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Reliable Risk Quantification
For Project Cost and Schedule
(Workshop W1)

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About the Speaker

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- Owner, Validation Estimating LLC since 2005; independent consultant for ***process industry owner companies***; 38 years diverse experience
- Lead author of AACE's ***Total Cost Management Framework***; a process for the management of portfolios, programs & projects
- Led development of AACE's ***Decision and Risk Management Professional*** (DRMP) certification (hold certificate #001)
- Led IPA Inc's ***Cost and Schedule Metrics*** program and project control practices research from 1998-2005 (IPA is a benchmarking firm)
- AACE Fellow, Honorary Life Member, past Board member and Director of ***Recommended Practices*** and recipient of their *Award of Merit*
  - Registered Professional Engineer, Certified Cost Professional, Certified Estimating Professional & Decision & Risk Management Professional

Abstract

- Project cost overruns and delays are all too often the rule rather than the exception.
- The consequences of overruns and delays can be devastating to company profitability, not to speak of our profession's lost credibility.
- Workshop attendees will first learn about the reality of cost and schedule estimate inaccuracy & our failed cost/schedule risk analyses
- This will be followed by discussion of research on successful methods and the demonstration of practical, realistic cost and schedule risk quantification methods that anyone can apply without reliance on complex software and consultants.
- The workshop includes several exercises in risk analysis and contingency estimating.

Agenda

- Risk Quantification within Risk Management; Setting the Context
  - Terminology and Process
- State of Industry Cost & Schedule Risk Quantification: Facing Reality
  - Common Risk Quantification Methods and Why They Fail

Break

- Principles of and Research on Best Practice in Risk Quantification
- Reliable Methods for Cost and Schedule Risk Quantification
- Communicating Risk Analysis & Contingency Estimating Outputs

Conclusions/Discussion

Terminology from AACE RP 10S-90
SCOPE

SCOPE

- The sum of all that is to be or has been invested in and delivered by the performance of an activity or project… Generally limited to that which is agreed to by the stakeholders in an activity or project. In contracting and procurement practice, includes all that an enterprise is contractually committed to perform or deliver
- Includes not only what, but how (i.e., the execution plan)

> - **"Scope" is widely misunderstood, but it is a critical term for all stakeholders to understand in respect to your risk management and quantification.**
>
> - **To Owners, Scope is the basic business premise of the project as understand by the Business Sponsor (which can be summarized in a few bullet points)**

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Terminology from AACE RP 10S-90 RISK & UNCERTAINTY and ISSUES

RISK

- There are alternate definitions; do not assume that the other party is using the same interpretation
  - E.g., Risk = Threats is common in safety and insurance business
  - **For Projects, Risk = Uncertainty (threats + opportunities)**
- At AACE; *Risk = "an uncertain event or condition that could affect a project objective or business goal"*
  - In Cost Engineering, our job is to quantify it all

ISSUES: Some define risks that have occurred as "issues" and removed them from the Risk Register. As orphans, they do not get quantified. As we will see, "issues" are the most significant source of uncertainty and must be given priority in risk quantification.

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Unknown-Unknown Speak is for Philosophers Only

- Everything that is uncertain in projects can be identified and quantified albeit not always very well. It has all happened before.
- Whether we address a risk or not depends on whether it "matters". What matters is what history tells us has mattered and what our current analysis shows is reasonably likely to apply.
- While U-U phraseology is philosophically interesting its usage always precedes the user disavowing responsibility for failure.
- Did you every ask yourself "what about the ***unknown-knowns***?"
  - This is the 4th horseman; the risks that matter most
  - These are the known risks we choose to ignore (or at best label them as "issues"; for example, "our risk methods are unreliable")

Terminology from AACE RP 10S-90
HOW WE "ACCOUNT" FOR RISK

- **Contingency**: An amount added to an estimate to allow for items, conditions, or events for which the state, occurrence, or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs or time (*i.e., one number that is expected to be spent*)
- **Management Reserve**: An amount added to an estimate to allow for discretionary management purposes outside of the defined scope of the project, as otherwise estimated.
  - May include amounts that are within the defined scope, but for which management does not want to fund as contingency or that cannot be effectively managed using contingency
- **Allowances:** Resources included in estimates to cover the cost or time of known but undefined requirements for an individual activity, work item, account or sub-account (*i.e., above-the-line*)
  - If it is not a specific, controllable item (i.e., can be progressed) or part of one, then it is a form of hidden or above-the-line Contingency

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Terminology from AACE RP 70R-12
SCHEDULE CONTINGENCY

- SCHEDULE CONTINGENCY: an amount of time added to the schedule to mitigate (dampen/ buffer) the effects of risks identified or associated with specific elements of the project schedule.
- **Principles** of schedule contingency are:
  - must be visible in the schedule
  - is time only and does not contain scope, resources or costs.
  - is only established based upon an analysis of schedule risk.
  - is NOT FLOAT (i.e. not Project Float nor Total Float)
  - is NOT LAG/LEAD (relationship durations)
  - is not hidden artificial lengthening of schedule activities
  - is not the improper use of "preferential logic"
  - is not a non-work period in the software calendar
  - is not Management Reserve.

Terminology from AACE RP 10S-90 ESCALATION

- **ESCALATION:** A provision in costs or prices for uncertain changes in technical, economic and market conditions over time. Inflation (or deflation) is a component of escalation
  - Changes in price levels driven by economic conditions
  - Can apply to a micro-economy (e.g., a region or industry) such as:
    - Prevailing industry productivity and technology
    - Prevailing Industry & regional markets (e.g., labor shortages)
  - Includes, but differs from inflation which is monetary conditions
  - Varies for different items, regions, procurement strategy, etc.

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Terminology from AACE RP 10S-90 ACCURACY

- **ACCURACY RANGE**: An expression of an estimate's predicted closeness to final *actual* costs or time. Typically expressed as high/low percentages by which actual results will be over and under the estimate along with the confidence interval these percentages represent. See: Confidence Interval.
- Accuracy is about Communication
  - It is a shorthand expression that we all use to communicate uncertainty in a way that does not delve into probability distributions that nobody will understand
  - That does not free us to be vague in our communication
    - Define reference point and confidence interval

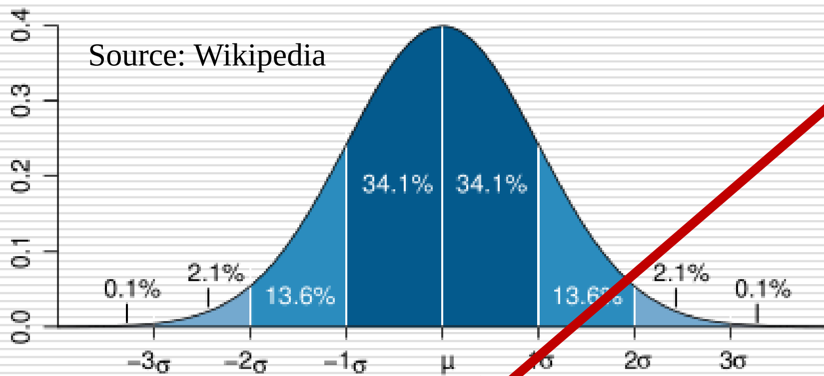
Terminology

DISTRIBUTIONS & CONFIDENCE

If you repeat a project many times (or ran a simulation) and plot a histogram of actual/estimate metric outcomes, you might get distributions like these

- **"Normal"**

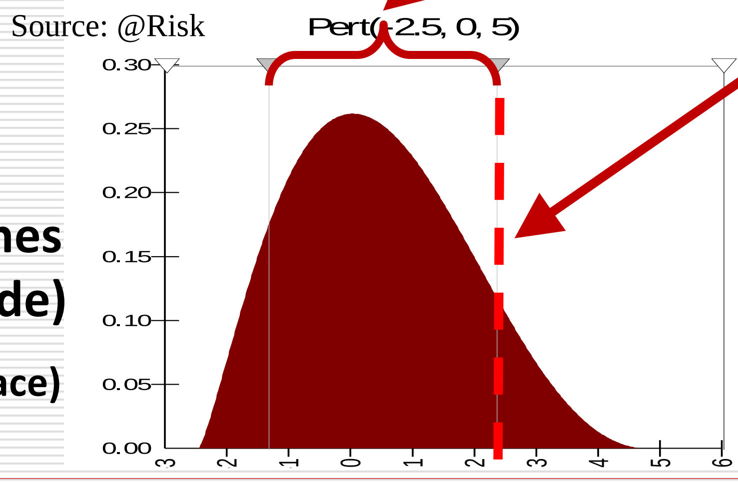
This rarely reflects actual/estimate outcomes



- **Skewed**

This is more typical for actual/estimate outcomes (i.e., long tail on high side)

(but, near "normal" in log space)



Confidence Interval

(e.g., "80% confidence")

% of projects <u>within</u> a +/- range

Confidence Level

(e.g. "P90")

% of outcomes <u>less than</u> a value

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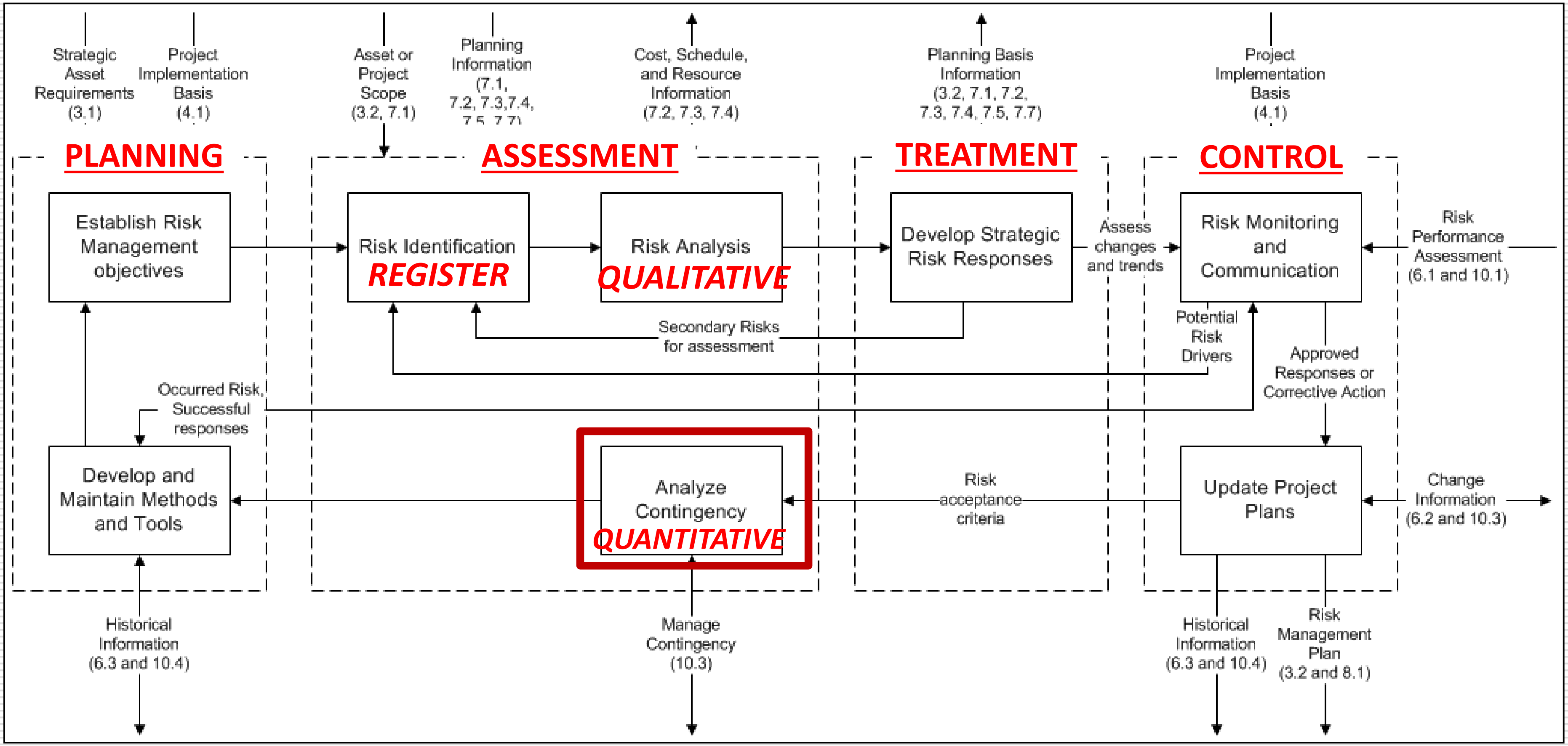
The Risk Management Process
AACE INTERNATIONAL TCM 7.6

The TCM Framework is the only industry RM process that explicitly addresses QUANTITATIVE analysis as a primary step (recycles residual risks through Assessment)



Qualitative Risk Analysis

- Purpose is to prioritize risks for *Treatment*
- Use a *Risk Matrix* (probability/impact matrix) to rate:
  - Probability of risk occurrence
  - Impact on each objective IF the risk occurs
- Ratings are "qualitative" in that narrative terms are used like "high" and "low"
- The premise of the *Expected Value* quantification method is probability x impact in consideration of risk response and cost/schedule trading
  - i.e., good screening is a precursor to quantification

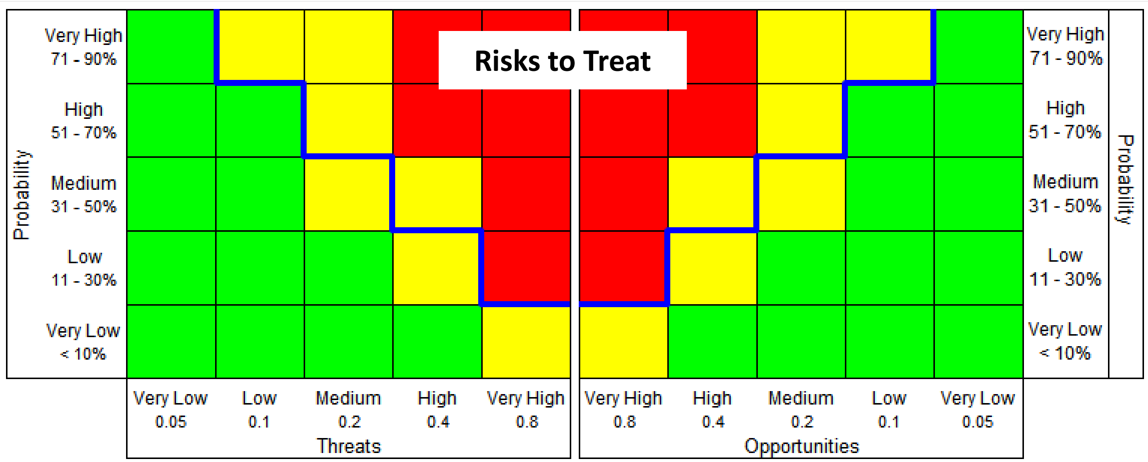
Risk Matrix Example

- Impact Ratings for Various Objectives

Rating	Cost	Schedule	Production
Very High	>5% of budget	>8 weeks	>10% under goal
High	4-5% of budget	5-8 weeks	6-10% under goal
Medium	2-3%	2-4 weeks	3-5% under goal
Low	0.5-1% of budget	1-2 weeks	1-2% under goal
Very Low	<0.5% of budget	<1 week	<1% under goal

- **Risk Matrix**

(including Probability and Impact ratings)



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Risk Identification/Risk Register

- Realistic risk quantification starts with **Risk Identification** and ends with quantifying those risks using methods aligned with each risk type
- The primary deliverable resulting from Risk Identification workshops and risk management tracking is the **Risk Register**
- **Risk Categories** that align risks with quantification methods:
  - **Systemic**: overarching attributes of the project system: *quantify using empirically -based parametric model*
  - **Project-Specific**: risk conditions and events specific to project scope: *quantify using expected value methods with Monte-Carlo*
  - **Escalation/Exchange**: impacts of overall economy: *quantify using econometric models with Monte-Carlo*
- The Risk Register should highlight which quantification type applies

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Typical Risk Register Content
Plus Quantification Type

- **Risk Title**: what is uncertain? Be as specific as possible (Issues are OK)
- **Cause**: what condition or event results in the uncertainty
- **Source**: internal or external (e.g., environment, regulatory, engr, etc.)
- **Probability of Occurrence**: qualitative ratings (e.g., VL, L, M, H, VH)
- **Impact**: qualitative ratings by *objective* (cost, sched, profit, reputation, etc)
- **Overall Rating**: combines probability and impact (e.g., P x I or other)
- **Risk Owner**: who leads planning for this risk's treatment?
- **Treatment Plan**: how will this risk be "treated" (accept, transfer, etc.)?
- **Status**: how is the risk treatment plan going (is the risk changing?)

Add Risk Type for Quantification to the Above:

- **Quantification**: Systemic (**S**), Project-Specific (**P**), Escalation/Exchange (**E**)

Rules-of-Thumb for Quantification Type:

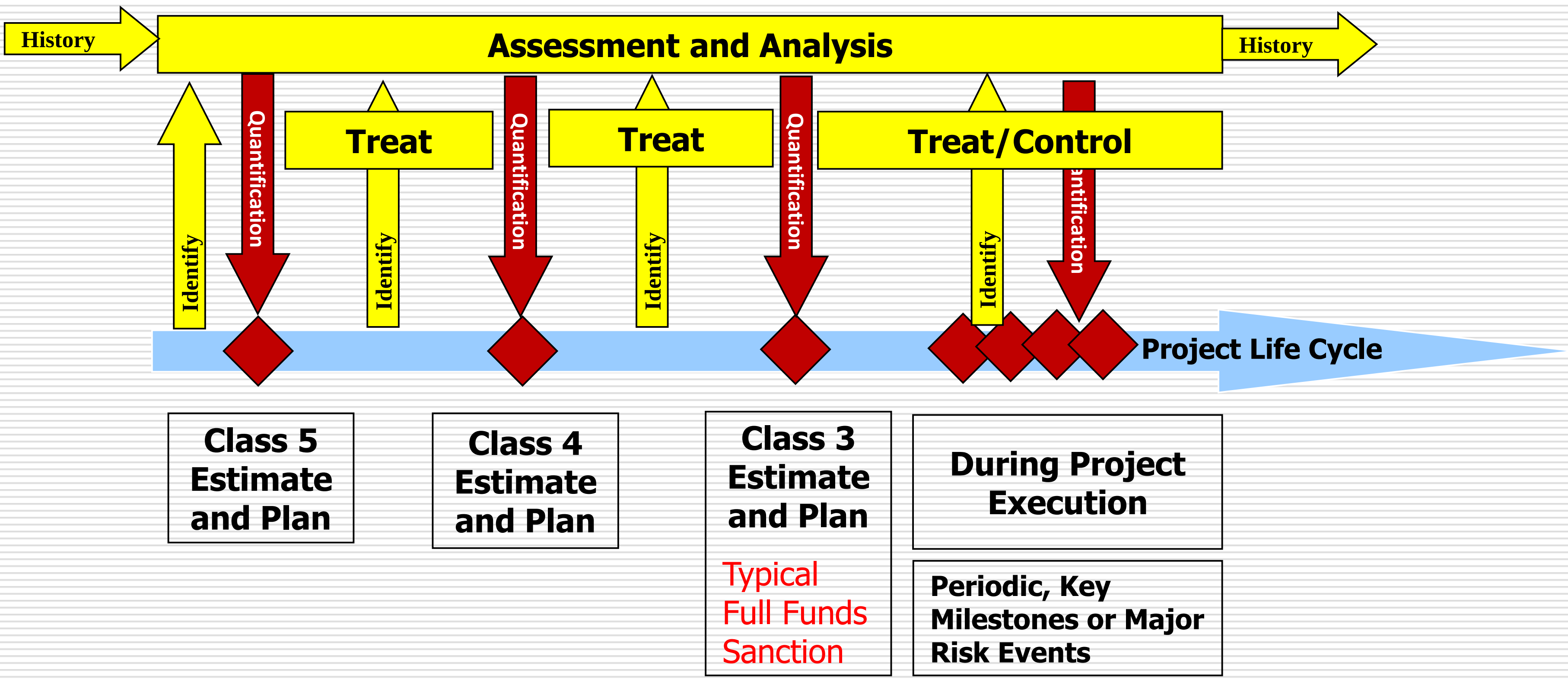
- If its not very "Specific" (who, what, when, where, how), it is likely Systemic
- General price trends are escalation, procurement practice driven are not
- If "issues" are not on your register, go get them—these are what matter!!

Exercise 1
Risk Identification For Quantification

For each register risk entry below, classify as S, P or E

1. Archeological find at crossing adds delay until alternate location found
2. Loss of critical manpower cause delays in construction
3. Horizontal drilling problems result in changing to open cut plan
4. Labor rates increase more than anticipated in final years of construction
5. Wildlife protection requirements uncertain and may add delay and cost
6. Construction manager leave coincides with negotiation causing delay
7. Early start of detailed engineering results in late changes in model
8. Sole sourcing of the main reactor results in higher prices than estimated
9. Slow decision making results in delays to procurement and contracts

Risk Quantification is Mainly Performed at Project Decision Gates



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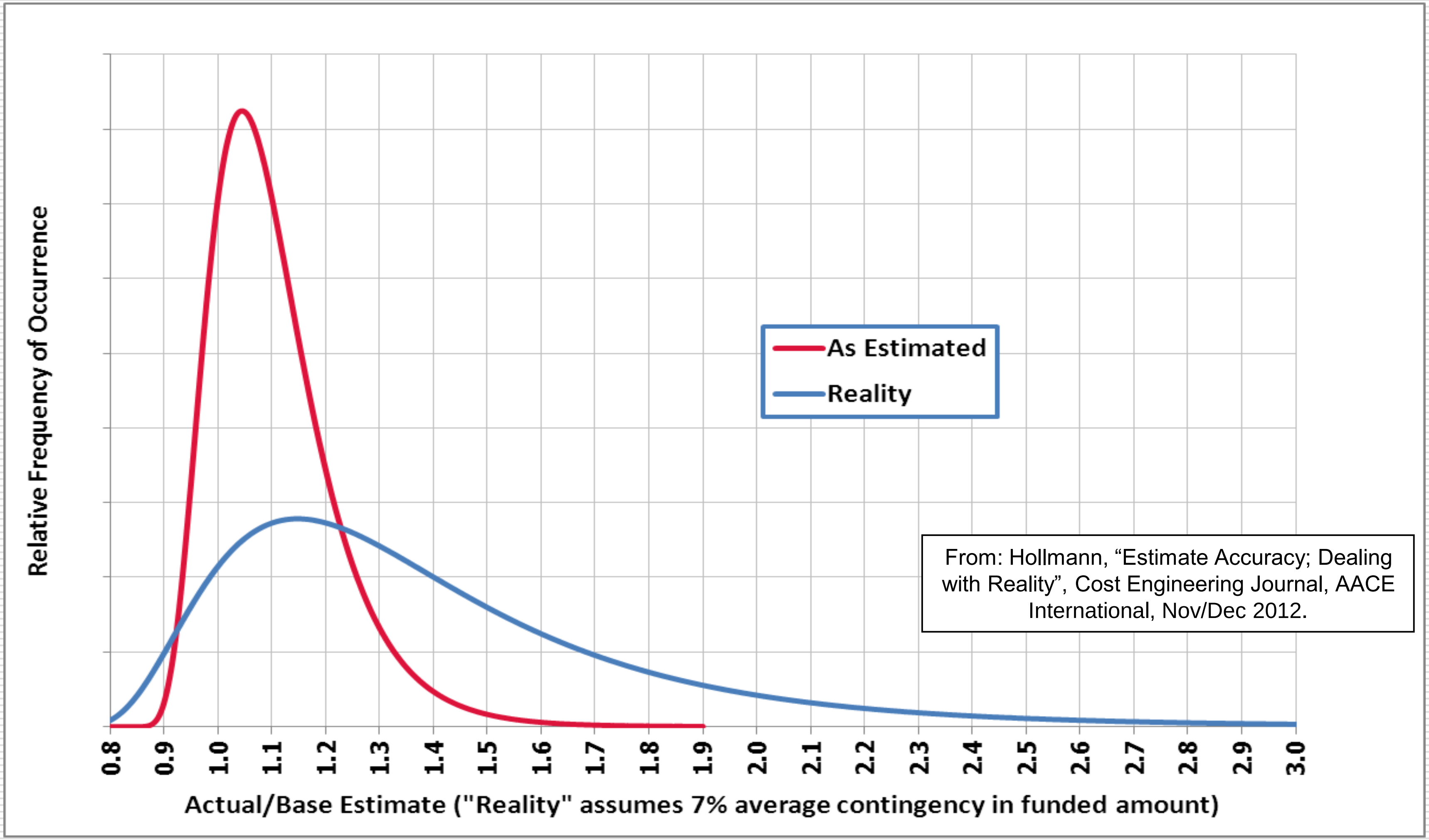
Conclusions/Discussion

Empirical Accuracy Studies (2012)

- In 2012 I presented a meta-analysis of over 50 years of empirical cost estimate accuracy research on large projects in the process industries[1]
- It showed how accuracy reality is dramatically different from expectations and analyses; our "standards" and forecasts are nowhere near to reality
- Actual project cost accuracy ranges are about 3X the width of our risk quantification outcomes
- This was confirmed by a concurrent study by IPA using their more controlled database[2]

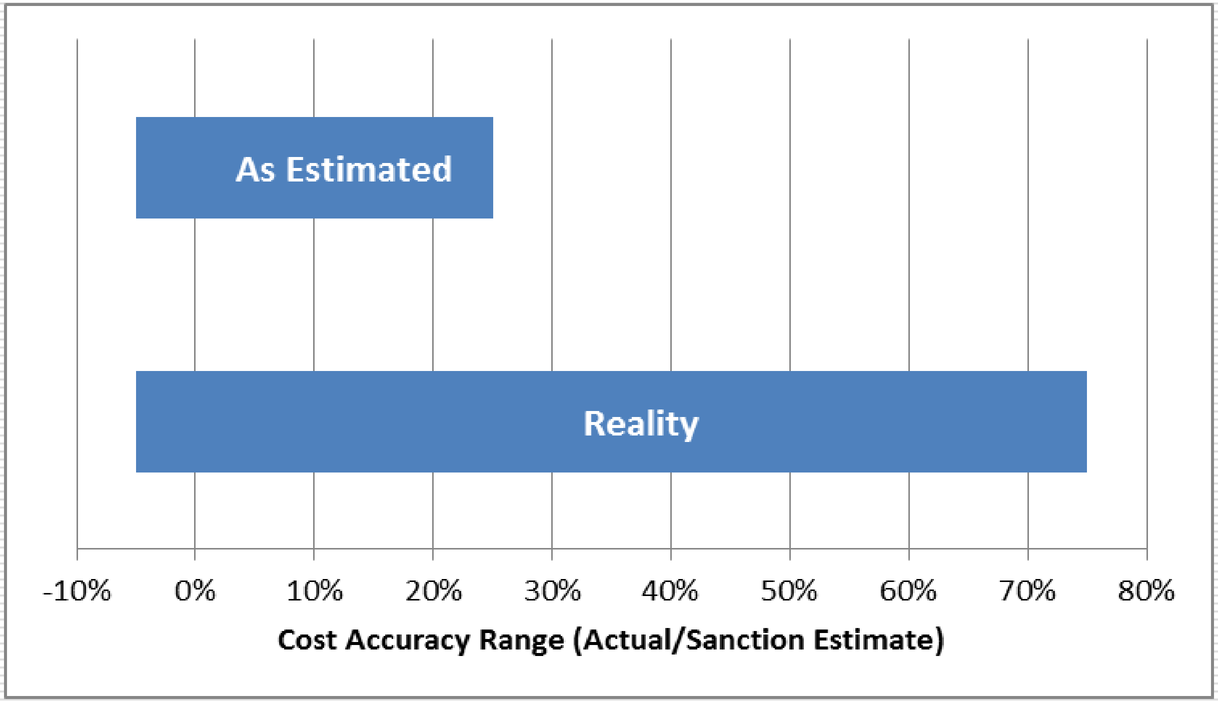
1 Hollmann J., "*Estimating Accuracy: Dealing with Reality*", Cost Engineering Journal, Nov/Dec 2012.
2 Ogilvie, A, et. al. (IPA), ""*Quantifying Estimate Accuracy and Precision for the Process Industries: A Review of Industry Data*", Cost Engineering Journal, AACE International, Nov/Dec 2012.

Predicted and Actual Accuracy Are Different



Example of how to read the X scale, 1.5 = 50% overrun of the base estimate

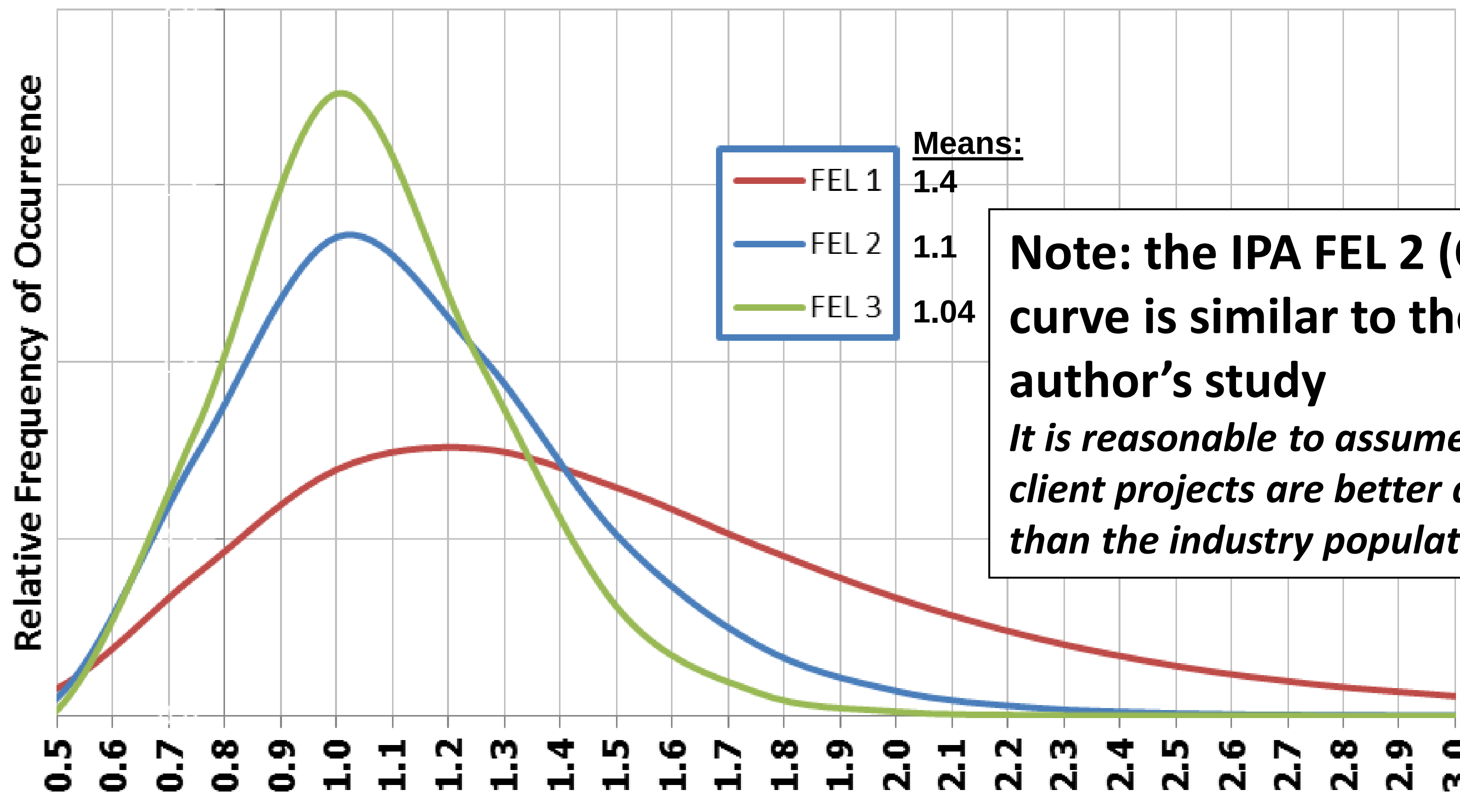
Another Way To Look At The Gap
80% Confidence Interval (p10 to p90)



Confirmation of the Gap By Phase

Accuracy Reality By Estimate Phase (IPA)

Lognormal Equivalents derived from Ogilvie, et al



Note: the IPA FEL 2 (Class 4) curve is similar to the author's study

It is reasonable to assume that IPA client projects are better defined than the industry population

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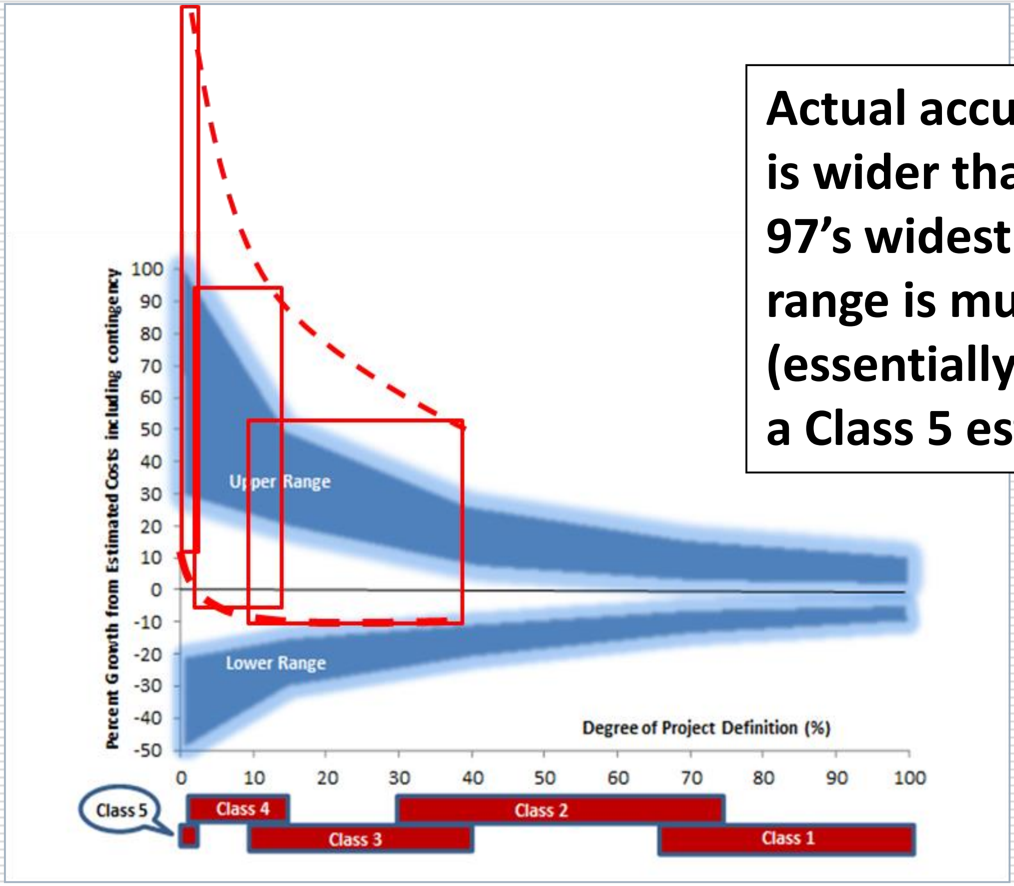
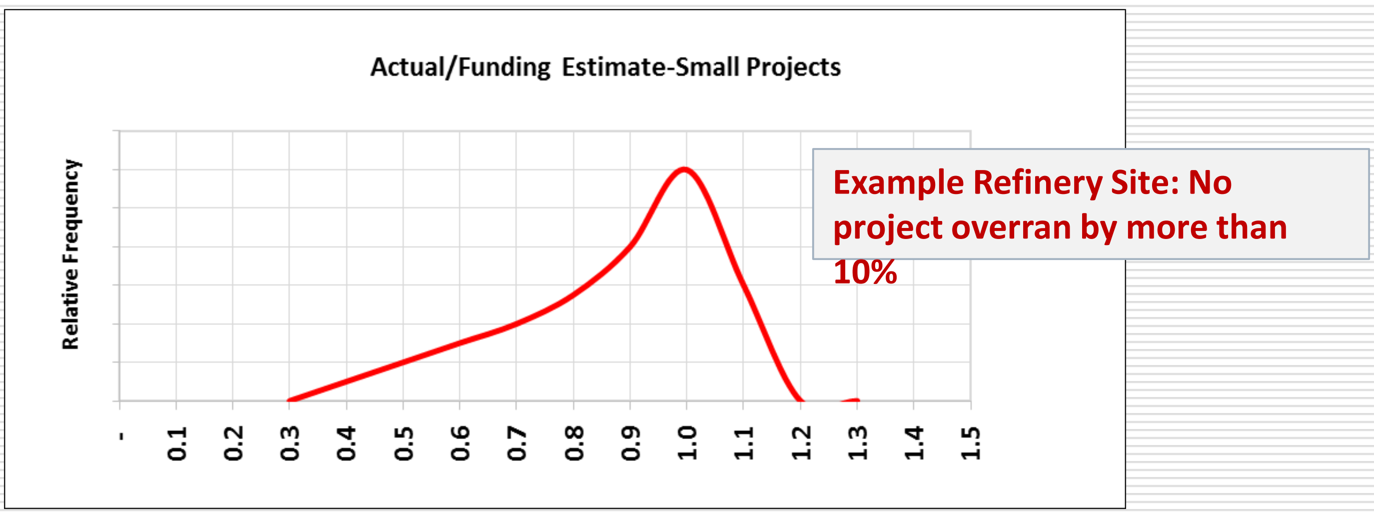
Yet Another Example: AACE Range-of-Ranges vs. Hydropower Project Study (Hollmann, et al, 2014)



Actual accuracy bandwidth is wider than AACE RP 18R-97's widest range and range is much more biased (essentially never underrun a Class 5 estimate)

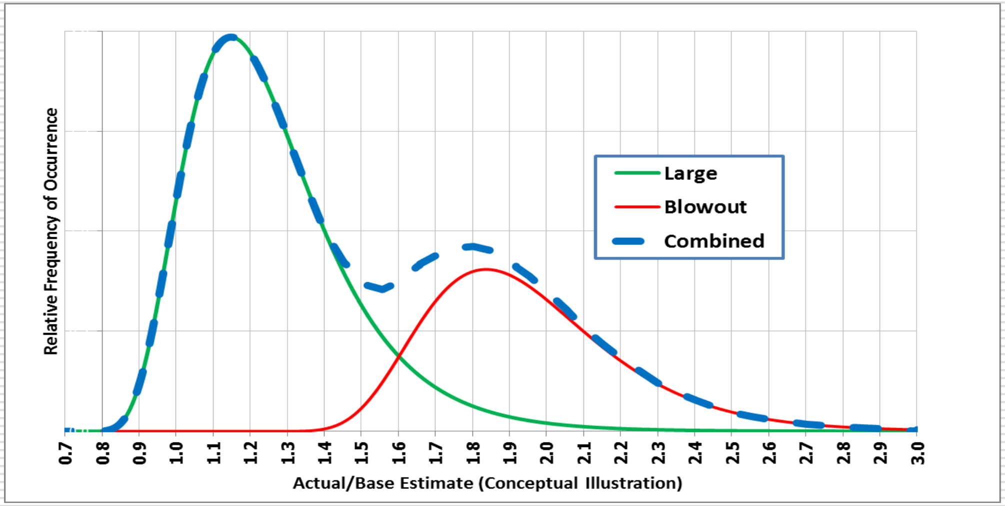
Special Case 1: Small Project Costs Tend to Underrun

- Small Project Systems (Plant Based) are dominated by punitive cultures with undisciplined practice and biased, *risk-loaded* base estimates (padding)
  - *"when a project team sets a soft target, about half of the unneeded funds are usually spent"…."about 70% of small projects underrun"* (*IPA "InSites"*)
- I call this the "cresting wave syndrome"; Actual example of one year's small project portfolio from a plant-based project system:



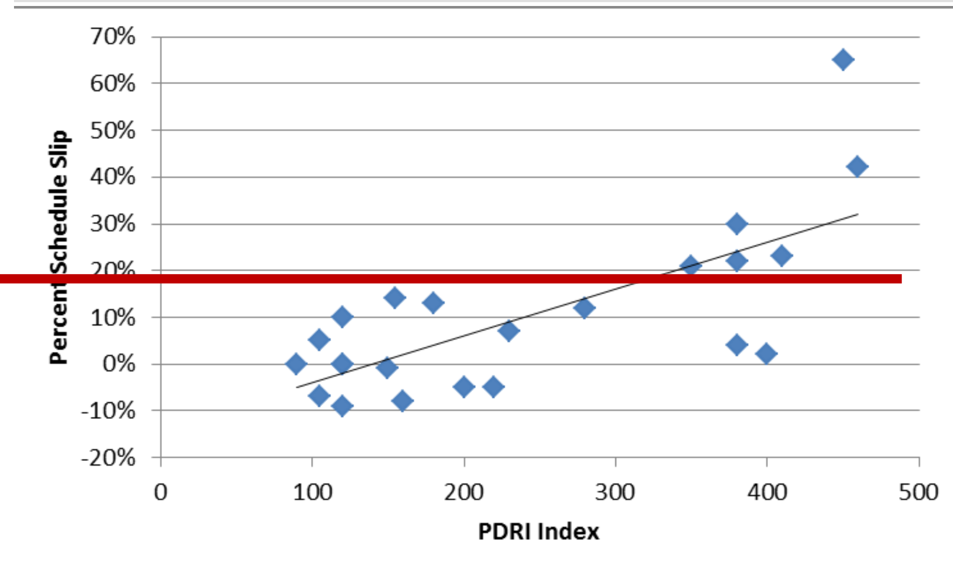
Special Case 2: Complex and Mega Project Cost Outcomes Are Bimodal

- Mega and complex project cost growth is either similar to that of merely large projects or it is in a class of its own--classic blowouts.
- Blowouts are characterized by a doubling or tripling of labor related costs
- Blowouts occur when PM and labor behavior transitions from an orderly state where control is effective, to a disorderly or chaotic state where traditional control fails and intervention is required to restore order.
- The "**tipping point**" occurs when complexity combines with systemic weakness (e.g. weak systems and teams) that is confronted with high stress (e.g., risk events)



Industrial Execution Schedule Duration Slip Is About 20% (e.g. 5 mos for a 24 month plan)

1 Merrow, E.(IPA), "*Industrial Megaprojects*", Wiley 2007
2 CII "Project Definition Rating Index (PDRI)-Industrial"



In my experience, it is rare to see explicit contingency included in a schedule. What would you do with this information?

Trading Cost for Schedule

- There is a weak correlation between cost growth and schedule slippage (proportionally less schedule slip)
- Projects often buy time to get the revenue stream going; risk responses seek to save the "first product" milestone
- Trading of cost for schedule means schedule performance may be merely mediocre (e.g., +20% slip) while costs are blowing out (e.g., >50% overrun)
- Reliable risk quantification methods must address this tradeoff explicitly

The Most Widely Used Method is a "Disaster"
Line Item Ranging (LIR) and Activity Ranging

- LIR Example
  - Civil is $20,000 with +50/-30% high/low range
  - …ditto for each line-item in the estimate (or activity in schedule)
  - Apply triangular distribution to each and run Monte-Carlo
  - Outcome: same every time (9% with +/- 4% at one std. dev[1])
- Why is it not recommended?
  - Empirical research shows that it fails[2]
  - Risk drivers are not addressed (particularly *systemic* risks)
  - Feeds management bias; gives them the 10% answer they want
- Good news; it works great if your project is well defined, has a strong team and system, nothing ever changes, and no risk events occur!

1 Merrow, E.(IPA), "*Industrial Megaprojects*", Wiley 2007
2 Juntima, G and S. Burroughs, "*Exploring Techniques for Contingency Setting*", AACE International Transactions, 2004.

Hypotheses For Our Risk Quantification Failure

- Hypotheses for Risk Quantification Failure:
  - Strategic misrepresentation/optimism bias; i.e., Dr. Bent Flyvbjerg
  - Failure to use best practices; i.e., Edward Merrow (IPA)
  - Failure to quantify our bias + practice failings (mine)
- Consequence
  - Our failings are now institutionalized
  - E.g. mining industry funds at p80 as a norm; they do this not because they are risk averse, but because our p50s are absurd
    - i.e., true p80 will kill most mining projects even in good times
- An ethical dilemma for our profession
  - This is a story of unknown knowns; i.e., willful ignorance

BREAK

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Conclusions/Discussion

Principles of Risk Quantification Methods
1) Explicitly Link Risks to Impacts

AACE International identified these principles in RP 40R-08

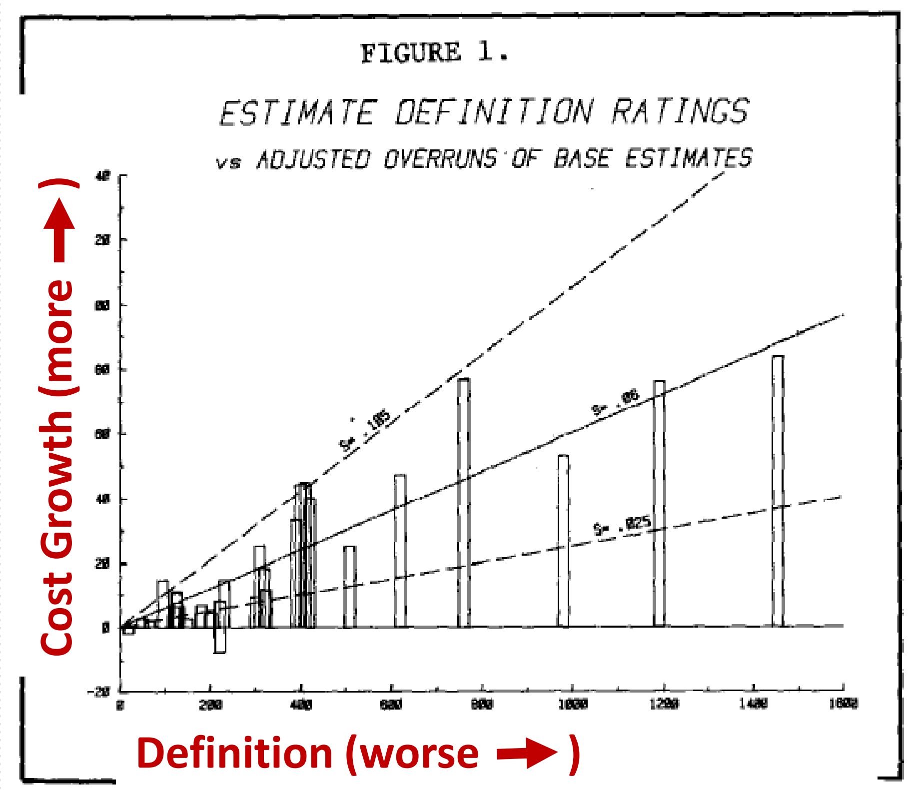
- Meet client objectives, expectations and requirements
- Part of and facilitates an effective decision or risk management process (TCM)
- Fit-for-Use
- Starts with identifying the risk drivers with input from all appropriate parties
- **Methods clearly link risk drivers and cost/schedule outcomes**
- Avoids iatrogenic (self-inflicted) risks
- **Employs empiricism**
- Employs experience/competency
- Provides **probabilistic** estimating results in a way the supports effective decision making and risk management

Principles of Risk Quantification Methods
2) *Empirical Research Must Be A Basis*

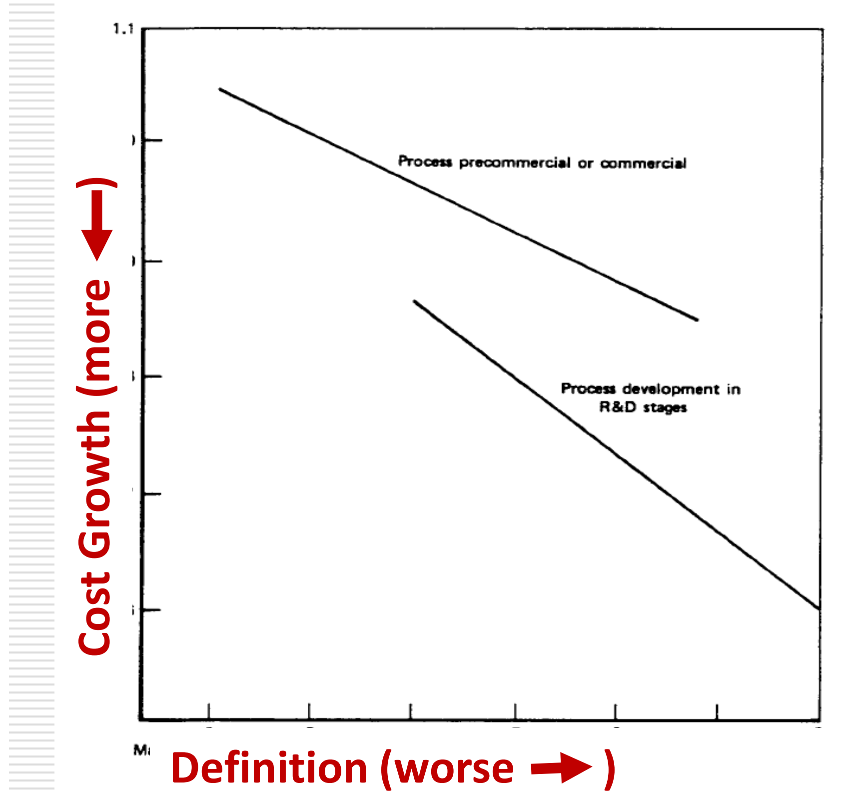
- Recap: we have reviewed the "reality" of large and small project cost overruns and schedule slip
  - Revelation 1: we know what causes these outcomes
  - Revelation 2: we have ways to link cause to impact
- Foundational research on <u>causes</u> and <u>link to impacts</u>:
  - John Hackney: 1965
  - Rand (later IPA): 1981 (cost) and 1986 (schedule)
- These studies are why we all have <u>Phase-Gate</u> systems

Hackney, J., "*Control and Management of Capital Projects*, 1st ed ition1965; 2nd Edition, AACE International, 1997
Merrow, E. et al., "*Understanding Cost Growth and Performance Shortfalls in Pioneer Process Plants"*, Rand Corporation, 1981
Myers, C. et al., "*Understanding Process Plant Schedule Slippage and Startup Costs*", Rand Corporation, 1986

These Studies Conclusively Linked Cost Growth With the Level of Project Scope Definition



John Hackney (1965)



Rand (1981)

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Principles of Risk Quantification Methods
3) *Methods Must Be Probabilistic*

- Statistics describe data and draw useful conclusions from it. **Inferential statistics** is what allows us to draw conclusions (inferences). There are two *practical* inferential methods:
  - **Regression** of empirical data (Multiple Linear Regression or MLR)
  - **Monte Carlo Simulation** (MCS) of theoretical data
- MLR models are inherently "realistic" being based on actual data
  - MLR identifies correlations between the dependent variable (e.g., cost growth) and independent variables (risk drivers); the relationships are highly conjectural; not amenable to guessing
- MCS uses a model based on assumptions about how risks relate to outcomes; it is "realistic" if the assumptions have little conjecture
  - LIR models fail both conditions (no links and total conjecture) and has unfortunately given MCS a bad name with many

Regression (MLR) Models (i.e., Parametric Models)

- MLR or parametric models result in relationships such as the following:
  - Y (the mean prediction) = constant + a*X1 + b*X2 + c*X3 + etc.
- For our use, Y is cost growth or schedule slip, and X are risks such as:
  - Cost Growth (est/act) = 1.076 - 0.059*Complex
- MLR and data have properties that allow us to generate distributions
- Most do not have data with which to perform MLR but Good News!
  - Systemic risks that drive outcomes are known and fairly universal
  - The research has been done for you!
- Independent Project Analysis Inc. (IPA) and the Construction Industry Institute (CII) are the 800 lb. gorillas of data collection and research.
  - Both are progeny of the Hackney/Rand foundations
  - The fundamentals are publically available for our use

Regression (MLR) Model
Research Findings

- **Research has found these risk drivers** ("systemic risks" per AACE):
  - The level of Scope Definition upon which the estimate is based
  - Process system attributes
    - Technology (e.g., never before applied in industry)
    - Complexity (e.g., number of continuous block steps)
    - Severity (solids, corrosiveness, etc)
  - Organizational/Methodological system attributes and practices
    - Team Development/Building
    - Project Control practices (incl quality of estimating/scheduling)
    - Execution Planning and Scheduling practices
  - Bias in culture and estimating and scheduling practice

Monte Carlo Simulation (MCS) Model Development

- Same model form as MLR, only assumed; for example
  - e.g., Cost Growth = constant + coefficient*(Complexity)
- With MLR we would gather actual data of growth and complexity; however, in MCS we have no data, only uncertain assumptions
- The best we can do is make educated guesses as to the constant and coefficient, perhaps based on gathering opinion from experts.
  - We can capture their range of opinion in probability distributions (PDFs) such as Triangular or Pert (easy to use with 3-point basis)
- By replacing the parameters with distributions, we derive a model that we think will represent how our pseudo population behavior:
  - Cost Growth = (PDF of constant) + (PDF of coefficient) * (Complexity)
- If the variables are not independent, we must specify their correlation

Monte Carlo Simulation (MCS) Model Simulation

- The MCS routine will randomly sample from the distributions that we defined for the uncertain risk parameters
- Using the sampling draw, MCS will calculate a predicted cost growth for the entered Complexity ratings in our example
- MCS will repeat this sampling and calculation of pseudo observations thousands of times (iterations) just as if we were gathering historical data from a real population of projects.
- It captures each of these thousands of observations and from that dataset of outcomes it generates a distribution of possible outcomes.

Monte Carlo Simulation (MCS) Model Applicability

- Again, MCS models are purely theoretical so it can only be relied on if the assumptions are rational with a minimum of conjecture!
- The only risks for which that is true are **Project-Specific** risks such as:
  - Soil conditions, Weather conditions, Logistics delays, etc.
  - These are primarily conditions uncertainty and risk events
- These risks can be modeled using **Expected Value** methods
  - Probability x Impact (input as 3-point distributions)
  - Well facilitated teams are pretty good at estimating P & I ranges

Econometric Modeling for Escalation/Exchange

- There is another type of systemic risk, but in this case the system is the external economy which affects resource pricing and availability
- As with systemic risk, the economy (price levels and currency valuation) are modeled using historical data; we call this **econometric modeling**. We must call in the experts for this; **economists**
- Escalation is changes in price level over time driven by the over-arching economy (can be a regional or industrial economy)
  - This can include changes in prevailing technologies, skills, and so (i.e., prevailing shortages of skilled labor raise wage levels)
- Escalation includes but is more than Inflation which is driven by monetary policy (printing money; e.g., quantitative easing)
- Escalation and exchange rate are somewhat related (weak currencies may result from inflation) but not purely so

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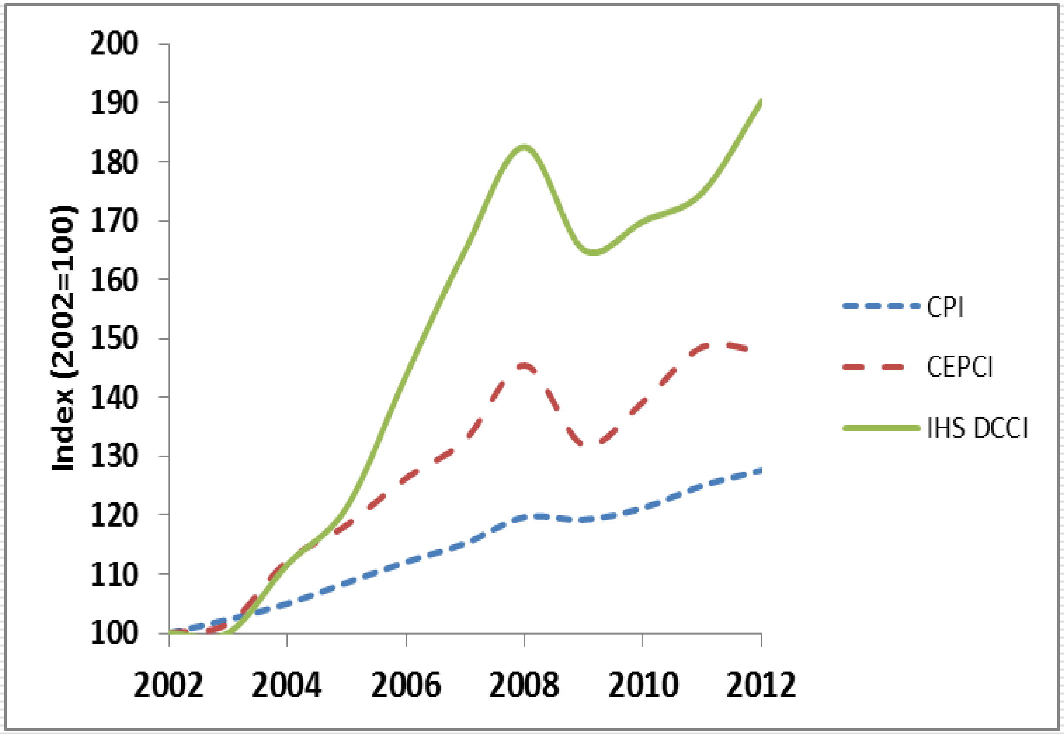
Escalation Can Be A Major Risk; It Depends Where You Are in the Price Chain

- Inflation (CPI) vs. Contractor Escalation (CEPCI) vs. Owner Escalation (IHS DCCI)

US Consumer Price Index (CPI); an inflation measure used by many companies. Given that almost none of the items in the CPI basket are items that go into a capital project makes this choice a particularly poor choice (Ref: US Bureau of Labor Statistics)

Chemical Engineering Plant Cost Index (CEPCI): this uses USBLS input cost data for items that go into a chemical plant project, but it reflects cost to a contractor (e.g., wages), not the price an owner must pay for services (e.g., bid price).

IHS Downstream Capital Costs Index (DCCI): this is based on the actual sell price that IHS owner clients actually experienced for downstream process plant projects. For owners in this industry, this is "escalation".



Escalation/Exchange Risk Quantification Methods

- The Economists provide us with forecasts of prices and exchange rates usually represented as indices
- With an index, a year is chosen as the base (e.g., 2000 = 1.00). The price level in later time periods is represented by a relative index (e.g., 2010 = 1.30 or 30% increase in price since 2000)
- The indices are for specific categories of cost items such as
  - steel, pipe (CS vs alloy), process equipment or wages
- The economist's model items will not match our estimates so we have to create weighted indices from economist inputs; i.e., recipes
  - e.g., fabricated piping includes pipe, fittings and shop labor
- The economists model items do not cover some of our items/markets so we may need to create proxy indices

Escalation/Exchange Methods Must Be Probabilistic

- As was seen, escalation/exchange can be highly uncertain and volatile
  - e.g., the 2003-2009 “super cycle” in commodities and subsequent collapse and the current instability in exchange rates/devaluations
- Therefore, escalation/exchange models must also be probabilistic
- This can be done by applying MCS to a traditional escalation estimate model wherein the following are treated as distributions:
  - Schedule duration (use output distribution from model)
  - Contingency costs (use output distribution from model)
  - Price levels and exchange rates (has a time series aspect)
  - Cash flow spend pattern (front or back end loaded)

Principles and Research Summary

- We covered the core risk quantification method principles:
  - Must be Risk Driven, Use Empiricism and Probabilistic
  - The foundational empirical models were shared
- We covered the two practical inferential modeling methods
  - MLR (Parametric) and MCS
- We covered how different risk types align with the modeling methods
  - Systemic Risks: MLR (Parametric)
  - Project-Specific Risks: MCS (Expected Value)
  - Escalation/Exchange: MLR (for indices by economists) then MCS (for application by us)
- Next, we will put these principles and research into practical models

Agenda

- Risk Quantification within Risk Management; Setting the Context
  - Terminology and Process
- State of Industry Cost & Schedule Risk Quantification: Facing Reality
  - Common Risk Quantification Methods and Why They Fail

Break

- Principles of and Research on Best Practice in Risk Quantification
- **Reliable Methods for Cost and Schedule Risk Quantification**
- Communicating Risk Analysis & Contingency Estimating Outputs

Conclusions/Discussion

What Risk Quantification Methods Are Recommended By AACE?

- From 2007 to 2013, AACE International developed a suite of Decision & Risk Management (DRM) Recommended Practices
  - First RP covered risk quantification "principles" (40R-08)
- This was followed by a development of a Decision and Risk Management Professional certification program (DRMP)
- The following slides outline the RPs that form the technical foundation of the DRMP Body of Knowledge
  - RPs are how-to guidelines for methods that a general consensus of experts agree can be efficacious
  - If a method does not accord with principles, it is not recommended (e.g., LIR)

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AACE International Risk Management *Recommend Practices*

- Decision and Risk Management in TCM
  - TCM 3.3: Investment Decision Making
  - TCM 7.6: Risk Management
- Risk Management Processes in TCM 7.6
  - 72R-12: Risk Management Planning
  - 62R-11: Risk Assessment
  - 63R-11: Risk Treatment
  - 67R-11: Contract Risk Allocation
- Risk Quantification Principles
  - 71R-12: Skills and Knowledge of a Decision and Risk Management Professional
  - 10S-90: Terminology (including Risk terms)
  - 40R-08: Contingency Estimating-General Principles
  - 66R-11: Selecting Probability Distribution Functions for Cost & Schedule Risk Simulation
- Risk Control
  - 70R-12: Schedule Contingency Management

AACE International Risk Quantification *Recommend Practices*

- Project-Specific Risks
  - 44R-08: Risk Analysis and Contingency Determination Using Expected Value
  - 57R-09: Integrated Cost & Schedule Risk Analysis Using Monte Carlo Simulation of a CPM Model
  - 64R-11: CPM Schedule Risk Modeling and Analysis: Special Considerations
  - 65R-11: Integrated Cost & Schedule Risk Analysis & Contingency Determination w/Expected Value
- Systemic Risk:
  - 42R-08: Risk Analysis and Contingency Determination Using Parametric Estimating
  - 43R-08: Example Models as Applied for the Process Industries
    - Includes functional Excel-based John Hackney and Rand cost and schedule models
  - 18R-97: Cost Estimate Classification for Process (also see Mining, Hydro and Commercial versions)
  - 27R-03: Schedule Classification System
- Escalation Risk:
  - 58R-10: Escalation Principles and Methods Using Indices
  - 68R-11: Escalation Estimating Using Indices and Monte Carlo Simulation

What is a Good Risk Quantification Method?

- **One that works:** investment decision makers depend on the reliability of our analysis to give confidence and contribute to success.
  - Explicitly link risk to impact, empiricism, probabilistic
  - Risk analysis is the only field I know where it has not mattered if our methods actually work. We need to change that.
- **Generally applicable:** works for all projects in a company's capital portfolio; simple and complex, large and small, conceptual or detailed, good or bad quality estimates and schedules, and so on.
- **Simple:** Per Occam's Razor, as simple as possible but not too simple; one should not be dependent on consultants other than from a "cold eyes" point of view (i.e., the outside view to counter bias)

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What Risk Quantification Methods Pass My Test?

- What methods meet my criteria and align with AACE's first principles?
  - **Parametric Modeling for Systemic Risks (42R-08)**
  - **Expected Value with MCS for Project-Specific Risks (65R-11)**
  - **Escalation Using Capex Market Adjusted Indices and MCS (68R-11)**
- Start with systemic risk, then project-specific, then escalation, accumulating their impacts along the way. This yields a "universal" capex outcome distribution to support decision analysis NPV models
- For programs, these methods can be applied in an "integrative analysis" pass to quantify risks that are unique from a holistic view
- Finally, the methods explicitly address the impact of complexity; i.e., they can model non-linear or chaotic behavior which results in bi-modal outcomes (i.e., potential blowout prediction.)

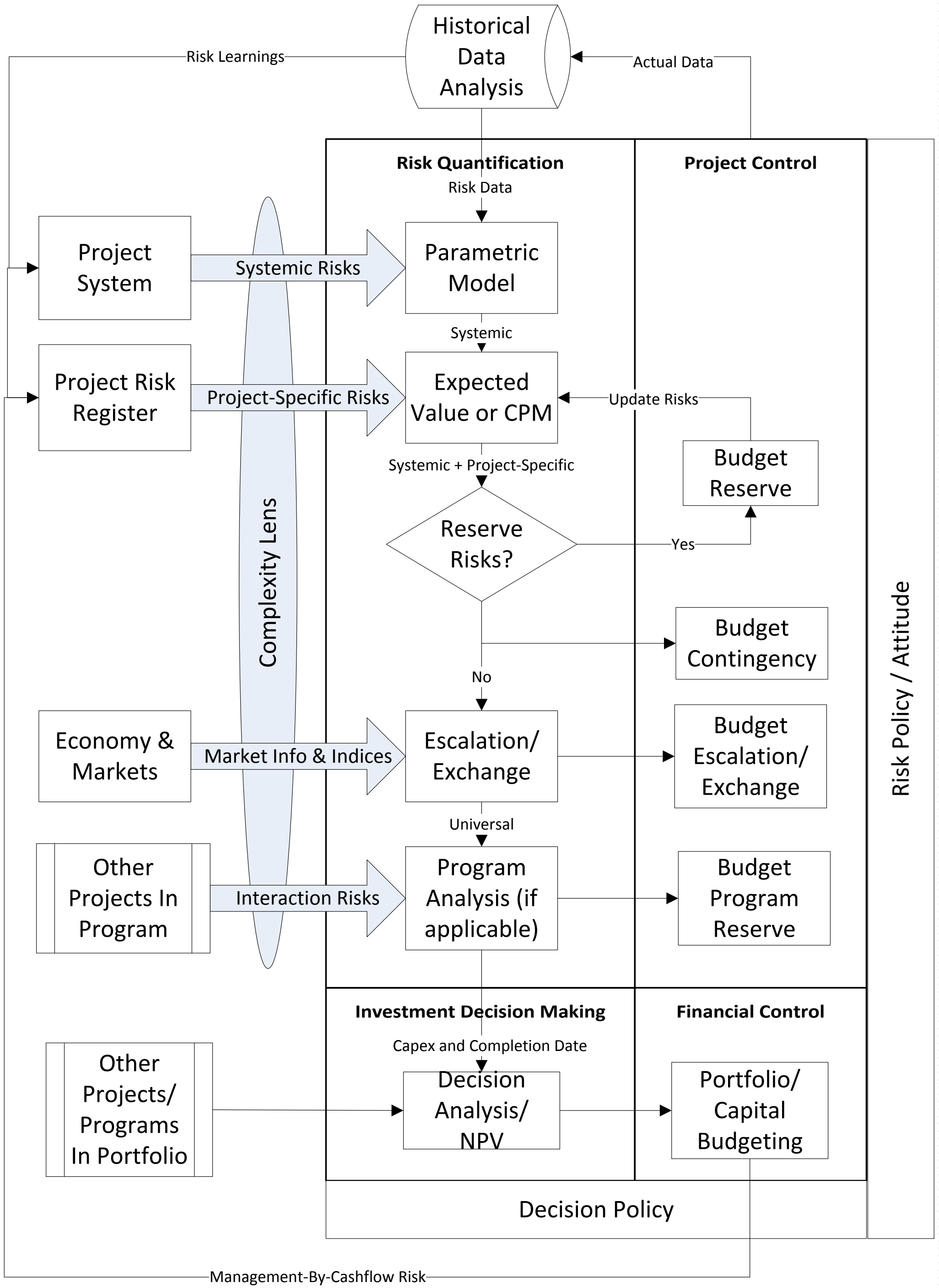
What About CPM Model Based MCS?

- I find that it is neither generally applicable or simple
  - A main concern is that it requires a high quality schedule that is simply not available when needed . An IPA study showed that only 13 percent of projects had a quality schedule[1].
  - Risk responses with cost/schedule trading often involve changing logic to preserve the completion milestone; that requires complicated conditional branching in CPM
  - Knock-on effects on productivity from delays are difficult to model in a CPM model, but intuitively simple with expected value
- That said, I strongly recommend the cost-loaded, risk driven CPM method for building quality, robust, risk tolerant schedules (a risk treatment tool as opposed to risk quantification)

1. Griffith, Andrew, "*Scheduling Practices and Project Success*", Cost Engineering Journal, AACE International, 2006.

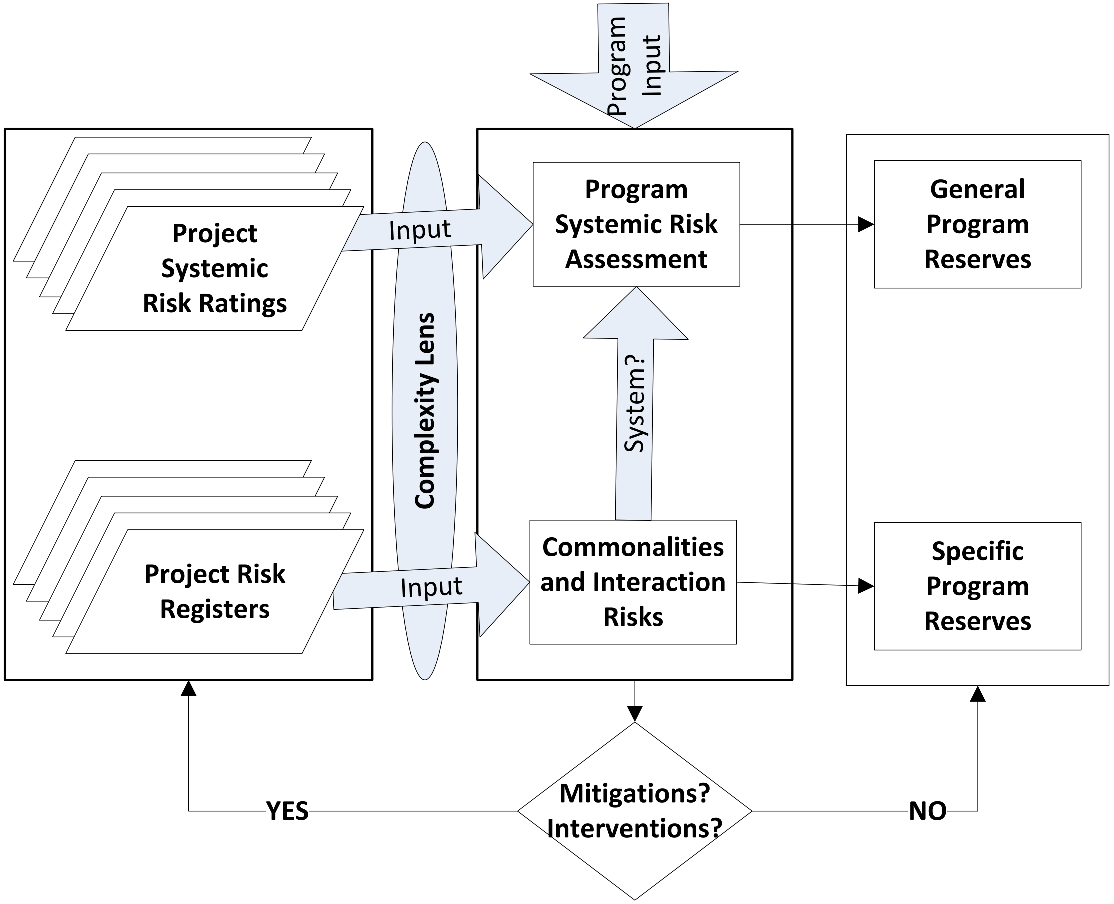
A Build-up Approach

- This process flow shows the stepped application of fit-for-use methods that best apply to the risk types (systemic to project-specific to escalation)
- The "complexity lens" is a filter to watch for a pattern of risks associated with the chaos *tipping point*
- The outcomes align with methods of *accounting* for risks for control and for use in *decision analysis*



At a Program Level Look For and Quantify Commonalities and Interactions

- At the program level, the emphasis is on assessing commonalities and interactions, recognizing the added complexity
- Generally, a program will benefit from having its own risk funding to deal with interaction risks and to assure that the enterprise is prepared to intervene in projects if warranted



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Getting Started: Know Your Scope

- The dominant risk drivers are typically **systemic**—these are attributes of your project system. Key systemic risks include:
  - Level of scope definition at sanction
  - Level of technology and process and execution complexity
- Most CPI companies use **phase-gate** processes to manage scope development
- Rate your project scope definition using
  - CII's Project Definition Rating Index (PDRI)
  - IPA's Front End Loading Index (FEL)
  - AACE's Estimate Classifications (Class)

Getting Started:
Know Your Base Estimate and Biases

- An estimate is not a number but starts there; i.e., it's the base
  - The base estimate excludes contingency and escalation
- Start with a documented **base estimate strategy**;
  - what does the base represent in terms of bias?
  - Is your goal predictability (conservative; e.g., historical norms) or competitiveness (aggressive: e.g., target costing)
- Every estimate is biased low or high
  - Small projects often conservative; less contingency
  - Large projects often aggressive; more contingency
- "**Estimate Validation**" exposes the bias
- Estimate quality effects range but not necessarily bias

Project Controls EXPO

Parametric Modeling for Systemic Risks (RP 42R-08)

- The difficult part of parametric modeling is creating the model
  - see next slide for a simple cost model for typical process plants
  - see the IPA execution schedule duration vs. FEL Figure for duration
- Application involves three steps:
  - Interview team leaders and rate the risk driver parameters
  - Determine bias using estimate and schedule validation
  - Entering the risk ratings in the model
- The outcome is the mean cost growth and schedule slip as a percent of the base with a distribution derivation
- This outcome is their first risk entered in the Expected Value model with MCS (probability = 100% & impact is the parametric distribution)

Typical Systemic Contingency Allowances Based on Project Attributes (Owner Perspective)

Ref: Hollmann, J. "Improve Your Contingency Cost Estimates For More Realistic Budgets", Chemical Engineering, Dec 2014

Systemic Contingency as % of Unexpended Base Estimate										
Scope Def.		**Class 3**			**Class 4**			**Class 5**		
Complexity		Low	Med	High	Low	Med	High	Low	Med	High
Tech-nology	L	**3**	**8**	**12**	**10**	**15**	**20**	**19**	**24**	**29**
	M	**6**	**11**	**15**	**13**	**18**	**23**	**22**	**27**	**32**
	H	**15**	**20**	**24**	**22**	**27**	**32**	**32**	**37**	**42**
Adjustments to the above (select from within the ranges):										
Impurities/ Severity		Feedstock or intermediate streams have solids, contaminants, corrosives, etc.: **+5 to +10**								
Bias		Aggressive Base/Target Pricing: **+10**; Conservative Base/Small Plant-Based/Punitive: **–10**								
Teams/Sys		Immature Weak/Indecisive/Understaffed: **+10**; Mature/Strong/Decisive/Full staff **–10**								
Fixed Price Basis		Separate out costs based on firm-priced quotes and use **50%** of above for that portion of the total cost								
Distribution (Rule-of-Thumb: Apply to a 3-point Pert)										
Best (p10)		After making adjustments above, the p10 is about **–0.5X**								
Worst (p90)		After making adjustments above, the p90 is about **3X**								

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Reference Notes for the Systemic Contingency Table:

- These are average allowances (about p55).
- They assume a large gas or liquids CPI project with 20% equipment cost and typical PM system maturity and biases.
- For Class 3 scope definition, it assumes that 5% of the total cost has already been spent on engineering and the Class is over-rated (i.e., few projects achieve ideal Class 3; most are funded closer to Class 4.)
- Low to High complexity ranges from <3 block flow process steps with a simple execution strategy, to >6 continuously linked process steps and/or a complicated execution strategy.
- Low to High technology ranges from <10% of capex for a process step with commercially unproven technology, to >50% of capex for new, R&D or pilot scale up steps.
- Make adjustments to the indicated table value as shown. The fixed price adjustment allows for less uncertainty for that element, but there is no such thing as fixed price for owners; change and risk events happen.
- An example of Best/Worst Case (p10/p90) is if systemic contingency is +10% (Class 4, med. complexity, no new tech), the P10/p90 would be -5% (-0.5 x 10) and +30% (3 x 10); note the best case underruns the base estimate.

Snapshot of a Parametric Model Tool (Less Subjective Than the Simple Table)

VALIDATION ESTIMATING

CONTINGENCY ESTIMATING TOOL

Rev:16Feb09

Project Title:	**enter title**
Estimate Description:	enter description
Case Description:	enter description
Date:	

Tailor the tool to the project scope type, company phase-gate scope maturity model and rating scheme (e.g., PDRI, Class or FEL)

Enter Base or Point Estimate Costs	1,000,000	($ or € thousands)	**Currency**	Canadian$
Enter Execution Schedule Duration	30	(months)		

SCOPE DEVELOPMENT/ESTIMATE MATURITY WORKSHEET

		Maturity Level:			Class	
	Business Ownership/Team Development	5	4	3	5,4 or 3	
	Business Leadership and Ownership	general	preliminary	defined	3	
note:						
	Environmental and Sustainability Definition	general	preliminary	defined	3	
note:						
	Stakeholders / JV Partnerships	general	preliminary	defined	3	
note:						
	Project Alignment with Corporate Strategy	general	preliminary	defined	3	
note:						
	Owner Project Team Development/Staffing	general	preliminary	defined	3	
note:						
	External Utilities & Other Infrastructure Contracts	general	preliminary	defined	3	
note:						
					Business & Team	3.0
	General Project Scope					
	Project Scope Description and Sign-Off	assumed	preliminary	defined	3	
note:						

Rating Philosophy

***"The project is only as strong as the weakest link"*; i.e., if there is no consensus as to a rating, chose the lesser rating**

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Exercise 2
Systemic Risk Quantification

Using the Table method presented earlier, estimate the mean, p10 and p90 contingency required to address Systemic risks given these parameters:

- Scope Definition: has not yet achieved Class 3 in all areas
- Complexity: 5 continuous block flow process steps and typical execution
- New Technology: 5% of capex
- Severity: Significant use of alloys due to corrosiveness and temperature
- System/Team: Project process is immature and not all roles filled
- Cost Strategy: using target price strategy (base is p40 of past actuals)

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Expected Value with MCS for Project-Specific Risks (RP 65R-11)

1. **Identify Critical Risks**: Critical risk #1 is Systemic; i.e., a risk with 100% chance of occurring and an impact equal to the parametric outcome. The rest of the risks are the "red" (or near red) project-specific risks from the screened register; lessor ranked risks tend to be noise covered by the range of the historically based systemic model. Escalation and exchange risks are excluded at this point.
2. **Consider Risk Response**: For each critical project-specific risk, answer "how would we respond if this happened?" The answer will depend on one's cost/schedule objective (what is important?) and will guide the quantification of cost and schedule.
3. **Quantify the Probability of Occurrence**: the register will have a qualitative ranking; get consensus from the team in a workshop as to the percent chance number

Expected Value with MCS for Project-Specific Risks (RP 65R-11)

4. **Quantify the Impacts**: Get consensus from the team in a workshop (and follow up elaboration as needed), with expert planning guidance, as to 3-point estimates of the cost and schedule impact specific to and integrated by the assumed risk response(s). Direct, indirect and time-dependent cost impacts are considered.
5. **Run the Monte Carlo Simulation**: The impacts are entered as distributions and if any risks are dependent include the correlations coefficients (if not sure, use 0.5)
6. **Set Aside Reserve Risks and Iterate Analysis**: If on reviewing the outcome any of the risks are not amenable to contingency (e.g., low probability, high impact), the can be removed from the list and the MCS re-run. Reserve risks will be funded or not in their own right.

Expected Value Example for One Risk

- Risk Identification
  - Risk:
  - Probability of Occurrence
  - Dependent on Other Risk?:
- Impact Estimate
  - Assumed Risk Response:
  - Schedule Impact Range:
  - Time Driven Cost Impact Range:
  - Non-Time Driven Cost Impact Range:
- Expected Value Outcomes (Expected Value = Mean)
  - Execution Schedule Duration
  - Cost

Snapshot of an Expected Value Tool

Enter the RISK RESPONSE

1	Risk Identifier/Name	Describe impacted work element (for which burn rate applies)			Contracts:	N/A	N/A	N/A
	Assumed risk response:	Describe the assumed risk response if risk occurs (schedule and non-time driven cost impact reflects this response)						
	Schedule Impact:	Impact (mos)	**Time Driven Cost Burn Rate:**	$x1000/Mo	**Non-Time Driven Cost Impact:**	Impact ($x1000)		
	Low	3.0	General & service contracts	$ 512	Low	$1,000	Total	
	Most likely	5.0	Other contracts (see selected)	$ -	Most likely	$5,000	Cost Impact	
	High	7.0	Burn Rate (can override):	$ 512	High	$20,000	($x1000)	
	Schedule Months (EV)	**0.0**	**Time Driven $ (EV)**	**$0**	**Non-Time Driven $ (EV)**	**$ -**	**$0**	

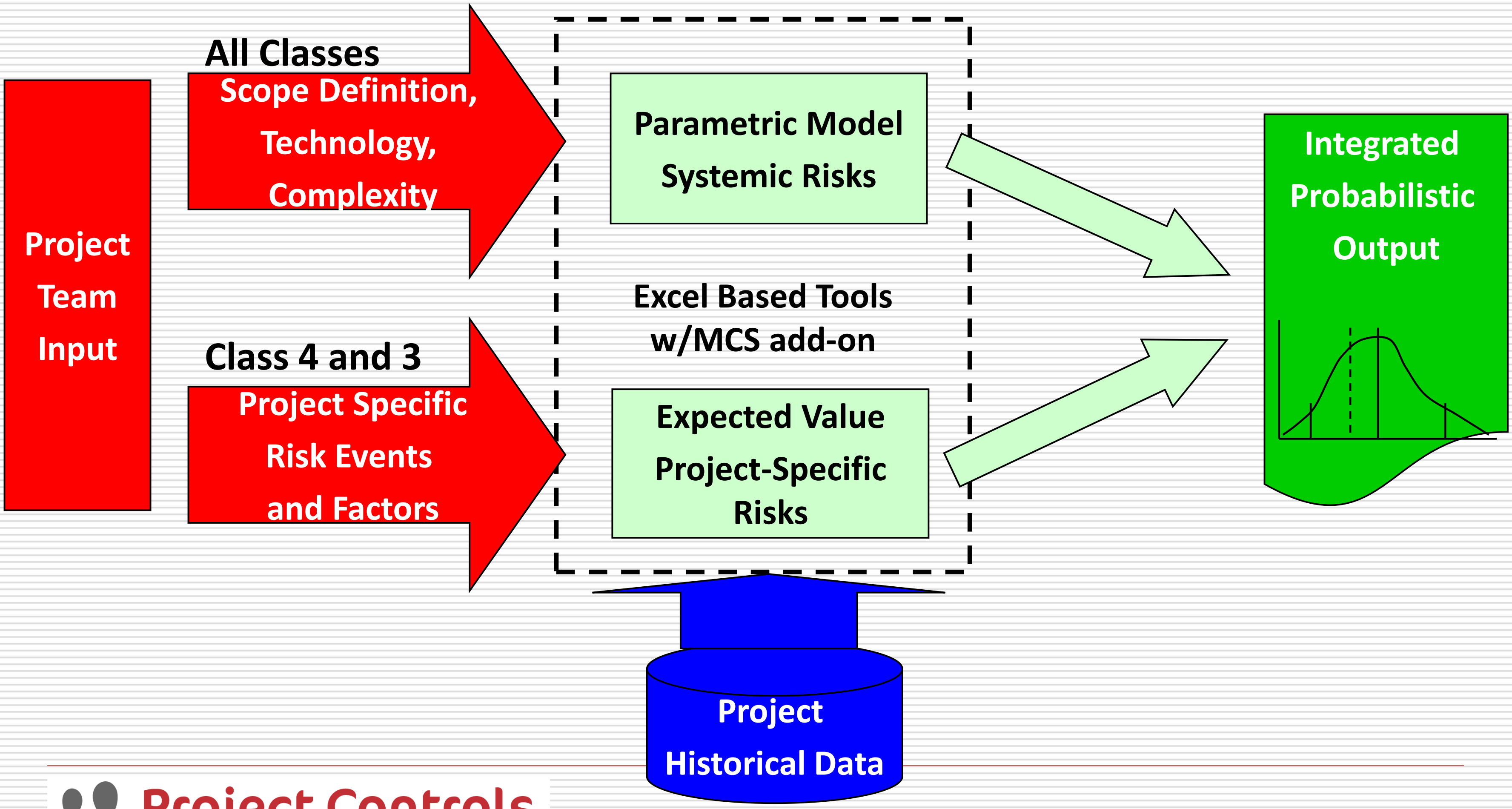
Enter the SCHEDULE Impact of each Risk

Enter the direct COST impact

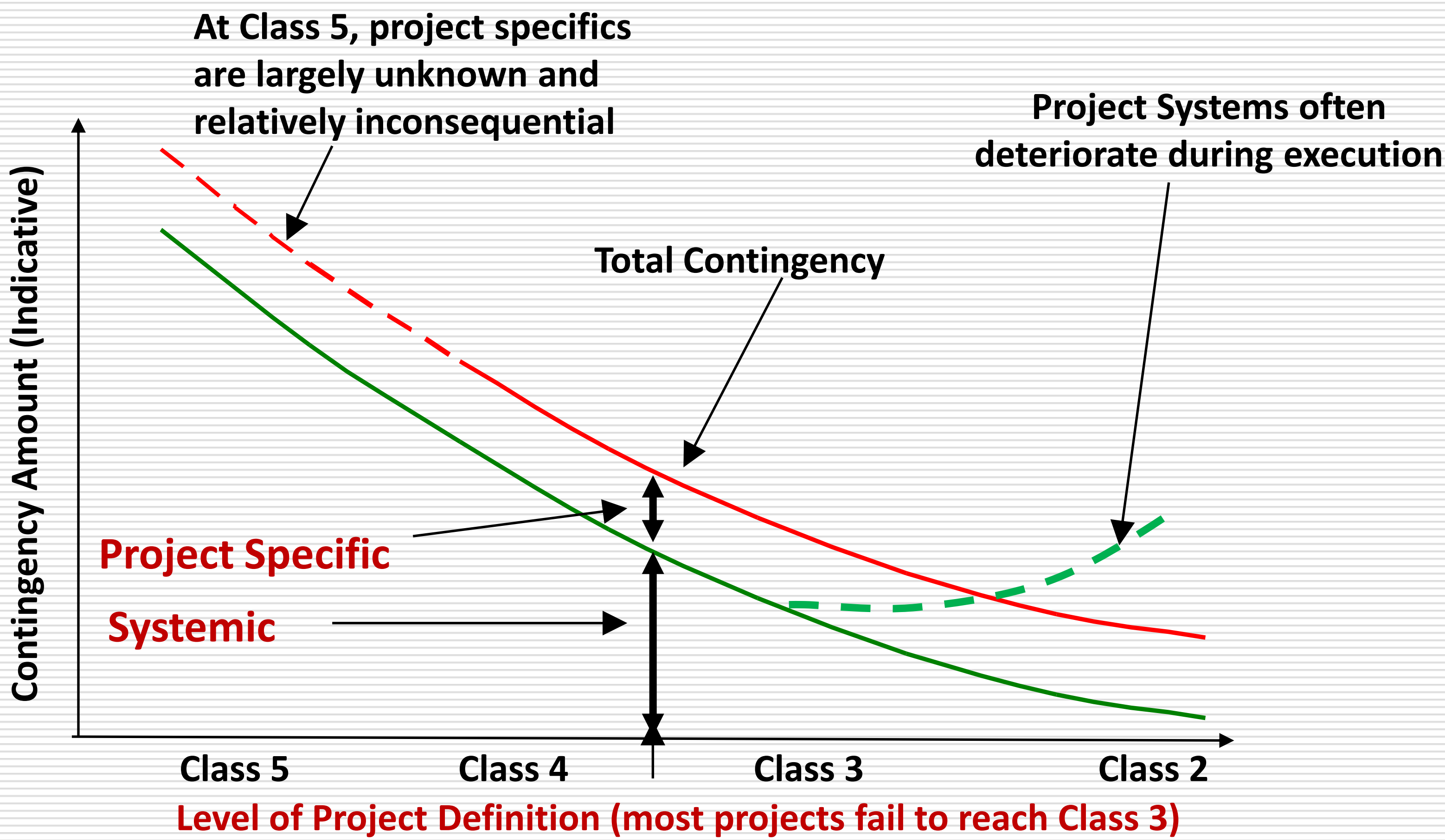
The time-dependent element of COST impact is based on the applicable burn-rate

The bottom row is the Expected Values for time and cost for this risk

Parametric and Expected Value Methods Are Used Together



Relative Contribution to Contingency of Systemic & Project-Specific Risks



Escalation Using Capex Market Adjusted Indices and MCS (RP 68R-11)

- Escalation Estimating Method Steps:
  - Determine cash/commitment flow by summary cost account
  - Establish base price indices to use and condition them for use
    - Develop weighted indices to match your cost accounts
    - Adjust the indices for the regional and item capex market*
    - Using the indices, calculate price increase by account by period
  - Multiply each time period's expenditure by the cumulative price increase percentage (compounded by period)
  - Sum the escalation amounts

* **Capex Market Adjustment**: There are no indices for service prices or items with few vendors (e.g., a hydrotreater vessel). Use regional capital spending indices to create market factors to adjust the base index (for example, in a hot market, bid prices may escalate at a 50% higher rate than underlying wage rates).

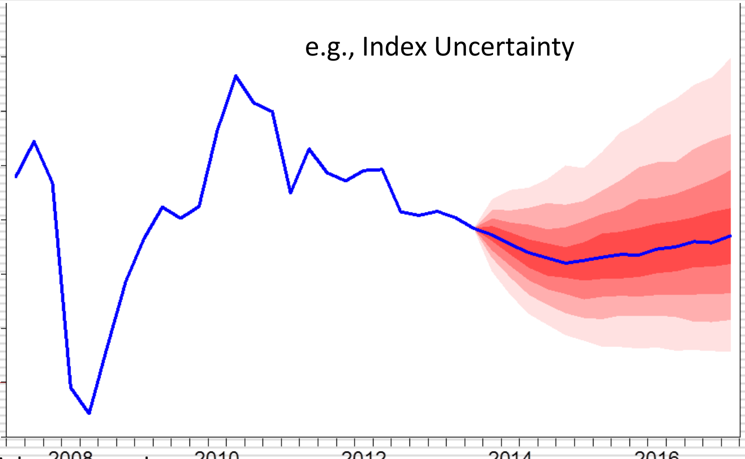
Additional Steps
For Probabilistic Escalation Estimates

- Start with base escalation estimating model
- Apply distributions to uncertain variables
  - Contingency in estimate
  - Schedule durations
  - Price Indices
  - Cash flow pattern

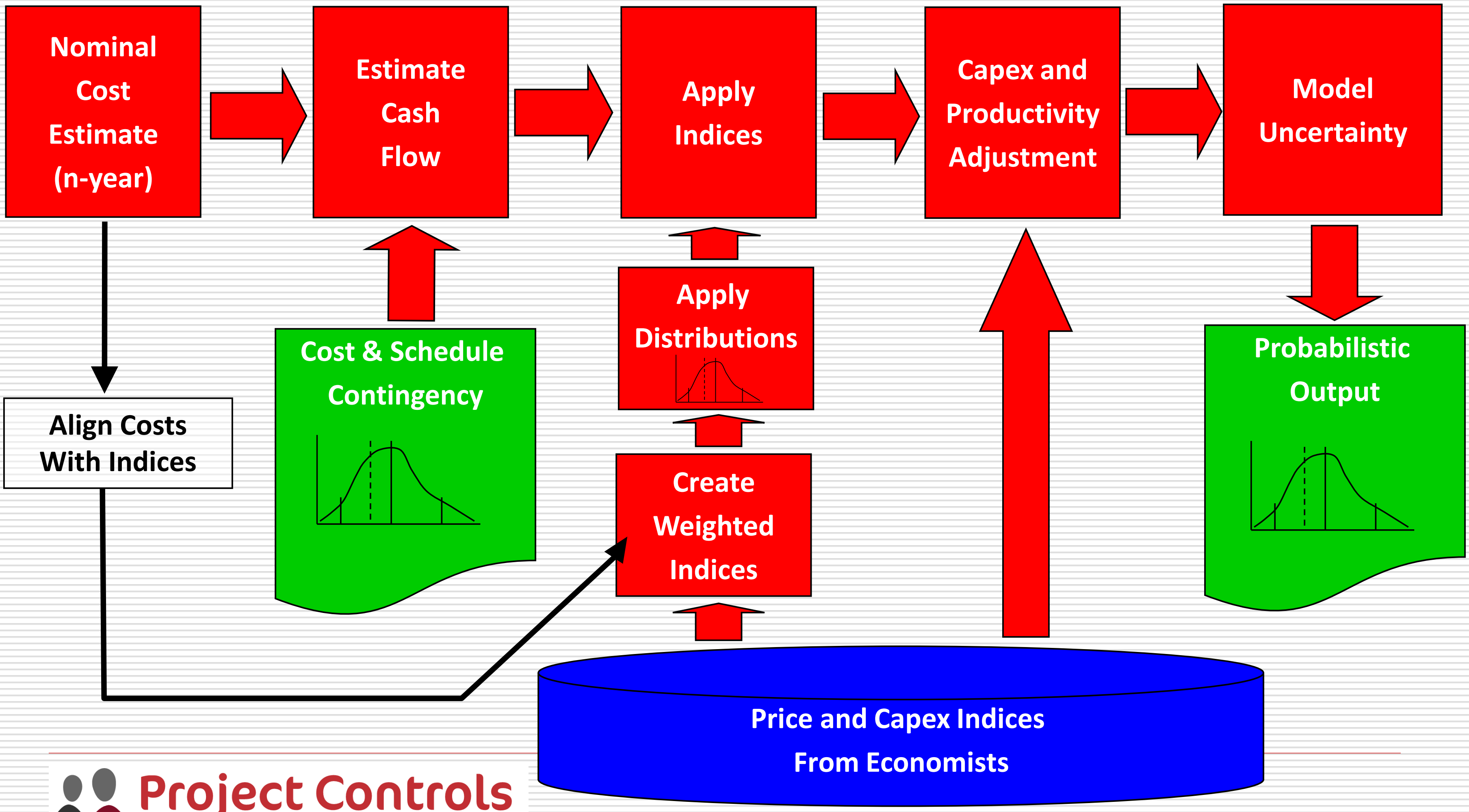
Contingency in estimate, Schedule durations: Distributions from contingency model

Schedule durations, Price Indices: These are most important

- Establish correlations/dependencies (prices tend to shift together)
- Run Monte-Carlo Simulation



Escalation Estimating Steps



Using Economic Scenarios

- While economists will rarely call for sharp "turns" as their "most likely" case (their models tend to "regress to the mean") they will provide possible range scenarios to let you play "what-ifs"
  - Acquire/pay attention to the economist's range statements
    - See the example range chart on the earlier slide
    - e.g., IMF July 2015: "*The distribution of risks to global economic activity is still tilted to the downside*"
- Business units usually have an assumed economic context or scenario for their revenue (e.g., *"$60-$70 oil price through 2016*")
  - Use the same scenario for capital escalation as for revenue

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The Tipping Point Indicator

- Warns management if **blowout** risk is threatening
- Based on selected systemic, specific and escalation risks and stressors

Complexity/Stress Factors (Tipping Point Factors)						
Systemic Risk Factors	Size	Decisiveness	Team	Aggressiveness	Complexity	**Overall**
Systemic Risk Indicators	🔴	🔴	🟢	🟢	🟡	🟡
Project Specific Risks	Considers whether top risk events or conditions might consume contingency					🟢
Market (Escalation)	Select prevailing contracting and purchasing conditions				Favorable	🟢
OVERALL						🟢

EXPLANATION: The distribution of project cost outcomes is bimodal or discontinuous. At some point, certain risks may push a project into a chaotic regime with significantly worse outcomes than forecast. The factors above represent complexity/stressor risks associated with the "tipping point". The base contingency model does not cover chaotic outcomes; the potential occurrence if such outcomes is flagged by this indicator.

Ref: Hollmann, J. "*Risk Analysis at the Edge of Chao*", Cost Engineering Journal, Jan/Feb 2015, AACE International

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Agenda

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- State of Industry Cost & Schedule Risk Quantification: Facing Reality
  - Common Risk Quantification Methods and Why They Fail

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Conclusions/Discussion

Communicating Outcomes When Realistic Methods Are Used

- When realistic methods are used, the task of communicating the outcomes can be VERY difficult (especially the first time) because…
  - Systemic risks belong to senior management and the ratings may not tell a flattering story about the state of the "system" they are responsible for developing. They own the risk.
    - How do you tell someone their rating is "poor" when they have been telling everyone else a different story?
  - Realistic P80 capex values will often not pass IRR hurdle rates
    - We are not trying to kill projects, but differentiate between alternatives in a meaningful way, and identify how risks can be reduced (albeit difficult for system changes)
- Using these methods at the last minute does not allow time for the difficult messages to be absorbed

Tornado Diagrams Are Less Useful When Risk Events Are Secondary

- That dramatic bar showing that "*late delivery of vessel X*" was the top risk takes a back seat; the role of most risk events is to act as **stressors** that expose systemic weakness and fragility. The 3 week late delivery leads to 3 month slip due to a breakdown in control discipline.
- Systemic risks tend to dominate. Scope definition, team development, technology, complexity, bias. Taken together, they threaten blowout
- Systemic risks manifest themselves in **insidious** ways. Combined in a witches brew, they show up as declining and uneven performance from the start; punctuated by risk events.
- Systemic risks work in the aggregate; one cannot draw deterministic tornado diagram bars that "team" adds x% and "complexity" adds y%.

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Example Of the Primacy of Systemic Risks

SYSTEMIC RISKS

Scope Development and Management

♦ Basic Scope: Incomplete Basic Engineering is and will penalize performance across the board

♦ Scope Management: "Cost Savings" (a defacto policy to change scope) can defeat good progress across the program, also indecisiveness and incentives can make Change Management processes ineffectual and counter-productive

Business Ownership and Team Development

♦ Teams: The turnkey units are fairly solid, but the more non-standard the scope and hybrid the execution strategy, the more inherently weak the teams will be.

♦ Business: The business unit has been indecisive and has invoked policies that are putting stress an increasingly overloaded capacity to deal with decisions.

Estimate and Schedule Basis

♦ Baselines: For the scope as it is, estimate & schedule are not integrated; Cost Savings prevents establishing a baseline.

♦ Control Processes: For each package, if left alone, their estimating and scheduling are assumed generally effective

Technology and Complexity

♦ Physical: There is no new technology. Process complexity of other facilities is relatively low, but overall program is highly integrated.

♦ Execution: Joint venture structure, incentivized lump sum, modularization, inclusion of turnkey subcontractors, and cross-project integration adds complexity.

PROJECT-SPECIFIC RISKS:

♦ Interaction: All of the "high or very high" risks in Area A will likely cascade into and effect all projects when their turn comes

Example of the Tipping Point Index

Overall

Indecisiveness in the face of complexity and a challenged system will cascade and compound into program overruns

Project Size

Together, these comprise a very large megaproject environment

Decisiveness

The risk registers and interviews indicate that business unit decisiveness on large and small matters is poor. This has been manifested in the large (Area A) and small (e.g., changes and procurements) decisions

Teams

The turnkey units are fairly solid but this is not expected on larger teams

Aggressiveness

"Cost Savings Initiative" is creating a fragile cost and schedule basis rather than robust

Complexity

There is no new technology. Process complexity of other facilities is low. However, program overall is very complex

Project-Specific Risks

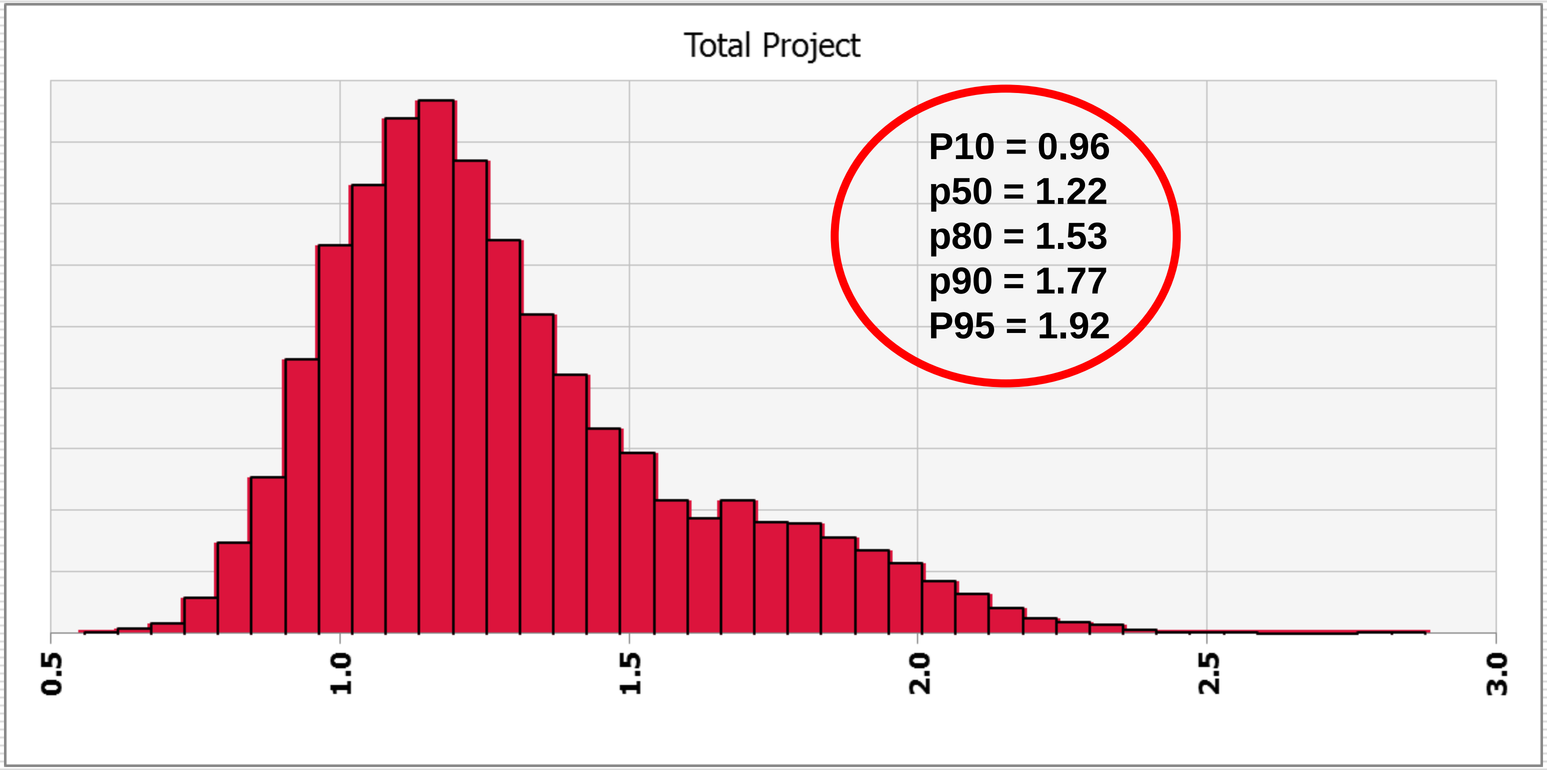
Not counting the client scope changes (Area A and Cost Savings), the project risks are moderate

External Market

While the global capex market is soft at this time, the program has created its own competitive micro-economy, aggravated by local content rules and labor restrictions

Example of how a typical LIR-based P80 (22% overrun) is the Realistic-based P50 and the Realistic P80 (53% overrun) will likely threaten the IRR

If Your Company Policy is to Fund at p80, What Do You Do?



Communicating Outcomes When Realistic Methods Are Used

- **Tell a story**: stats, charts and tornados only go so far. Be able to tell the managers a coherent story (elevator pitch) about their system, the economy, and its interaction with the project and the project risks. Don't mince words if there is a real chance of failure.
  - e.g., "*Indecisiveness and aggressiveness combined with inherent complexity and a challenged system result in significant cost blowout risk*"
- **Impartiality/Independence**: The risk analyst's career must be secure. Consultants are used to delivering painful messages
- **Benchmarking**; Most systemic risks apply to all the projects in the capital portfolio. Benchmark your system as an ongoing improvement effort. Remove the rating surprise from the heat of a project decision

Agenda

Conclusions/Discussion

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