The Cost of Bureaucracy

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Outline

- Background
- Database overview
- Cost estimating relationship development & results
- Schedule estimating relationship development & results
- Conclusion

National Nuclear Security Administration

INNOVATE. COLLABORATE. DELIVER.

Protect the Nation by maintaining **a safe, secure, and effective** nuclear weapons stockpile

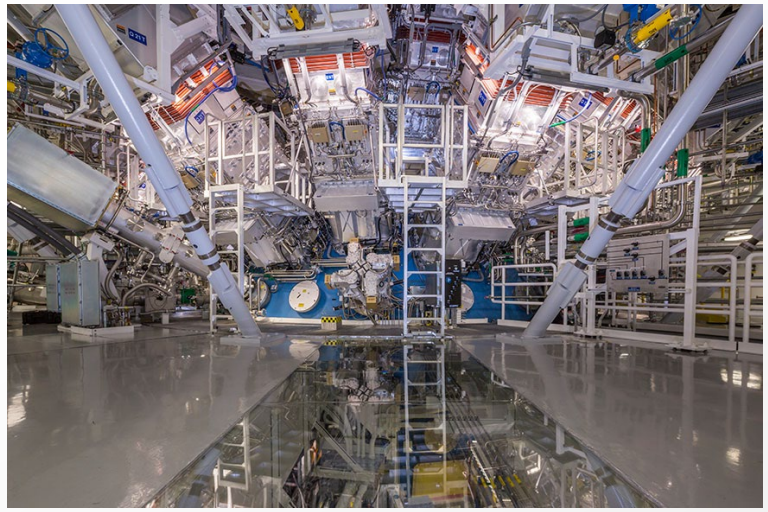
Reduce global **nuclear threats**

Provides the U.S. Navy with militarily effective **nuclear propulsion**

The NNSA is a semi-autonomous agency within the U.S. Department of Energy responsible for enhancing national security through the military application of nuclear science.

National Nuclear Security Administration

Sample NNSA Facilities



National Ignition Facility, LLNL

Highly Enriched Uranium Materials Facility, Y-12

Livermore Computing Facility, LLNL

New Mercury Modernization bldg., NNSS

New Superblock Storage Area Installation, LLNL

Background

- The Office of Programming, Analysis, and Evaluation (PA&E) supports the NNSA by providing analytical services such as cost analyses to aid informed planning and decision-making.
- To fulfill its mission, the NNSA owns and operates facilities across the country, some dating back to the Manhattan Project.
- When planning and budgeting for future facilities, NNSA has separate management processes and requirements for capital construction projects depending on project size.
- **Research question -- Does the management process affect project cost and schedules?**

Projects with Enhanced Scrutiny

- Over $50 million
- Approved by Congress
- Must follow more thorough project management process
  - Dictates division of funding and specific milestones

Projects with Standard Scrutiny

- Under $50 million
- Internally funded by the NNSA Office of Infrastructure
- Relatively less guidance and fewer requirements surrounding project's development

Project Data

	Enhanced Scrutiny Project Range	Standard Scrutiny Project Range
Project Count	Cost Data: 17 Schedule Data: 58	Cost Data: 13 Schedule Data: 143
Gross Square Footage (GSF) Added	9,260 – 696,968	80 – 28,736
Total Estimated Cost (BY21$)	$17,574,370 – $6,000,540,472	$233,498 – $17,313,426
Hazard Category	1. Nuclear Hazard Category 2/3 2. Chemical & High Explosive 3. Radiological 4. Nanoparticle & Beryllium 5. Biosafety Levels 1/2 & No Hazard	1. N/A 2. Chemical & High Explosive 3. N/A 4. N/A 5. Biosafety Levels 1/2 & No Hazard
Equipment Complexity	1. Custom scientific or production equipment 2. Off-the-shelf industrial or scientific equipment 3. Office or light laboratory equipment	1. N/A 2. Off-the-shelf industrial or scientific equipment 3. Office or light laboratory equipment

Note: For the purposes of this analysis, we excluded certain project management costs which are tracked for enhanced scrutiny projects but not standard scrutiny projects. The true cost of the project is equal to the Total Estimated Cost plus the additional project management costs.

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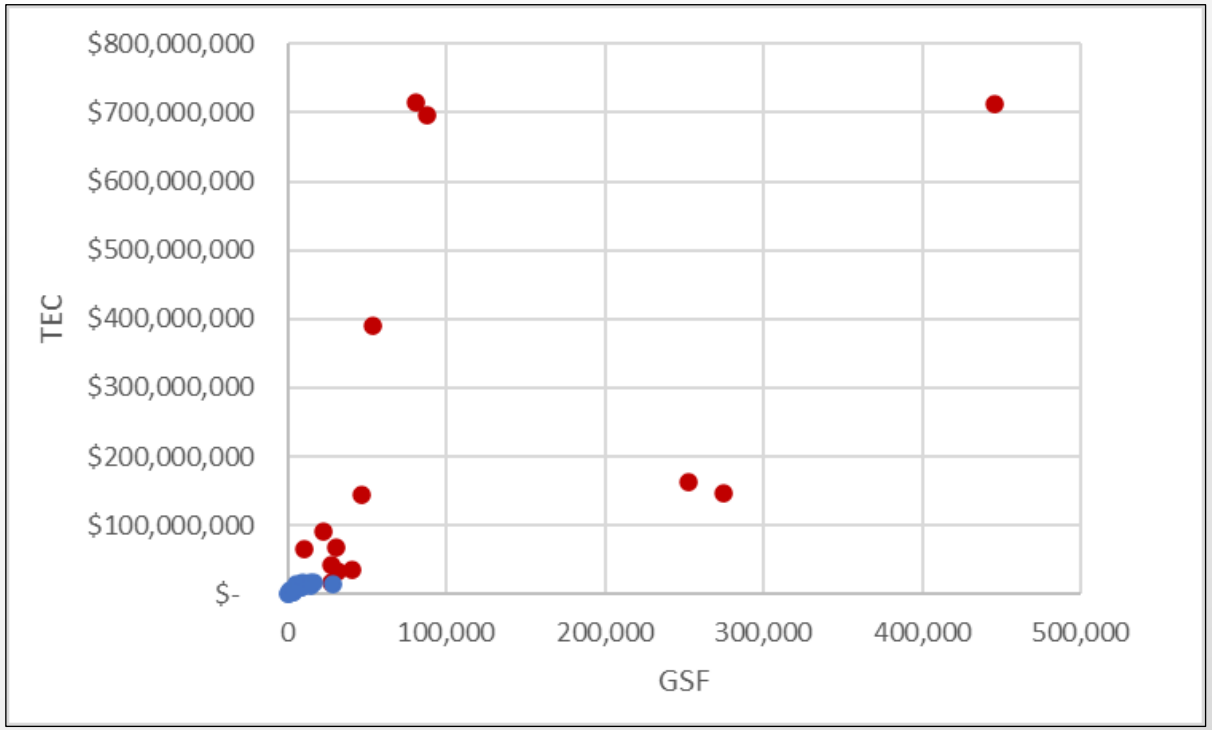
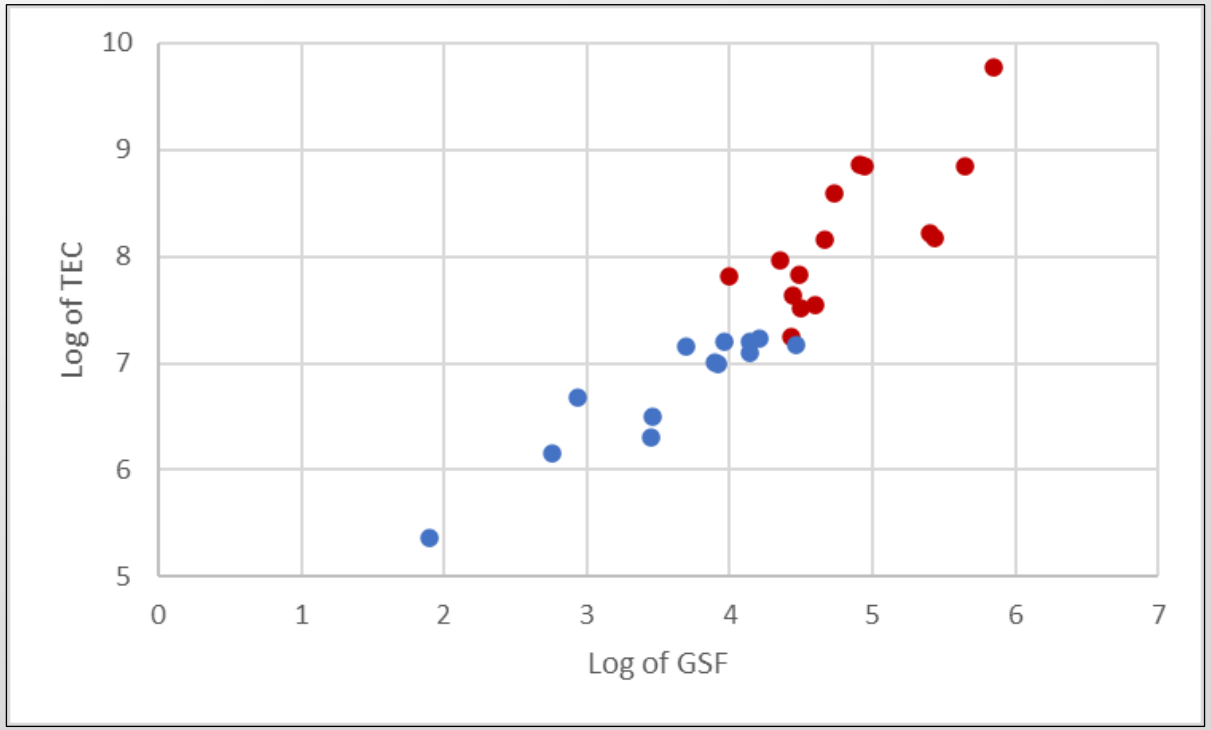
Cost vs. Gross Square Footage (GSF)

- Enhanced Scrutiny Project
- Standard Scrutiny Project

Total Estimated Cost (TEC) vs. Gross Square Footage



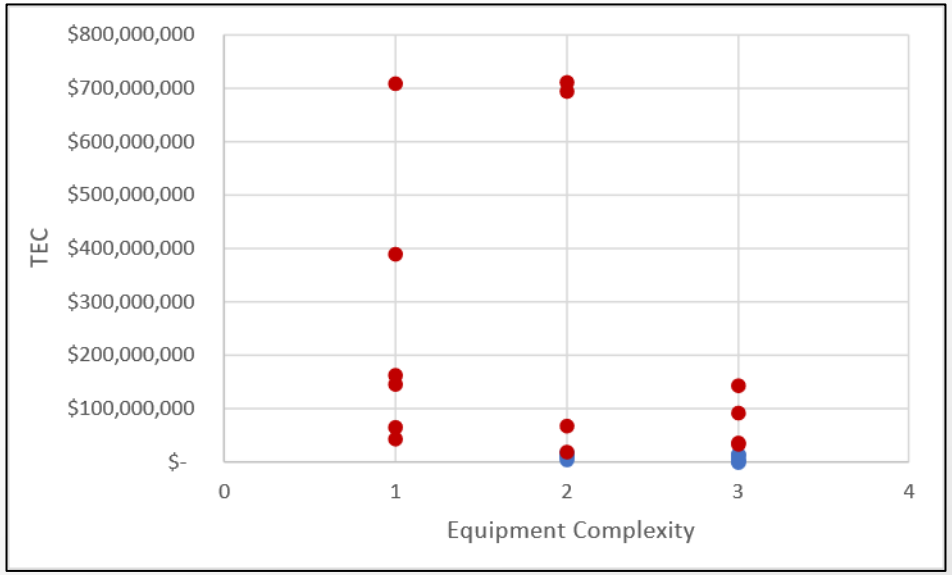
Log of TEC vs. Log of GSF



For NNSA projects, log(TEC) grows linearly with log(GSF). In other words, facility size is a strong predictor of facility cost.

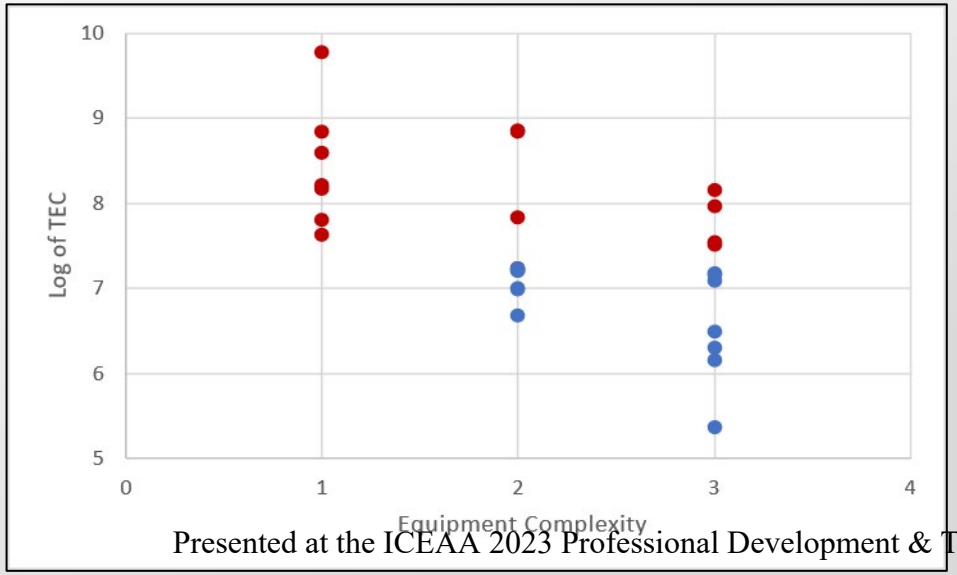
Cost vs. Equipment Complexity

Total Estimated Cost (TEC) vs. Equipment Complexity



Bin	Equipment Complexity
1	High
2	Medium
3	Low

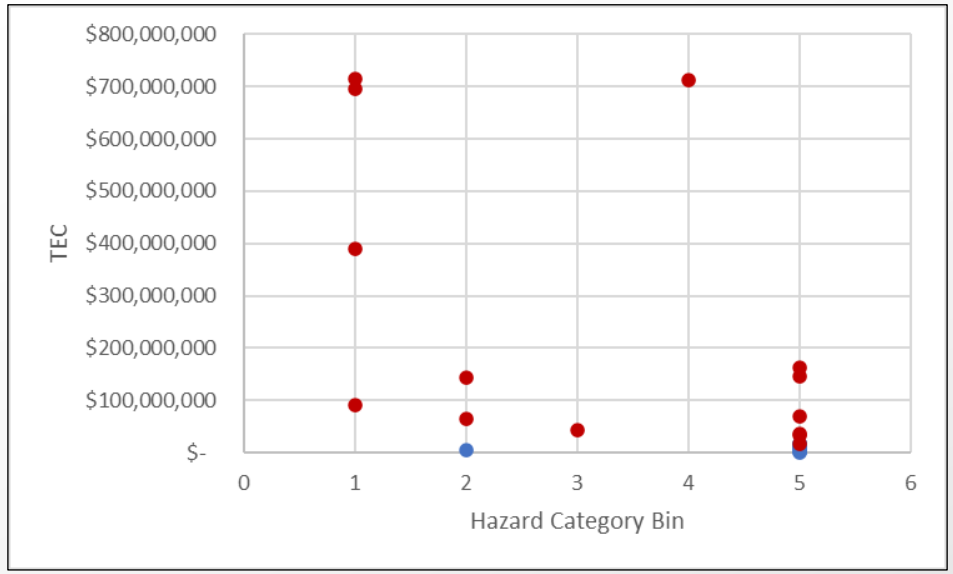
Log of TEC vs. Equipment Complexity



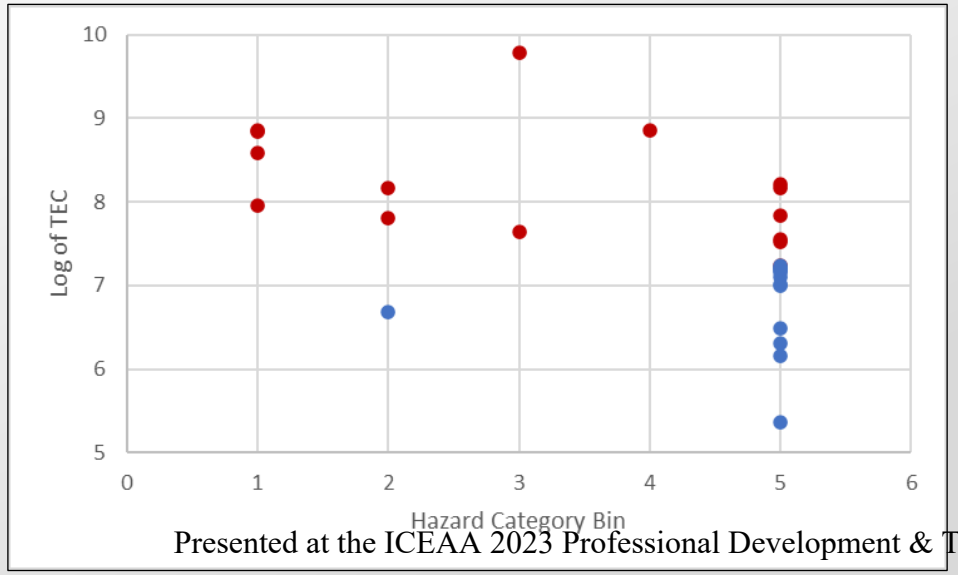
Perhaps surprisingly, we find that log(TEC) has a linear relationship with the categorical variable Equipment Complexity.

Cost vs. Hazard Category

Total Estimated Cost (TEC) vs. Hazard Category



Log of TEC vs. Hazard Category



Bin	Hazard Category
1	Nuclear Hazard Category 2 Nuclear Hazard Category 3
2	Chemical High Explosive
3	Radiological
4	Nanoparticle Beryllium
5	Biosafety Levels 1 – 4 No Hazard

As with Equipment Complexity, we find that log(TEC) varies [approximately] linearly with the categorical variable Hazard Category, as defined in the box above.

CER Formulation

Base model inspired by previous CERs

Equation 1 $$\boldsymbol{log(TEC) = \alpha + \beta * log(GSF) + \gamma * HC + \delta * EC}$$

Introduced additional categorical (i.e., dummy) variable for project management (PM) process

Equation 2 $$\boldsymbol{log(TEC) = \begin{array}{c} \alpha_1 + \beta_1 * \log(GSF) + \gamma_1 * HC + \delta_1 * EC + \\ PM * (\alpha_2 + \beta_2 * \log(GSF) + \gamma_2 * HC + \delta_2 * EC) \end{array}}$$

$$PM = \begin{cases} 0 \; if \; enhanced \; scrutiny \\ 1 \; if \; \text{standard} \; scrutiny \end{cases}$$

Performed regression analysis, only keeping statistically significant variables (p-value < 0.05)

CER Results

Significant coefficients in orange

$$log(TEC) = \begin{matrix} \alpha_1 + \beta_1 * \log(GSF) + \gamma_1 * HC + \delta_1 * EC + \\ PM * (\alpha_2 + \beta_2 * \log(GSF) + \gamma_2 * HC + \delta_2 * EC) \end{matrix}$$

None of the coefficients associated with the PM variable were statistically significant.

Therefore, the project management process **does not** affect project total estimated cost (TEC).

Combined vs. Individual Results

Combined Model: standard and enhanced scrutiny projects

Enhanced Scrutiny Model: enhanced scrutiny projects only

Standard Scrutiny Model: standard scrutiny projects only

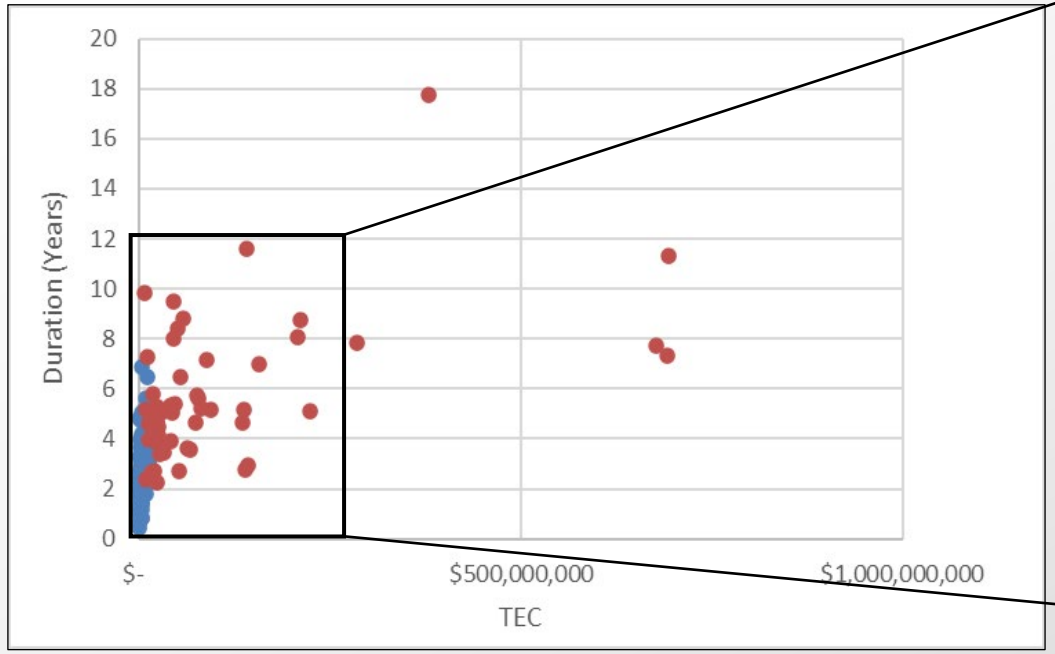
Model	SSE – Enhanced Scrutiny Projects	SSE – Standard Scrutiny Projects	R^2 – All Projects	CV – All Projects
Combined	0.369	0.273	0.939	0.020
Enhanced Scrutiny	0.368	-	0.882	0.046
Standard Scrutiny	-	0.301	0.920	0.023

Not only do we fail to observe a significant difference between project costs based on project management process, but a combined model using data from both processes out-performs our separate, process-specific models.

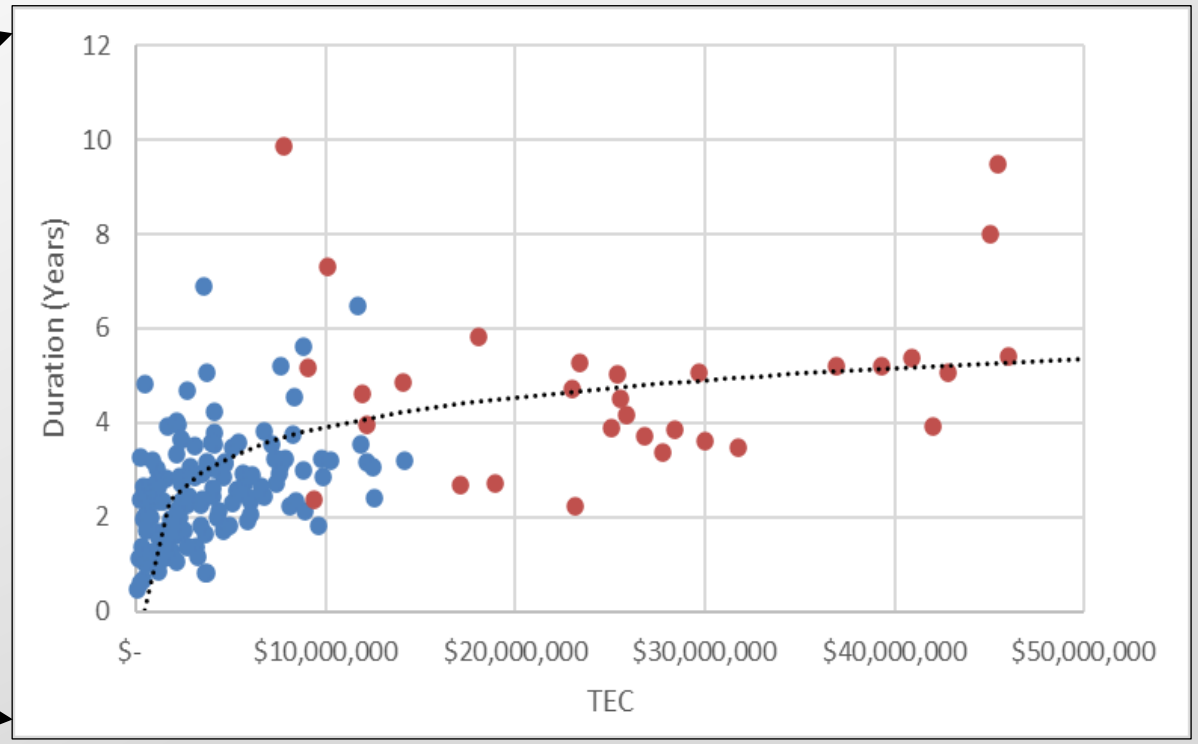
Cost vs. Schedule

- Enhanced Scrutiny Project
- Standard Scrutiny Project

Duration vs. TEC



Duration vs. TEC under $50M



The two project types **overlap** around the **$7M – $15M** range.

The durations of the 33 data points that fell in this range seem to have a **linear relationship** with increasing TEC.

SER Formulation

Base model inspired by previous SERs

Equation 1 $$\boldsymbol{Duration = \alpha + \beta * TEC}$$

Introduced additional categorical (i.e., dummy) variable for project management (PM) process

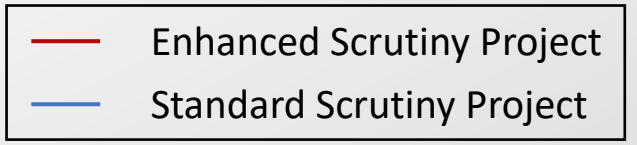
Equation 2 $$\boldsymbol{Duration = \alpha + \beta * TEC + \gamma * PM + \delta * PM * TEC}$$

$$PM = \begin{cases} 0 \; if \; enhanced \; scrutiny \\ 1 \; if \; \text{standard} \; scrutiny \end{cases}$$

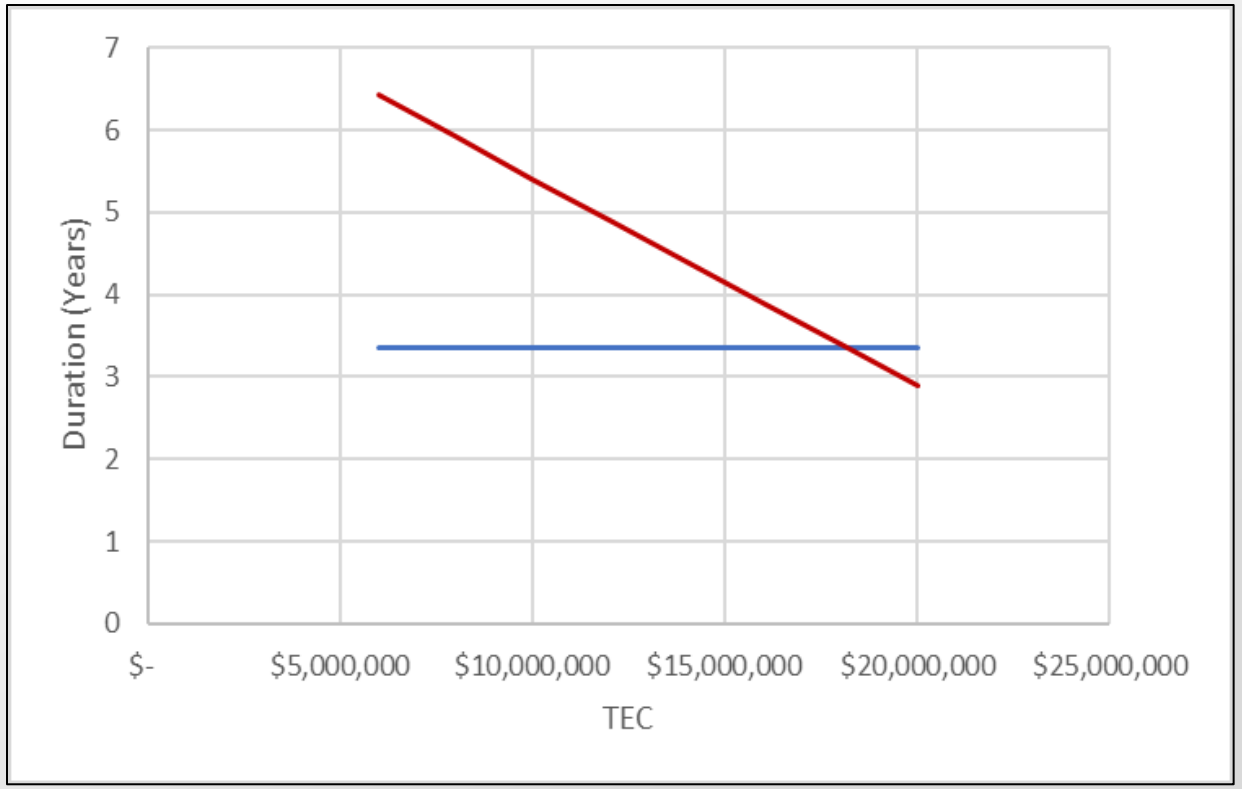
Performed regression analysis, only keeping statistically significant variables (p-value < 0.05)

SER Results

Significant coefficients in orange



$$\boldsymbol{Duration = \alpha + \beta * TEC + \gamma * PM + \delta * PM * TEC}$$



Model is **counterintuitive** as there is a decreasing relationship between TEC and duration

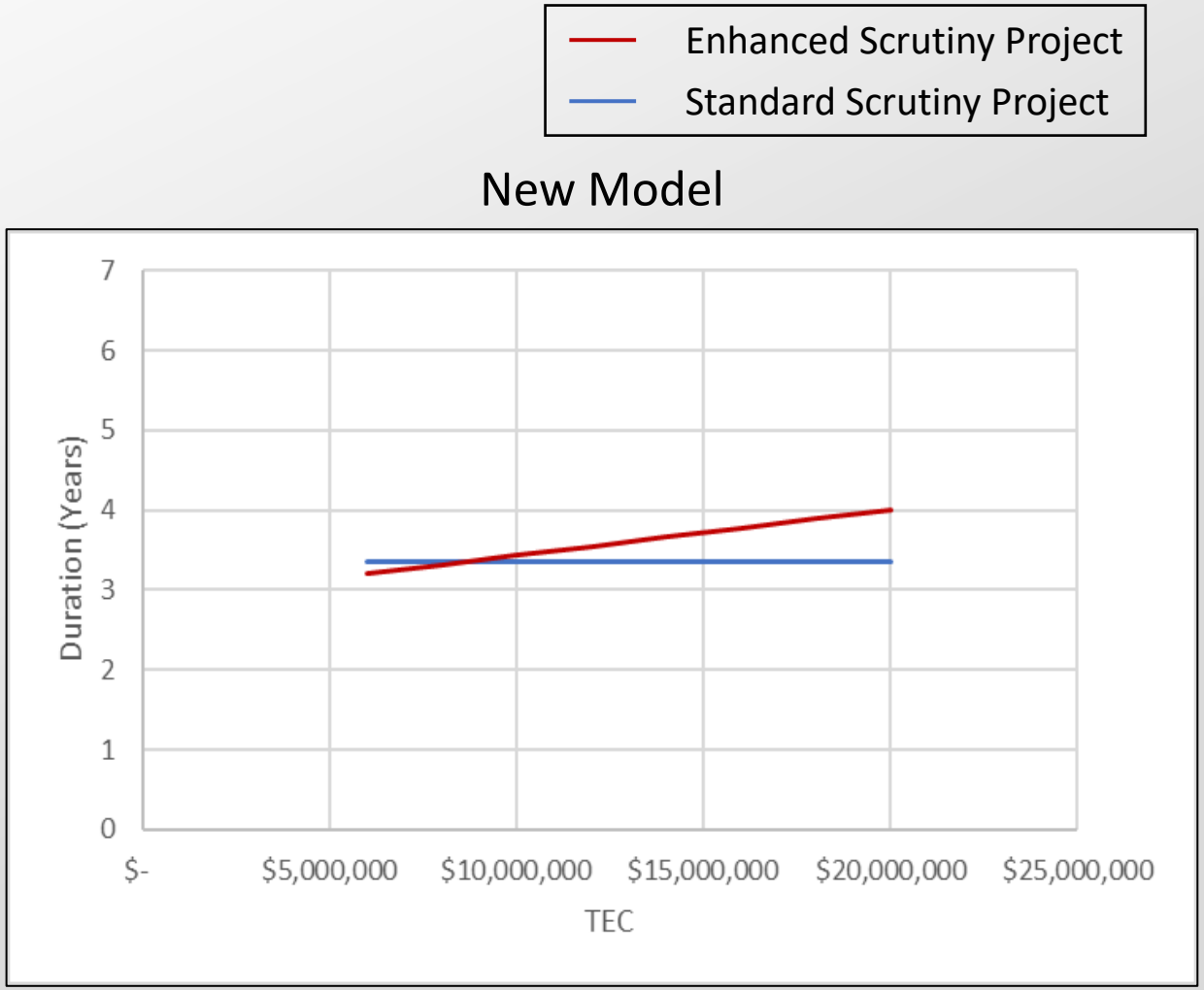
Performed **influential data point** analysis to determine if one or two data points were driving this decreasing relationship

Schedule Results

2 enhanced scrutiny projects were identified as high-influence points

The new model behaves more intuitively, but **none of the coefficients** are now considered statistically **significant**

Therefore, we conclude that the project management process **does not** affect project duration



Conclusion

- Project management process has little-to-no impact on NNSA project cost or duration
- It's important to note that this analysis excludes certain project management costs which are not tracked for standard scrutiny projects.
- Next steps:
  - Determine whether non-NNSA DOE projects have similar cost and schedule to NNSA projects
  - Increase fidelity of cost model by using advanced techniques to identify 'unknown knowns'