Foundational Cost Models

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Outline

RESEARCH OBJECTIVE

STATE OF THE ART

DATA OVERVIEW

CER REPOSITORY

LABOR APPROXIMATION ANALYSIS

UNCERTAINTY ANALYSIS

RECOMMENDATIONS

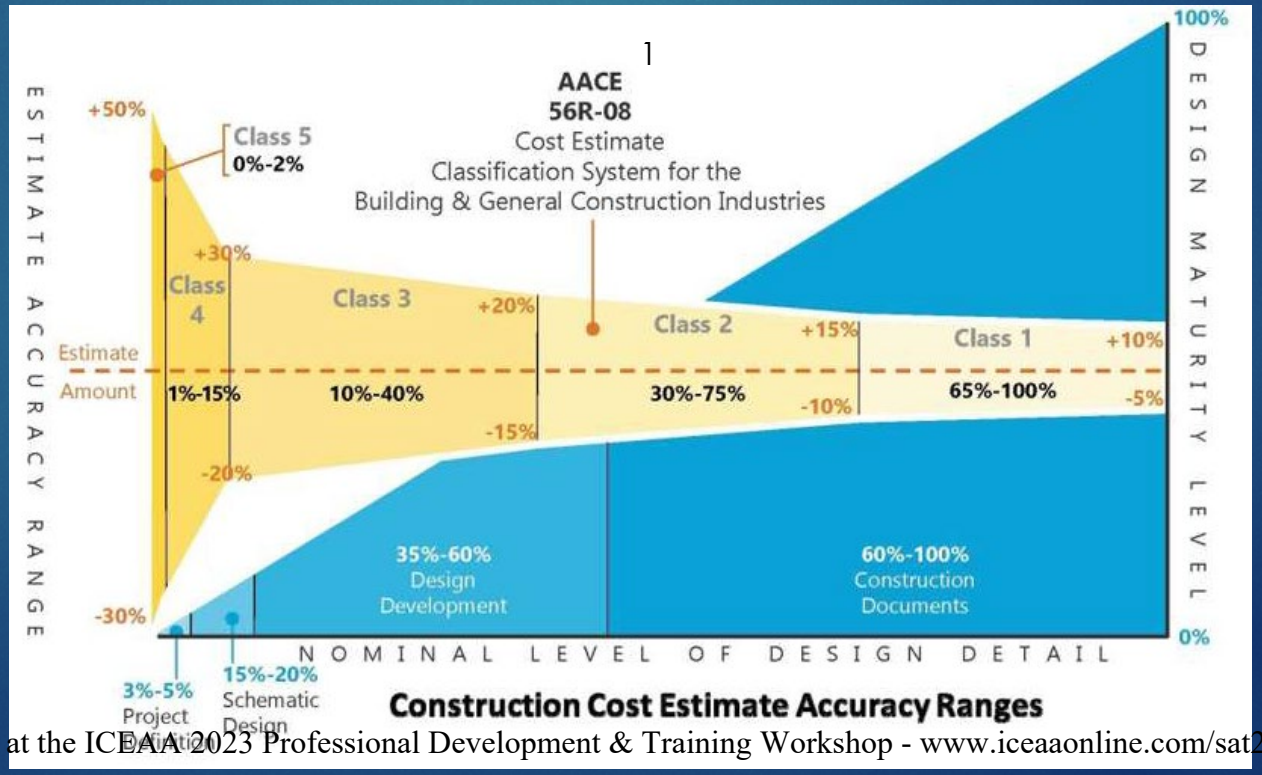
Research Objectives

Improve the accuracy of DOD construction estimates and expedite them by...

1. Compiling a repository of unit cost relationships
2. Exploring ways to extract time-dependent costs (especially labor)
3. Identifying uncertainty distributions to apply

State of the Art

1. Low-level equipment, material, and labor cost data is difficult to find or expensive to acquire, square footage is the default
2. Available data is already totaled
3. Little uncertainty distribution guidance, so estimators rely on "Contingency Factors"



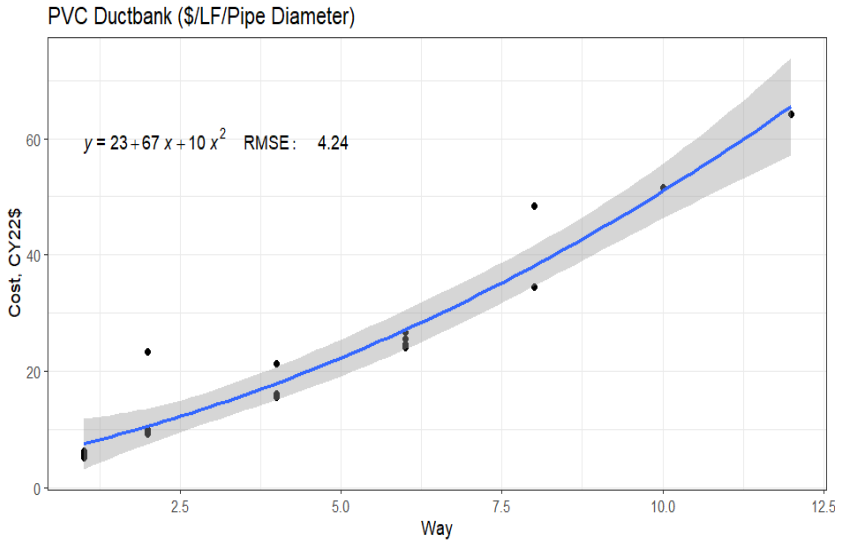
Data Sources

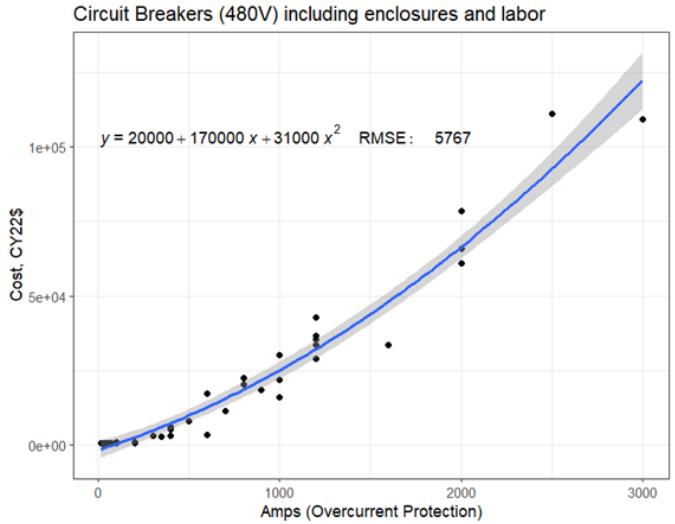
1. Army Corps of Engineers' Programming and Execution (PAX) System Newsletter[2]
2. Army Corps of Engineers' Engineering Pamphlet (EP) 1110-1-8[3]
3. NELO PMO-Commissioned Studies
4. Internet Research and quotes
5. Craftsman National Electrical Estimator 2022[4]
6. OASD(S) *Military Construction Status Reports* to Congress[5]*

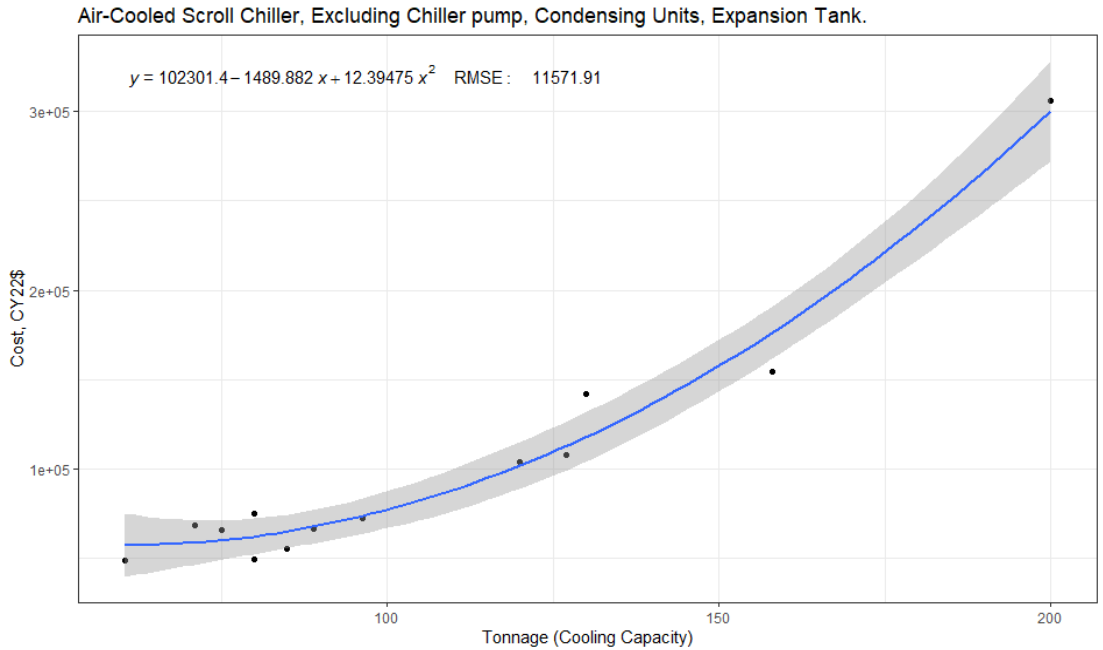
*Fully burdened

CER Repository Methodology

- Methods
  1. Explore traits (predictors) already listed in the databases.
  2. Consider a variety of fits, linear, non-linear, multiple regression, etc.
  3. Choose models on the basis of visualization and Root Mean Squared Error (RMSE) rather than R-squared. [6,7,8]







CER Repository Results

MORE THAN FIFTY STRONG UNIT COST RELATIONSHIPS

CER Repository Takeaways

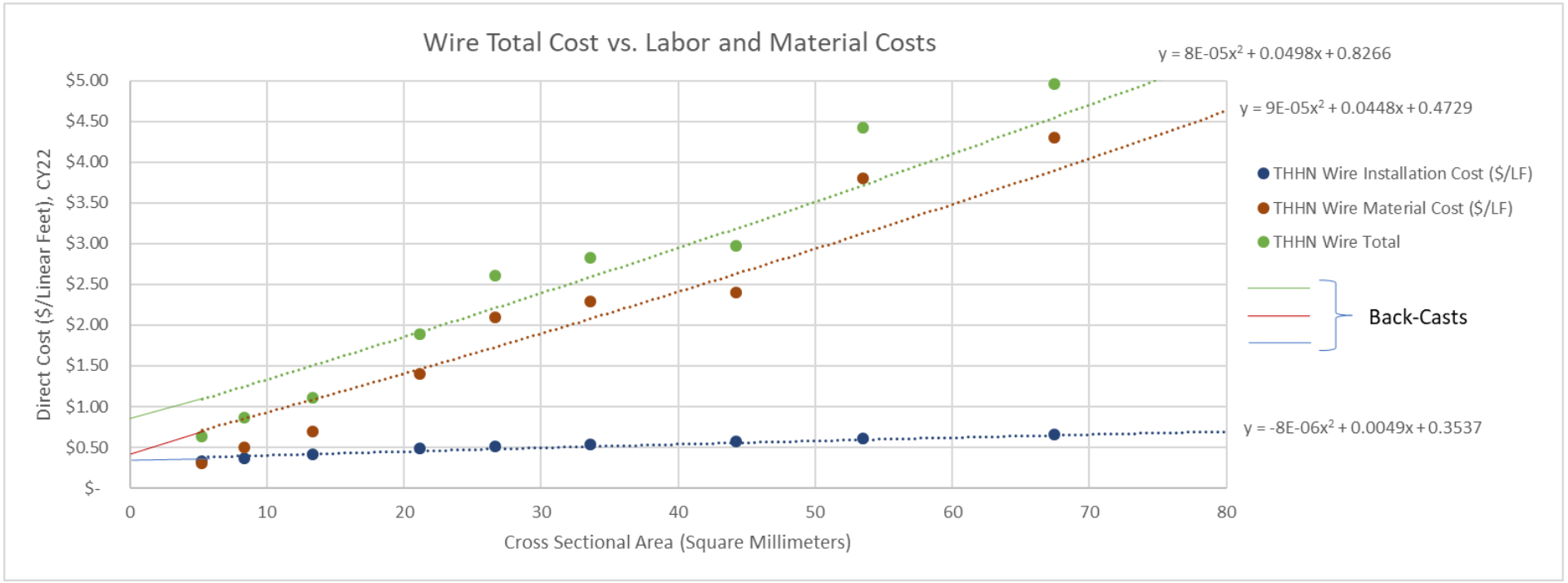
a) Estimates could provide population means
b) Faster than soliciting quotes, cheaper than commercial databases
c) Applicable to multi-purpose facilities or renovation
d) Key limitation: no way to adjust duration of labor

CER Category	Count
HVAC	6
Power Distribution	19
Power Generation	6
Lighting	3
Structural	4
Liquid Storage	2
Lift Equipment and Transport	4
Plumbing	7
Other	4

Labor Approximation Methodology

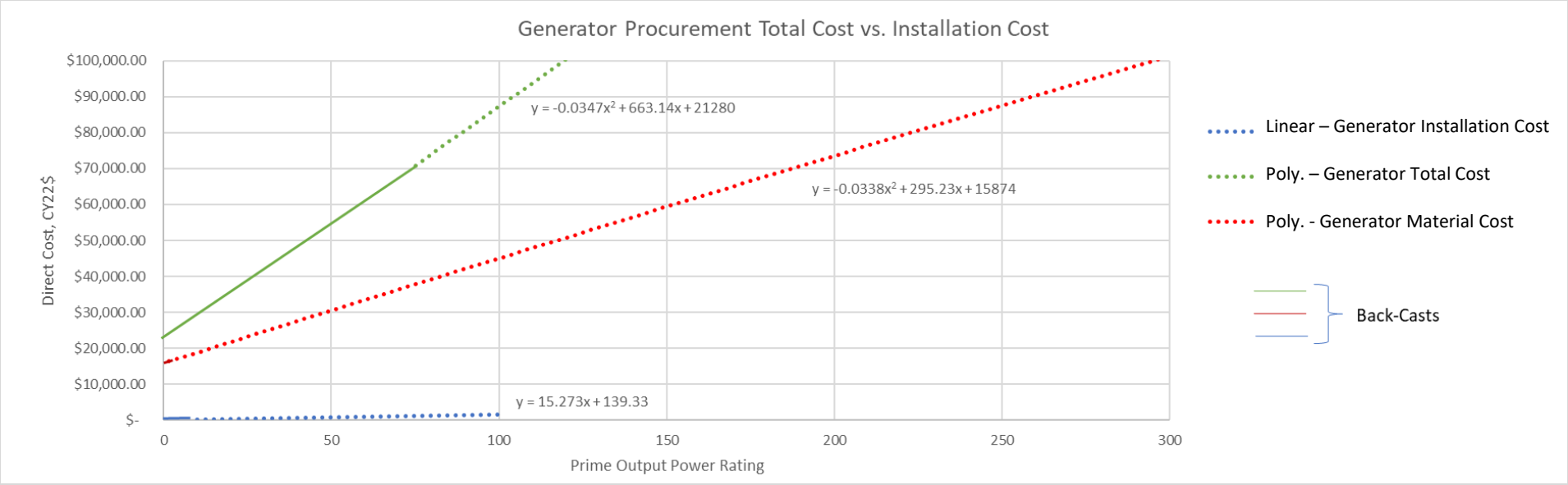
- According to Elbeltagi, labor constitutes **30-50%** of construction expenses.[9]
- One Navy project estimate showed **35%** of direct cost would be labor.
- Hypothesis: back-casting to the intercept may isolate approximate labor cost underlying composite expense data.

Labor Approximation Results



- Intercepts behave as expected
- Difference may be due to manufacturing labor: 0.8266-0.4729=.3537

More Generator Research Needed



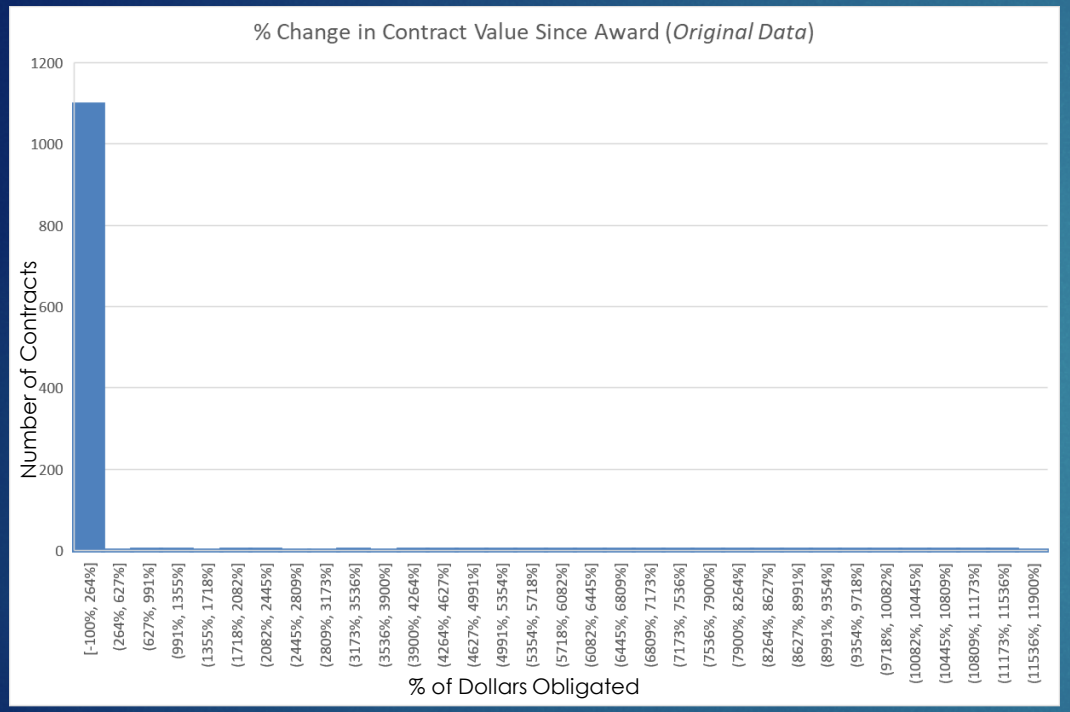
- Intercepts far overestimate labor necessary to build and install a generator at kW=1, likely due to different manufacturing processes and accessories.
- Stick to range of x-values

Labor Approximation Takeaways

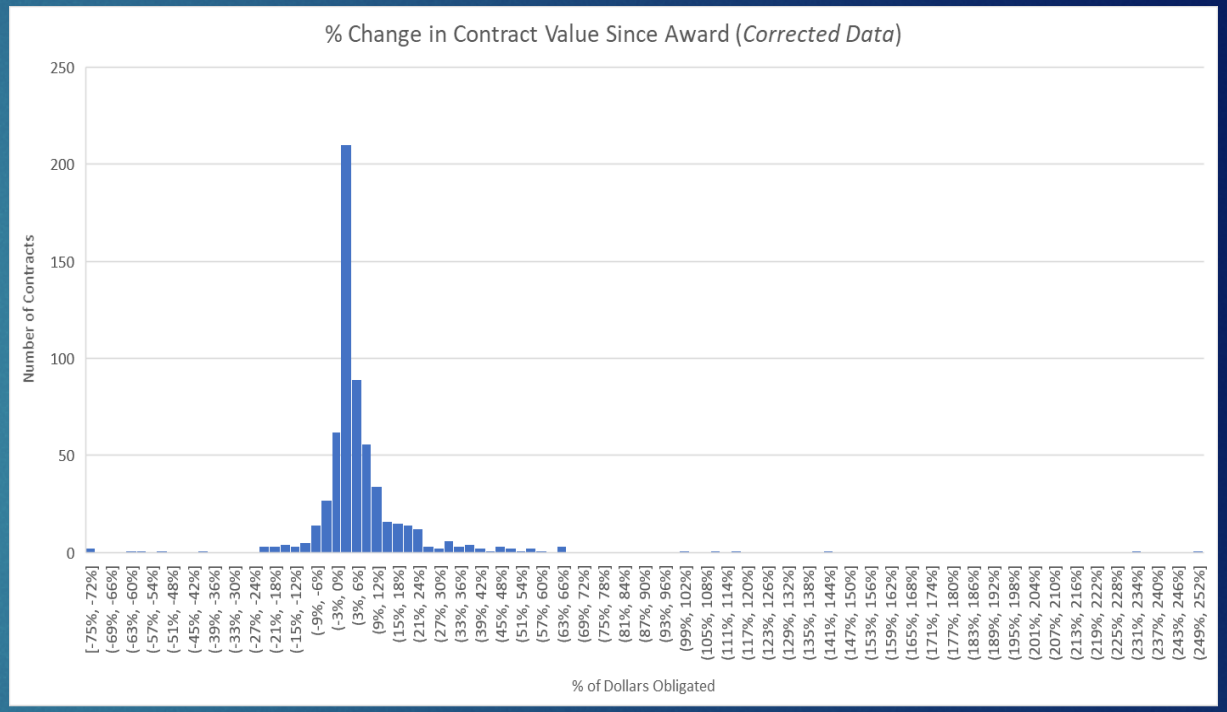
- There's mixed evidence as to whether back-casting is a viable way to extract labor data.
- Physical attributes (size, weight) may be more appropriate for this technique than performance attributes (power output, horsepower, etc)
- When in doubt, consider trying the Elbeltagi factor (30-50%)

Uncertainty Analysis Data Introduction

Before



After



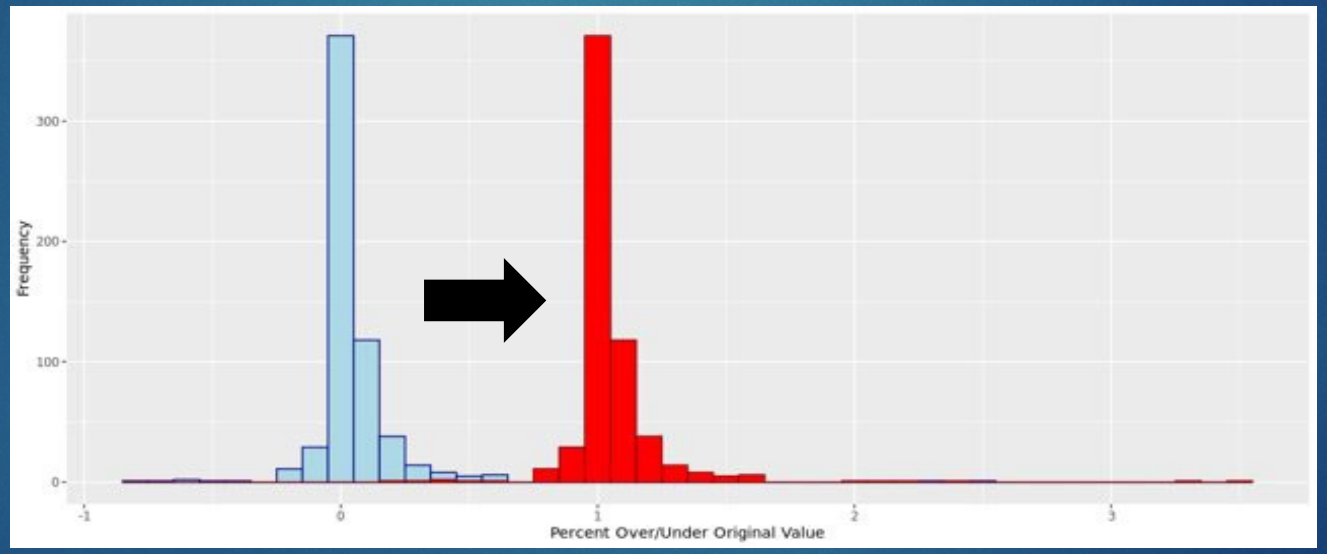
- MILCON status reports by OASD(S) form the backbone of the uncertainty analysis. Corrected with the Federal Procurement Data System (FPDS)
- Histograms can reveal whether data needs attention
- Data: https://github.com/paul-navy/Foundational-Cost-Models.git

Uncertainty Analysis: Put a Name to a Face

1. Study the distribution of contracts exceeding their initial values per congressional reports such that

$$Percent\ Cost\ Overrun = \frac{(Final\ Value - Original\ Value)}{Original\ Value}$$

2. Shift to apply distributions on positive real line {0,Inf.}



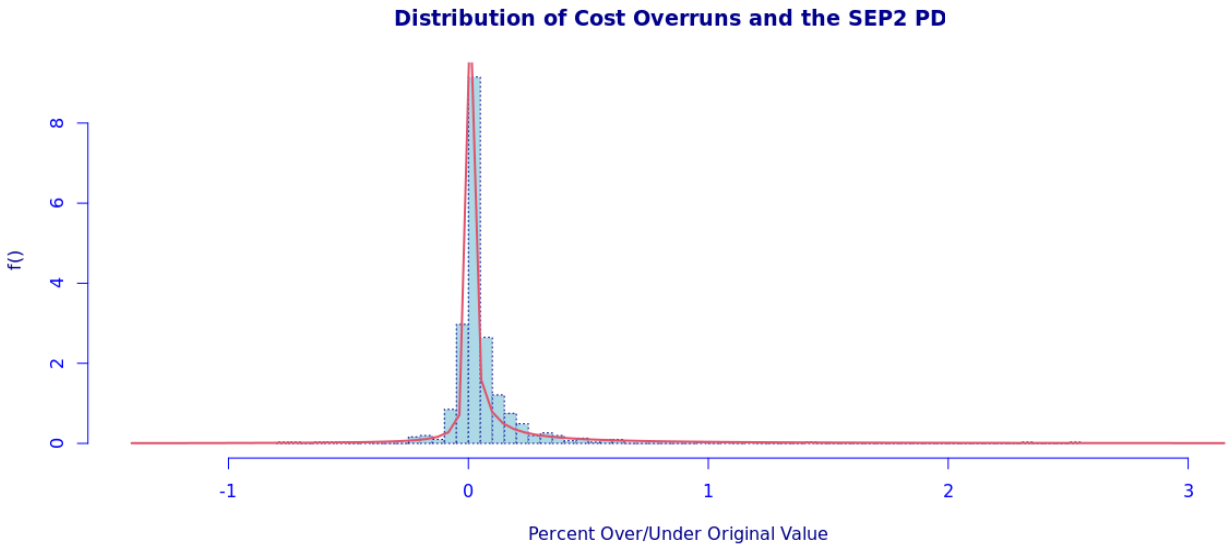
3. Consider >50 distributions, select via Akaike's Information Criterion (AIC).[10] Which distribution is best?

$$AIC = -2logL(\hat{\theta}) + 2k$$

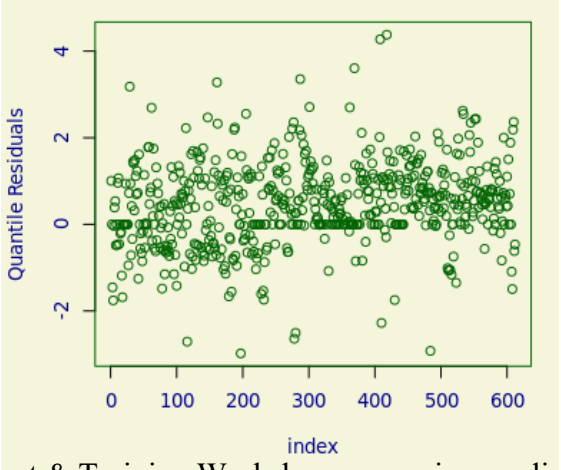
Best Fit: SEP Type II

- Family: Skew Exponential Power (SEP) Type II.[11]
- AIC: -1949 (Least amount of data information lost among attempted curves)
- n=612 completed MilCon contracts

- It's the best fit, but is it a good fit? Residuals suggest yes.

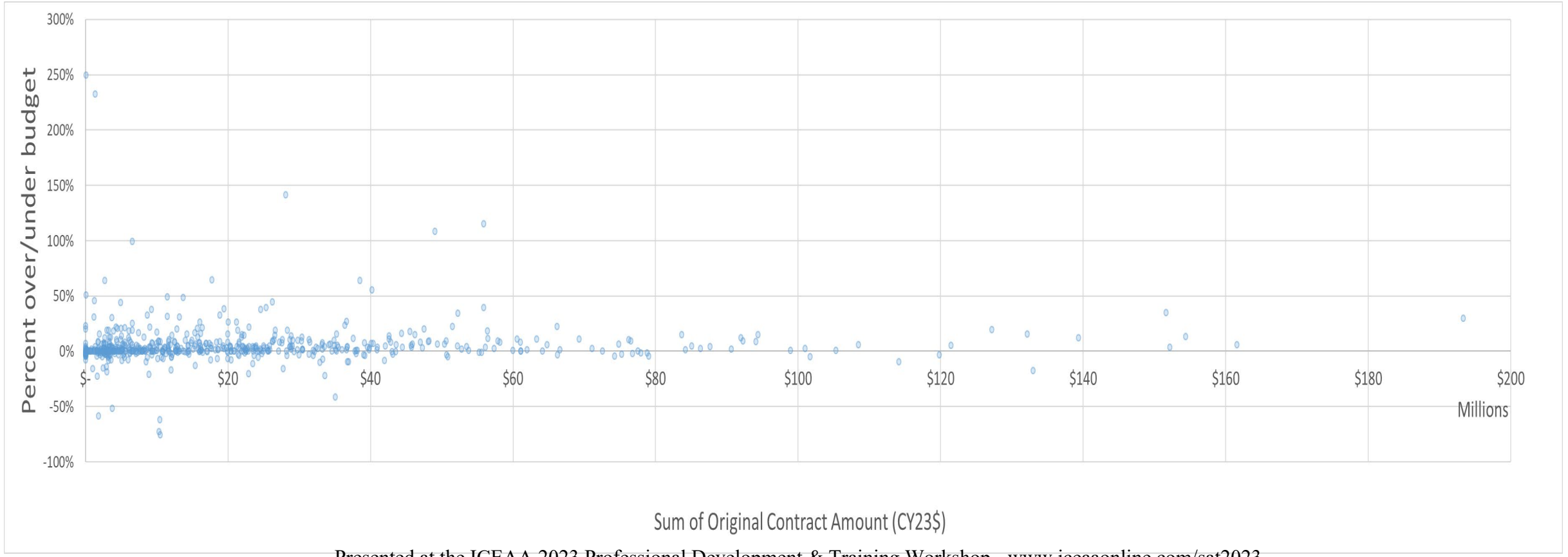


Actual Residuals



Simulated Residuals

Smaller Contracts Have a Wider Range



Uncertainty Analysis Takeaways

- Parametric models suggest DOD construction errors tend toward a Skew Exponential Power (II) Distribution.
- Evidence that we should not always default to lognormal.[12]
- Combined with our CERs, we have several uncertainty parameters for our simulations.
- Small contracts have a wider uncertainty range.

What's next?

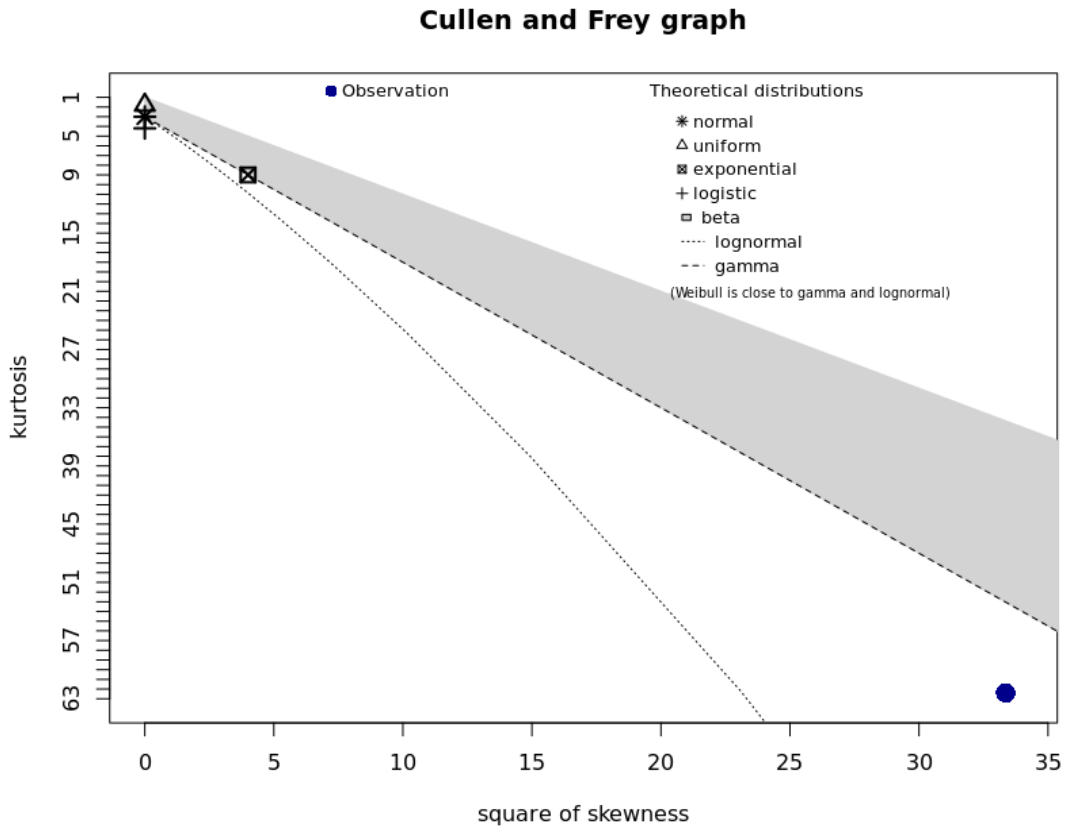
a) More potential CERs in these databases

b) Replicate uncertainty analysis with contract schedules

c) Explore switch from raw to orthogonal polynomials

d) Plot Skewness vs. Kurtosis for more families (Cullen and Frey Chart[14])

With these methods, we could more definitively state whether costs are SEP distributed and gain schedule insight.



Recommendation Summary

PLOTTING CERS CAN LOCATE CENTRAL TENDENCIES AND SAVE TIME VIA INTERPOLATION

USE CAUTION WHEN APPROXIMATING LABOR VIA BACK-CASTING

APPLY EMPIRICAL OR SEP II DISTRIBUTIONS TO OUR CONSTRUCTION SIMULATIONS

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    This is the R package used to perform the analysis. Also see https://www.gamlss.com/wp-content/uploads/2018/01/DistributionsForModellingLocationScaleandShape.pdf for a full definition of the SEP Type II distribution.
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