impacts to a project's risk profile are shown in Figure 5 [9]. Each of these traits are not in and of themselves causes of project variance, rather they are symptoms of the seven underlying root causes discussed earlier. When a project falls into these archetypes, project managers can expect a project with a higher risk profile and less predictable scope, schedule, and budget outcomes.

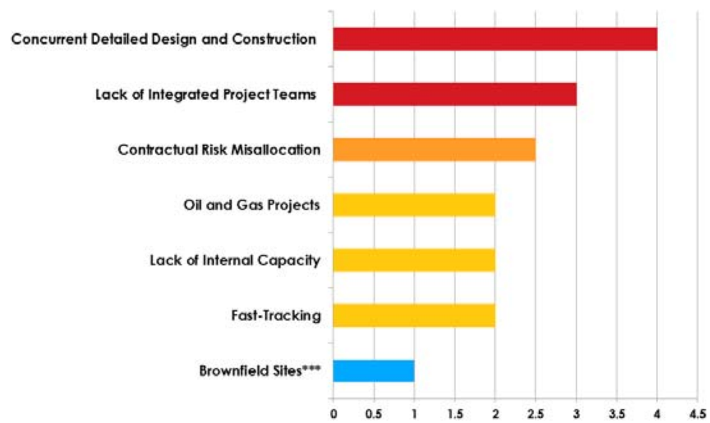

FIGURE 5 TRAITS ASSOCIATED WITH INCREASED RISK PROFILES

Concurrent Detailed Design and Construction. By their nature alternative delivery projects like design-build, are sanctioned prior to knowing as much about the project as is required for traditional execution methods. While there are numerous business reasons to combine detailed design with construction, by employing a concurrent execution strategy risks are created. This is a manifestation of the number one variance driver: limited project planning prior to sanction. Empirical evidence has shown that projects with this execution trait can have up to four times the level of cost variance than projects that proceed with traditional design-bid-build delivery method.

Non-Integrated Project Teams. At its peak, a half-billion dollar project will use hundreds of people working full time over the course of several years. This is roughly the size of many medium sized ongoing businesses. Project proponents often fail to identify, fund, and develop the organizational structures required to support such a complex entity and in doing so can triple their risk profile. Co-located, cross-functional, dedicated, and consistent team members throughout the life of the project dramatically reduce the risk associated with it. This trait is another manifestation of the largest root cause of project failure: lack of up-front planning. Too often project proponents are overly focused on engineering designs and specifications while, at their peril, ignoring the human resources and work-flow processes required to execute a project of large magnitude. It is little wonder that one-third of the PMBOK's areas of knowledge directly relates back to the forming, storming, norming, and performing of project teams [1]. Non-integrated project teams can triple a project's risk profile.

Contractual Risk Misallocation. To obtain optimal project results, risks must be owned and managed by those best able to do so. Too often this is ignored in convoluted contractual documents which attempt to align the business interests of the parties. Evidence indicates the greater the attempt at marrying interest in "alliance" contracts, the greater the rate of project failure as shown in Figure 6 [9]. Why is this the case? It may be because the fundamental interests of vendors rarely perfectly align with owners. A possible source of this alignment mismatch arises because consultants and contractors must expense project cost overruns as losses. Since these firms are not typically able to absorb large losses, they must win the change order game or risk going out of business. Conversely, owners are able to capitalize project overruns on their balance sheets and treat them, ironically enough, as assets. The Darwinian nature of capitalism leads to the conclusion that only contractors and consultants who can win the change order game stay in business.

Effective up-front planning includes the identification and response planning of risks and determination of who is best able to absorb which risks. With this lens, contractual risk misallocation is directly related back to limited project planning prior to sanction and can increase a project's risk profile by 150%.

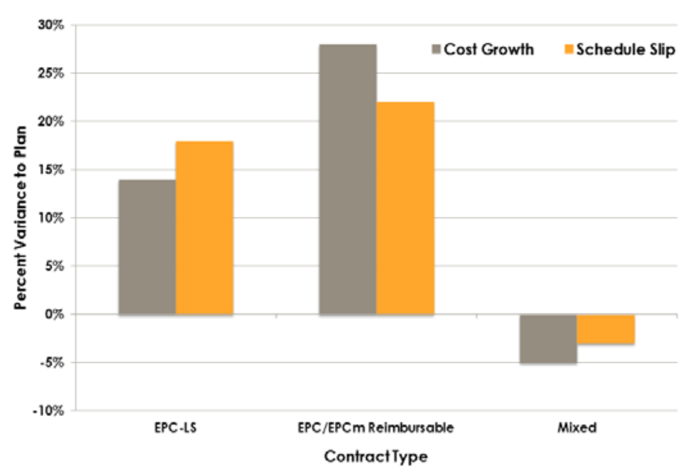

FIGURE 6 COST AND SCHEDULE VARIANCE BY CONTRACTING STRATEGY

Fast-Tracking Projects. High profile projects are prone to the management dictate of "fast tracking". This occurs when a project purposely skips regular project development stages and gates. Effective stage-gate processes are in place to ensure successful project development, establish deliverable expectations, reduce project development time, and prevent squandering of limited resources on bad projects [26]. Shortening or abandoning a uniform, methodical project development process is directly related back to limited project planning prior to sanction and can double a project's risk profile. Additionally, fast tracked projects will artificially compress long-duration, low-spend activities such as preliminary engineering and regulatory application processes. Not understanding regulatory regimes is one of the seven root causes of project variance while insufficient front end planning is number one.

Lack of Internal Capacity. No matter how well crafted a contract or supply agreement is, it is the Authors' opinion that there will never be full alignment between a vendor, contractor, or consultant and the owner. Owners need to have a detailed understanding of the work required to progress the project, as well as the ability to effectively assess the quality of that work. While outsourcing may appear a savvy business decision on paper, it systemically erodes an owner's ability to effectively manage a project. With the North American energy production and transportation renaissance, the successful pipeline companies will include those that can execute projects on time and on budget. A lack of internal capacity can preclude proper project planning prior to sanction and can double a project's risk profile.

Oil and Gas Industry. This industry is twice as likely as any other to have cost and schedule variations. Oil and gas firms are more likely to outsource, change leadership, fast track projects, run afoul of regulatory requirements, and/or have overly ambitious schedule and project costing estimates.

Brownfield vs. Greenfield Site. Contrary to popular opinion, brownfield projects are no more prone to cost and schedule variances than their greenfield counter parts, *provided suitable project planning occurs prior to sanction*. This proviso is the key. Most of industry's stage-gate project development processes implicitly assume a greenfield project and as a result systemically ignore the requirements of a brownfield site. This might be as simple as assuming prior as-built drawings are correct or that community consultation is not required as the project is all within existing battery limits.

OBSERVATIONS ON PROJECT VARIANCE

A key observation of the causes and traits associated with project variance is that all of these root causes are *systemic* in nature and common to all capital projects. Even the top risk profile multipliers are really just manifestations of the underlying *systemic* root causes. Understanding how these root causes influence variability is key to predicting project scope, schedule, and cost outcomes, as well as to improving the odds of a successful project. An honest assessment of what is known on a project and how well it is known is the key to forecasting project outcomes, estimating contingency requirements, and improving the odds of project success.

Contingency Concepts

Business (Product) Scope vs. Project Scope. Business or product scope are the features and functionality that define the desired outcomes of the project. Project scope is the work that needs to be accomplished to deliver the business or product scope [1]. Project scope develops and refines the means to accomplishing the business scope. Business scope is what the project is supposed to accomplish, and project scope is how the project will do that. As an example project:

1. Business Scope:
   - 200 kbbl/d between "here" and "there"
   - Connectivity at terminal
   - Batching capability
   - System reliability of 99%
   - System availability of 95%
   - Satisfies current safety and operational requirements
2. Project Scope
   - 36" pipe line with a certain MAOP
   - Selected route along existing ROW
   - Four pump stations located at A,B,C, and D each with two-5000 hp pumps, VFD, live spare and auto-pig bypass systems
   - 4 x 300 kbbl tanks at terminal
   - Leak detection
   - Block values at all major river crossings

Definition of Contingency: "*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." [11]*

Contingency covers all development and progressive refinement of project scope and does not cover changes to business scope.

Definition of Escalation: "*A provision in cost or prices for uncertain changes in technical, economic, and market conditions over time." [11]*

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 addresses 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. With that understanding, contingency is escalated.

CONTINGENCY ASSESSMENT METHODS

There are two main basis for assessing contingency: expert based and empirically based [12-14]. Each basis has two options in regards to level of detail as shown in Figure 7. The four options–expert opinion, range estimating, predetermined guides, and parametric (systemic)–have different levels of effort, benefits, and accuracy ranges.

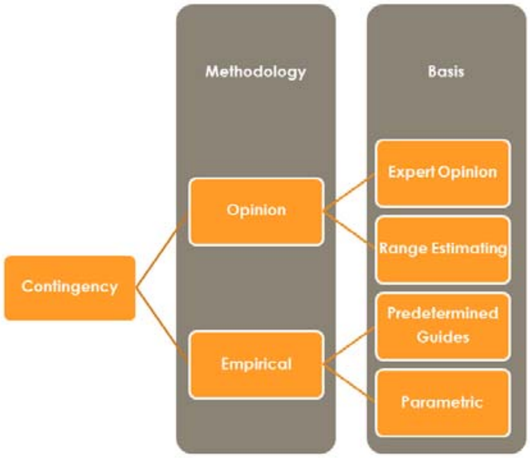

FIGURE 7 CONTINGENCY BASIS AND DETAIL

Opinion Basis

The opinion-based contingency methods are expert opinion and range estimating. In practice the difference between these two options is simply the level of detail at which the opinion is estimating. Expert opinion is typically at the first level of the work breakdown structure (WBS) whereas range estimating applies this opinion on the lowest possible level of the WBS.

Expert Opinion is where the project team or similar subject matter expert simply provides a contingency value. 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.

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 by the development of probabilistic ranges of cost, quantities, and production rates. Ideally these ranges are based on data and evidence; however, often in practice the ranges are developed based on expert opinion. When this approach is used, it often becomes the expert opinion method with a greater level of detail. While this method provides a range of cost and schedule outcomes, it is labor intensive and requires the estimation of risks that are inherently unknown and unquantifiable on an individual basis. It is also prone to the central limit theorem: when the number of independent variables increases, the resulting distribution becomes narrower. 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 as they often neglect to correlate the variables. For instance millwrights' rates in a given region are not correlated to rain-delay days but are correlated to electrician rates in the same region and should be accounted for in a model. One of the differences between a professional Monte Carlo simulation and an amateur one lies in the level of detail in the correlation matrix. 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.

A complimentary concept to range estimating is Expected Value and its sister approaches of event modelling and fault tree analysis. 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 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 general project risks.

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.

Empirical Basis

The contingency methods based on empirical data are predetermined guidelines and systemic. Both fundamentally attempt to evaluate the level of project definition and correlate that to historical results.

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 in which the project's contingency is based roughly on the work completed. A class III estimate, assuming the accurate production of the required deliverables in the AACE guidelines [15], typically gives a cost accuracy of +30 to -20%. Though, the basis of these rules is unclear to the aurthors, they have stood the test of time because they appear to work making this method both cost effective and repeatable. The only drawbacks are that it does not incorporate project risks or provide a range of possible outcomes. In the authors' experience the main problem with this approach is that 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. Empirical data tells us that cost estimate accuracy comes from the level of effort, not from engineering skill. A true class III estimate means that project deliverables are 10-40% complete, and that the cost estimate is based on take-offs or assembly level components from those deliverables [15]. This results in accuracy in the range of +30% to -20%.

The estimation methodology drives the accuracy range, not the other way around.

Systemic Contingency, or parametric modeling, uses historic cost and schedule outcomes and correlates those with the degree of project development at sanction. As this paper has reviewed, the majority of project outcome variance is directly related back to common, systemic causes. This approach starts with actual results and maps them to the project in question. The drawbacks of the systemic contingency approach are that project teams are 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 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.

Comparison of Contingency Methods

Risk Recognition. Due to the basis of the four contingency methods options, they fundamentally recognize risks differently. The opinion basis is rooted in knowing about the specific project whereas the empirical methods focus on understanding how this project compares with data-based history. This calls to mind a famous quote from Donald Rumsfeld, former United States Secretary of Defense, about risk:

"*... there are known knowns; there are things we know that we know. There are known unknowns; that is … there are things that we now know we don't know. But there are also unknown unknowns – there are things we do not know we don't know.*"

In practice all project base estimates should include all known-known conditions. Opinion based contingency methods are grounded in what we know and as a direct result cannot recognize the unknown-unknown risks. Empirical approaches on the other hand attempt to capture all the possible outcomes by using every project's actual results as its database. The larger the database, the more likely it is that a particular "unknown-unknown" risk actually occurred to some project within that database. A contingency assessment based on this database then implicitly includes this risk. This is where predetermined guidelines also fall short of systemic contingency assessments: the predetermined guidelines are static and purposely created to be immutable over time, whereas with the systemic approach one can regularly update the curves based on the best, most recent and most relevant database available. A visual metaphor for risk recognition by contingency method is shown in
Figure 8.

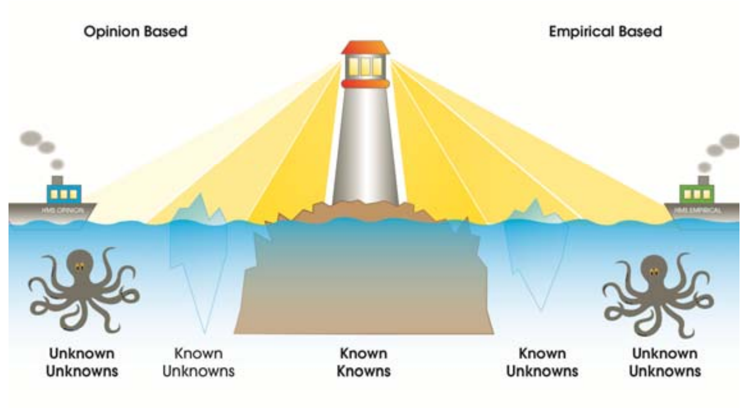

FIGURE 8 RISK RECOGNITION BY METHOD

Effort-Benefit. Having used all four methods, Figure 9 illustrates the author's opinion of the relative strengths and weaknesses of each option. Project insight is a combination of attributes that include:

- Project-centric risk evaluation
- Identification of project risk drivers
- Speed of assessment
- Probabilistic results
- Understanding of project status
- Comparison between projects

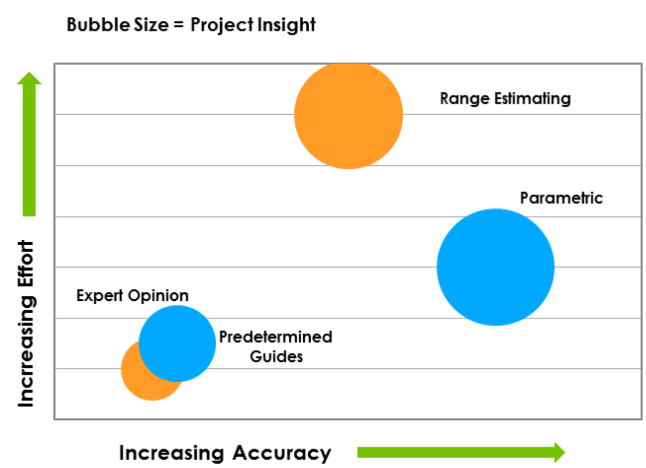

FIGURE 9 CONTINGENCY ASSESSMENT OPTIONS

Accuracy. The key advantage of the systemic approach is its accuracy. It is the only method that uses proven historical results as a starting basis rather than trying to develop a forecast from scratch. While to the author's knowledge there is not a study that compares contingency methods on the same set of projects, the meta-data illustrate the accuracy of the four main methods and their attempt to capture reality is shown in Figure 10 [15-17].

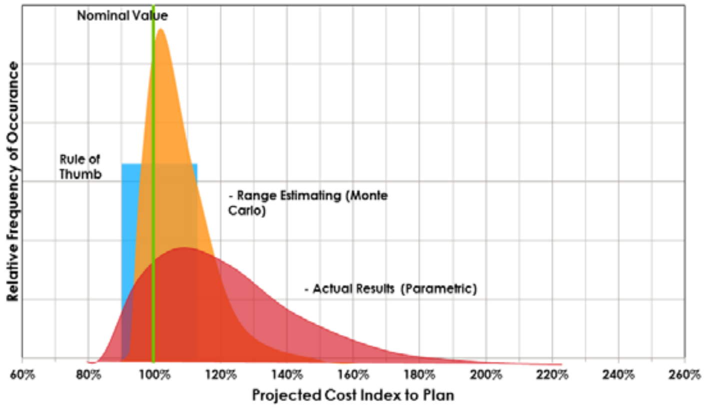

FIGURE 10 ACCURACY OF CONTINGENCY METHODS

While many owners do not like the range of actual cost outcomes, the systematic (parametric) approach most accurately predicts actual project outcomes.

OPTIMAL CONTINGENCY ASSESSMENT METHOD

In careful examination of Figure 2, the percentages presented may not add up to 100% or indeed may go over 100%. The reason for this is that while the majority of cost variance is due to the seven main root causes, these root causes do not account for all of the risk in a project. The seven root causes are the primary drivers of project variance, but they are not the only drivers. While the process of project delivery may be common to all projects, the details are different. The remainder of project variance can be attributed to project-specific risk as illustrated in Figure 11. An optimal contingency assessment process needs to account for both the systemic and project-specific risks by combining the use of a systemic contingency model with an expected value risk register.

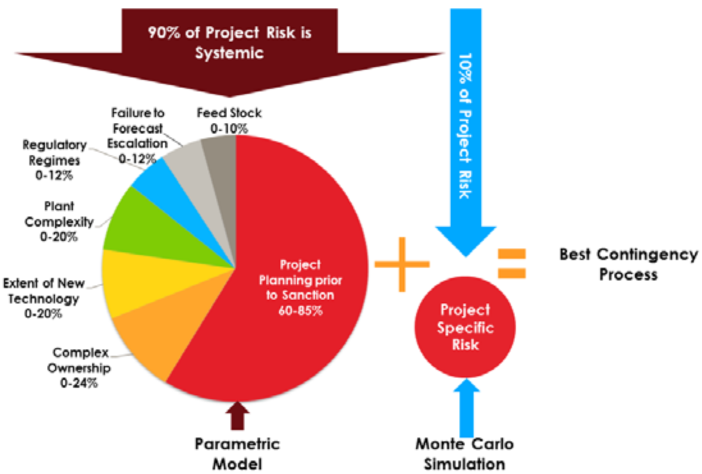

FIGURE 11 OPTIMAL CONTINGENCY PROCESS

Project Specific Vs Systemic Risk

A systemic contingency approach still requires the development and maintenance of a risk register. A critical success factor in implementing the hybrid systemic contingency process is the ability to identify which risks within the risk register are truly unique to the project (project specific) or common to all projects (systemic). Based on the author's experience, project specific risk can account for as little as 0-5% of the total risk for low-risk projects with emerging project definition, and up to 20-40% for high-risk projects with substantial project definition. Systemic risks are common to all types of projects and are the bread-and-butter of day-to-day project management. Typically, if subject matter experts cannot provide probabilities or impacts of a given risk it is usually systemic.

Examples of systemic risks include:

- Uncertainty in project deliverables
- Rain delay-days
- Rework
- Owner-contractor-consultant miscommunication
- Variable labor productivity
- Late delivery of materials onsite
- Incomplete or erroneous engineering drawings

Contrasting systemic risks are project specific risks. These risks are truly unique to the project and are often created by the scope, schedule, budget constraints, and assumptions that exist. The probability and impact of a project specific risk can typically be quantitatively evaluated or calculated based on data. Examples of project specific risks include:

- Knowingly ignoring site conditions
- Hurricanes in the Gulf Coast
- Excluding a possible regulatory hearing from the base schedule
- Regulated or limited construction windows
- Repurposing or re-using equipment
- Accessing unique resources

A metaphor for the relationship between systemic risks and project specific risks is shown in FIGURE 12. The explanation of the metaphor is that the tall grass (systemic risk) hides animals (project specific risks). As the grass is "mowed" animals (project specific risks) are more fully revealed, and can be sequentially dealt with as more details emerge. The grass is "mowed" by progressive project development which:

- Reduces overall project risk
- Replaces systemic risk with project specific risk
- Improves risk identification

- Improves risk management

As risks emerge from the systemic “grass”, they are partially uncovered and their probabilities and impacts are not fully known: true risks. When they are fully revealed they are understood either to be irrelevant –and can be safely expired - or realized - and incorporated into the execution plan and cost-schedule forecast.

FIGURE 12 RISK IDENTIFICATION METAPHOR

SYSTEMIC–PROJECT SPECIFIC MODEL

Stantec has implemented the systemic-project specific contingency model on several pipeline and terminal projects for the Oil and Gas industry. The core of this approach is the systemic model. The Stantec model is based on the extensive amount of research that has been published over the past fifty years on systemic risk. Unlike earlier models that produced symmetrical or prorated curves [13], the Stantec model is based on five asymmetrical curves from publicly available sources that correspond to the level of the project’s maturity. these levels are:

1. Unclassified
2. AACE class 5 / FEL1
3. AACE class 4 / FEL 2
4. AACE class 3 / FEL 3
5. AACE class 2 / projects in detailed design and execution / “FEL 3+”

An illustration of these curves is shown in Figure 13.

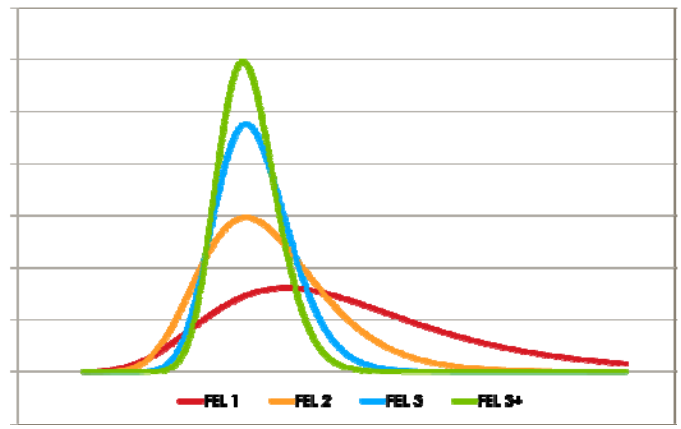

FIGURE 13 COST CURVES BY PROJECT MATURITY

As a project matures both the mean and standard deviation are reduced as the curves shift tighter and to the left. Since the curves are asymmetrical, the P50 or median is not equal to the expected value, or mean, which roughly corresponds to the P55. This reflects that the opportunity to have cost overruns is larger than the ability to have cost underruns.

The model asks 57 multiple-choice questions broken down as follows:

- Business fundamentals – 3 questions
- Scope definition – 2 questions
- Project planning – 11 questions
- Design – 11 questions
- Engineering deliverables – 11 questions
- Project team disposition – 8 questions
- Reviews – 6 questions
- Base risk modifiers – 5 questions

The answers to these multiple choice are sets of five verbal anchors corresponding to the five levels of project definition. With over 50 questions and 275 possible answers, the influence of any single question and errors created by erroneous answers is heavily muted. The cost to this approach is that completing the survey takes about two hours of the entire project team's time. While this may seem daunting, it is a fraction of the team resources required for a Monte Carlo or range estimating approach.

Model Benefits and Limitations

In the use of any theory, one must completely understand the limits of that theory. Newtonian mechanics do not work at relativistic speeds or on the molecular level but do fine for explaining everyday life. Application of any model outside its limits will give erroneous results. The limitations of this approach are:

1. Relevance to small projects
2. Statistical requirements
3. Schedule forecast accuracy during construction
4. Level of sophistication

The underlying probability curves are derived from larger projects and there is significant empirical evidence that smaller projects have a longer tail (probability) of cost underruns whereas large and megaprojects have a longer tail for cost overruns. While the underlying curves can be altered for smaller projects, it is possible that the cost and effort required to apply this system may not be economic for projects in the $1 to $10 million dollar range [16].

Since this approach is fundamentally driven by statistics, it also has the limitations of statistics; and in order for it to work it requires enough variables to be relevant. For instance, the expected value of a $1 fifty-fifty ticket in a charity raffle is $0.50; this outcome cannot be achieved by a single participant, but is rather the expected value of all the participants. As an example this approach may work for a project consisting of 50 crossings, but would not be relevant for a project consisting of a single horizontal directional drill.

Just as this approach is grounded in large projects, the schedule component assumes long durations with multiple moving parts. As projects move into construction, assumptions inherent in the model may become invalid. For this reason critical path methods and simulation approaches during project execution may be more appropriate and accurate.

Finally, this approach requires a level of project management and controls sophistication that may not be present for all owners. Just as project deliverables need to be uniformly developed, project controls, including risk and contingency management, also need to be deployed.

This approach implicitly requires a reasonable degree of sophistication in scope, schedule, and budget development processes and controls. If the project team lacks basic project management skills or controls, there may be better economic returns in deploying a project's limited resources in improving these areas before embarking on sophisticated risk and contingency processes.

Benefits. The benefits of this systemic-project specific approach are:

1. Accuracy
2. Speed of application
3. Probabilistic outcomes
4. Focus on key drivers that cause project variance
5. Project risk based
6. Repeatable
7. Comparison between projects and portfolios
8. Ease of management review

Accuracy. The systemic-project specific model starts with actual project results and works backwards providing a potential level of accuracy difficult to match by competing methods. Unlike simulation methods, this approach does not require users to estimate the unknown-unknowns.

Speed. In comparison to simulation methods, the systemic project-specific model requires a fraction of the resources and effort to complete an assessment. While a typical simulation model may require days of data collection and risk sessions, the systemic approach can be applied in under two hours with a simplified existing risk register. At the request of a client, Stantec simultaneously performed a Range estimating contingency and the recommended approach. Both provided similar results (comparable means with very different confidence intervals); however, the cost of the systemic approach was roughly one-third that of the Monte Carlo.

Probabilistic Outcomes. Like simulation contingency options, the systemic-project specific method provides ranges of outcomes rather than a single point estimate.

Focus on Risk Drivers. The systemic-project specific approach directly evolves from the seven root causes of project variance. Its application provides clarity on the activities that need to be taken to reduce scope, schedule, and budget risk.

Risk Based. The use of a risk register forces project teams to truly consider what makes their project unique. Given these risks are often rooted in scope, schedule budget constraints, and assumptions, actionable responses are easier to develop.

Repeatable. This approach does not require significant opinion or consensus building when properly facilitated. This allows the same approach to be applied on a project over a time range to support contingency draw down.

Comparable. Without consistency in both approach and application, contingency comparison between projects and portfolios is impossible. This level of consistency is extremely difficult to obtain with the opinion based method of simulation modeling. The fact based foundation of the systemic project-specific approach and its repeatability allows projects and portfolios to be fairly compared to each other.

Ease of Understanding. Management can be forgiven for having an aversion to statistics and a desire for straightforward answers. This approach allows management to visually see how one project compares to another, and lends itself to direct questions and lagging indicators that can be addressed to reduce a project's risk profile.

CONCLUSION

The majority of project risk is driven by seven root causes:

1. Extent of front end loading
2. Ownership structure
3. New technology
4. Plant complexity
5. Regulatory regimes
6. Failure to forecast escalation
7. Feedstock

These root causes are common to all projects and are systemic in nature. While to some extent these issues can be "managed" out of projects by various means to limit their impact, their presence can never be eliminated. These root causes are manifested in numerous traits some of which are shown above. The unknown-unknowns will continue to plague projects despite the best project team's diligence and even after several rounds of mitigation on known risks. Eventually all risks are accepted and need to be accommodated by contingency. The optimal contingency forecasting method needs to be grounded with this understanding and rooted in empirical data.

The systemic-project specific contingency approach provides the best tradeoff between implementation cost, accuracy, and management benefits of the four main contingency methods because it is rooted in empirical data. It captures the benefits of each approach such as project focus, risk-based probabilistic outcomes, empiricism, and risk capture while avoiding their pitfalls–bias, resource demands, unrealistic models, and taking opinions over facts. The speed and repeatability of this process allows contingency, and hence contingency draw down, to be monitored cost effectively on a periodic basis while comparing projects and portfolios. By being grounded in the project front end loading, it encourages project teams to focus their limited resources on those areas that are prime drivers, or those whose development is being neglected. In this sense, proper use of this approach not only improves forecast accuracy but implicitly improves project results.

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