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Forecasting Realistic Time and Cost Contingencies for Large and Small Projects

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About the Speaker – Colin Cropley

Chemical engineering graduate of the University of Melbourne, PMP & Certified PRINCE 2 Practitioner

Over 40 years experience in Project Management, Project Controls and Risk Management, including project and risk management consulting, software development, training and lecturing, in sectors including infrastructure, oil & gas, mining & minerals processing, IT, power and defence.

Colin has conducted risk management processes, schedule and cost risk analyses and training for companies including BHP Billiton, BP Australia, CSL Behring, Downer EDI, Leighton Contractors, Oman LNG, Origin Energy, Santos, South32, Talisman Energy (now Repsol), Tenix Defence, Thiess and Woodside Petroleum.

He was chairman of the Victorian Primavera Users Group from 1997 to 2009.

Guest lectured at universities from 1991 to 2018. Presented at national & international conferences. Member of AACE International and EA's Australian Cost Engineering Society (ACES) and Risk Engineering Society (RES).

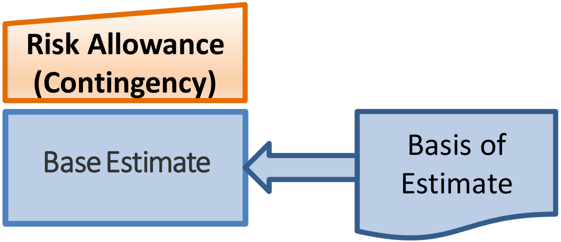
Presentation Outline

- How are projects estimated?
- Brief history of estimating contingency
- Our experience
- What works best?

How are projects estimated?

Structure of an Estimate

Detailed estimates are built from the bottom up, starting with definition of the project scope.
The Basis of Estimate (BoE) documents the overall project scope, the assumptions and exclusions, enabling a reader with capital project experience to understand and assess the estimate.
The Base Estimate includes all known and quantifiable costs defined to be within scope.

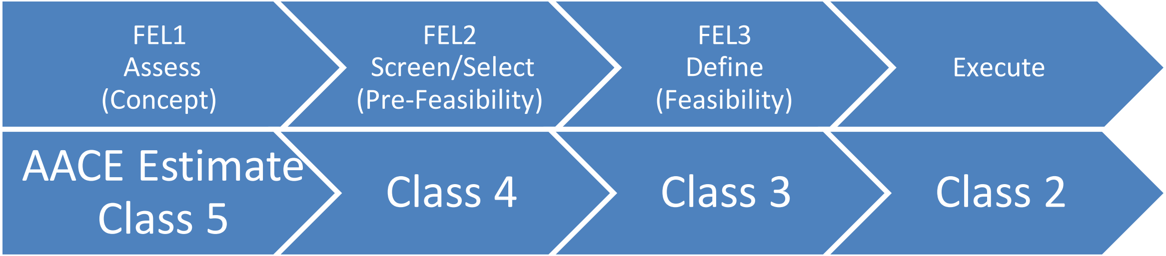


A Risk Allowance is an essential representation of costs additional to the Base Estimate due to two kinds of uncertainty:

- Inherent risk, certain to occur, due to drivers of risk and inability to estimate exactly
- Contingent risk comprising risk events less than certain to occur with variable impacts

Projects are developed in phases

This is because scope definition is a progressive process as more is learned about the project and the time, effort and cost required to execute it. Different industry sectors have their own terminology[1] for these phases, but the common basis is that successive stages produce better scope definition and understanding of the project as increasing engineering effort is made



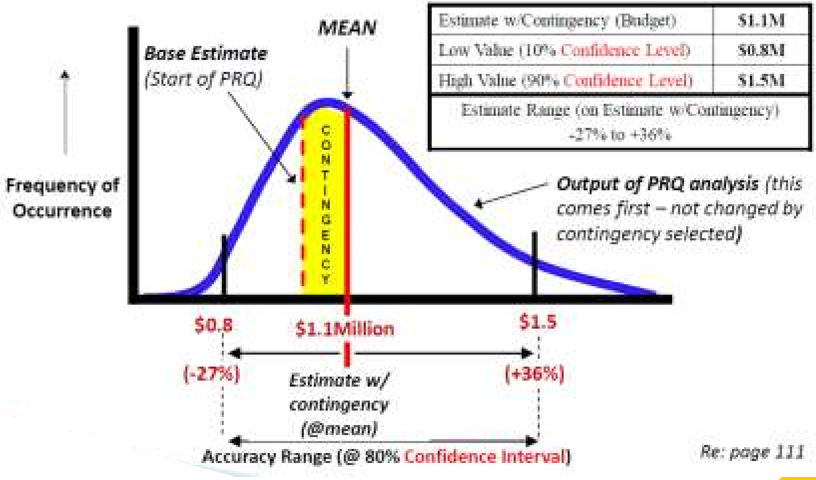
As scope is better defined, improving accuracy is expected to be achieved, as defined by AACE Estimate classes

[1] FEL="Front End Loading" – By Independent Project Analysis, Inc. (IPA)

Project Risk Quantification Concepts: Base, Contingency & Accuracy

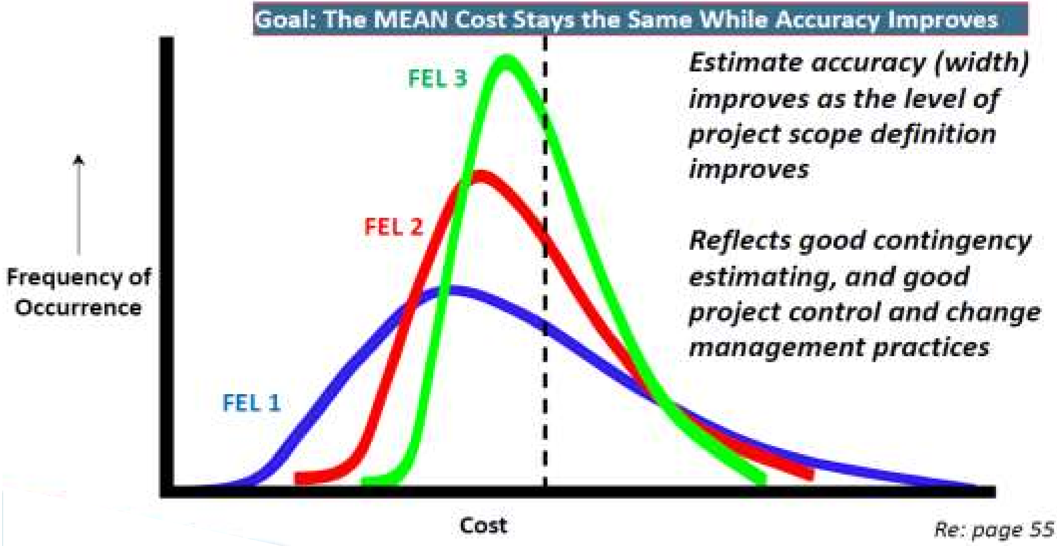
John K Hollmann (JKH), developer of AACE's Total Cost Management Framework and a world leader in developing understanding of project contingency, published "Project Risk Quantification" (PRQ) in 2016. I am indebted to John for permission to use graphics from his book and lectures in some of the following slides.

Page numbers refer to PRQ.

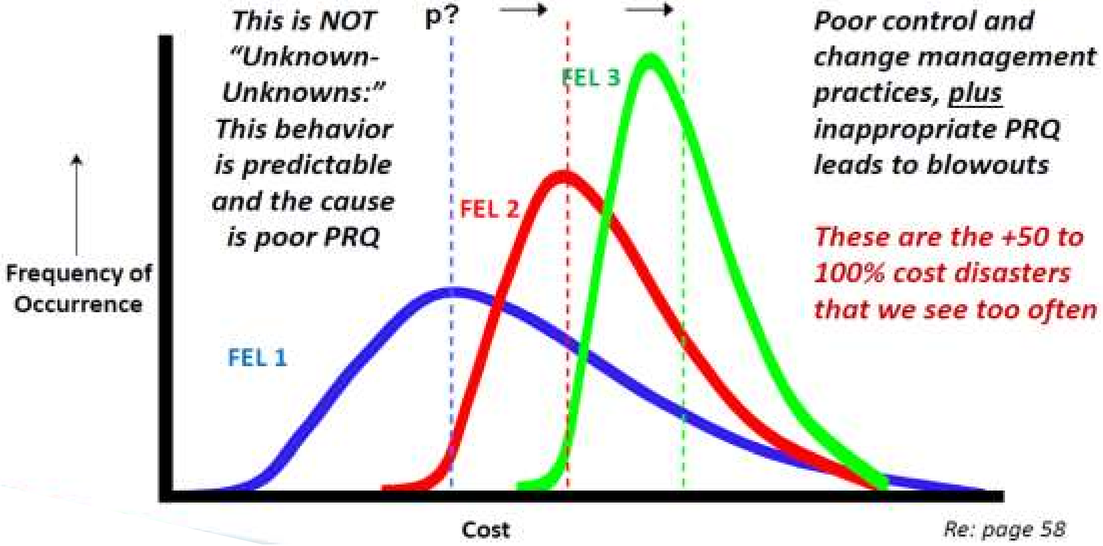


https://riskinteg.com

Accuracy and Funded Amount: Ideal Situation



Frequent Accuracy Reality: Scope Creep & Underestimated Contingency



Brief History of Forecasting Project Contingencies

First systematic assessments of what drives project cost outcomes created parametric models using Multiple Linear Regression. Through analysis of completed projects, they created "top down" models that realistically forecast cost and subsequently, schedule outcomes, based on systemic risk factors such as scope definition, quality of leadership, organisation and project controls.

- 1965: John Hackney publishes first parametric cost growth model
- 1981: Rand Corporation publishes Cost Growth & then Schedule Slip (1986) models based on internal project risk factors, scope the biggest
- 1987: IPA forms, acquires Rand data, starts benchmarking projects & refining Rand models
- 1997: AACE defines estimate classes 5-1, aligning with IPA FEL numbers 1-3+ Execution. Progressively issues Contingency Recommended Practices
- 2016: JK Hollmann publishes "Project Risk Quantification", drives renewed interest in & uptake of parametric modelling

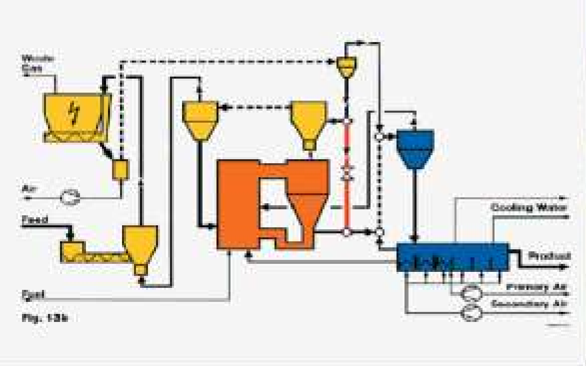
In parallel, Monte Carlo Simulation (MCS) based Project Cost Risk Analysis and Schedule Risk Analysis were developed. These "bottom up" models replaced discrete values for costs and durations with probability distributions. Subsequently cost & schedule impact risk events from project risk registers and CPM-based Integrated Cost & Schedule Risk Analysis methodologies were added.

- 1963: RAND applies MCS to PERT for USAF. 1964: David Hertz applies MCS to DCF calcs
- 1987: First PC-based MCS tools for CRA introduced: @Risk and Crystal Ball
- 1990s: Project planning software combined with MCS to produce Schedule Risk Analysis software
- 2011: "Integrated Cost-Schedule Risk Analysis"(ICSRA) published by Dr David Hulett based on use of Pertmaster/PRA
- 2019: Practical method of combining parametric and ICSRA methodologies presented at AACE conference

How did our Team end up here?

1980s - Project Manager

PM for first fluidised bed alumina calciner project in Australia, at Queensland Alumina Ltd (QAL) in Gladstone, 1980-1984. Project suspended 12 mths for town infrastructure "catch-up". Lurgi 1350 MTPD Circulating Fluidised Bed Alumina Calciner, used to "cook" Aluminium Hydroxide ("wet sand") to Aluminium Oxide powder feedstock for aluminium smelters at around 1,000°C, saved about 60% of the energy used in the previous inclined rotary kilns. First serious exposure to critical path method (CPM) planning and Risk Management.



Standard Lurgi CFBC Flowsheet

2017 Aerial View Queensland Alumina Ltd

1990s - Project Planner

BHP Iron Ore wanted Hot Briquetted Iron (HBI) to make flat products in SE Asian markets.

Project “self-executed” by BHPIO - promised Board threshold 15% RoI by cutting $400m capex.

Poor PM & controls resulted in 1-year delay & 50% cost overrun ($1.6b to $2.4b). BHP Board sacked BHPIO Mgr & PM team.

I was part of BHP Engineering “rescue team” as Planning Manager in 1997. We integrated 4 construction & commissioning schedules & established valid critical path planning, enabling reliable forecasting of project completion for the first time.

97/98 Asian Financial Crisis occurred during construction. FINMET Process killed maintenance workers. Plant was shut down then razed to the ground. Nothing remains, next to the Port Hedland Golf Course.

HBI Project Lifecycle

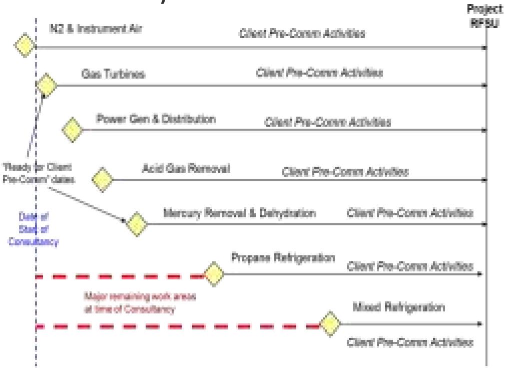
BHP HBI Project During Construction

Plant was shut down then razed to the ground

2000s – Schedule Risk Analysis

About 5 months from planned startup of NW Shelf LNG Train 4, Woodside needed confidence in probable LNG production startup date, but schedule was slipping 1w each weekly update. Several SRA iterations were required to reflect the expected startup approach in the schedule. Final SRA Report came within 3 days of actual startup date by client's criteria.

A year later a similar need arose for confidence in completion timing of an LNG train in Oman, about 4 months from startup. Construction schedule had not been connected to commissioning schedule. Linkages had to be created. Several iterations of the SRA model with project team resulted in forecast of Ready for Startup within 1 day of actual RFSU >3 months later.



NW Shelf LNG Train4 RFSU Startup Sequence

Qalhat LNG Train RFSU Celebration on P50 Forecast date

2009-2015 – ICSRAs for Gladstone LNG

We led all the SRA & ICSRA modelling for SANTOS GLNG project between 2009 and end 2015. Included SRA modelling of whole project (single train basis) in Q1 2010, based on planned First Shipment of LNG in July 2014 that forecast P50 in May 2015 and P90 at end of September 2015. Actual First Shipment occurred 17Oct15 (from train 1 of 2 trains).

ICSRA model of the entire program (CSG Field Development, Pipeline, Single train LNG Plant & Port) was provided to partners in the Decision Support Package in late 2010 to enable FID. P50 was >$13bn.

From Q2 2013 to Q4 2015, we led ICSRAs for many GLNG Upstream FEED projects, worth up to $1.3bn.

GLNG Single Train Project Model for Decision Support Package

Model of Santos Scotia Central & Flank 1 Hub

2009-2015 – ICSRAs for PNG O+G Exploration

Talisman Energy (TE, now Repsol) explored for gas & condensate in Western Papua 2009-16. Difficult terrain, climate, logistics and community relations made planning & estimating unachievable in first couple of years. Costs were too high. We offered ICSRA for forecasting time & cost outcomes. TE's Ops VP broke exploration process into Lean Manufacturing "Unit Ops" of Seismic Survey, [Interpretation], Drilling Site Prep, Drilling Rig Move & Assembly and Drilling. Each became a cost loaded schedule including mapped risk events after generic workshops (except for Rig Move).

Following tabulated results compare forecasts with actual results for two wells. Rig Move was deterministic while Drilling was probabilistic

K-1 Well:

	Rig Move (Un-risked)		Act/Plan	Drilling (Risked)		Act/Plan	Actual
	Plan	Actual	%	Plan	Actual	%	Cf Forecast
Total days	21 days	40 days	190%	51 days	53.8days	105%	P87
Total cost	$5.79m	$7.9m	136%	$16.2m	$15.4m	95%	P45

M-1 Well:

	Rig Move (Un-risked)		Act/Plan	Drilling (Risked)		Act/Plan
	Plan	Actual	%	Plan	Actual	%
Total days	35 days	45 days	129%	31 days	29.5days	95%
Total cost	$8.23m	$9.63m	117%	$10.2m	$9.7m	95%

PNG Oil & Gas – Drilling Site

Photo shows one of the drilling sites during Rig Move.

Western Province exploration location was in tropical rainforest without any roads.

Everything had to be helicoptered in:

- Equipment
- Materials
- People

Risk was non-linear and cumulative. ICSRA simulation produced realistic planning and estimating and won back credibility with TE's Head Office.

Problems with CRA & ICSRA

Problems with CRA / ICSRA

We found that cost distributions did not replicate the known experience of higher incidences around P90 of higher cost outcomes, particularly for large projects, despite careful application of correlation.

We recognised that the methodology did not meet the AACE RP40R-08 "Contingency Estimating – General Principles" criterion of Employing Empiricism. Most directly, this means analysis of past performance and assignment of systemic risk through multi-linear regression, otherwise known as Parametric quantification or modelling.

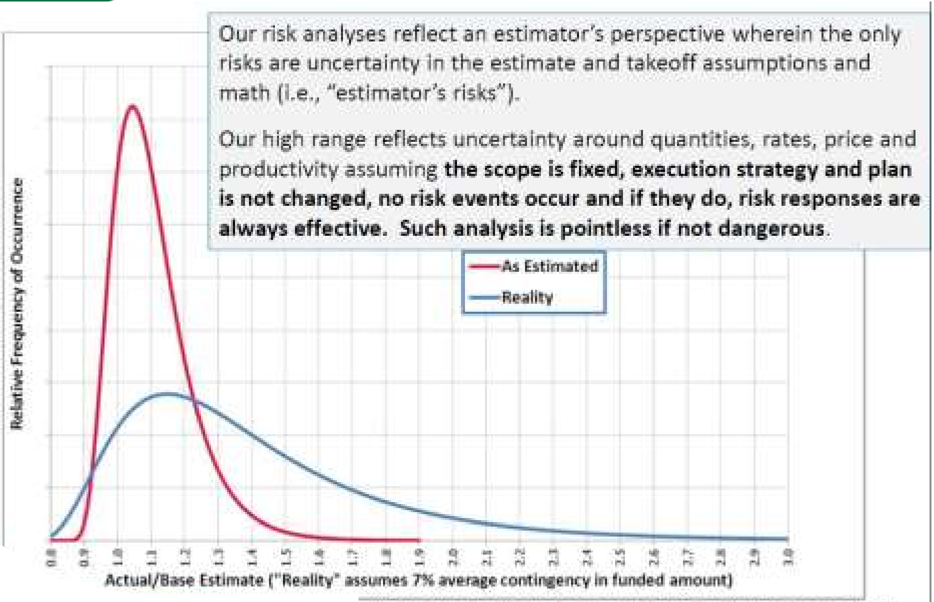
The more indirect approaches to incorporating past performance identified by RP 40R-08 are:

- Use of lessons learned;
- Benchmarking; or
- Validating analysis results against historical data.

Our methodology, as for most practitioners, was not formally including any of these.

Real outcomes were not being realistically reflected in cost contingency assessments, as indicated in the next graphic…

Industry analyses vs. Reality



"Estimate Accuracy: Dealing With Reality", Hollmann, 2012.

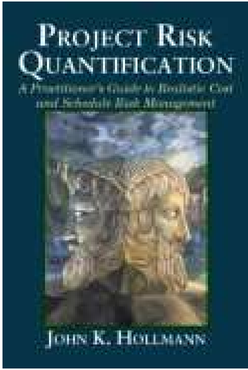
This graphic describes industry CRAs more generally than our IRA methodology, which includes mapping cost & schedule impact risk events into the costs-overlaid schedule model. However, it does point to the failure to represent the long pessimistic tail of actual project cost outcomes realistically.

Incorporating Parametric assessment of risk

Publication of “Project Risk Quantification”

John Hollmann’s book gave a different view of project risk:

- Based on how it is quantified, rather than
- Bottom-up analysis view whether it is innate (“Inherent”, 100% Prob) or arising from an uncertain event (“Contingent”, <100% Prob)



Hollmann asserts that the major source of time and cost risk in projects is Systemic, arising from the systems involved in delivery of projects.

The principal system is the project delivery system comprising the organisation’s structure and culture, leadership, project team, processes and capabilities.

Hollmann advocates a Hybrid methodology for quantifying risk:

- Parametric (P) modelling of Systemic Risk in a top-down process based on past performance, with
- Expected Value (EV) assessment of major Project Specific Risks using MCS, including the systemic risk quantified by the Parametric method

A key point is that project owners do not have to accumulate their own project performance, but can draw on generic project data to use the P+EV method.

Developing P+IRA Methodology

Conscious of the need to improve cost contingency forecasting using IRA methodology, the author combined P+IRA in a paper presented to the 2017 AACE Annual Meeting (Cropley, C, Modelling Realistic Outcomes using Integrated Cost and Schedule Risk Analysis, AACE® International 2017 RISK-2510 Technical Paper)

But the paper was criticised for "double-dipping" Systemic Risk because it included duration and cost ranging plus parametric modelling using schedule and cost risk factors.

During the first half of 2018, through further thought and attending a PRQ course run by John Hollmann, the author realised that probability distributions can be subtracted using MCS and that this could enable P+IRA methodology to be valid and practical.

The methodology was described in detail in a paper presented at the 2019 AACE Annual Meeting (Cropley, C, Combining Parametric and CPM-based Integrated Cost-Schedule Risk Analysis, AACE® International 2019 RISK-3037 Technical Paper). A summary is presented here.

The methodology has been successfully implemented with clients since mid-2018.

Overlap of risk types & methods

Common elements of CPM-based ICSRA methodologies are as follows:

- Assess Inherent Risk by developing duration & cost ranges and risk factors for the tasks and overlaid costs in the model using Subject Matter Experts (SMEs) in workshops or individual interviews
- Map treated risk events with material probabilistic time or cost impact on the project into the CPM-based model

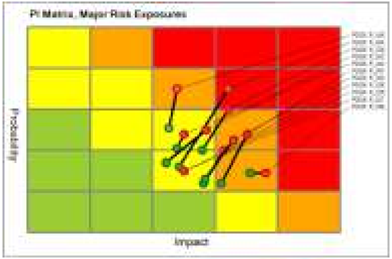
Parametric methodology assesses Systemic Risk by asking senior project & corporate managers in the owner organisation a series of questions about:

- scope definition, project controls,
- organisational maturity, engineering deliverables,
- estimate & schedule basis and
- project technology & complexity

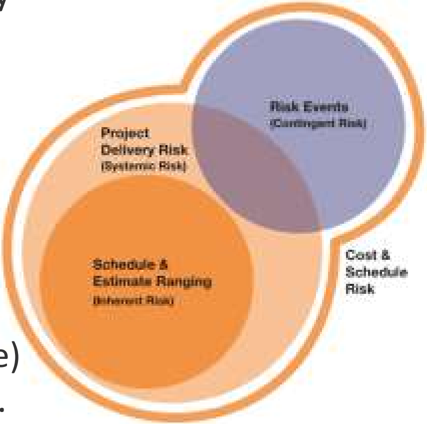
The responses shape the correlation coefficients of the parametric model that forecasts the systemic risk cost and schedule contingencies, represented by the larger, light orange circular domain in the Venn Diagram.

Replacement of EV by IRA

The EV stage of P+EV selects for the major project-specific treated risks in the Risk Register (red or amber in a heatmap), ignoring systemic risks and lower level project-specific risks. To these are added the systemic risk. All are subject to MCS, producing cost & schedule probability distributions.



P+IRA methodology replaces the EV stage by mapping the same risk events into the IRA model, letting schedule logic take care of the effects of float at the task level.



Net Systemic Risk (light orange annular domain not overlapping with Ranging or Risk Events) is determined by MCS subtraction of the base IRA model distributions (cost & schedule) from the Parametric distributions (cost & schedule) and added to the IRA model as Cost & Schedule Risk Factors.

What methodology works best?

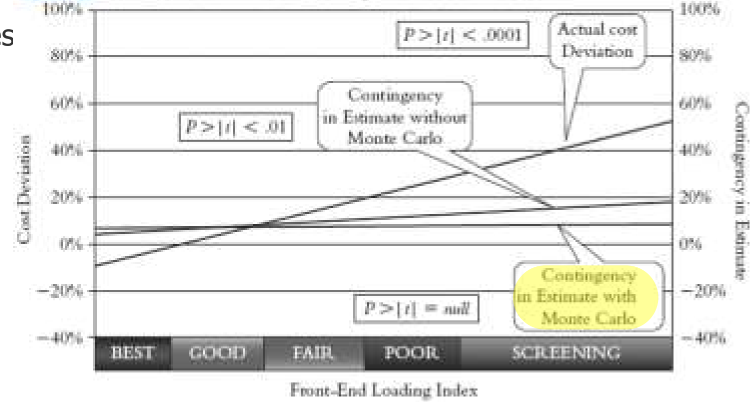
IPA Reporting of SRA vs. CRA

IPA's founder and CEO Ed Merrow, in his book "Industrial Megaprojects" (2012, Ch12) states that SRA is very useful, but that CRA is worse than useless! It is unclear whether he means Cost Range Analysis or includes the addition of probabilistic risk events. Merrow backs this up with analysis of outcomes of projects vs. their scores on correlated Front End Loading (FEL) practices that improve project cost forecasting accuracy, as shown:

He states that the MCS distributions "are not based on historically observed distributions of outcomes, nor do they have any first principles basis. They are opinion."

In contrast to their negative view of CRA, Merrow states that IPA has measured with the use of SRA at project authorisation "a 27% decrease in the amount of execution schedule slippage". This plays out in "lower project startup failure and better operability", apart from better cost contingency accuracy.

Figure 12.7 Monte Carlo Generated Cost Contingencies Are Unrelated to Risk



Parametric modelling benefits

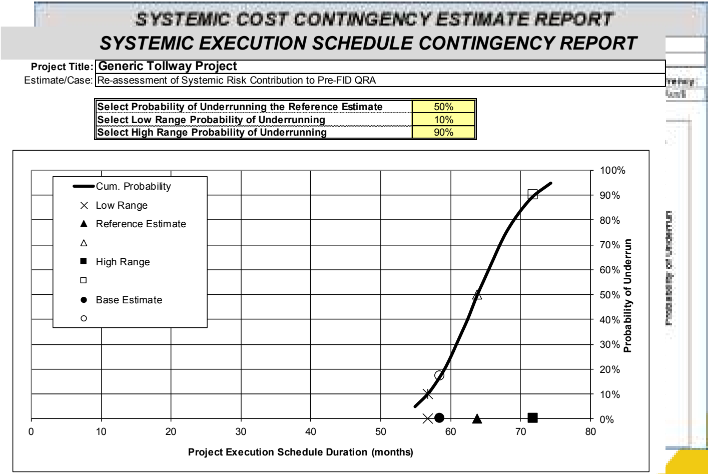
Incorporating Parametric modelling of Systemic Risk ensures contingency assessments are based on past performance and avoid optimism bias.

P+EV provides overall cost and schedule forecasting of project outcomes without the need for detailed Schedule Risk Analysis, while including the combined effects of systemic risk and major project-specific risk events.

The Parametric model produces log-normal distributions of cost and schedule outcomes, based on the strengths & weaknesses of the project delivery system.

EV MCS adds project specific risk events to produce overall execution phase cost & schedule distributions for contingency setting

P+IRA subtracts base IRA cost & schedule distributions from these systemic risk distributions and adds the net systemic risk distributions as risk factors to the full IRA model including project specific risk events.



When to use P+EV?

P+EV does not require a schedule.
Therefore it is a good solution for projects that are small or in their early phases of development.
So far, RIMPL has used John Hollmann's P+EV methodology on the following:

- Two mining tailings dam projects at Pre-Feasibility Study (PFS) stage.
- One mining tailings dam project at Feasibility Study (FS) stage. A parallel SRA was also conducted.
- One complete metallurgical coal mine PFS. A parallel SRA was also conducted.
- A medium scale highway relocation project is about to be assessed by P+EV.

The overall Schedule contingencies from the SRAs were in good agreement with the P+EV contingencies. The SRAs enabled contingencies for other / intermediate milestones to be assessed.

When to use P+IRA?

P+IRA does require a good quality schedule and significant time and effort. Through the inclusion of Schedule Risk Analysis overlaid with costs, it enables schedule and time-dependent cost risk to be optimised.

P+IRA is therefore justifiable for medium scale projects just prior to funding and for major and complex projects at the end of FS and PFS if a good schedule is available.

So far, RIMPL has used P+IRA methodology on the following:

- A complex pharmaceutical industry project (analysed provisionally and later in full detail)
- A minerals processing megaproject (fully analysed then using later inputs as an update)
- A medium scale natural gas peak shaving plant expansion dependent on the commercial viability of the expansion for it to proceed

In each case, RIMPL prepared IRA analyses and P+IRA analyses and in each case, P+IRA produced significantly wider spreads for schedule and cost. **The clients who had stated a preference for the internationally recognised IRA methodology opted to use the P+IRA results.**

Conclusions

CPM-based ICSRA, a bottom-up MCS methodology, has been combined with Parametric modelling, a top-down configuration methodology derived from >50 years of industry-based research on the drivers of cost and time outcomes of projects.

This P+IRA methodology enables risk optimisation and realistic cost and schedule contingency forecasting to be combined.

For earlier stages of project development (Concept and Prefeasibility) where suitable quality schedules are not available, or for small projects, P+EV is quicker and costs less.

For smaller projects where suitable quality schedules are available, P+EV and SRA in parallel can provide realistic cost and schedule contingency and schedule risk can be optimised cost-effectively.

Questions?