



PROBABILISTIC RISK-BASED COST AND SCHEDULE ESTIMATING

Federal Highway Administration

Office of Infrastructure

Dave Platz, PE, PTOE

Team Leader

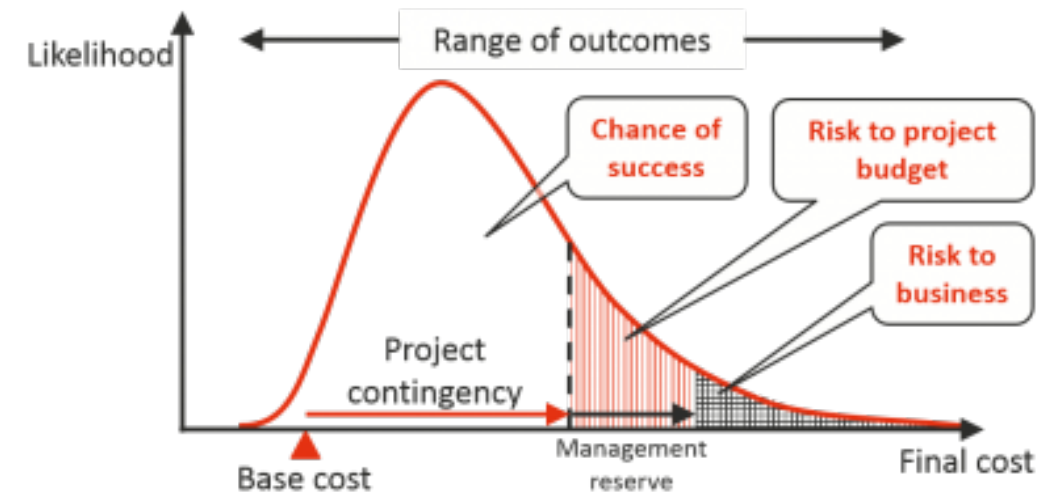
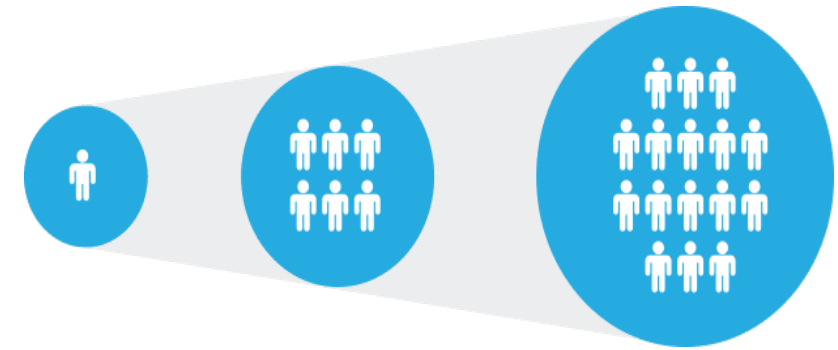
Ian Cavanaugh

CSRA/PRBE Program Manager

What is **P**robabilistic **R**isk-**b**ased **E**stimating (**PRBE**)?

- **Scalable** process that removes deterministic contingency from a **traditional** estimate
- Replaces deterministic contingency with explicit estimates of **risks** using **simulation**
- Output includes **confidence-based estimate** of cost and schedule and identification of **significant risks**

Apply the right amount of resources given project size & complexity



Why is PRBE Used?

TRADITIONAL ESTIMATE	PRBE
Deterministic based	Probability (<u>stochastic</u>) based
Single value	Probability distribution
Contingency based on the estimator's experience, historical records, and industry guidelines	Contingency based on risks to cost and schedule; a quantitative assessment of risks and uncertainties
Communicates a false sense of certainty	Communicates a true sense of uncertainty
Unknown reliability	Known reliability
Unidentified risks	Identified risks
Reactive risk management	Proactive risk management

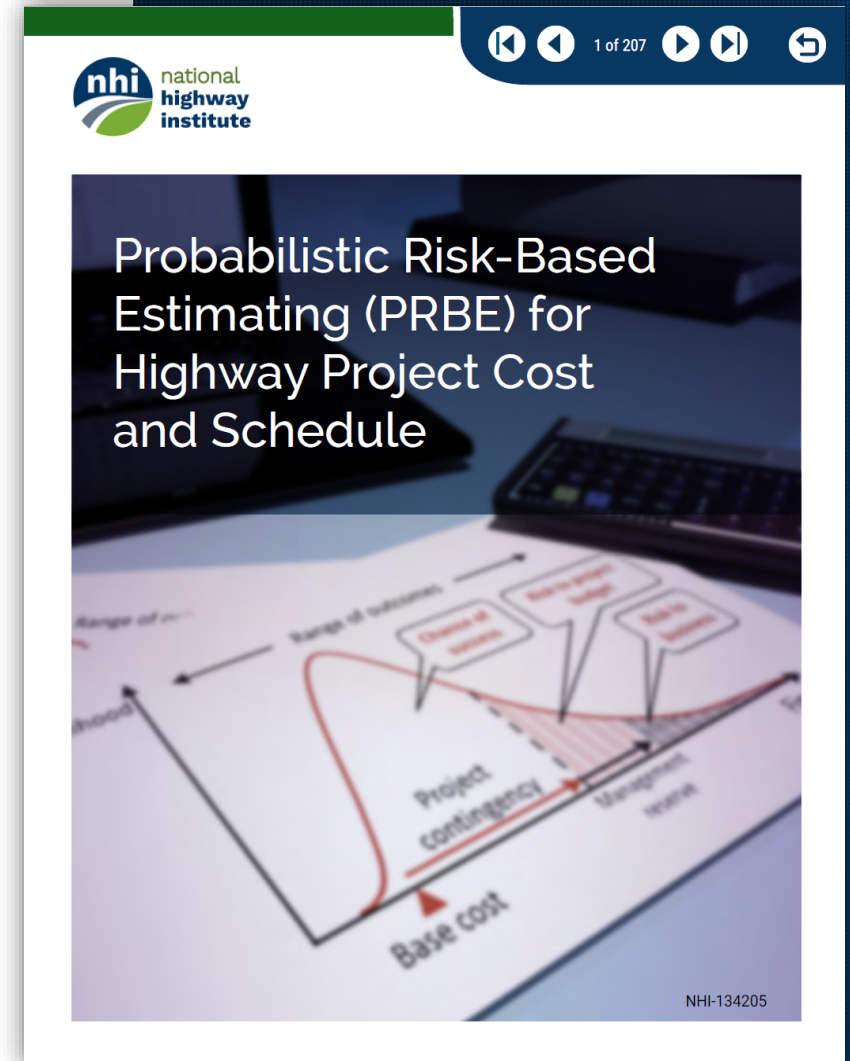
Why is PRBE Used?

- Greater Certainty on Cost and Schedule
- Better Planning & Decision Making
- Risks: Identification, Assessment & Mitigation
- Improved Transparency
- Required for Major Projects per 23 USC 106(h)
 - Inform Initial Financial Plan
- **FREE** FHWA PRBE Tool Can Be Used

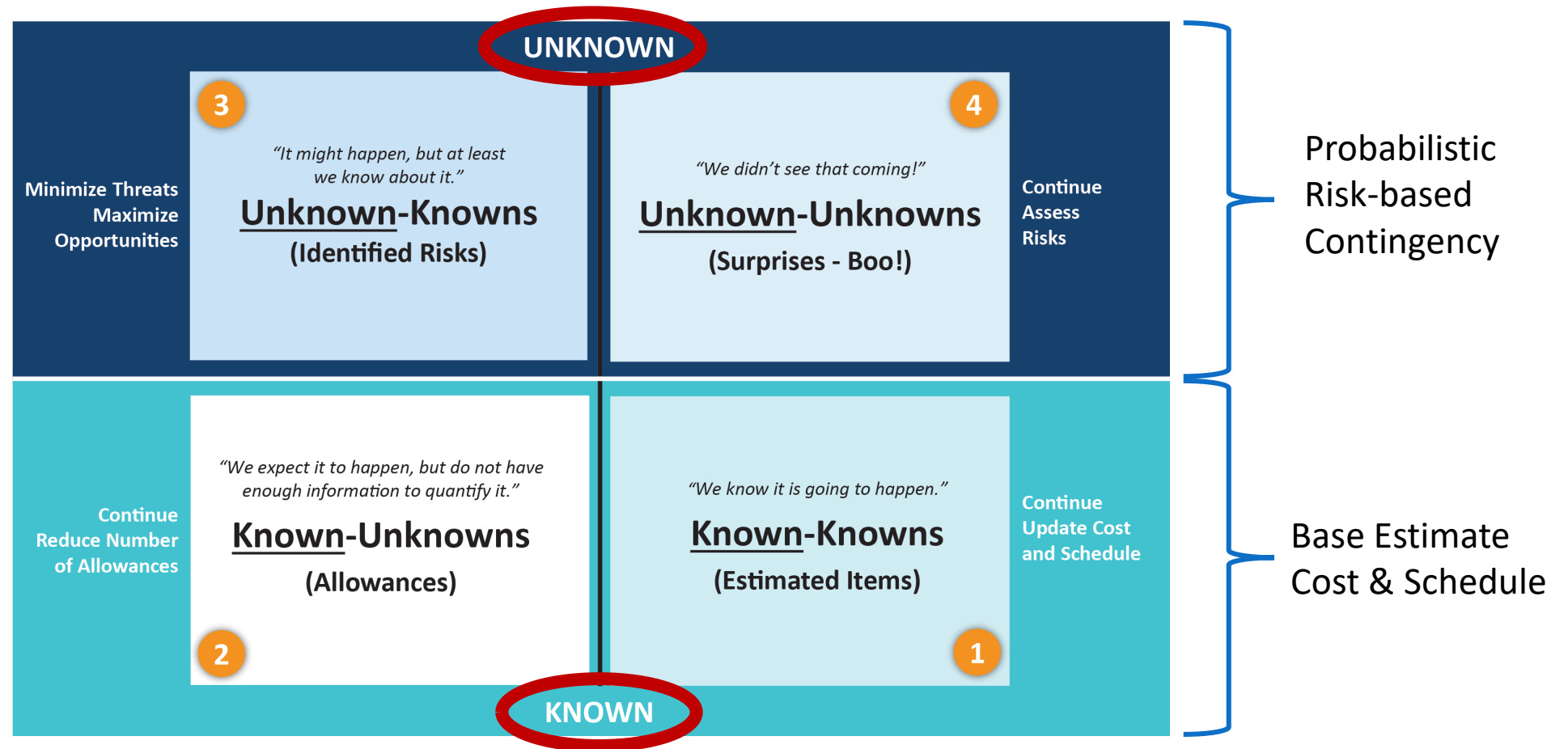
NHI Online eBook Course

- Prerequisite to In-Person “PRBE Tool” Workshop:

- Federal Highway Administration National Highway Institute
- PRBE Course No. NHI-134205
- [NHI Home | FHWA](#)
- 10 - 15 Hours to Complete Self-Paced Course
- No registration fee



Components of **Uncertainty** in a Risk-based Estimate



Contents of A PRBE Model

Base Estimate

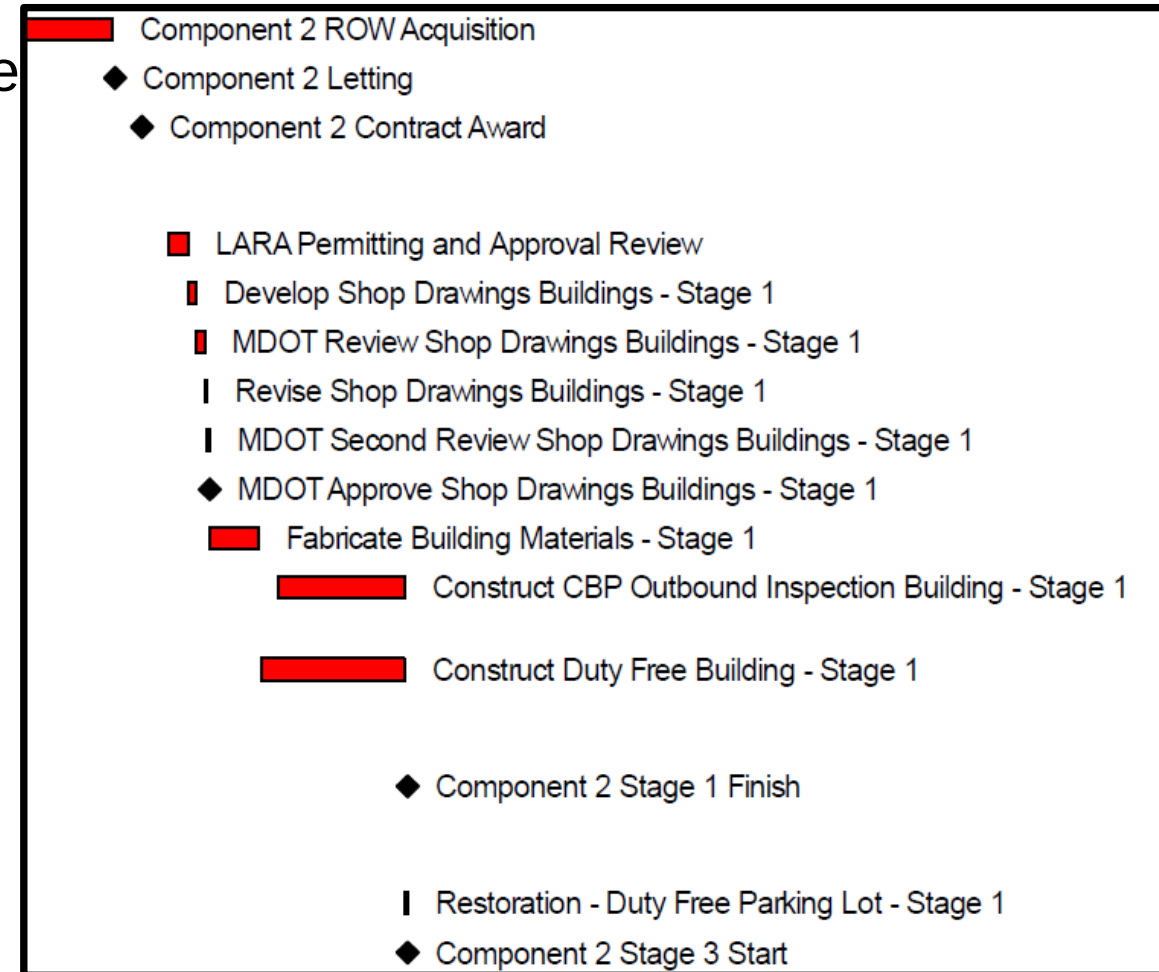
- A prediction of probable costs for a given scope, a defined location, and point of time
 - Planning level estimate
 - Scoping estimate
 - Engineers estimate (i.e. for bid evaluations)
- Uninflated, Unbiased & Neutral
- FHWA CSRAs Evaluate Total Project Cost (NEPA-Construction + Prior & Fixed Costs)
 - Can be scaled and phase specific on non-MPs
- Cost Estimate for each unique item
 - Example: Seg. 1 Design, Seg. 1 ROW, Seg. 1 Con
Seg. 2 Design, Seg. 1 Utilities, Seg. 1 Con
 - Remove Traditional Contingency

Construction Estimate as of 3/1/2024				
Item	Unit	Quantity	Unit Price	Total
Aggregate Base	Ton	6,850	\$8.50	\$58,225
HMA, 5E-3	Ton	12,950	\$82.73	\$1,071,353
Steel, Epoxy Coted	lb	53,200	\$15.60	\$829,920
Concrete, Pvt, 12"	Syd	158,652	\$102.50	\$16,261,830
Construction Total (Estimated Items)				\$482,612,000
Allowances				
Maint. Of Traffic (3%)	LS	1	\$14,478,360	\$14,478,360
Signs, Pavt Markings (5%)	LS	1	\$24,130,600	\$24,130,600
Allowance Total				\$38,608,960
Grand Total =				\$521,220,960
Contingency (15%)	LS	1	\$78,183,144	\$78,183,144

Contents of A PRBE Model

Base Schedule

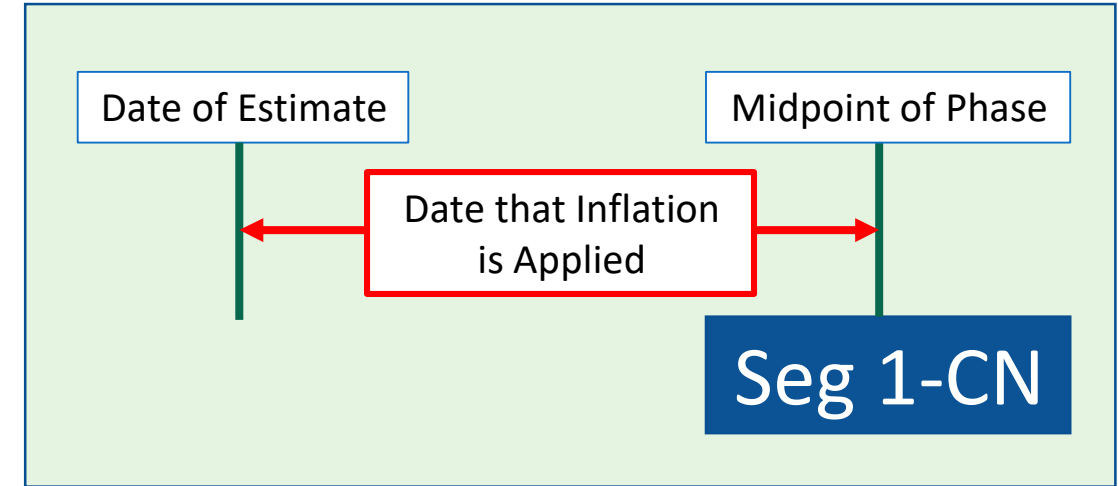
- Schedule Needed for Each Remaining Cost Phase
 - Seg. 1 Design, 4/1/2024 – 4/1/2025
 - Seg. 1 ROW, 4/1/2025 – 9/1/2025
 - Seg. 1 Con, 9/2/2025 -12/31/2029
 - Seg. 2 Con, 4/1/2030 – 12/31/2034
- Remove Contingency (if Applicable)
- Identify Linkages Between Cost Phases
 - Seg 1 ROW ends Before Seg. 1 CON Begins
- Inflation based on Date of Estimate and Mid-Point of Each Phase



Contents of A PRBE Model

Inflation

- Applied from the date of the estimate to the midpoint of each phase
 - CSRA and PRBE Tool Models Allow for 4 Inflation Scenarios
- Flexible by Year and Phase
- Used for Year of Expenditure (YOE) Calculations
- Considerations
 - Recent and Historical Trends
 - Industry Projections
 - Inflation vs. Escalation
 - ❖ Increase Across the Industry
 - ❖ Increases for Specific Items



CNIInflationTab		Cumulative Factor (by Month)											
Year	0	1	2	3	4	5	6	7	8	9	10	11	12
2023	10.0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.01	1.02	1.02
2024	8.0%	1.03	1.04	1.04	1.05	1.06	1.06	1.07	1.08	1.08	1.09	1.10	1.11
2025	7.0%	1.11	1.12	1.12	1.13	1.14	1.14	1.15	1.16	1.16	1.17	1.18	1.18
2026	4.0%	1.19	1.19	1.20	1.20	1.20	1.21	1.21	1.21	1.22	1.22	1.23	1.23
2027	3.0%	1.23	1.24	1.24	1.24	1.25	1.25	1.25	1.26	1.26	1.26	1.26	1.27
2028	3.0%	1.27	1.27	1.28	1.28	1.28	1.29	1.29	1.29	1.30	1.30	1.30	1.31
2029	3.0%	1.31	1.31	1.32	1.32	1.32	1.33	1.33	1.33	1.34	1.34	1.34	1.34
2030	3.0%	1.35	1.35	1.35	1.36	1.36	1.36	1.37	1.37	1.38	1.38	1.38	1.39
2031	3.0%	1.39	1.39	1.40	1.40	1.40	1.41	1.41	1.41	1.42	1.42	1.42	1.43
2032	3.0%	1.43	1.43	1.44	1.44	1.44	1.45	1.45	1.45	1.46	1.46	1.46	1.47

Contents of A PRBE Model

Uncertainty Modeled in PRBE Process

Three general sources that contribute to uncertainty:

1. Base Variability,
2. Market Conditions, and
3. Risk Register Events

Identified Risks (Unknown knowns)

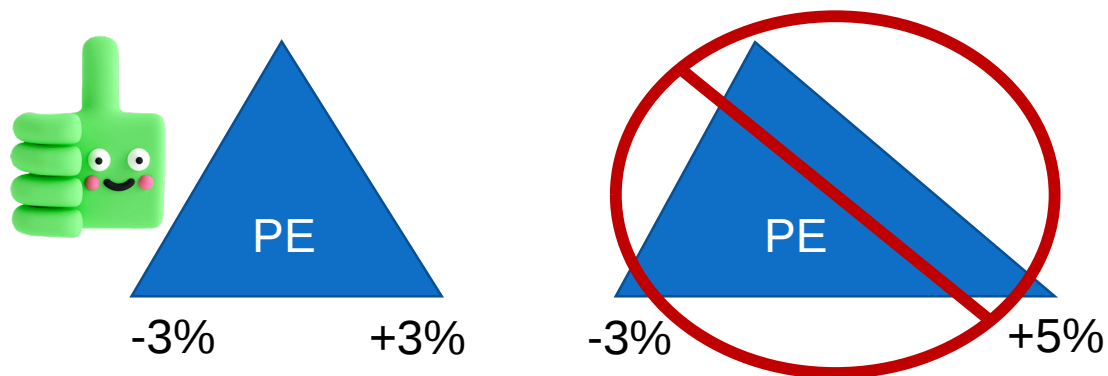
Base Uncertainty

- Base Variability
- Market Conditions

Risk Register Events

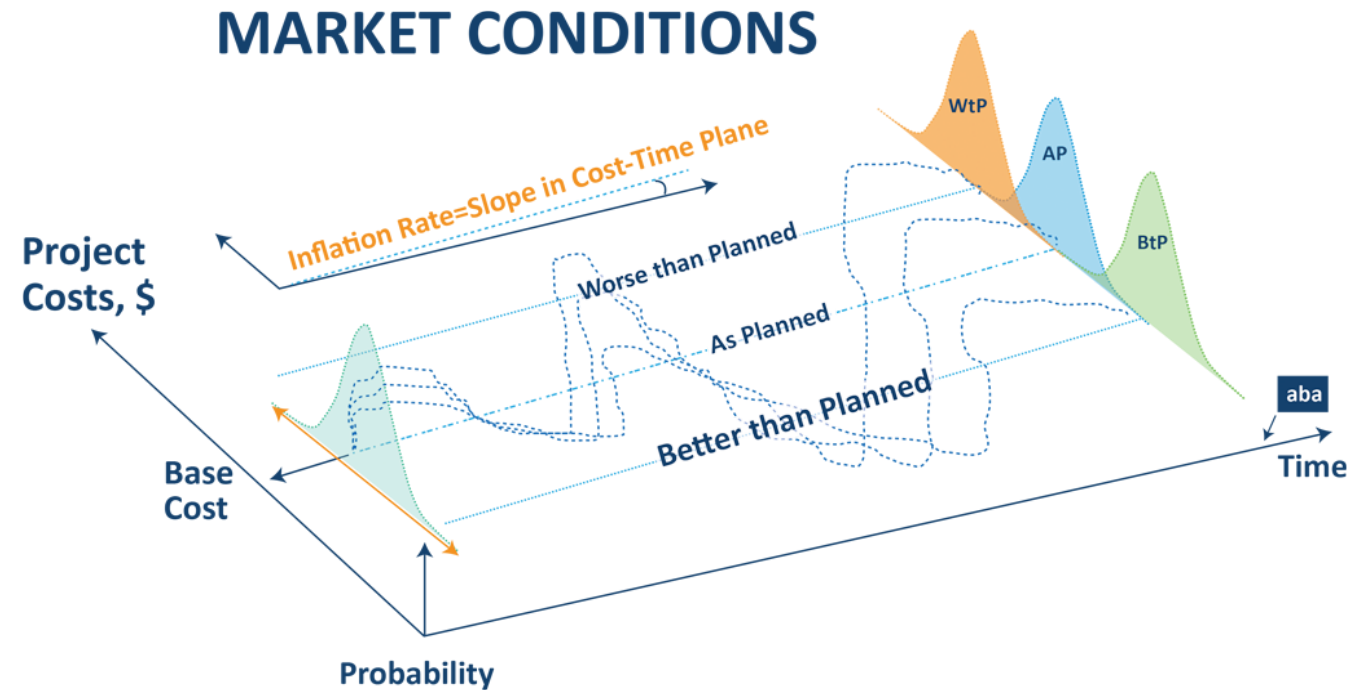
Base Variability

- Defined: The inability of the estimator to know—at a precise level—exact quantity, unit cost values, and durations.
 - A perpetual risk, always present.
 - **Inherent** to the estimating process
 - Not caused by risk **events**, nor does it include them.
 - Non-symmetric distributions should **not be used**
 - Should be relatively small (less than +/-10 percent) and gets smaller as design advances.
 - Specific to each phase

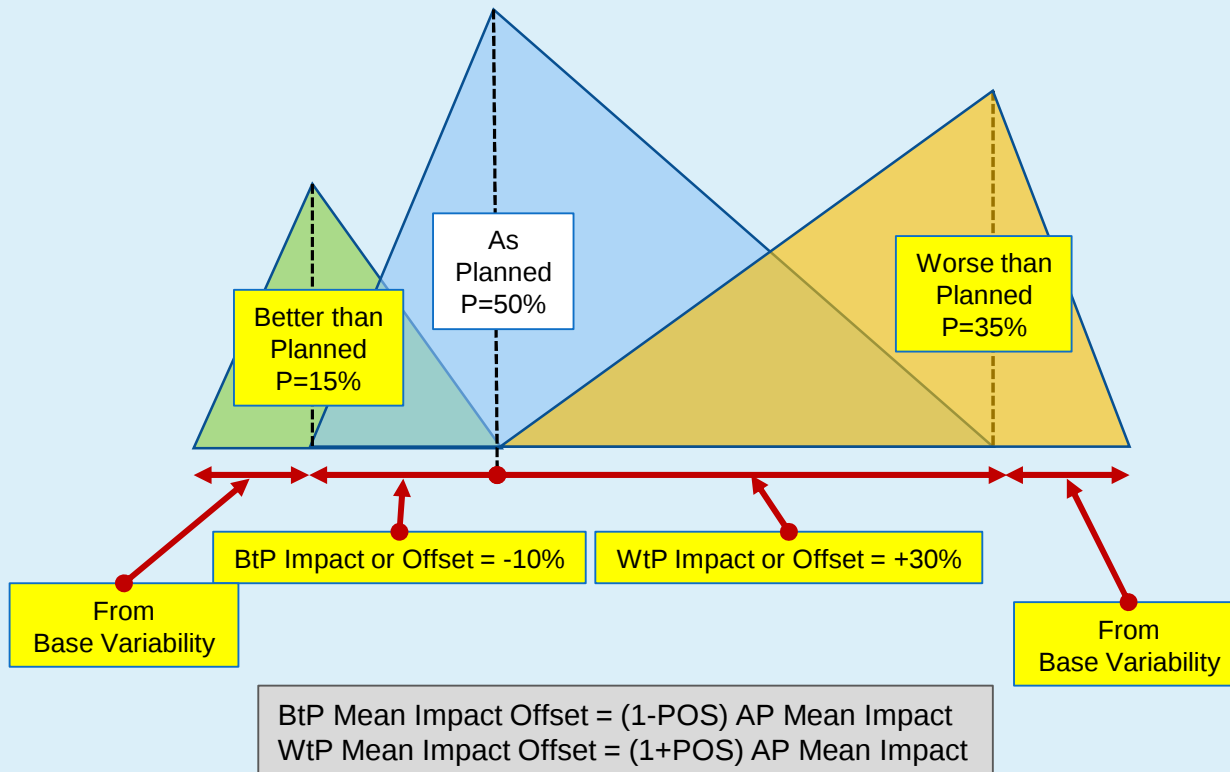


Market Conditions

- Market conditions refer to the bidding environment at the time of advertising, bid, and award (aba).
- ✓ Consequence of supply and demand in a market economy.
- ✓ Separate from inflation.
- ✓ Labor conditions and resource availability, while a part of market conditions, should be modeled as a risk within the risk register.



Market Conditions Model



• 2 Key Inputs

- **Probability** a given market condition scenario will occur
- **Impact** (i.e. percent offset from the AP distribution).
- Only Better than Planned (BtP) and Worse than Planned (WtP) probabilities are required
 - As-Planned (AP) Scenario Calculated from BtP and WtP
- Scenarios are mutually exclusive (i.e. only one can occur at a time)



Contents of A PRBE Model

Project Specific Risks

- The effect of uncertainty on objectives.
 - Threat or Opportunity
 - Cost and/or Schedule
 - Dependent on other Risks
 - Correlations with other risks
 - Significant or Minor
- When modeling risks, every iteration must produce an outcome that can occur



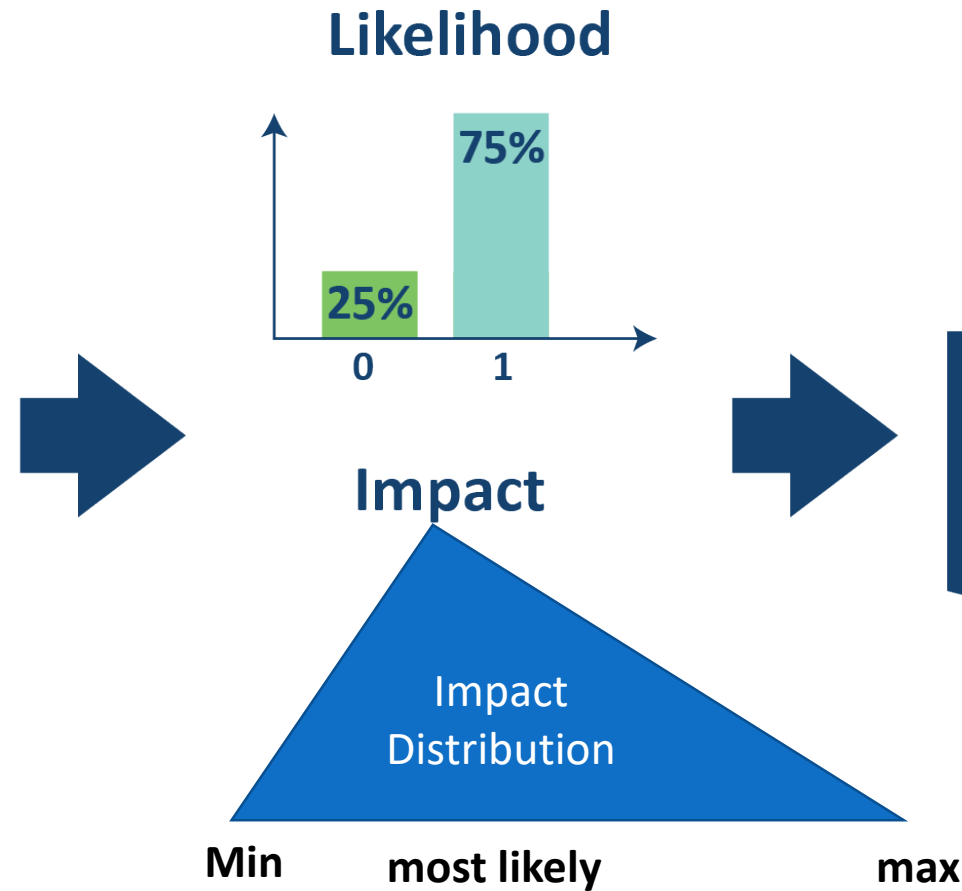
Risk Develops Contingencies

- Contingency

- An amount added to the base estimate to account for risks.
- Contingency **excludes**:
 - ❖ 1) major scope changes such as changes in end product specifications, capacities, and project location;
 - ❖ 2) extraordinary events such natural disasters uncommon to an area;
 - ❖ 3) management reserves;
 - ❖ 4) allowances (i.e. Traffic Control estimated at 5%) and
 - ❖ 5) inflation.

Contingency is often confused with allowance, and/or comingled together.

Risk Register Events



- **Likelihood:** The probability a risk event affects potential outcomes.

- **Impact:** The result or change in project outcome if a risk occurs, usually a change to cost or schedule.

Monte-Carlo Simulation

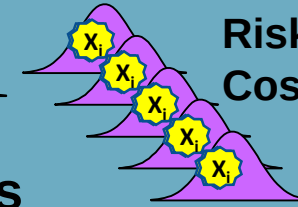
$$\text{Cost Estimate} = \text{Base Cost} + \text{Sum}$$



Base
Variability Conditions

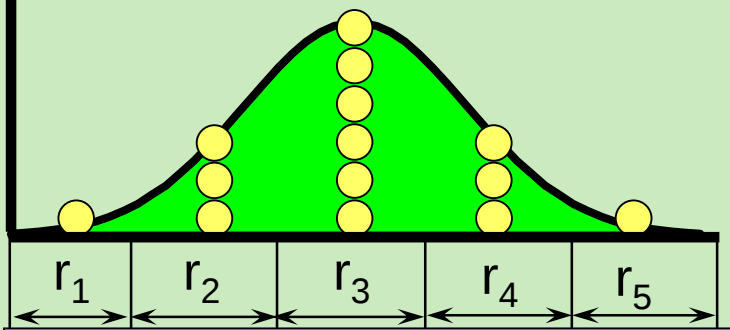


Market
Variability Conditions



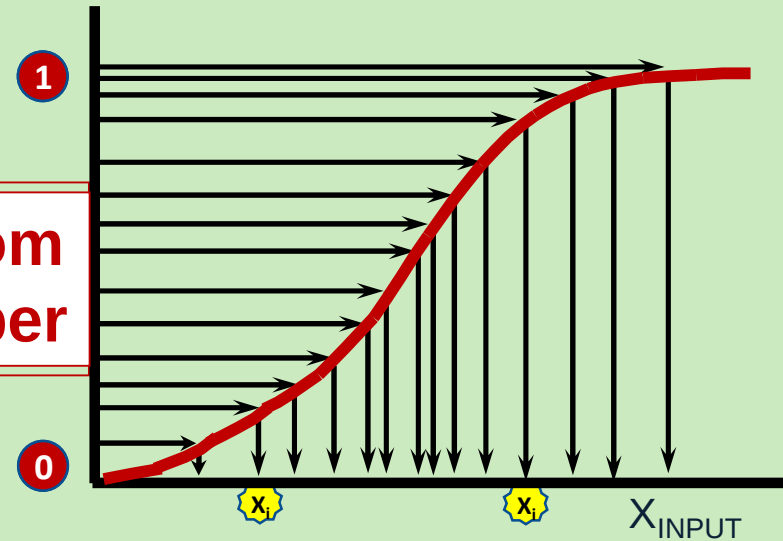
Risk Register
Cost & Schedule

Frequency, %



Outputs: Binned Results

Random
Number



Sample all
possible inputs
to create a
distribution of
results.

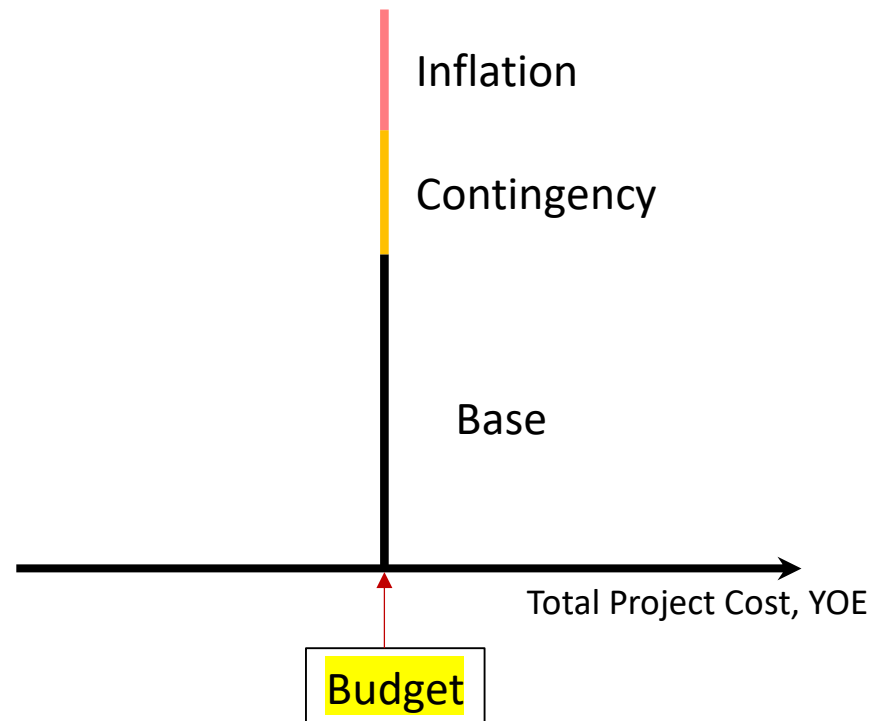
Inputs: Sampled Values (x_i)

Distribution Curve

- Define model **INPUT** uncertainty
 - Occurrence distribution for market conditions and risk impact
 - Impact distributions for base uncertainty, market impact, and risk register
- Define model **OUTPUT** uncertainty
 - Sum of Cost Risk and Sum of Delay Risk
 - Project Duration and Completion Date
 - Total Project Cost

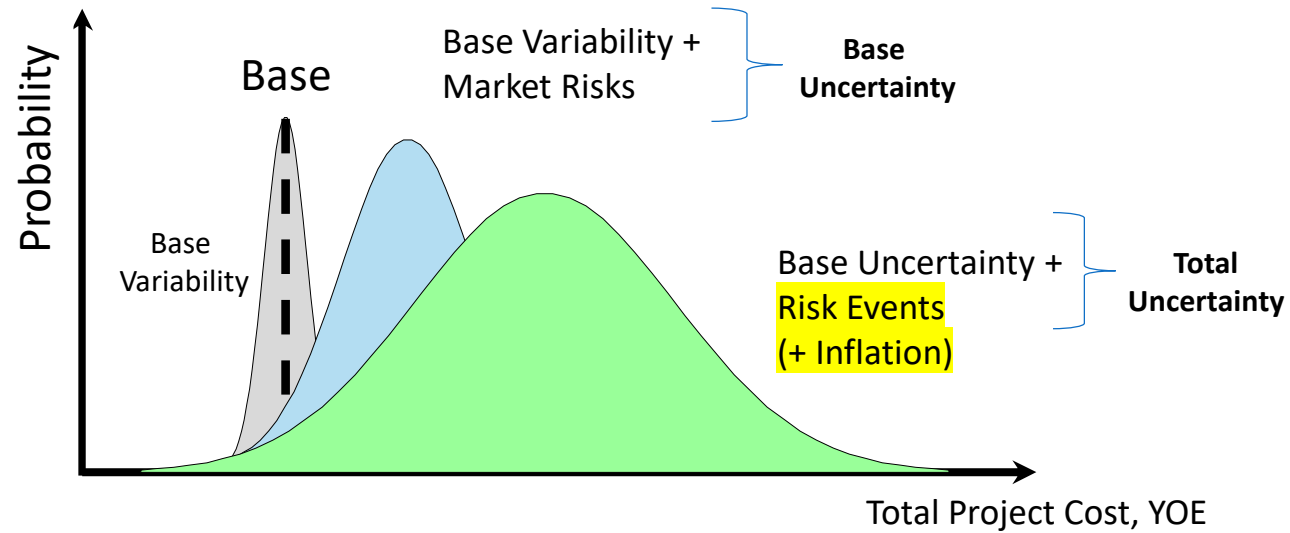
Year of Expenditure (YOE) Estimate

Traditional Estimate



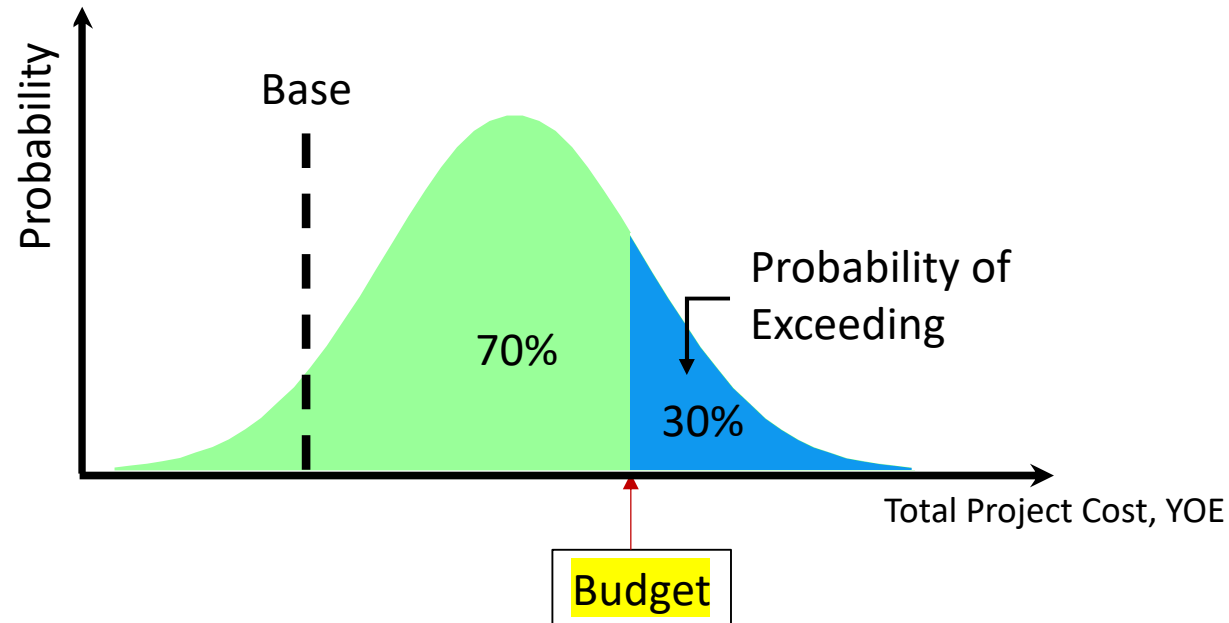
YOE Estimate

Probabilistic Estimate, YOE

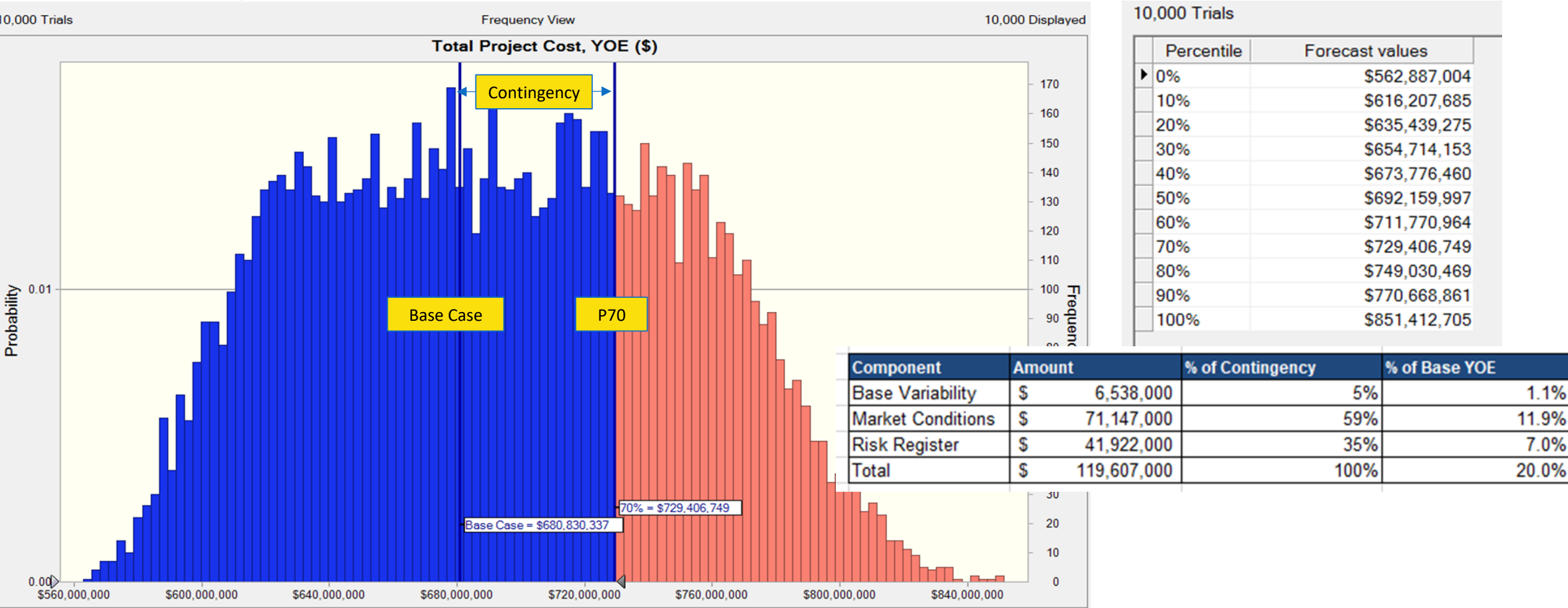


Estimate Confidence

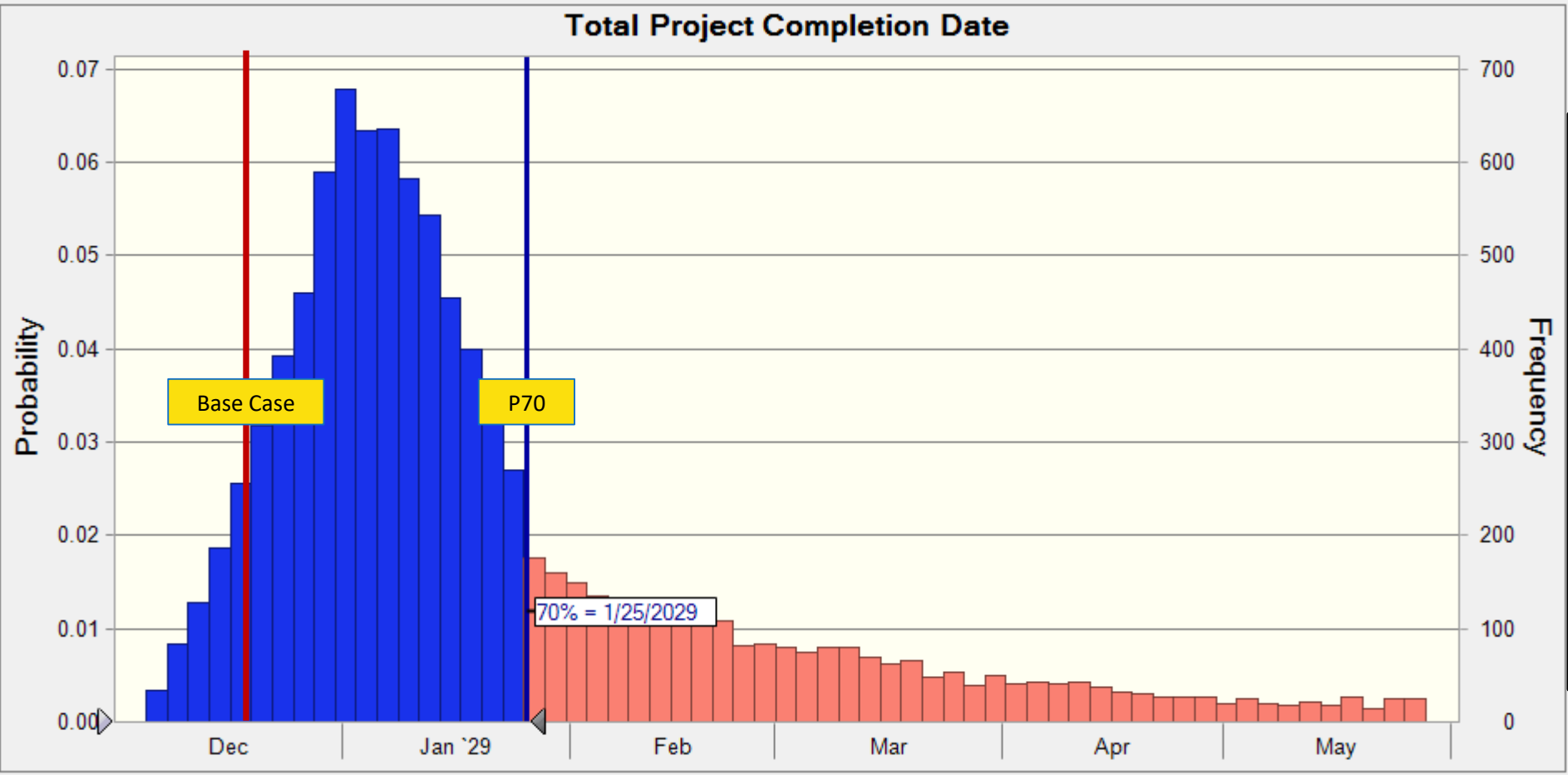
Probabilistic Estimate, YOE



PRBE Model Outputs – Total Project Cost



PRBE Model Outputs - Schedule



Forecast: Total Project Completion Date

Edit View Forecast Preferences Help

10,000 Trials

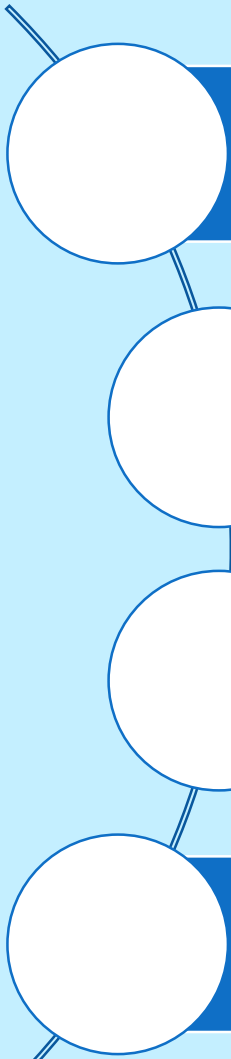
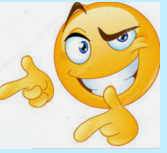
Percentile	Forecast values
0%	12/4/2028
10%	12/21/2028
20%	12/27/2028
30%	1/1/2029
40%	1/5/2029
50%	1/10/2029
60%	1/16/2029
70%	1/25/2029
80%	2/15/2029
90%	3/23/2029
100%	11/1/2029

Goals of PRBE Risk Workshop



- Validate cost and schedule **base** estimates.
- Validate Inputs (i.e. Risk and other uncertainty assumptions)
- Replace traditional project “contingency” with identified uncertainty and risks.
- Identify and quantify significant risks.
- Perform a Monte Carlo simulation analysis to produce probability distributions for probabilistic risk-based cost and schedule estimates.
- Establish contingency based on PRBE.

PRBE Benefits – *when done right!*



Improved **RELIABILITY** of cost and schedule estimate.

More detailed and **EARLIER** understanding of the project and its associated risks.

More useful, **CREDIBLE** way to manage budgets and **COMMUNICATE** risks to public and stakeholders.

Enhanced **COLLABORATION** during risk workshops, increasing team understanding, and ability to **ACHIEVE** project objectives.



Completed Major Project Cost Performance

Time Frame (Project Start Dates)	Number of Projects Completed	IFP Initial Cost Projection (Billions)	Final Cost (Billions)	Amount Over/Under Initial Estimate	Percentage Over Initial Estimate
2005 & Before	16	\$27.44	\$43.38	\$15.94 Billion Over	+58%
2006 thru 2010	29	\$25.38	\$25.06	\$0.32 Billion Under	-1.3%
2011 and Later	22	\$21.28	\$21.18	\$0.10 Billion Under	-0.5%
2021 and Later	13	\$16.6	\$15.6	\$1.0 Billion Under	-6.1%

(As of September 2025)

[illegible]