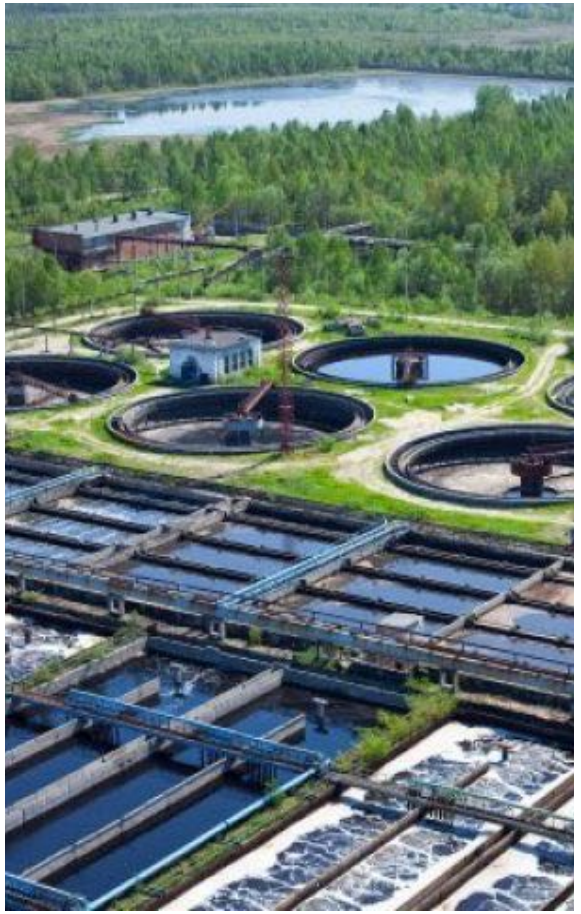
32nd Annual INCOSE international symposium
hybrid event
Detroit, MI, USA
June 25 - 30, 2022

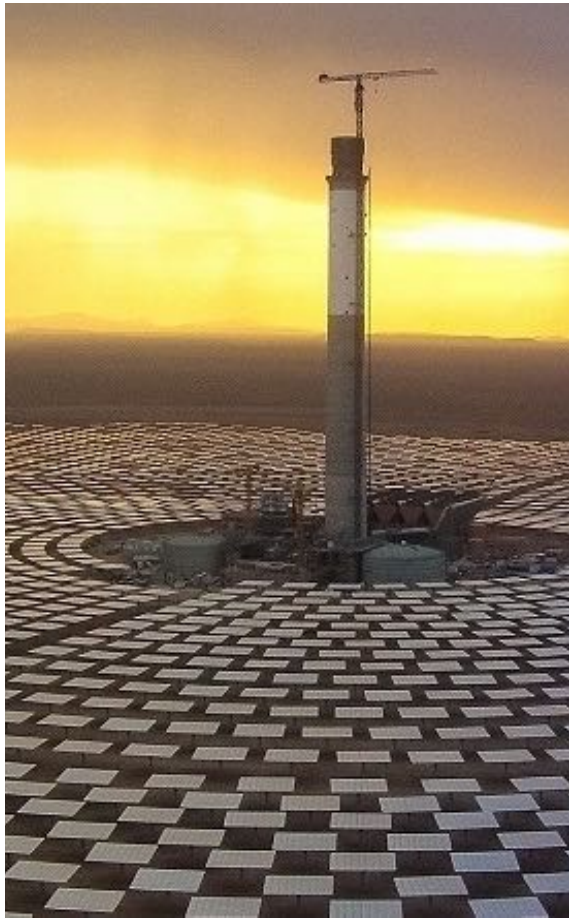
Benefits of Systems Engineering in Large Infrastructure Projects

The much anticipated empirical proof

www.incose.org/symp2022

Large Infrastructure Projects

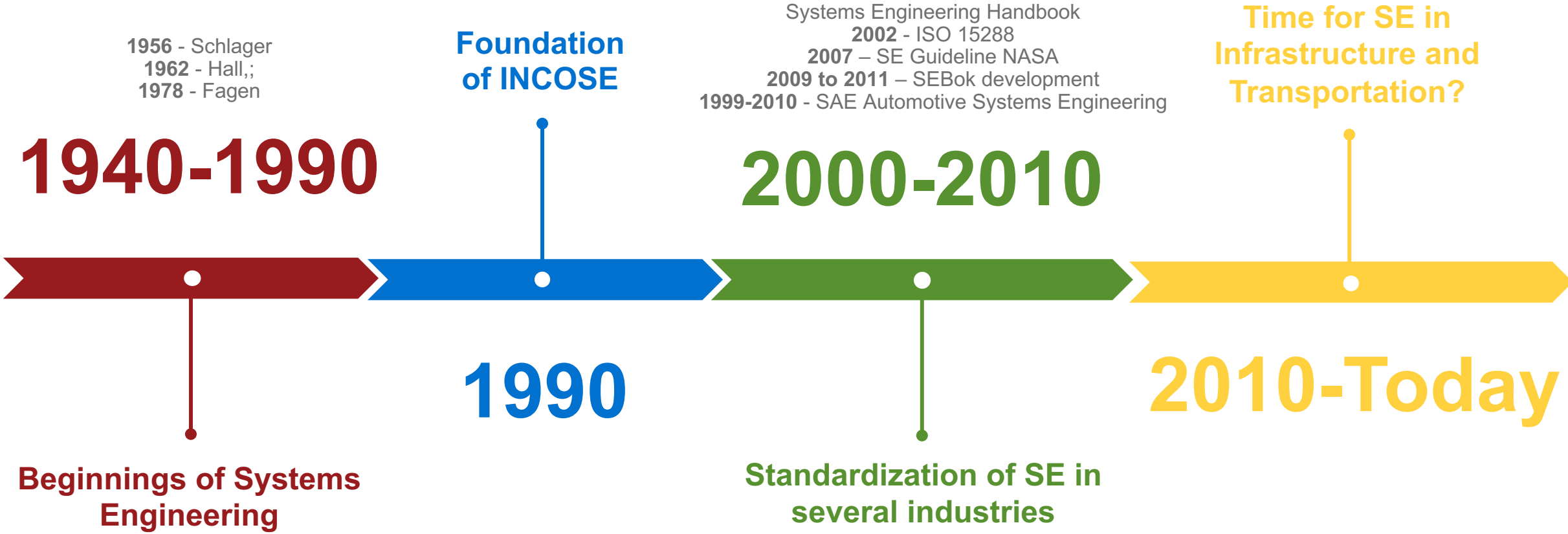


A Change of Management Paradigm

- Increasingly massive costs and schedule overruns.
- Traditional project management has not necessarily kept pace with evolving processes successfully adopted in other industries.
- Substantial changes to the initial project scope suggests that current technical management approaches require enhancements to these types of projects.
- Systems engineering is gaining popularity and acceptance in its applications to LIPs.
- This presentation fosters the application of systematic SE in Large Infrastructure Projects and contributes to demonstrate their benefits in:
  - containing budget and schedule overruns for Constructors, Governments and Administrations,
  - and increasing project margin for contractors.

Understanding the Context

Systems Engineering Timeline



Systems Engineering in Infrastructure and Transportation

Why Systems Engineering in infrastructure and transportation?

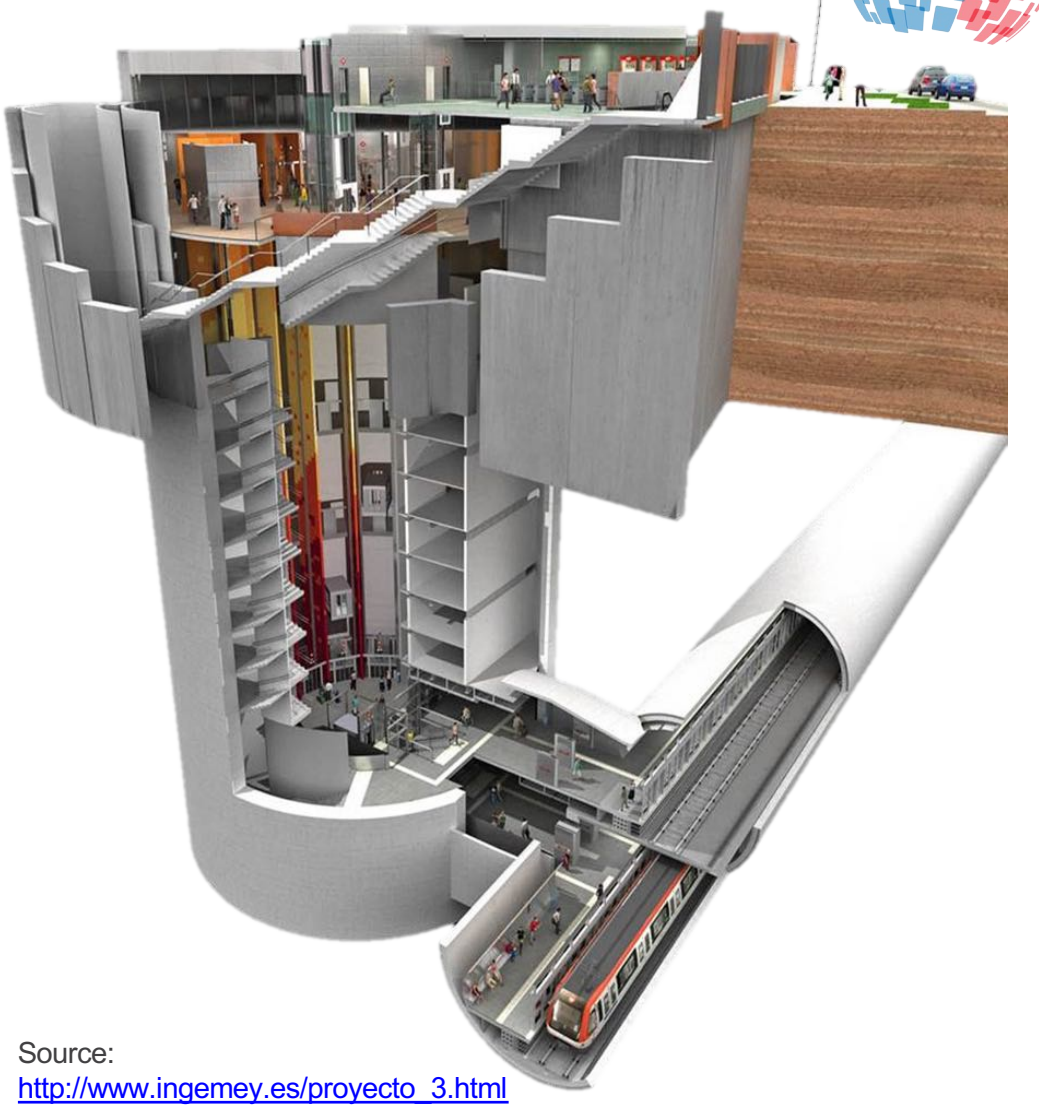
- Extremely high budgets
- Large number of stakeholders and subcontractors
- It is a System of Systems (Interoperability)
- Different geographical distribution of multicultural teams

Systems Engineering is being applied at some level in all projects, but:

- It is not systematized
- There is not a specific process or set of processes
- It is mixed with technical and management tasks, so it is not perceived as Systems Engineering

When the client requires systems engineering…

- Seems to represent an over cost to the project because SE is not yet systematized
- It can look like SE is not beneficial → Nothing further from the truth!



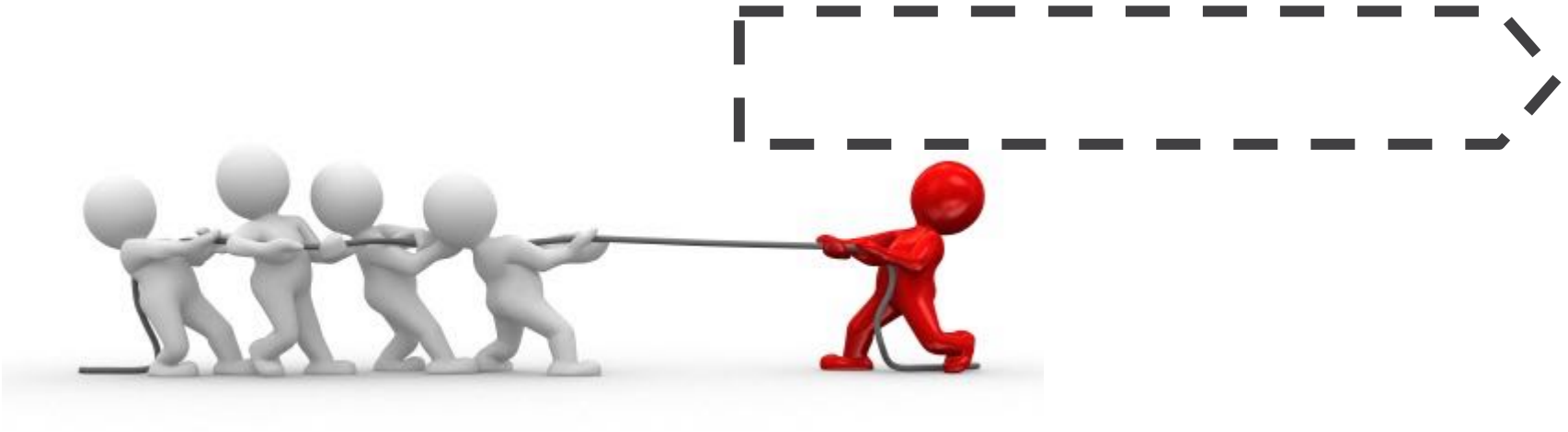
Source: http://www.ingemey.es/proyecto_3.html

Tendency towards SE, but is it enough?

Methodology already proven in several industries

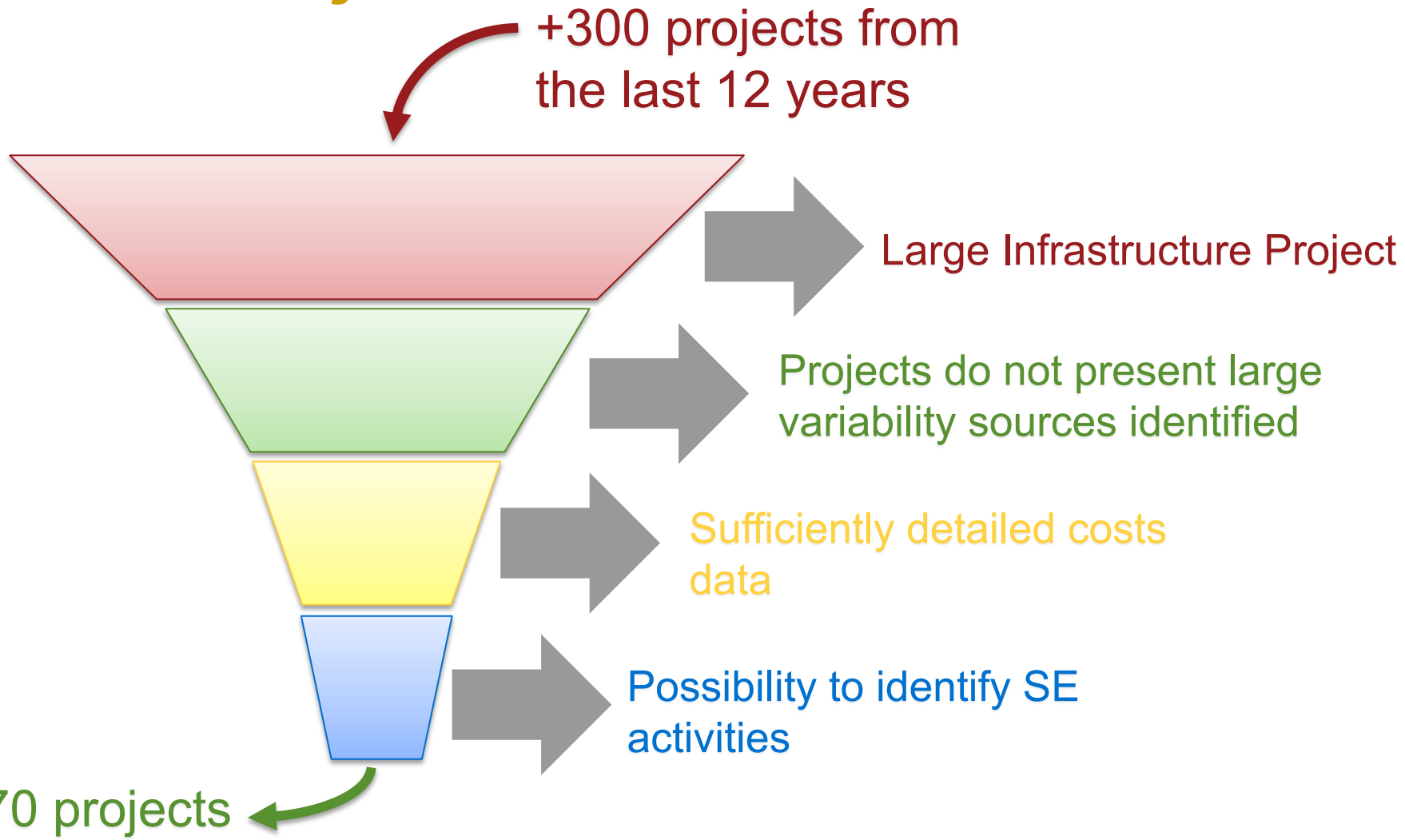
Administrations start to require systems engineering

Relevant case studies in Large Infrastructure Projects



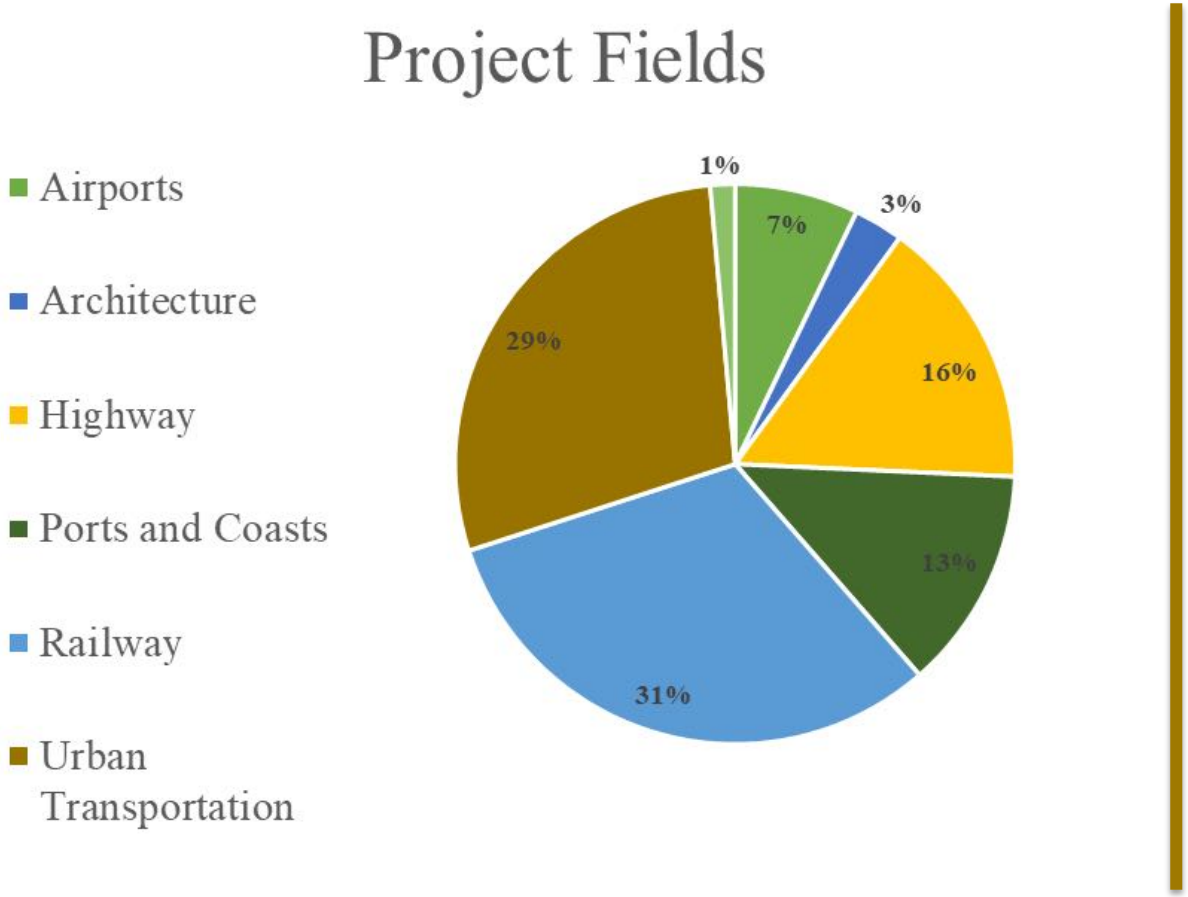
Collecting the Data

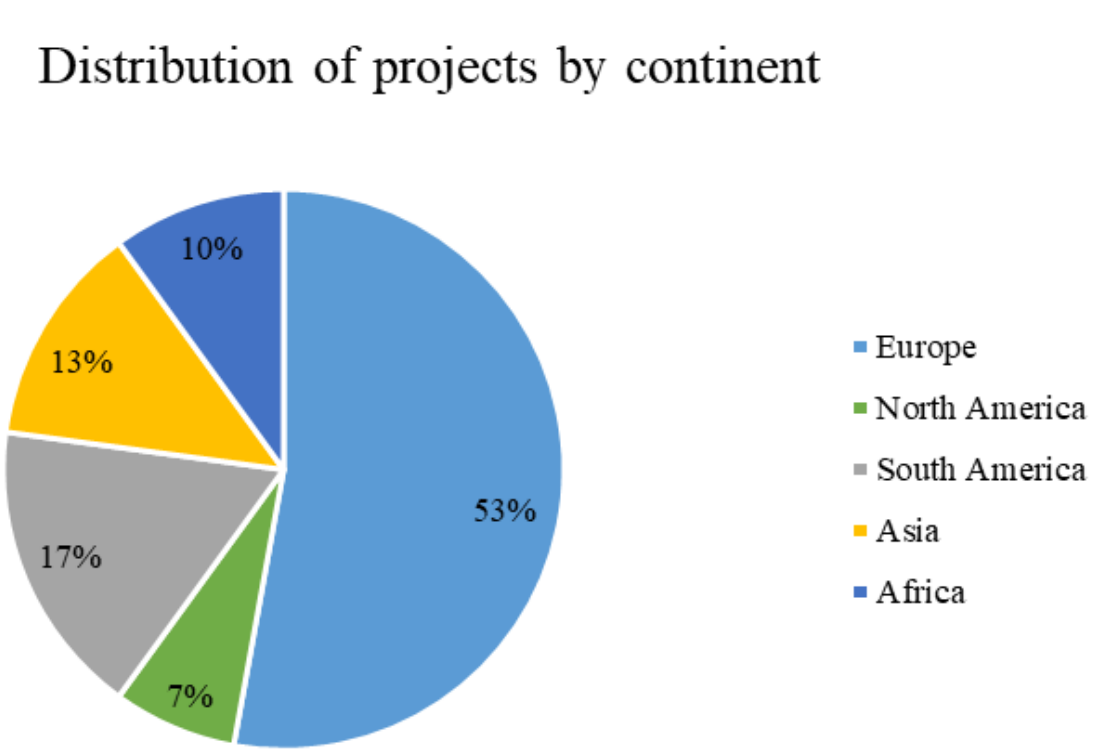
Selecting the Projects



Final Set of Projects

Projects distributed in different fields and in different levels of cost





Gathering Systems Engineering

The data on Systems Engineering was not well recorded:

Need for a transformation method

Over 50 interviews with project managers

(sample)

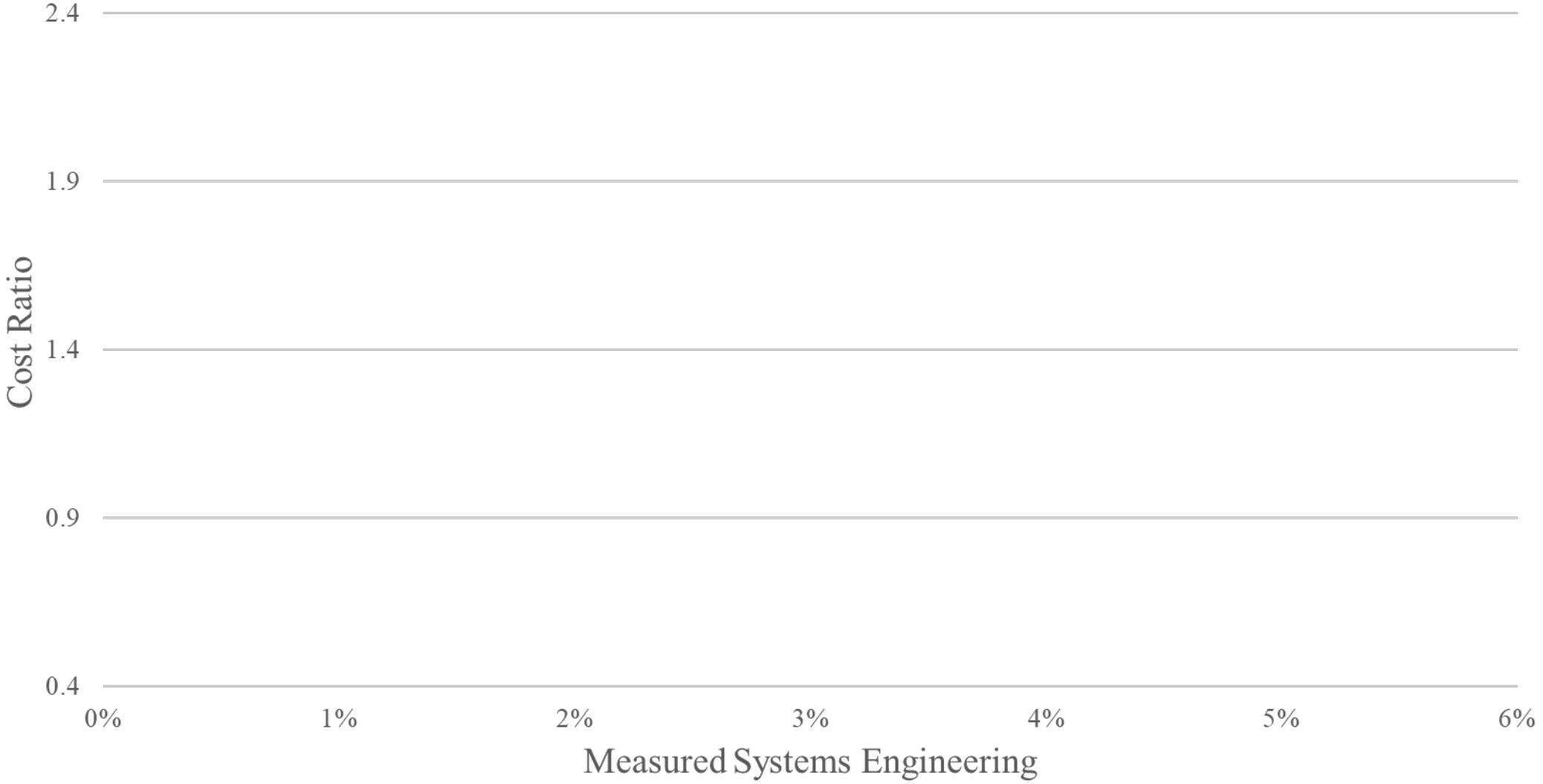
Task	Systems Engineering Activity	Activity on the project allocated to
Requirements elicitation, analysis and validation	Requirements Management	Project Management
Creation of a System Breakdown Structure	System Architecture Management	Project Management
Creation of Interface Matrix	Interface Management	Technical Design
System Verification	Verification and Validation	Technical Design and Quality Assurance

Getting the Results

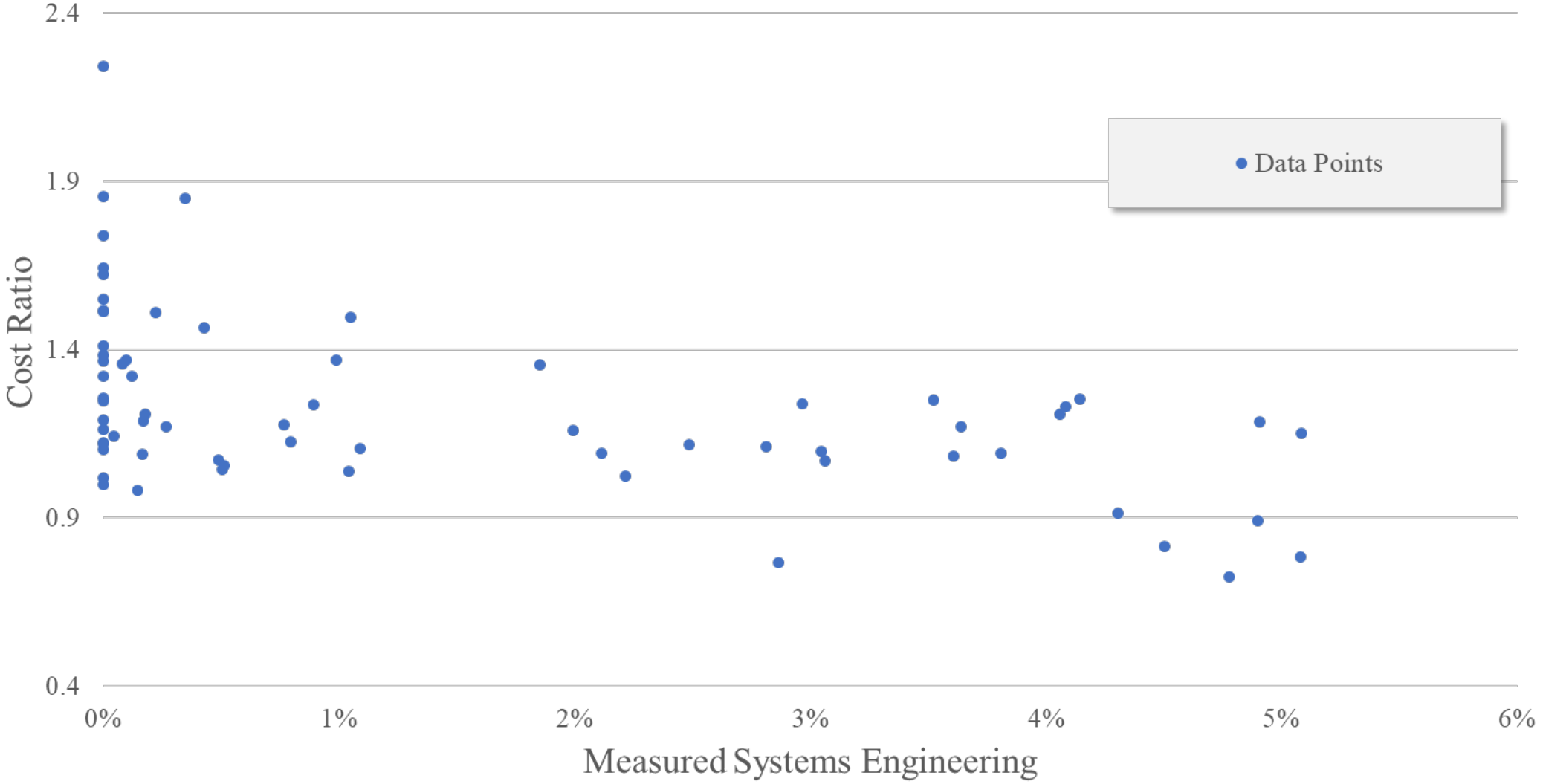
Statistical Data

- Measured Systems Engineering → $SE = \frac{Cost\ spent\ on\ Systems\ Engineering}{Total\ Project\ Cost}$
- Cost Ratio → $CR = \frac{Total\ Project\ Cost}{Forecasted\ Project\ Cost}$
- Minimum Sample Size (99% CI) → 60 Projects
  H_0 normal distribution → Accepted (Jarque-Bera Test)
- Minimum R^2 significant (99% significance) → 0.093

Measured SE vs. Cost Ratio



Measured SE vs. Cost Ratio



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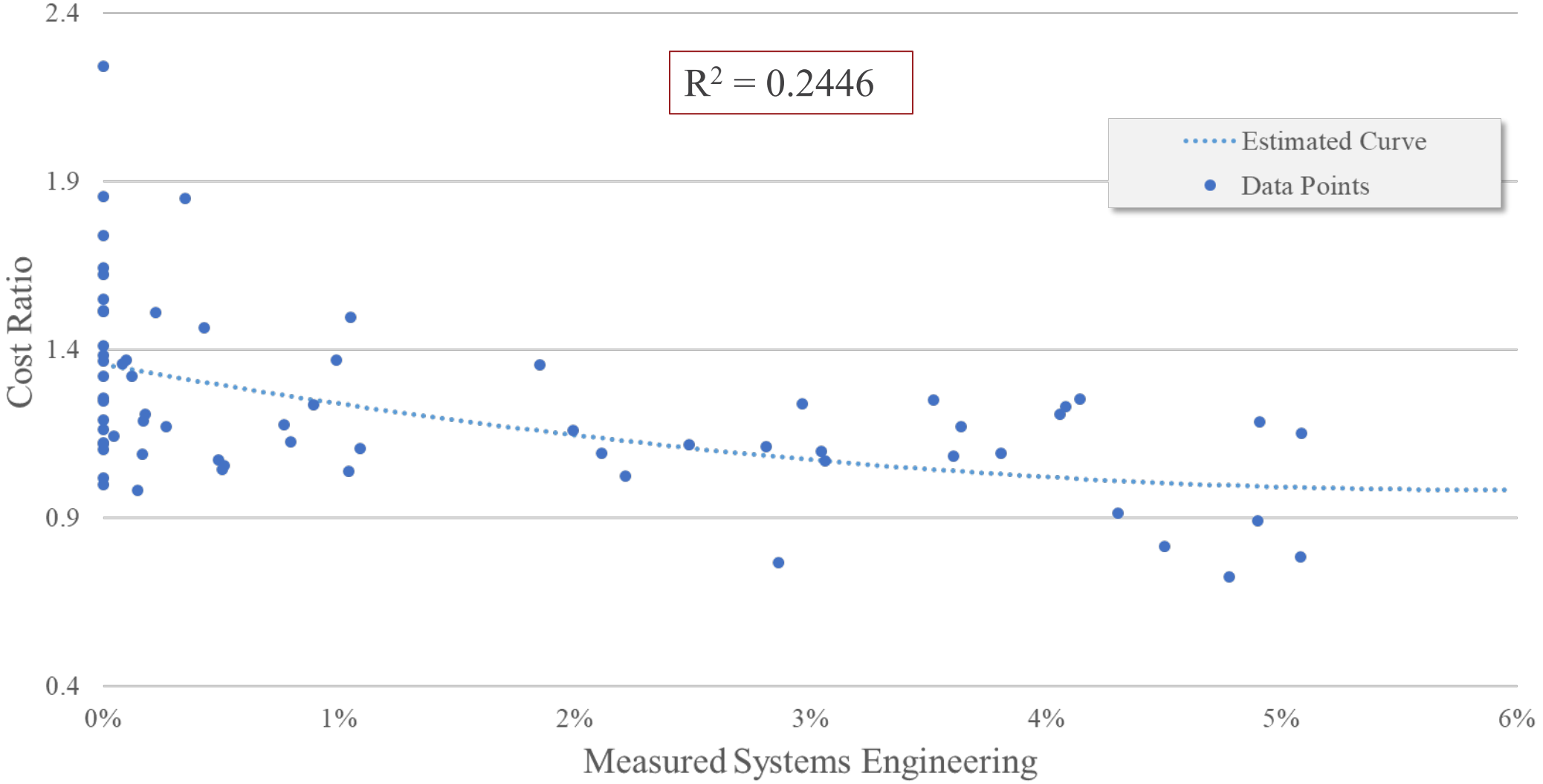

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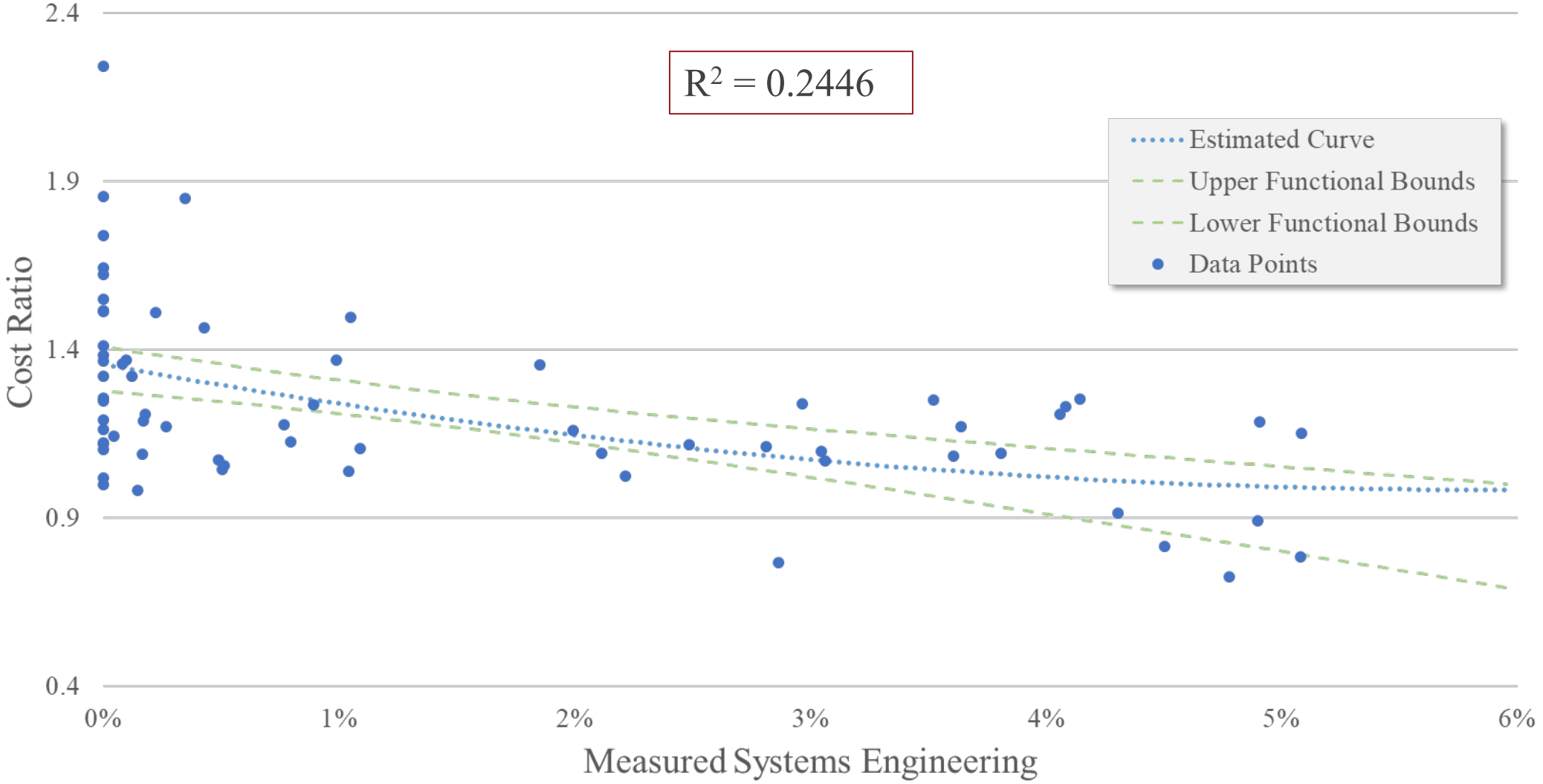

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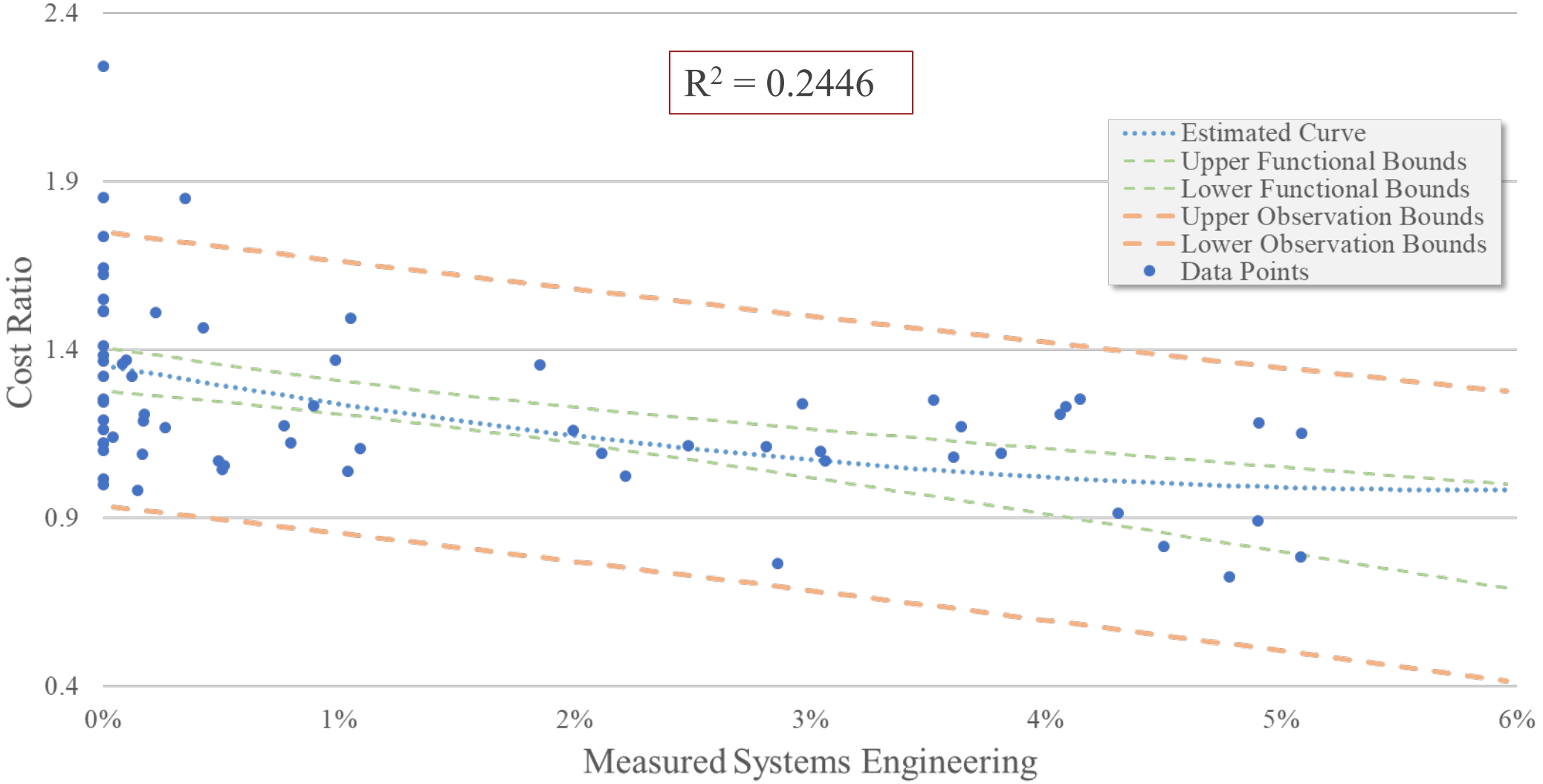
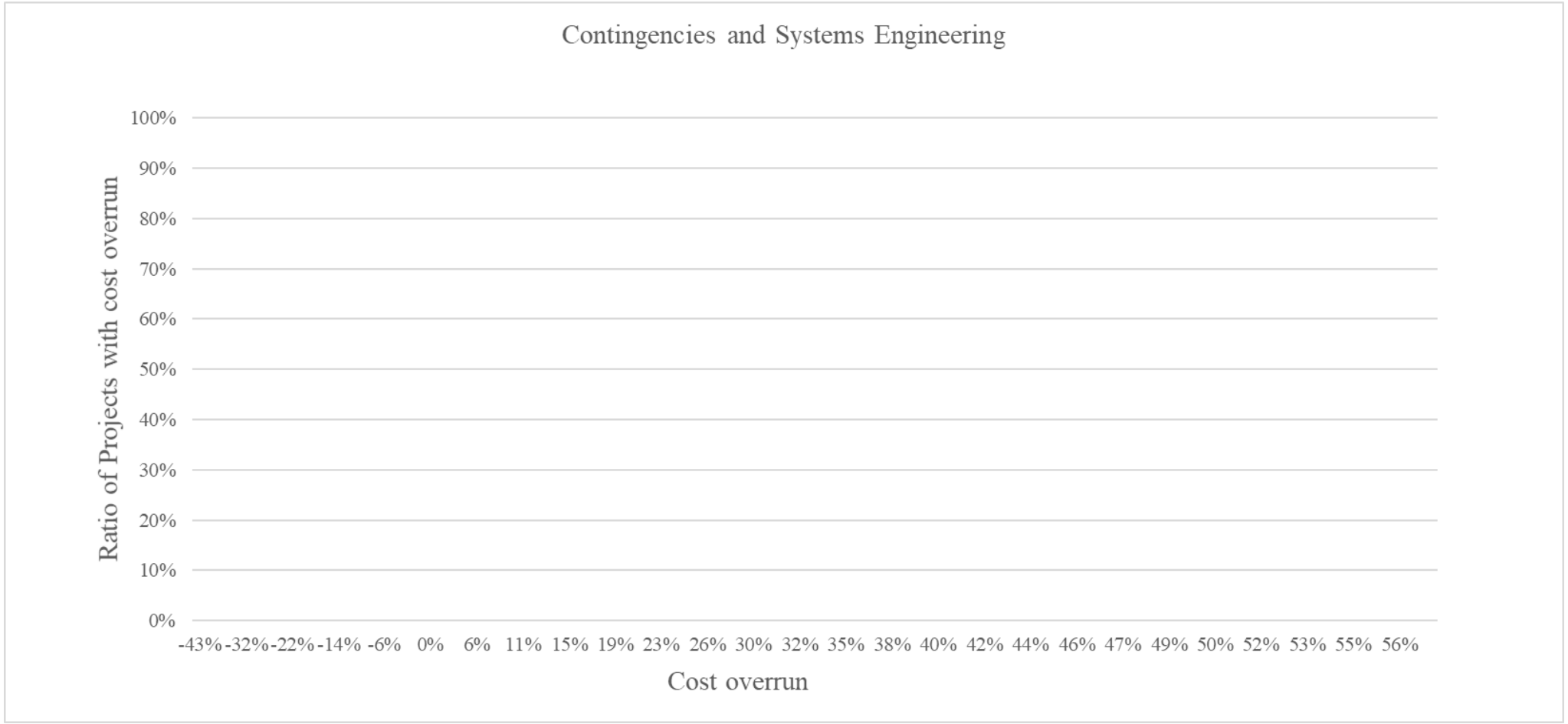


Systems Engineering and Project Margin

And what is really the effect of Systems Engineering on the project earnings?

Let's understand it's effect on cost overrun and contingency!

Systems Engineering and Project Margin



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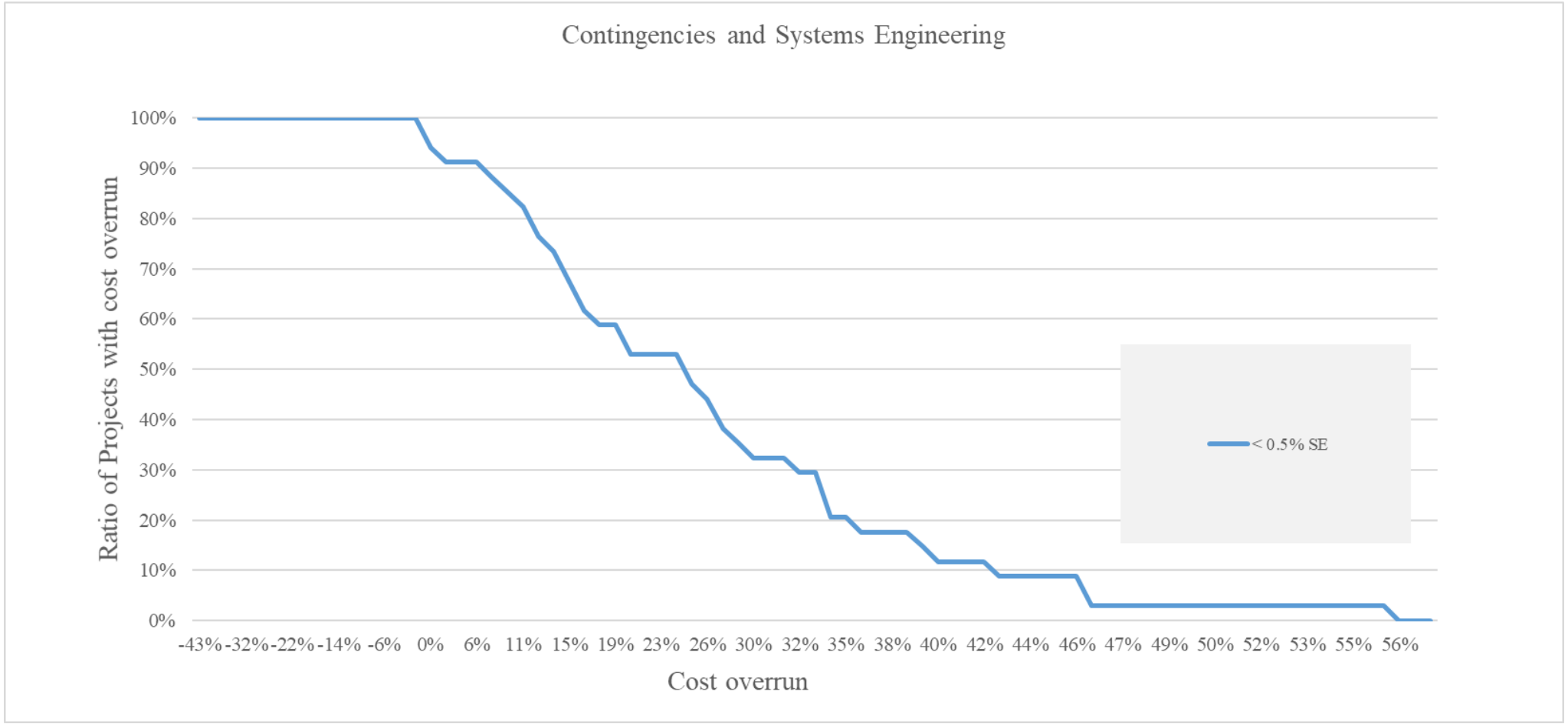

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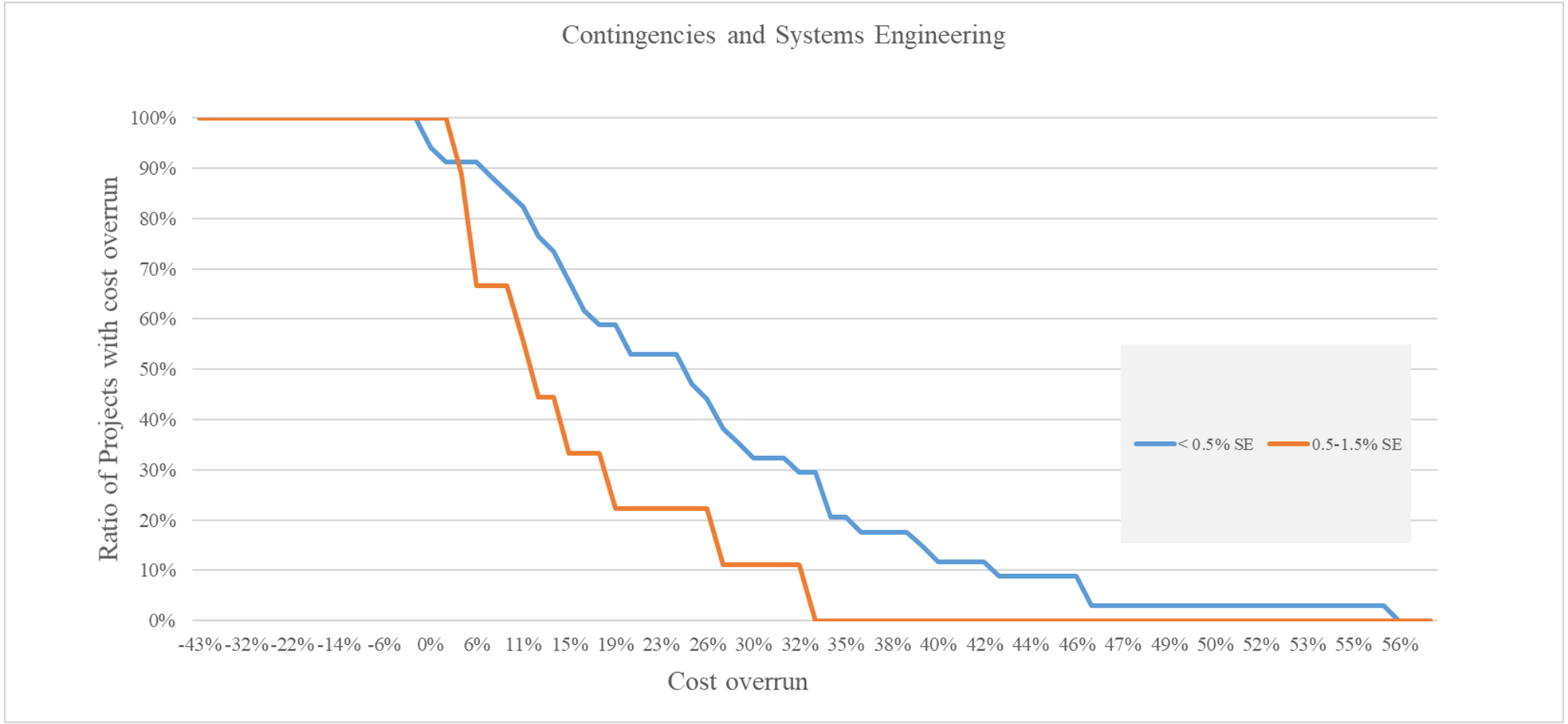

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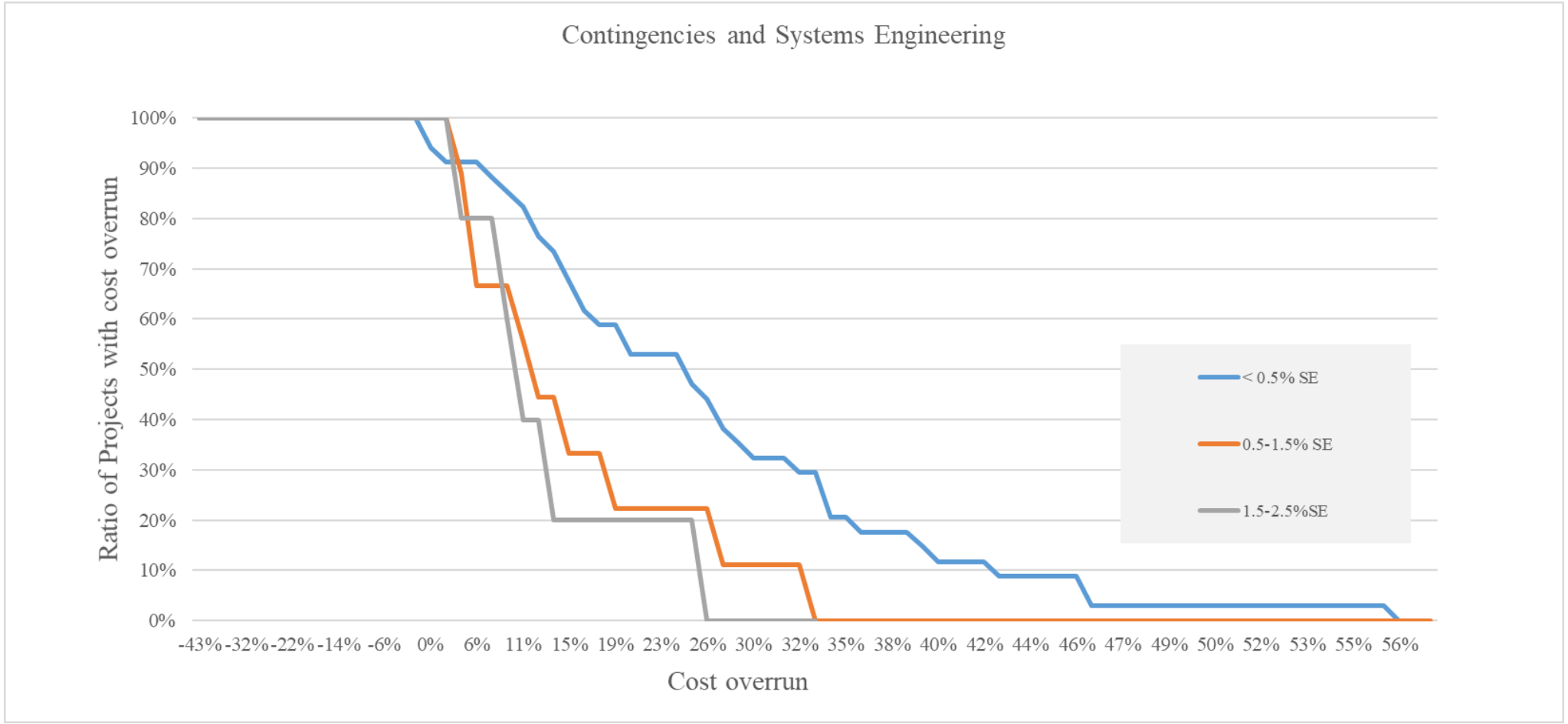

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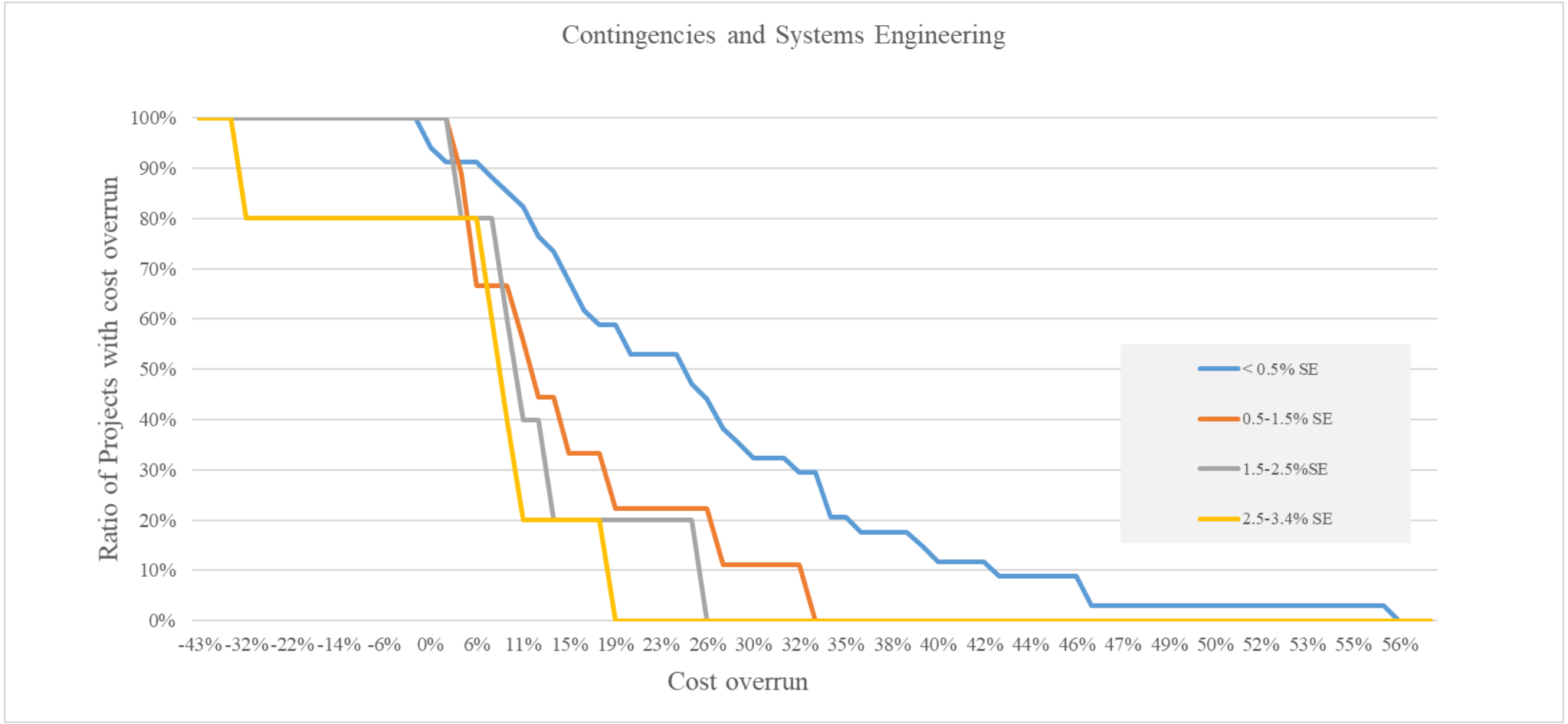

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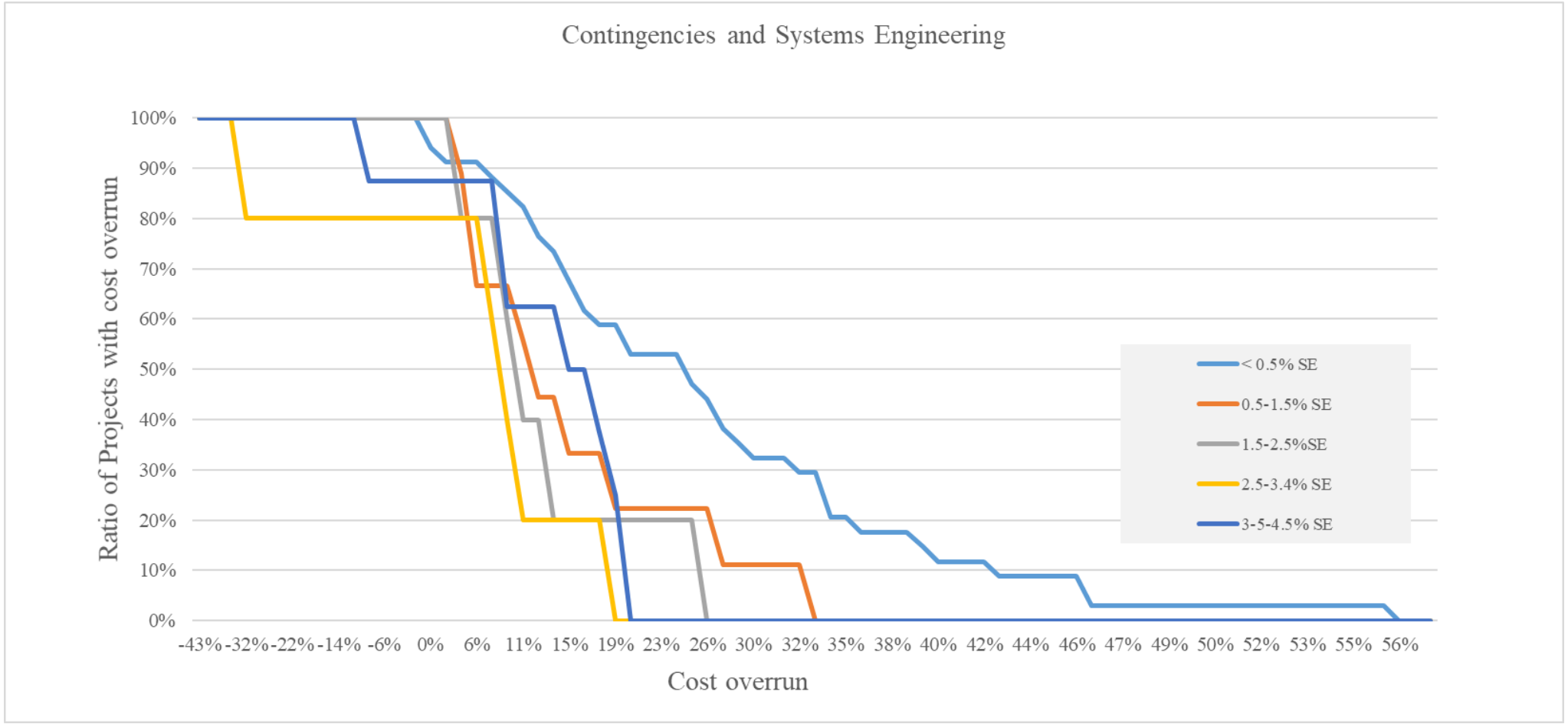
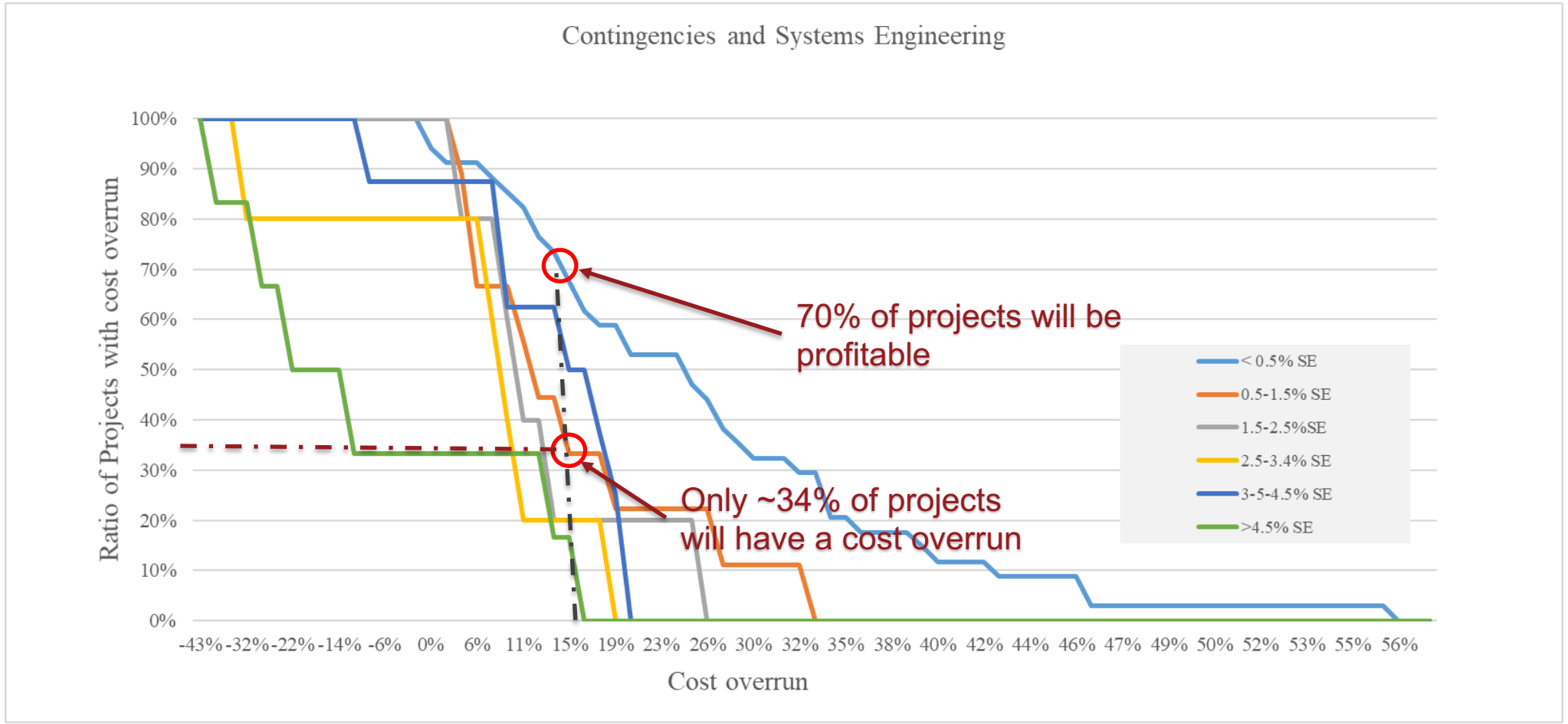


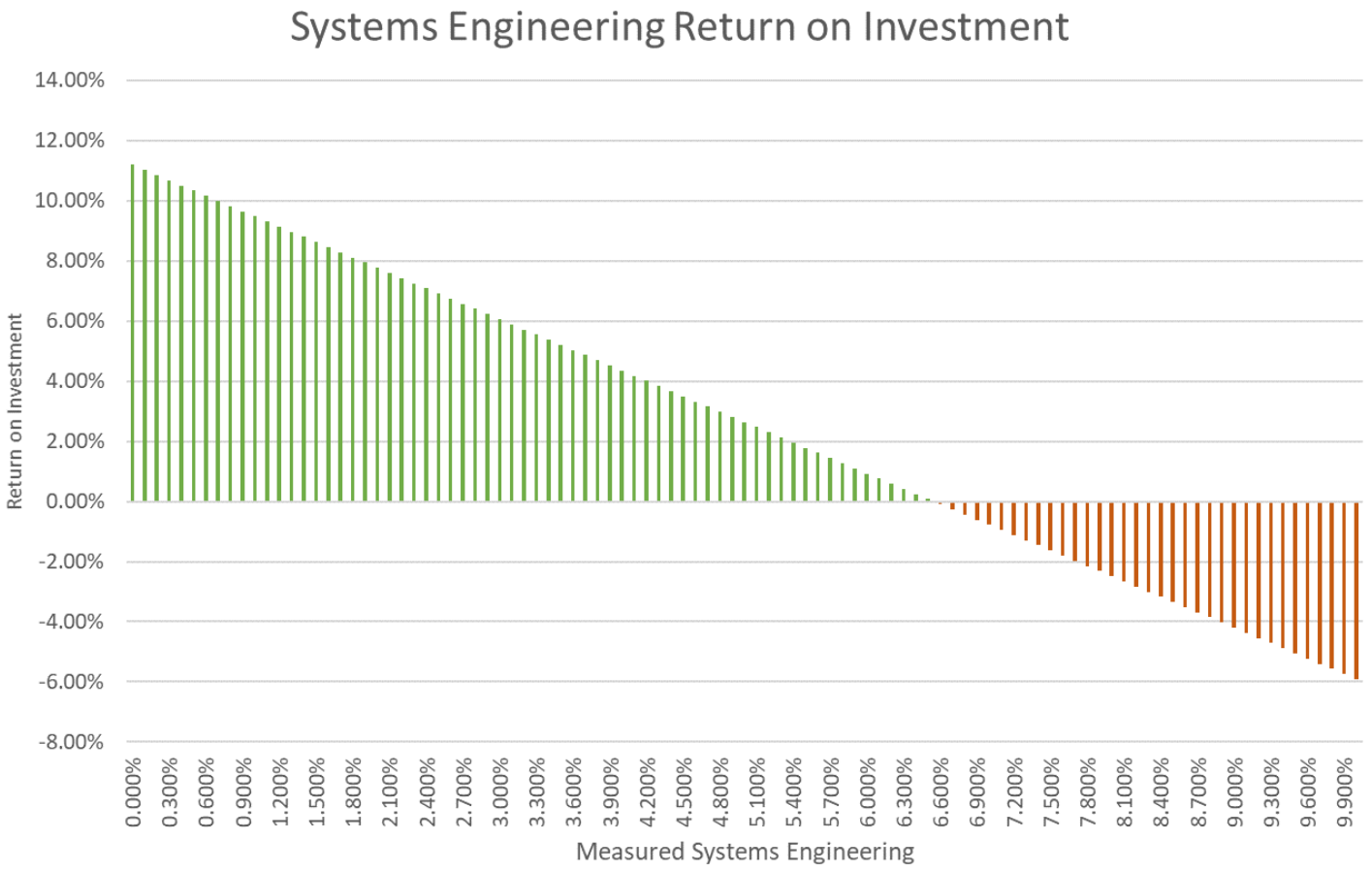
Systems Engineering and Contingency



The implications

Return on Investment

Measured SE	ROI
0%	11.19%
2%	7.77%
4%	4.35%
6%	0.93%
8%	-2.49%
10%	-5.91%



The Path Forward

- Optimal point approximately **6.5%**

Room for improvement

- Average SE applied in the studied projects **1.5%**

We need more Systems Engineering in Infrastructure

What's Next?

- Foster Systems Engineering in your organizations
- Optimize and systematize Systems Engineering processes for infrastructure
- Requiring SE in contracts saves money to Governments and Administrations
- Applying SE in projects reduces cost to contractors

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