An Ex-Ante Method to Verify Commercial Nuclear Power Plant Decommissioning Cost Estimates

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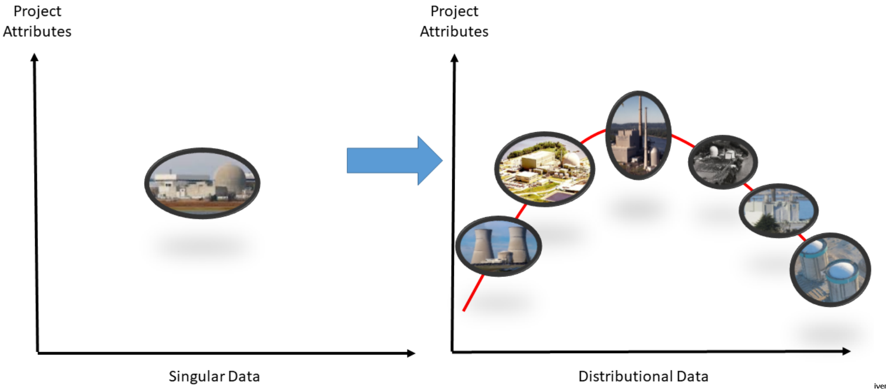
What? Decom costs hard to estimate & verify *ex ante*

Figure: Zion Nuclear Power Station Decommissioning 2016
Source: Energy*Solutions*

- Decommissioning can last **decades**
- Cost est. range **$400M-$1B per unit** in USA
- Scarce experience decommissioning & estimating costs
- **Cost overruns** in long-duration, complex projects are notorious
- Concern that decom funds **inadequate** & unfunded costs will be **public burden**
- Both overruns and high contingency are **inefficient** use of funds

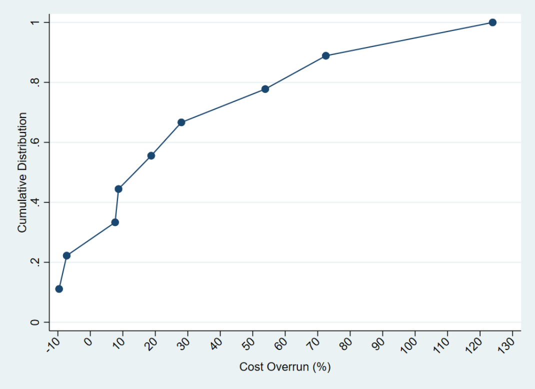
Reference Class Forecasting

- Two psychologists propose generic causes of cost overruns in industries: "optimism bias" & "strategic misrepresentation"
- Use similar completed projects ("Reference Class") to project cost overruns



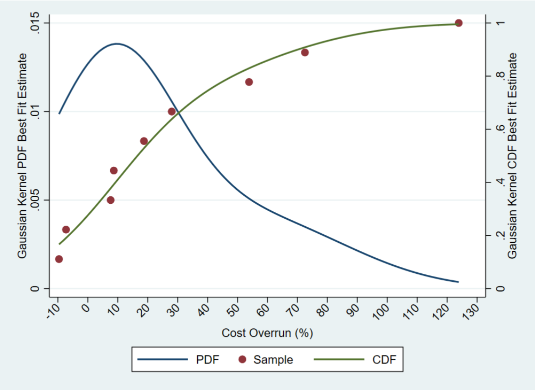
Reference Class Forecasting Procedure

1. Identify relevant Reference Class
2. Aggregate, clean, harmonize data on cost estimates & outcomes
3. Generate CDF of projects by cost overrun
4. Calculate uplift based on risk tolerance, using line connections



- With the standard RCF method, we calculate an empirical contingency of approx. 57%.

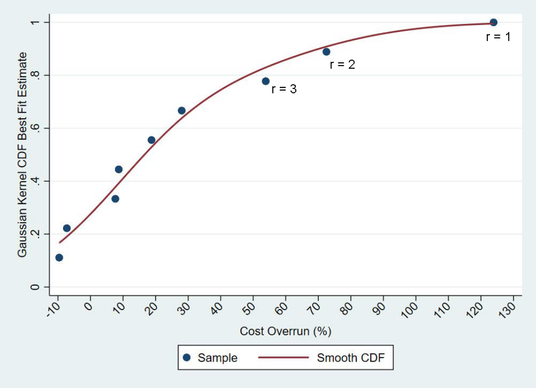
Kernel Estimation



- Gaussian adaptive kernel density estimator of best fit curve
- Non-parametric method
- 'Adaptive' kernels estimate bandwidth based on data density
- Resulting curve better fit of data

- Using our "Best-Fit RCF" method, the contingency is 48%.

The Wilks' Formula



"Best-Fit RCF" analysis with Wilks' Formula.

- Method from nuclear safety (i.e., BEPU)
- Non-parametric method
- Provides upper/lower limits (i.e., one or two-sided)
- Alternative Monte-Carlo, but need a lot of data

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So What? Our Results...

- **Evaluating the Fleet:**

Sample Size (n)	Ordered Observation (r)	Cost Overrun (%)	Proportion Population < r obs (γ)	Confidence Level (β)
9	r=1	124%	80% aka P80	87%
9	r=2	72.5%	80% aka P80	56%
9	r=3	53.9%	80% aka P80	26%

- 87% confident that 80% population experience overruns < 124%
- Confidence declines quickly, need more data points
- Also solve for number of observations and proportion of population

Wilks' Formula for Population & Sample Size

Sample Size (n)	Ordered Observation (r)	Cost Overrun (%)	Confidence Level (β)	Proportion Population < r observation (γ)
9	r=1	124%	95%	72%
9	r=2	72.5%	95%	57%
9	r=3	53.9%	95%	45%

- 95% confident 57% of population will have overruns < 72.5%

Ordered Observation (r)	Confidence Level (β)	Proportion Population < r observation (γ)	Sample Size (n)
r=1	95%	80%	14
r=2	95%	80%	22
r=3	95%	80%	29

- Numerically solve for sample size to be 95% confident that 80% of true population is less than r

Now what? Applications...

- First empirical estimation of contingency for decommissioning
- Largest dataset of nuclear decommissioning cost estimates & realizations
- Method can be applied in other industries:
  - Any large, long-duration, complex projects
  - New builds, decommissioning, etc.
  - Can estimate distinct sub-project contingency & aggregate (we have done this in other projects)
- Method suitable for both cost overruns & schedule delays
- Would like to validate methods in industry with more data

Thank you for your attention.
Questions and Comments, Please!