

Project Delivery Method Performance Evaluation for Water and Wastewater Capital Projects

by
Jeffrey Feghaly

A Thesis Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Science

Outline

Background

Literature Rev.

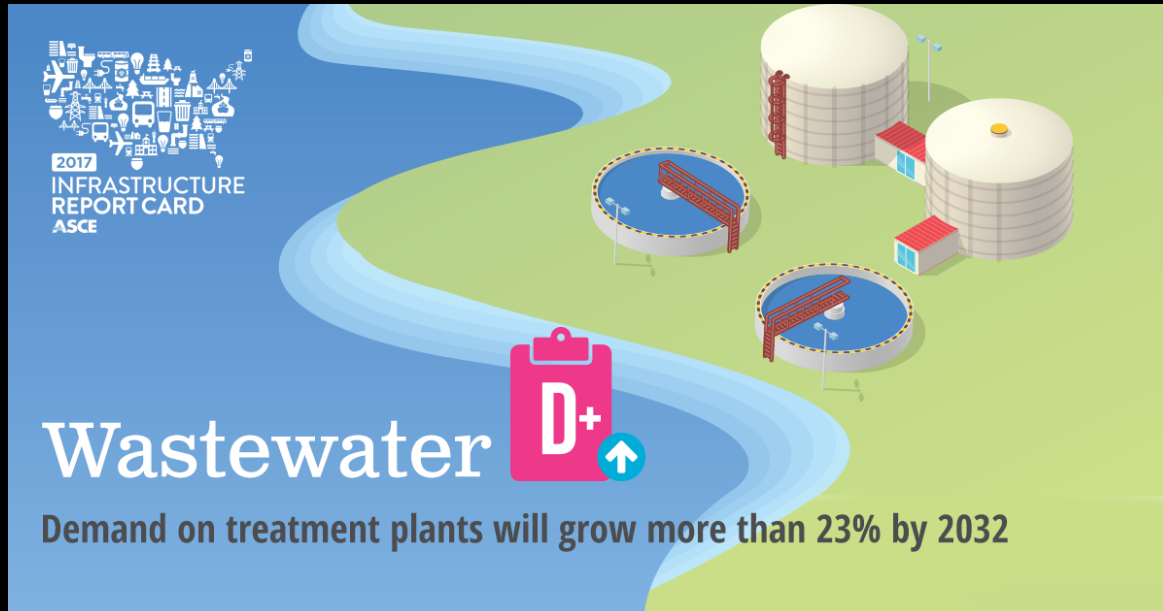
Obj. & Method.

Characteristics

Performance

Conclusion

Background



ASCE (2017)

Background

Literature Rev.

Obj. & Method.

Characteristics

Performance

Conclusion

Background

- AWWA Estimated that **\$1 trillion** is necessary to meet demands over the next 25 years
- Federal funding for water utilities has fallen from **\$16 billion** in 1967 to **\$4.4 billion** in 2014

AWWA (2016); CBO (2016)

APDM are touting benefits such as lower cost, faster schedule, and higher quality



Background

Literature Rev.

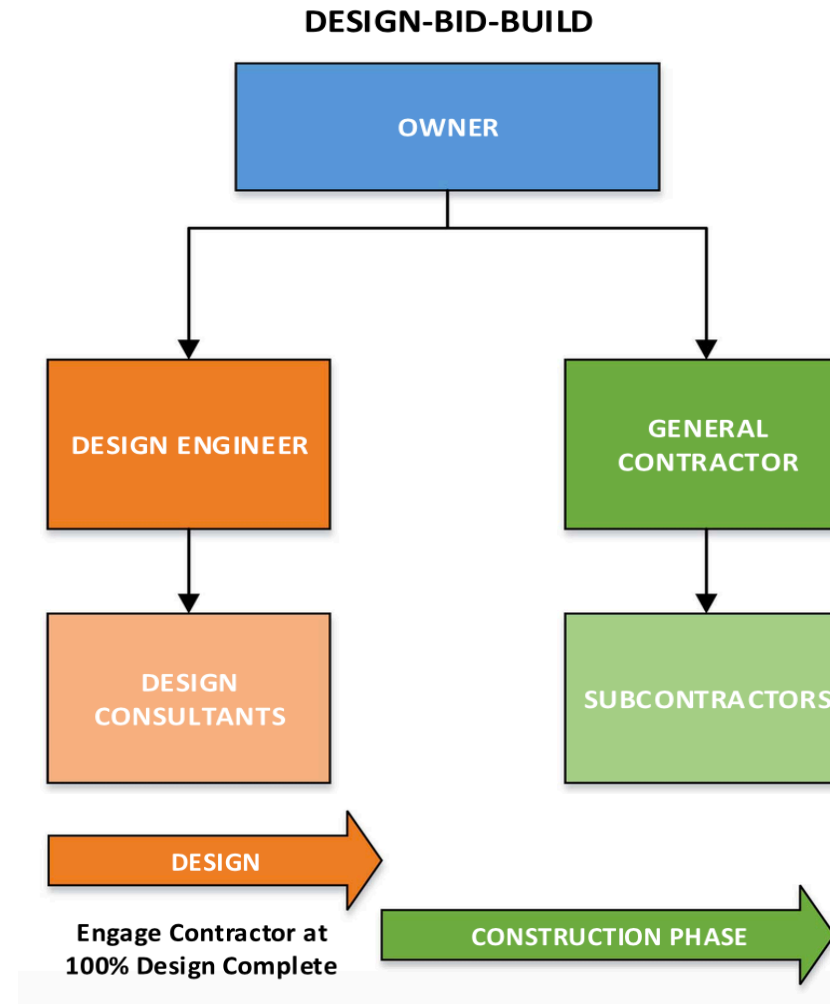
Obj. & Method.

Characteristics

Performance

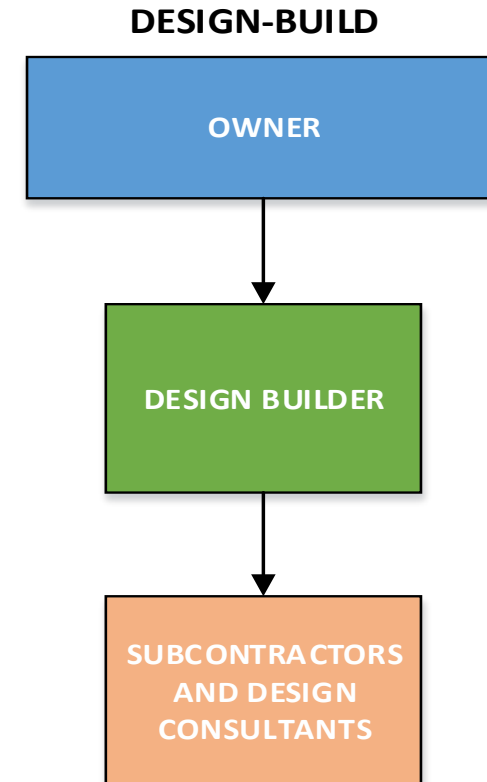
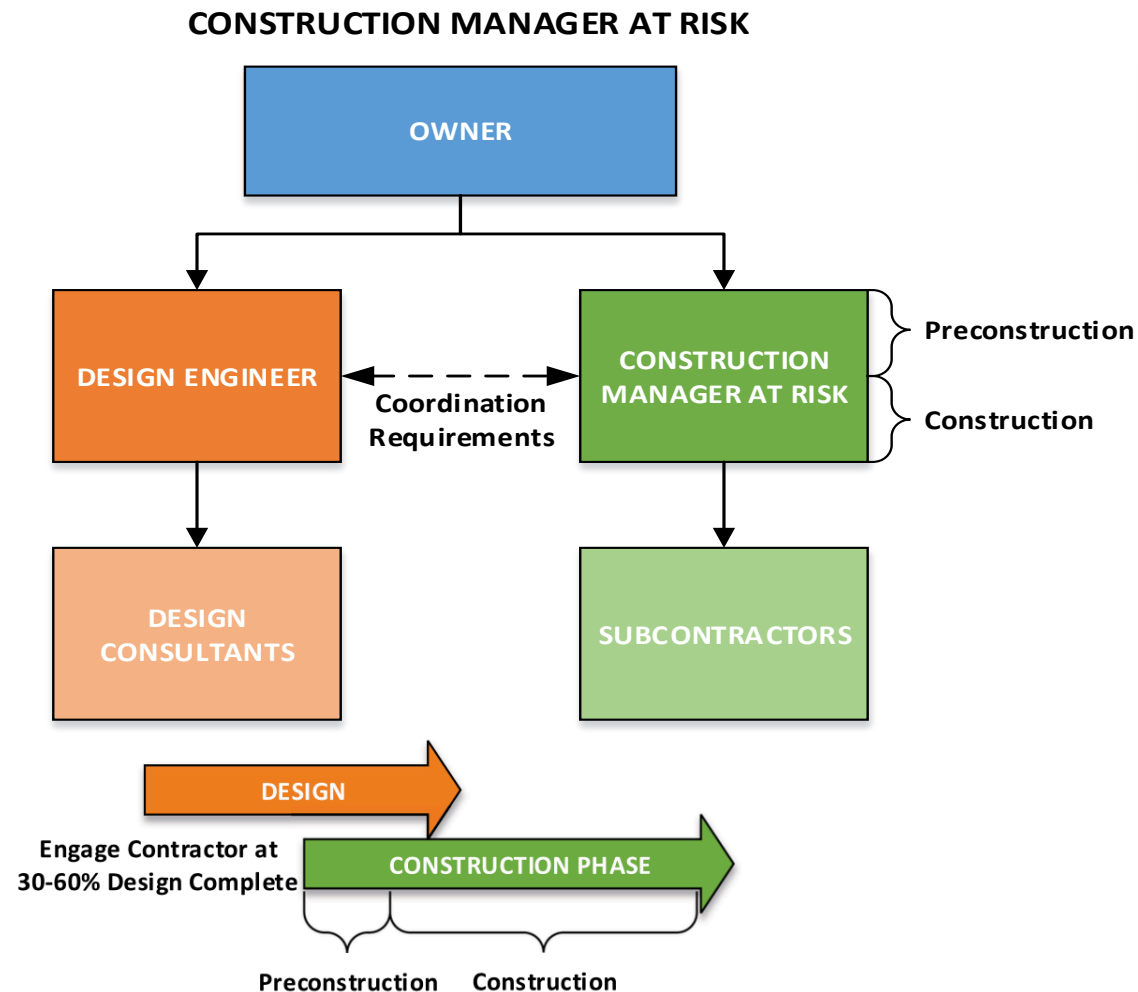
Conclusion

Traditional Method: DBB

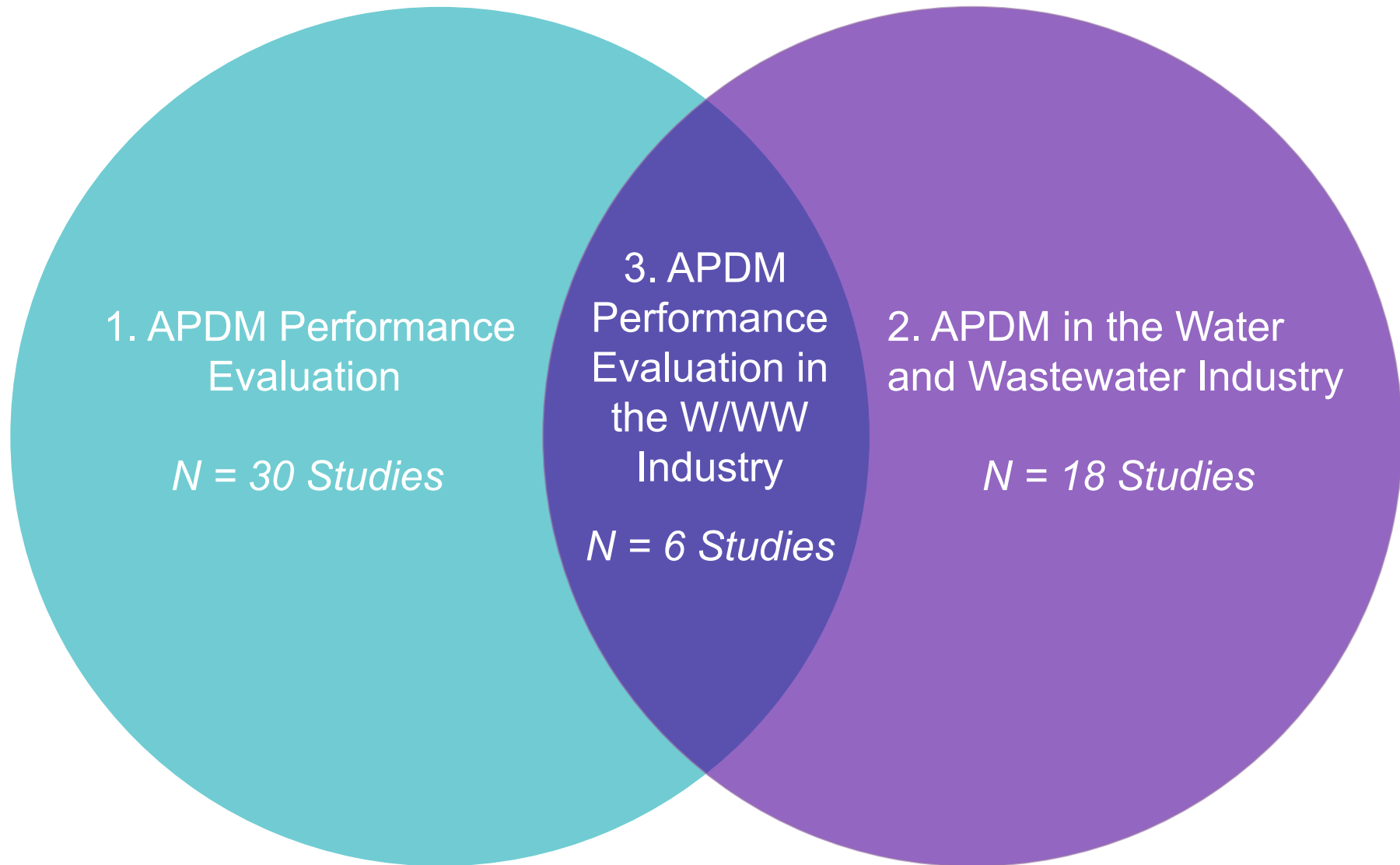


Francom et al. (2016)

Alternative Project Delivery Methods: CMAR & DB



Francom et al. (2016)



Background

Literature Rev.

Obj. & Method.

Characteristics

Performance

Conclusion

There is a **need** to further develop the knowledge of APDM performance impact for water/wastewater capital projects

Background

Literature Rev.

Obj. & Method.

Characteristics

Performance

Conclusion

Objective

To quantitatively assess the **performance impact** of APDM on water/wastewater capital projects

Background

Literature Rev.

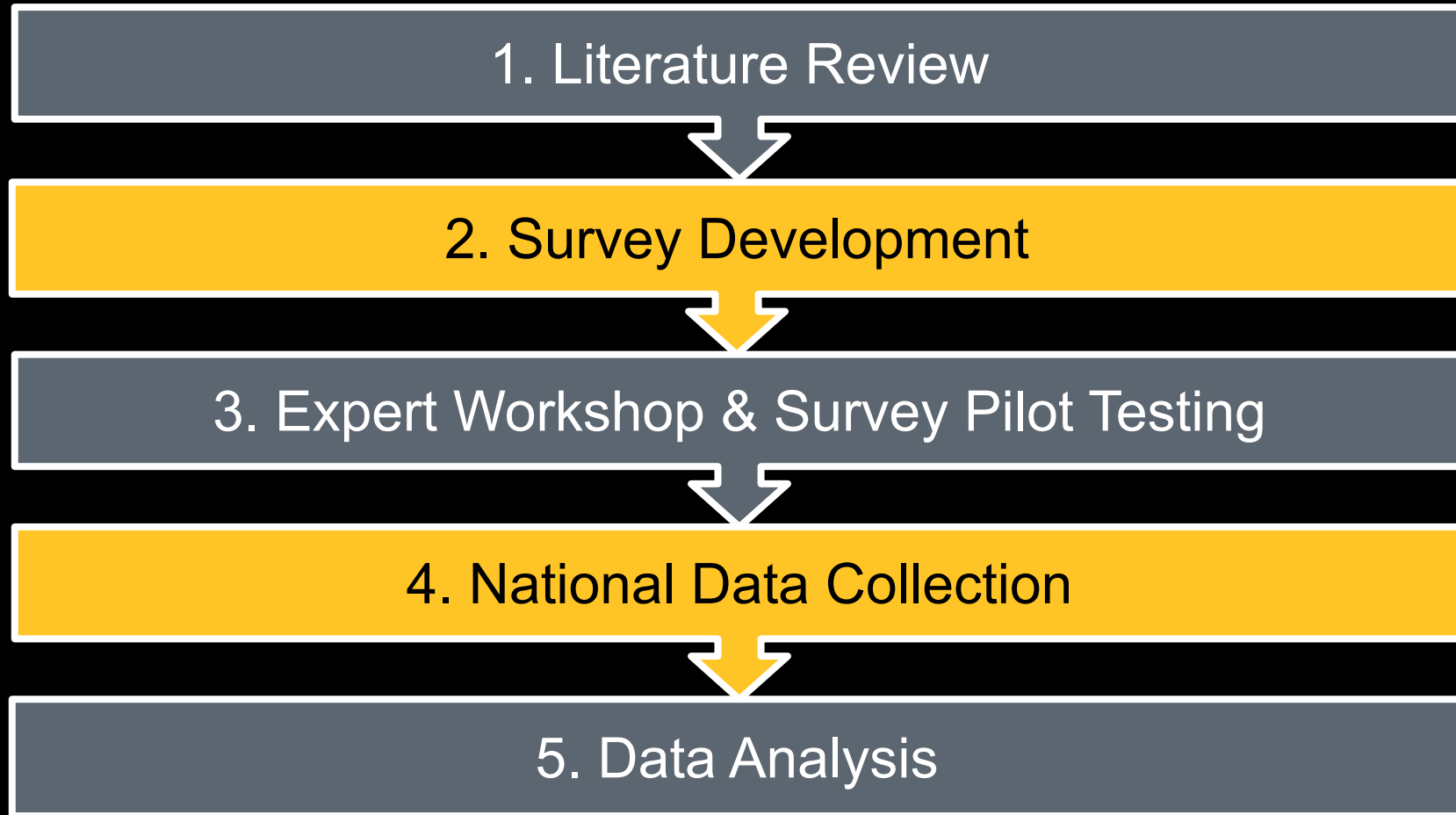
Obj. & Method.

Characteristics

Performance

Conclusion

Methodology



Background

Literature Rev.

Obj. & Method.

Characteristics

Performance

Conclusion

Survey Sections

- General Project Characteristics
- Project Delivery Method Selection
- Procurement Types & Compensation Methods
- Experience, Involvement, & Communication
- Scope Changes, Warranty Issues, & Latent Defects

Expert Workshop



Background

Literature Rev.

Obj. & Method.

Characteristics

Performance

Conclusion

National Data Collection

- Consisted of **67** questions (Qualtrics)
- Only submit data if they had been **intimately involved**
- Only projects completed **after 2005**
- Only plant projects, of different **sizes** and **capacities**

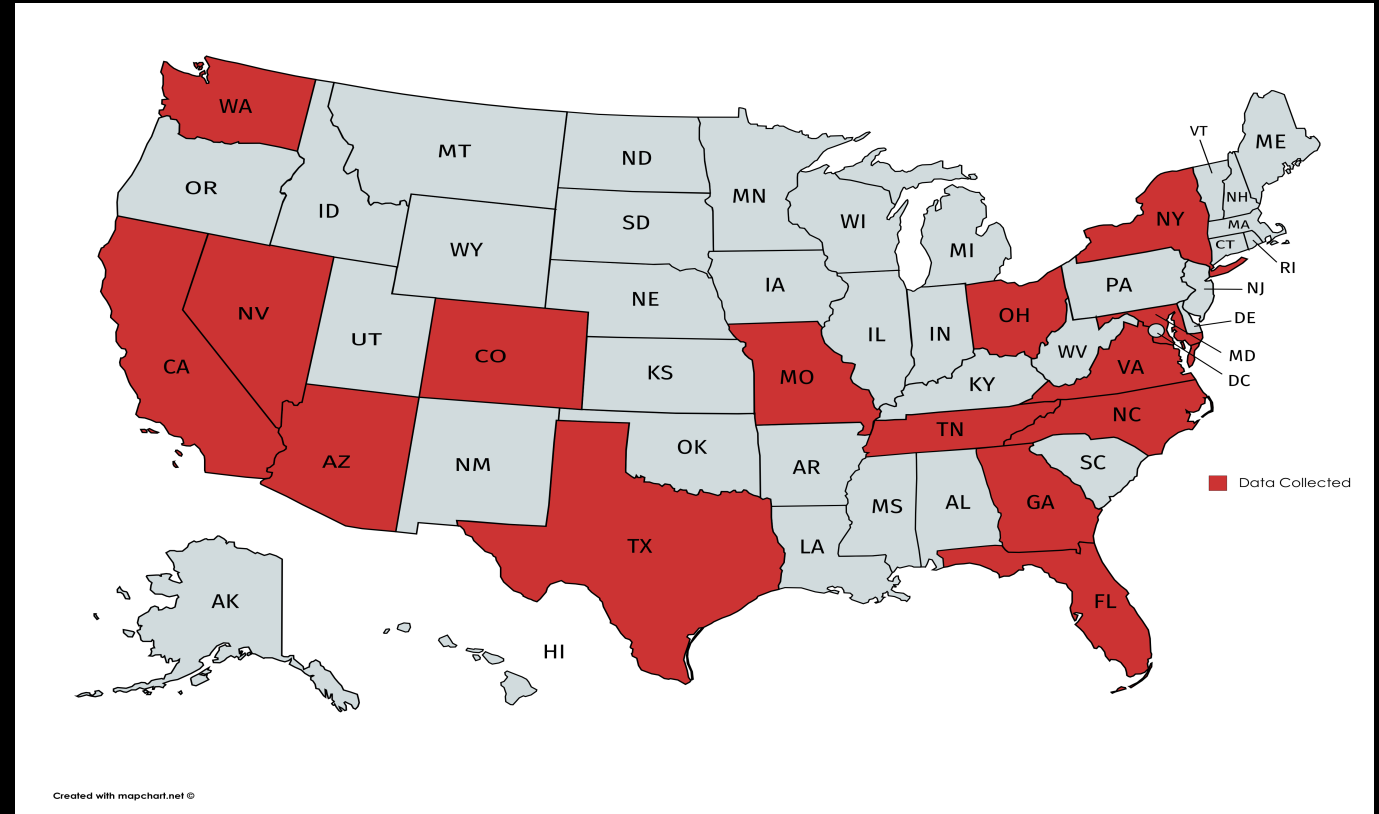
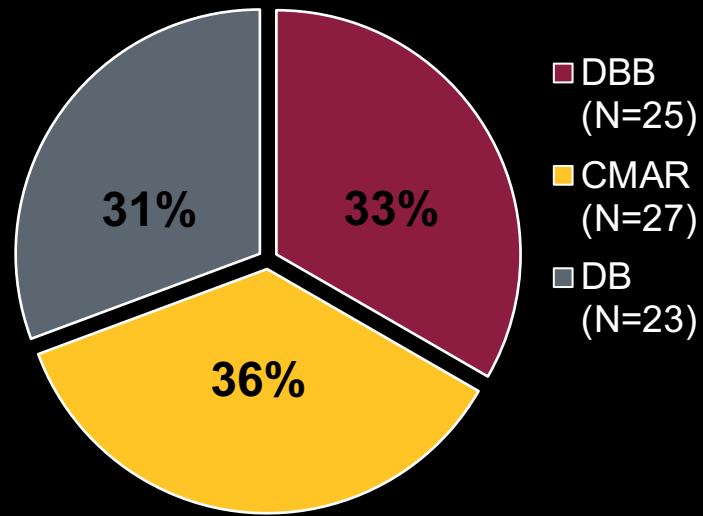
- Sent to about **200 industry** professionals ($RR \approx 37\%$)
- Responses were collected from **Aug. 2017** to **Jun. 2018**
- Data was **validated** using online public information

Data Analysis

- Boxplots
- Descriptive statistics
- One-way ANOVA or Kruskal-Wallis tests to test for statistically significant differences ($\alpha=0.05$)
- Quantile-to-quantile (Q-Q) plots
- Tukey's outlier detection method

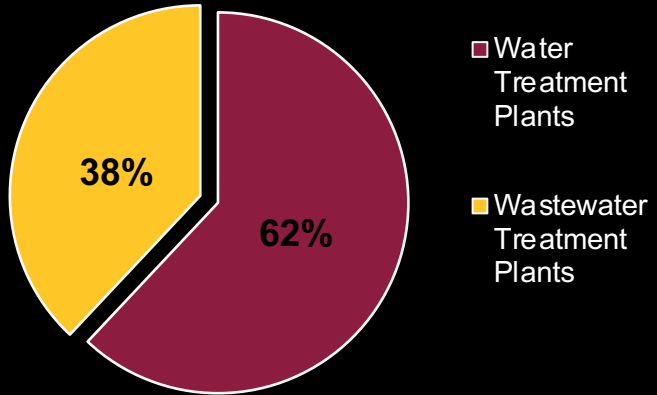
Data Characteristics

Distribution of Projects Based on Delivery Method

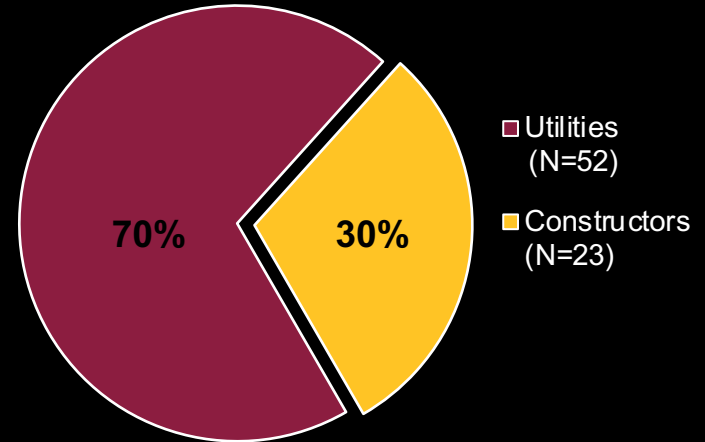


- Total dollar amount of all projects combined was about **\$4.1 billion**

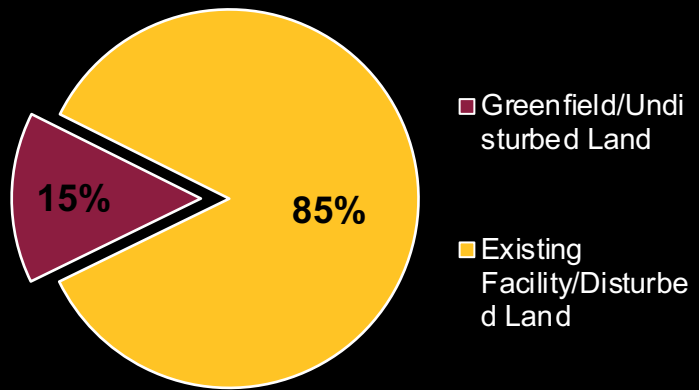
Treatment Plant Type



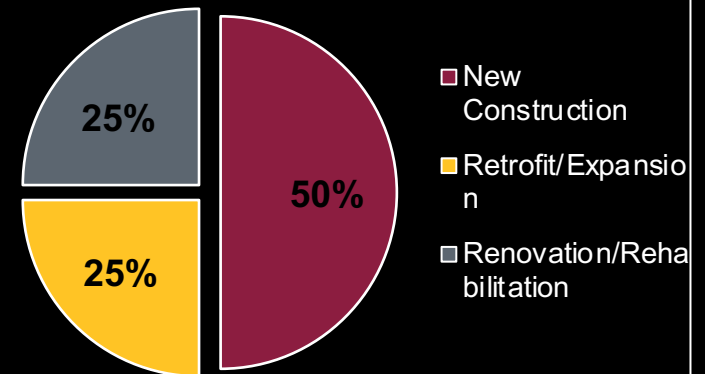
Organization Type



Project Site

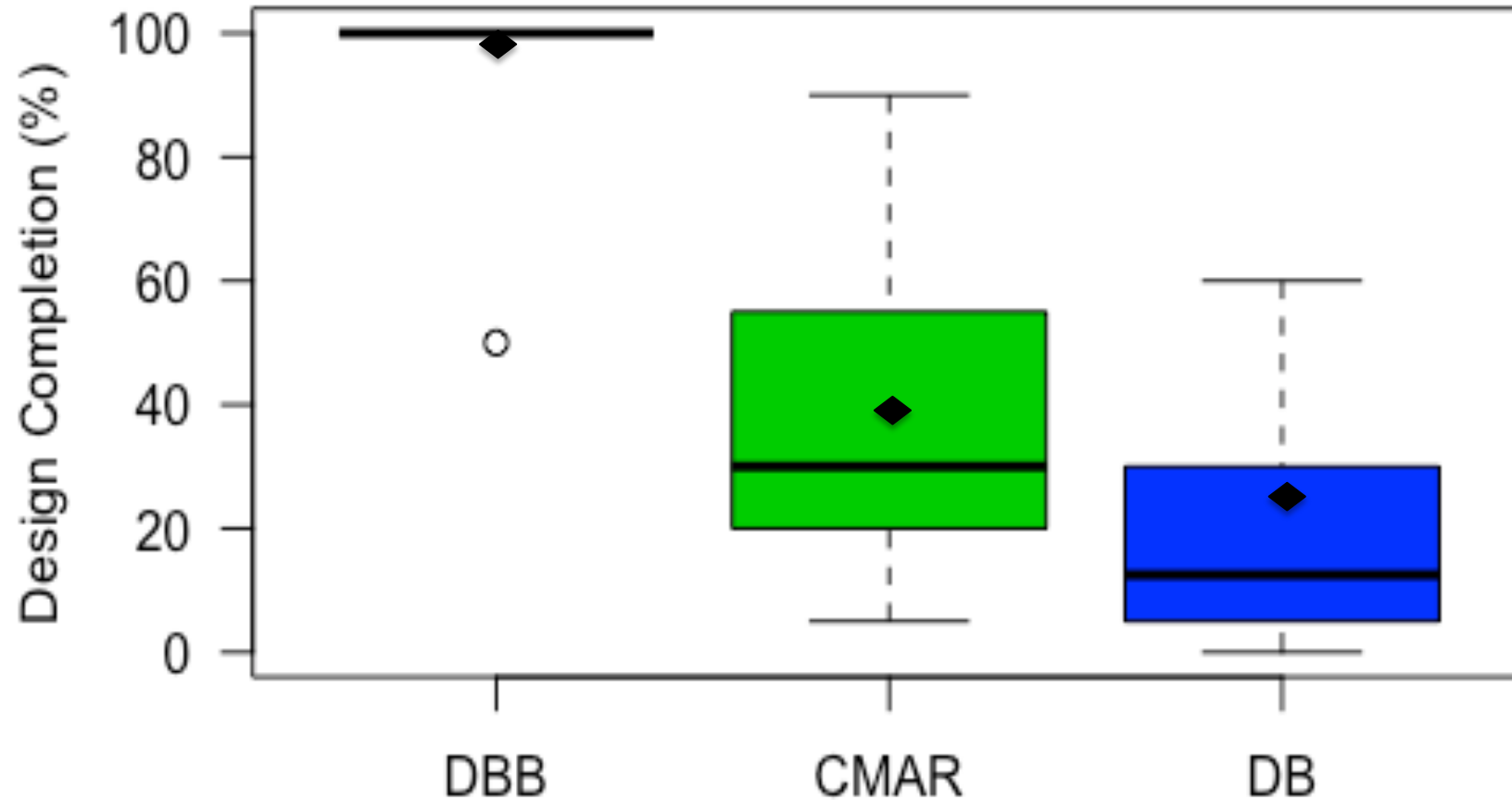


Construction Project Type



Sample Size
(N) = 75

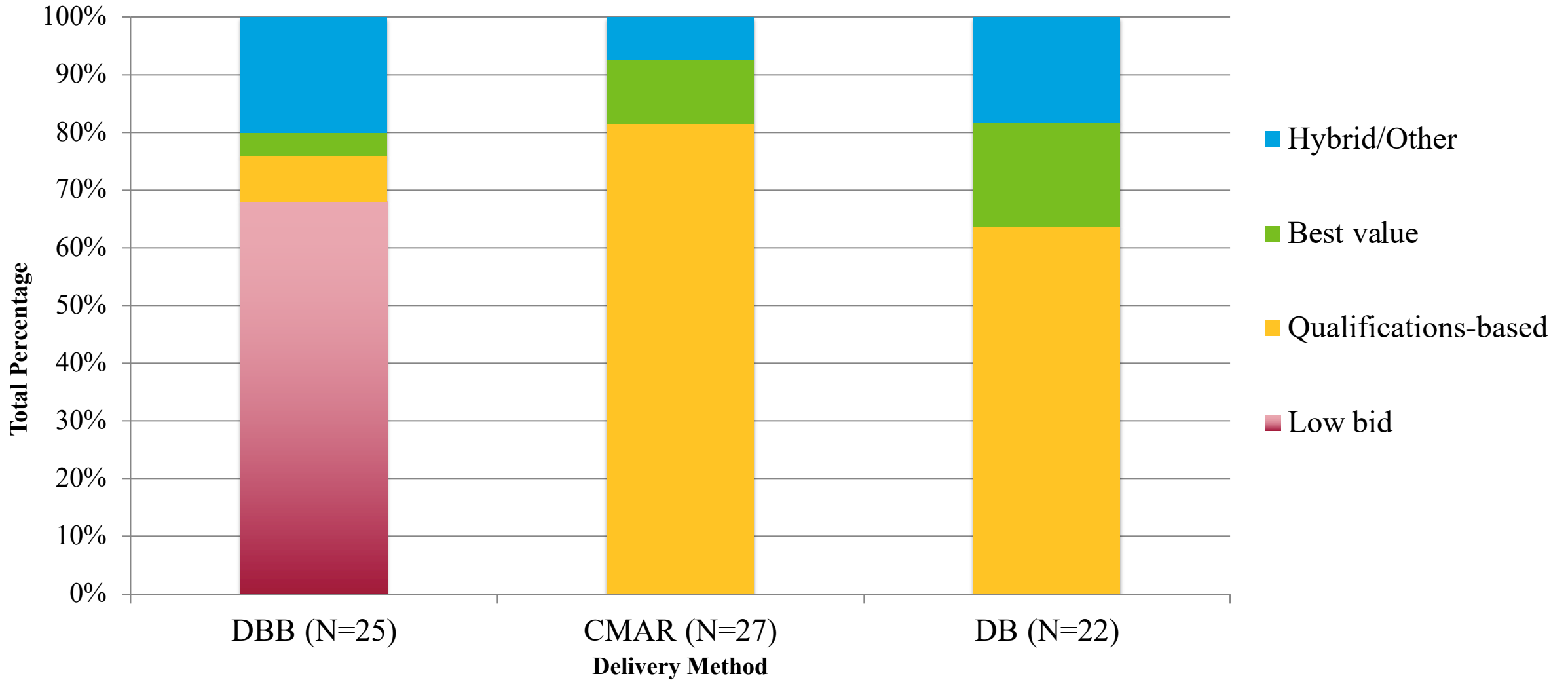
Percent Design Complete Before Constructor Engagement



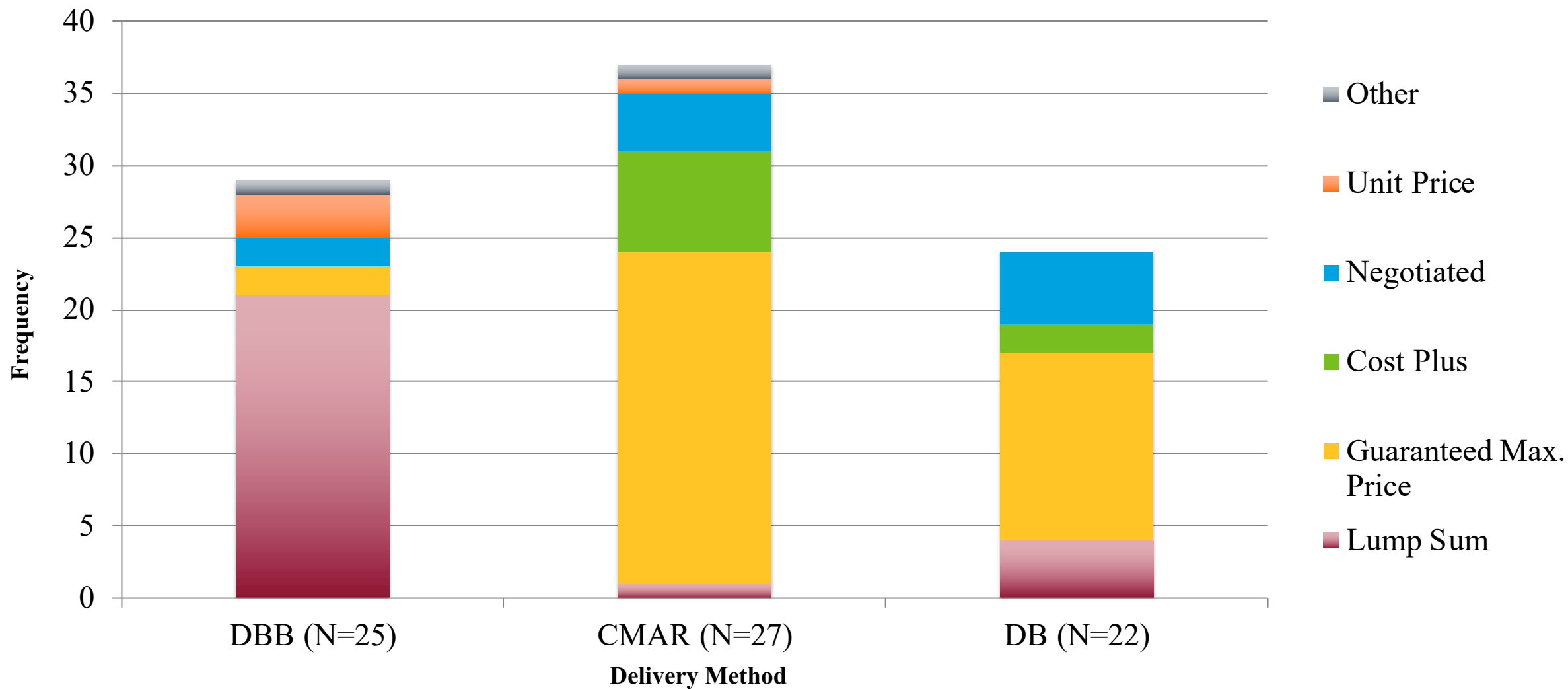
Delivery Method	Median	Average
DBB	100.00 %	97.92%
CMAR	30.00%	38.96%
DB	12.50%	22.00%

Sample Size (N) = 75

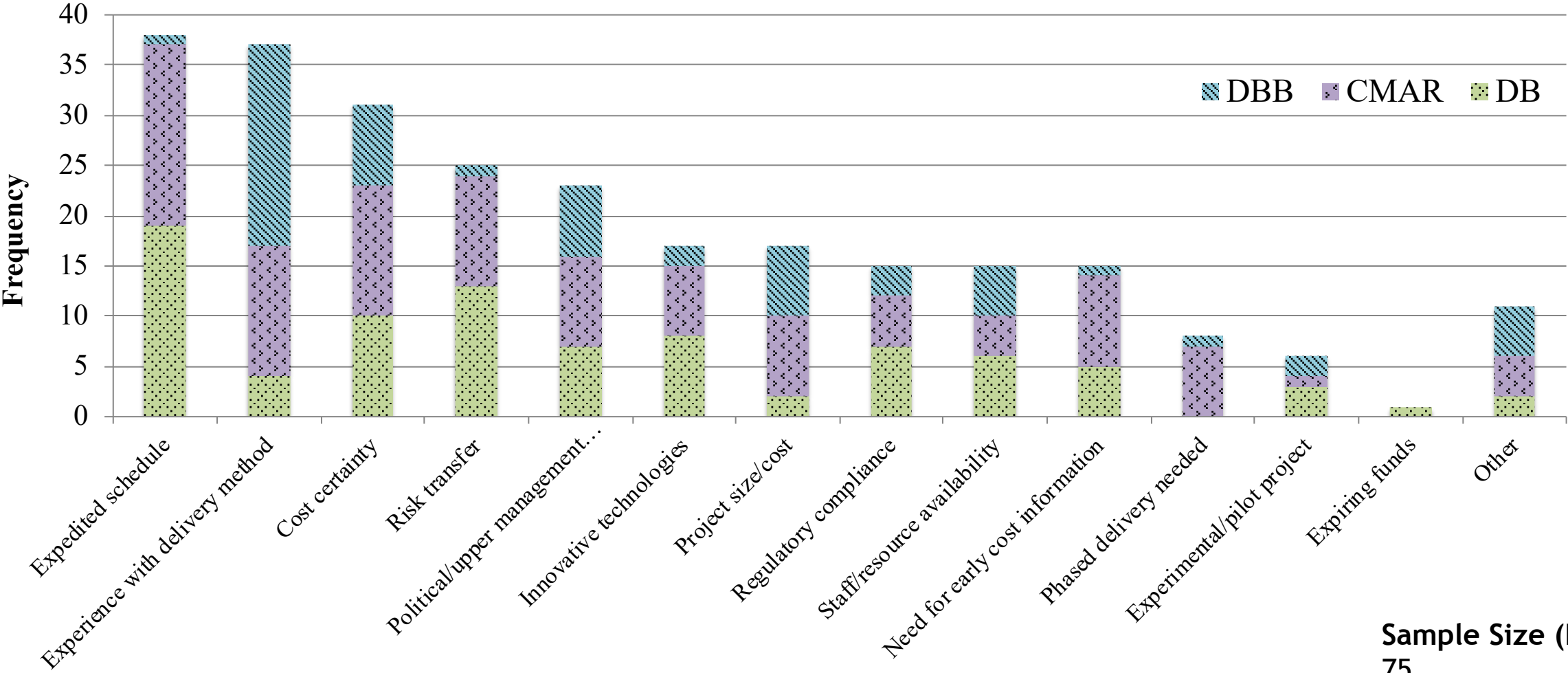
Procurement Process



Compensation Type

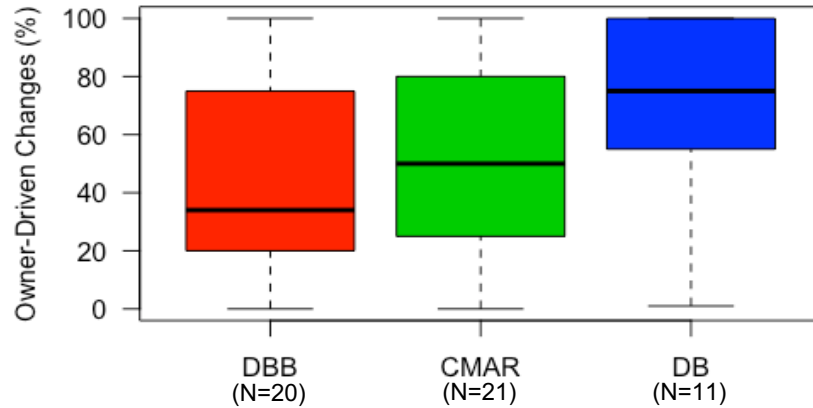


Factors for Project Delivery Method Selection



Scope Changes

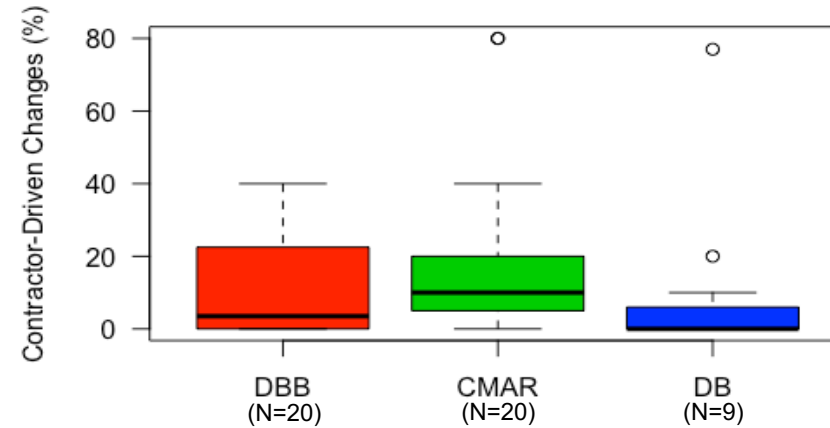
Owner-Driven Changes (%) vs. Delivery Method



p -value = 0.530

N = 52

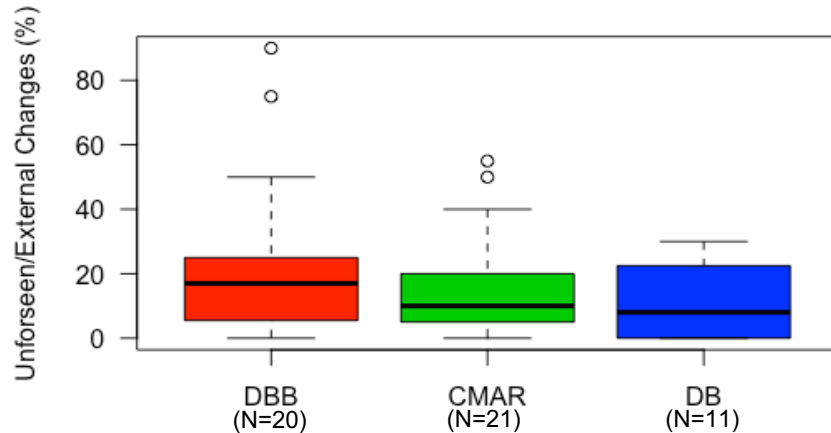
Contractor-Driven Changes (%) vs. Delivery Method



p -value = 0.014*

N = 49

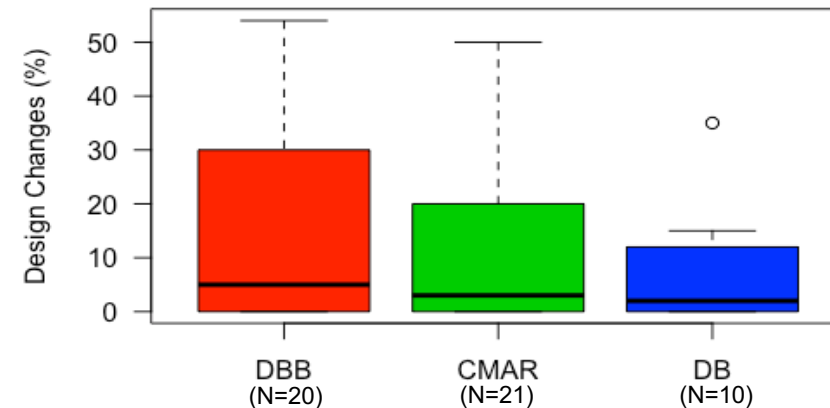
Unforeseen/External Changes (%) vs. Delivery Method



p -value = 0.413

N = 48

Design Changes (%) vs. Delivery Method



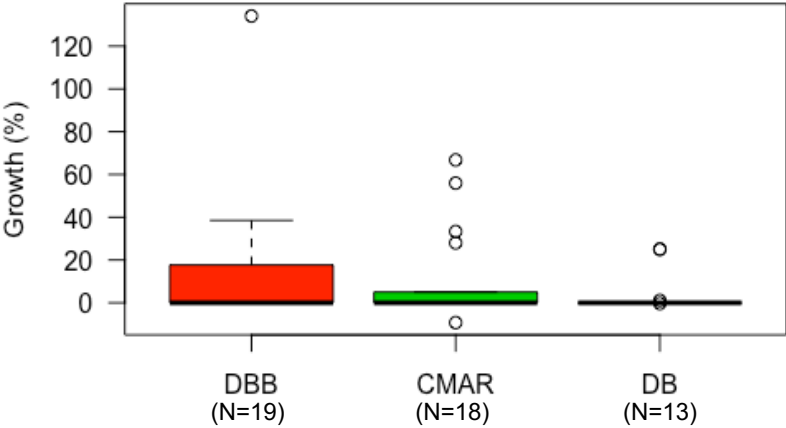
p -value = 0.367

N = 51

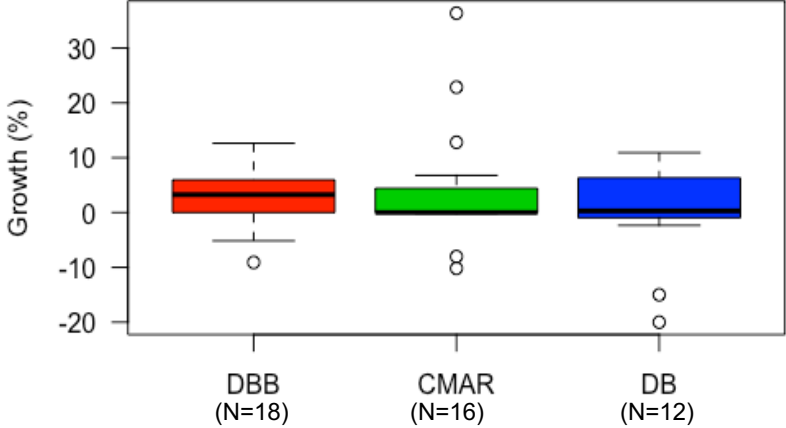
Cost Performance Metrics

p-value = 0.155
N = 44

Design Cost Growth vs. Delivery Method

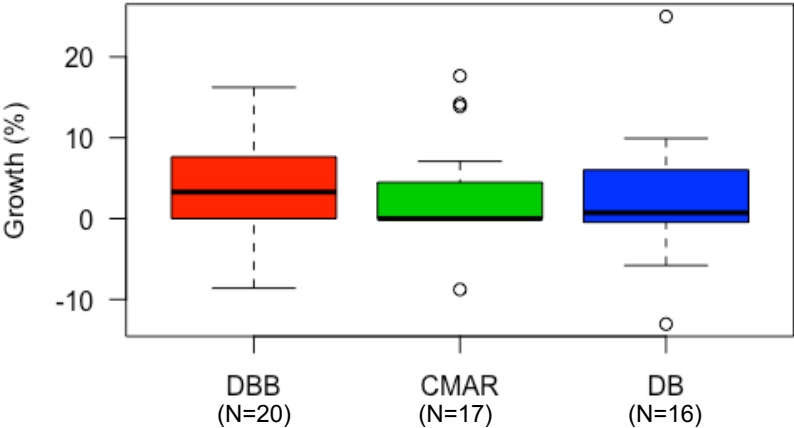


Construction Cost Growth vs. Delivery Method



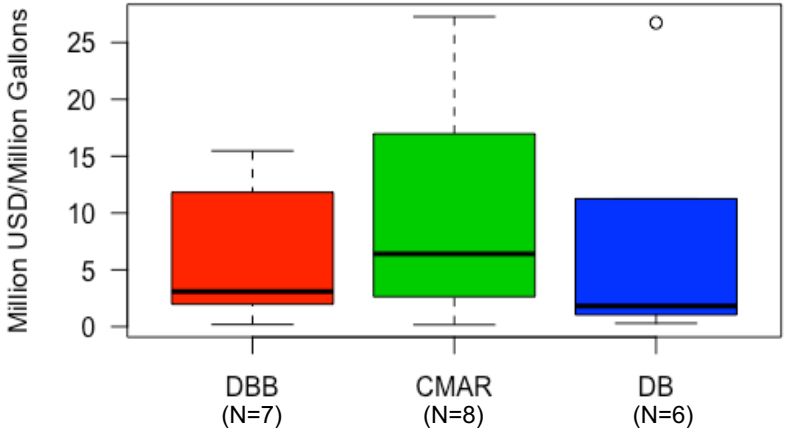
p-value = 0.445
N = 46

Total Cost Growth vs. Delivery Method



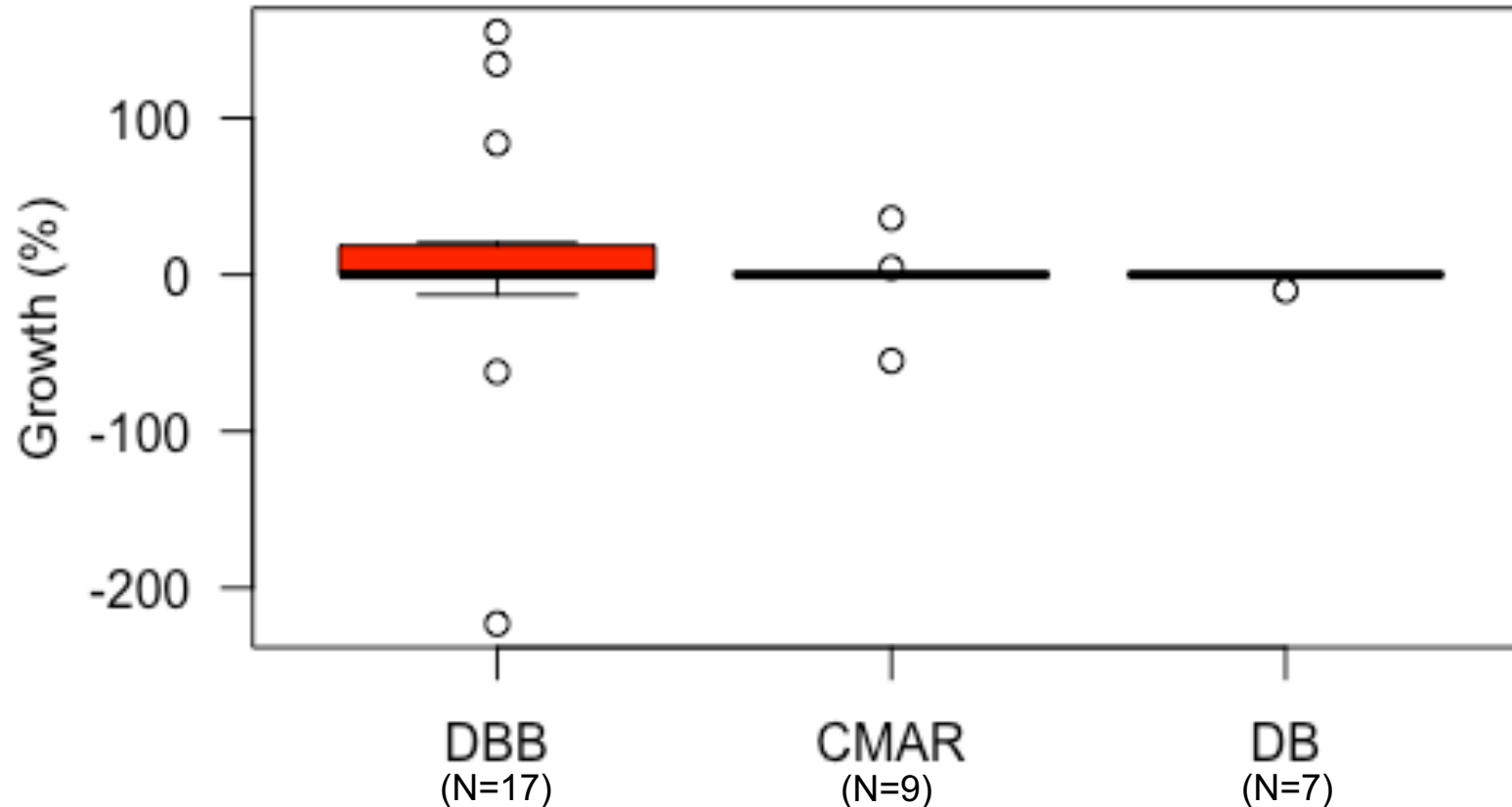
p-value = 0.465
N = 49

Unit Cost vs. Delivery Method



p-value = 0.632
N = 21

SCHEDULE: Design Schedule Growth



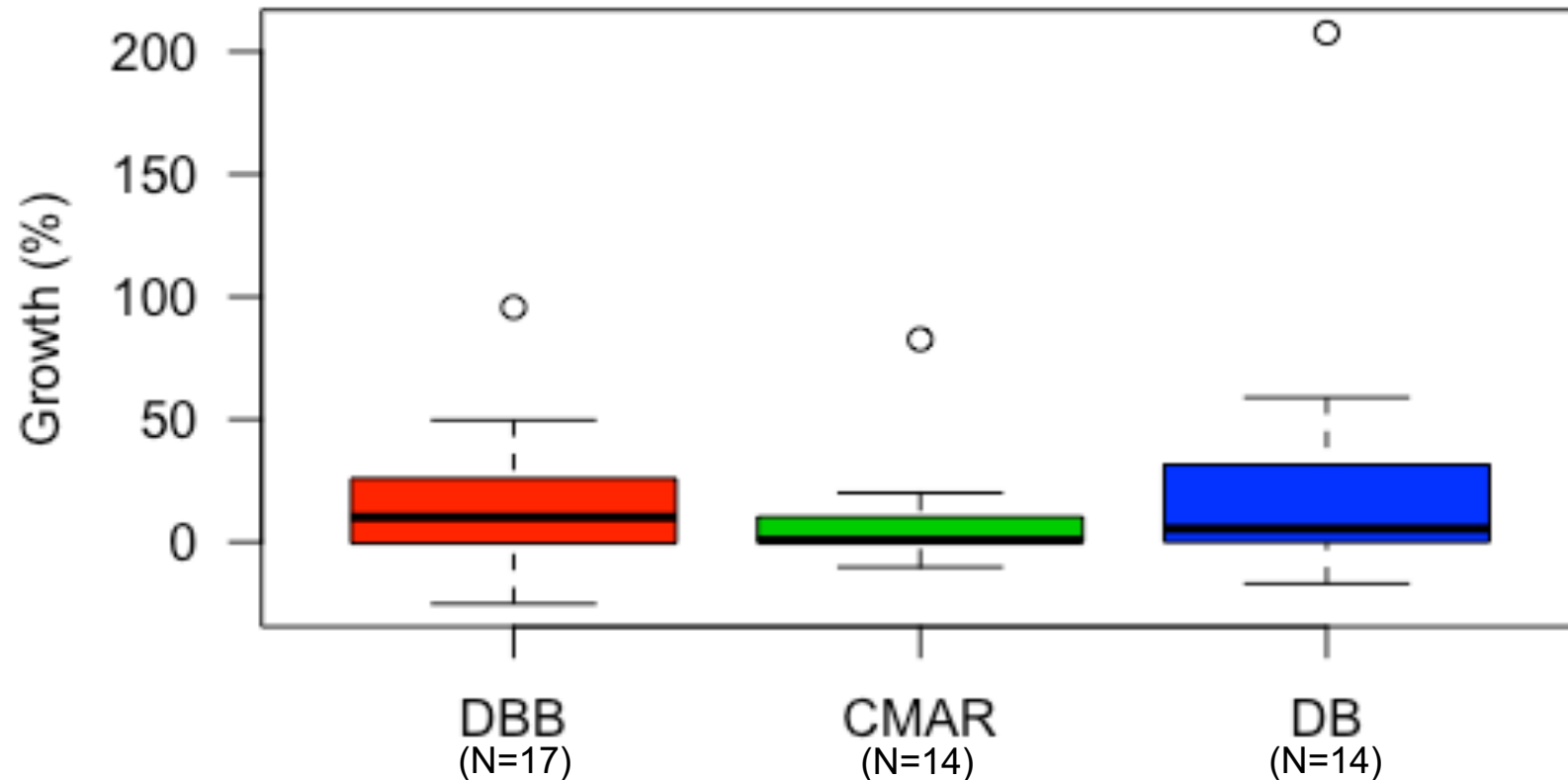
Delivery Method	Median	Average
DBB	0.00%	7.52%
CMAR	0.00%	-1.61%
DB	0.00%	-1.43%

- **Design Schedule Growth:** Variance of schedule of the actual design phase to the planned design phase (as a percentage)

p-value = 0.311

Sample Size (N) = 25

SCHEDULE: Construction Schedule Growth



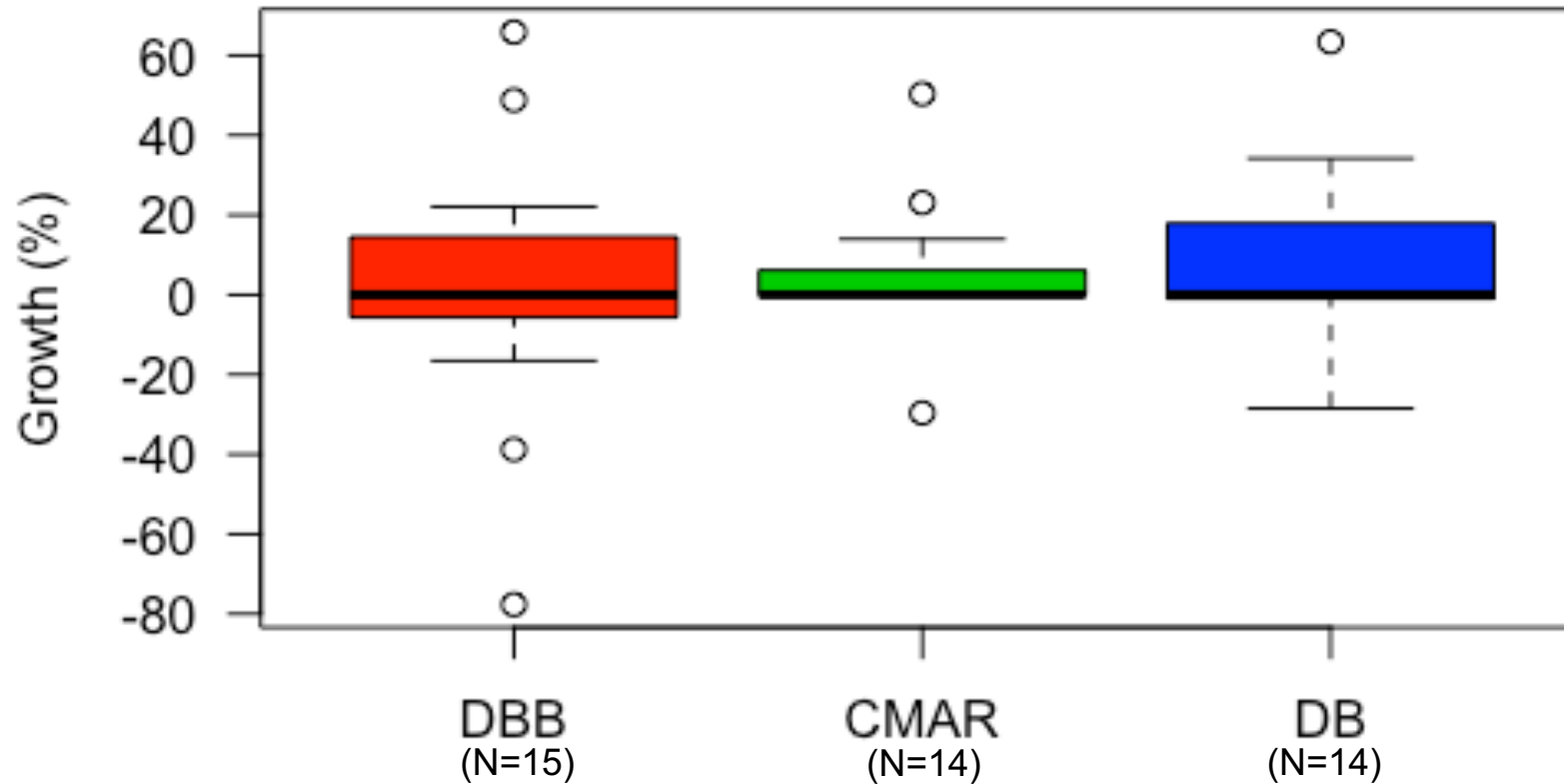
Delivery Method	Median	Average
DBB	10.09%	14.71%
CMAR	5.44%	9.43%
DB	0.73%	27.75%

- Construction Schedule Growth:** Variance of schedule of the actual construction phase to the planned construction phase (as a percentage)

p-value = 0.651

Sample Size (N) = 41

SCHEDULE: Total Schedule Growth



Delivery Method	Median	Average
DBB	0.00%	2.72%
CMAR	0.00%	4.96%
DB	0.00%	8.05%

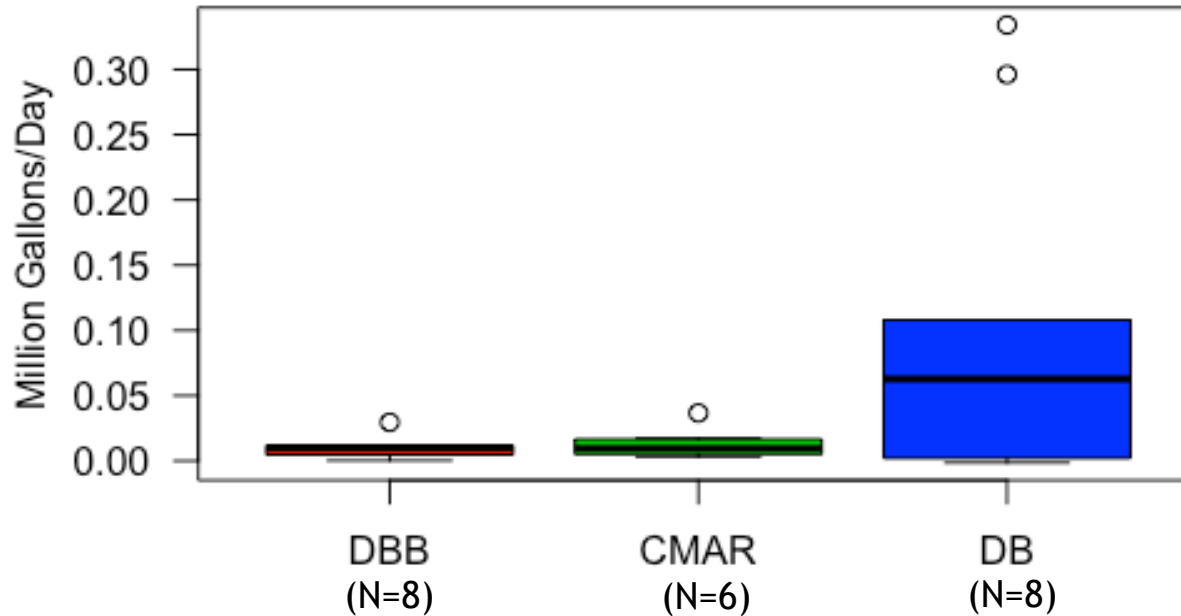
- **Total Schedule Growth:** Variance of schedule from design initiation to the actual substantial completion date to design initiation to the planned substantial completion date (as a percentage)

p-value = 0.940

Sample Size (N) =
37

SCHEDULE: Speed

Speed vs. Delivery Method



Delivery Method	Median	Average
DBB	0.0097	0.010
CMAR	0.0095	0.013
DB	0.0627	0.102

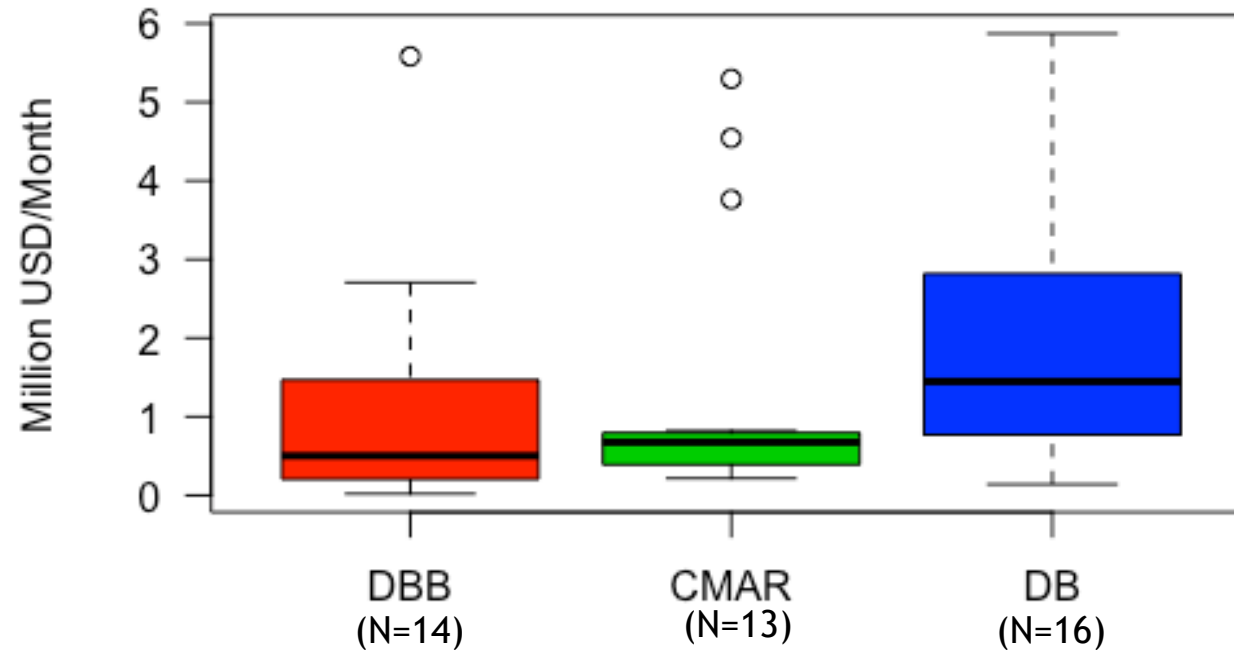
$$\text{Speed} = \frac{\text{Increased Capacity (Million Gallons)}}{\text{Day}}$$

$p\text{-value} = 0.026^*$

Sample Size (N) = 22

Intensity

Intensity vs. Delivery Method



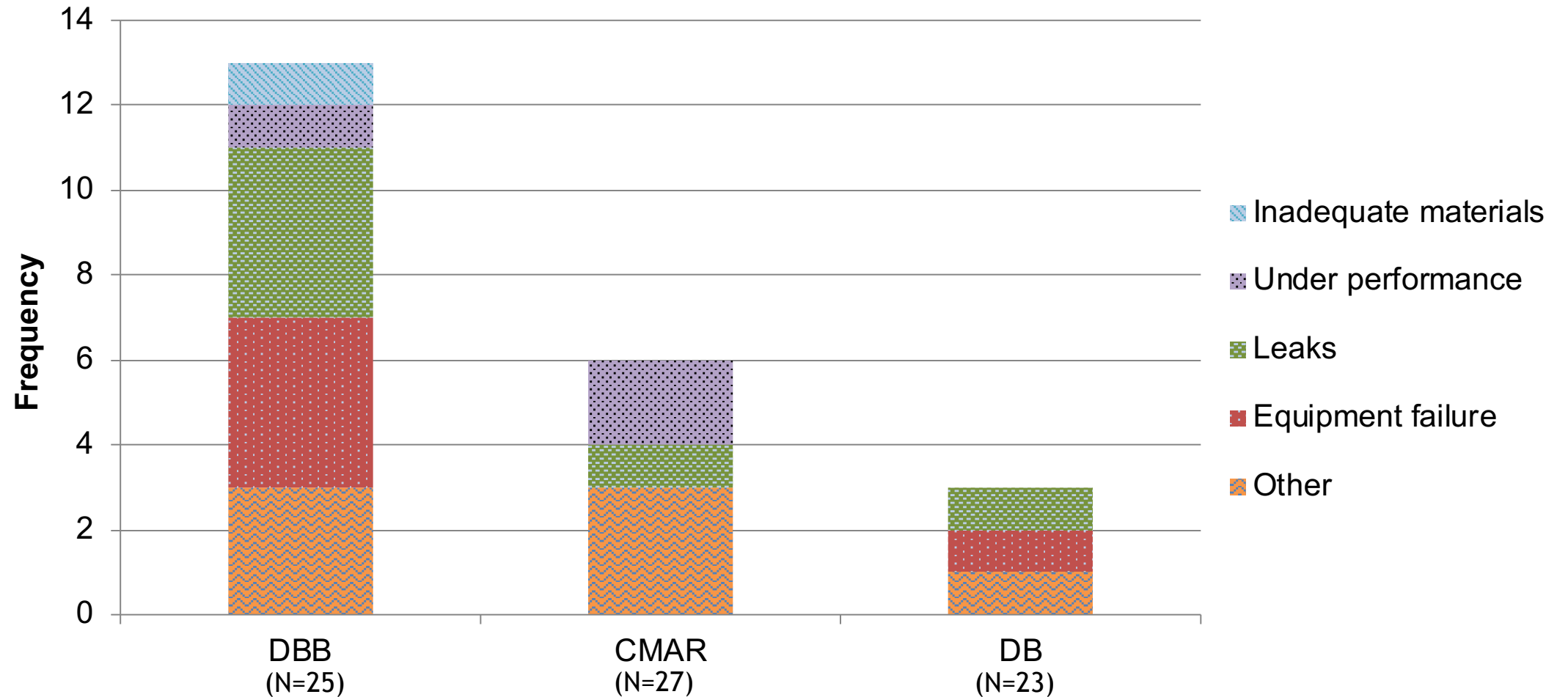
Delivery Method	Median	Average
DBB	0.50	1.16
CMAR	0.68	1.23
DB	1.45	2.07

$$\text{Intensity} = \frac{\text{Total Project Cost (\$Million)}}{\text{Total Project Duration (Months)}}$$

p-value = 0.008*

Sample Size (N) = 43

Warranty & Latent Defects



Conclusions

- The data set contained a sample size of **75 plant projects** focusing on **three delivery methods**: DBB, CMAR, and DB
- **DB statistically outperformed DBB** in terms of project speed and intensity
- Similar investigations **may increase the sample** size even further, and measure the performance impact of APDM for **water and wastewater pipeline** projects
- Ongoing research for developing a water and wastewater industry project delivery method **decision-support tool**

Technical Report

Ariaratnam, S., El Asmar, M., and Feghaly, J. (2018). Analyzing the Current Performance Impacts of Alternative Project Delivery in the Water and Wastewater Industry: Water Research Foundation Research Report. Water Research Foundation. Denver, CO (under review)

Journal Article

Feghaly, J., El Asmar, M., and Ariaratnam, S. (2018). Assessing the Performance Impact of Alternative Project Delivery Methods in the Water and Wastewater Industry. American Society of Civil Engineers Journal of Construction Engineering. Reston, VA (in process of submission)

Conference Presentations

- DBIA Design-Build for Water and Wastewater 2018 Conference. Portland, OR
- ASCE Pipelines 2018 Conference. Toronto, Canada

Industry Workshop

- American Water Works Association ACE 2018 Conference. Las Vegas, NV
- Industry Experts Workshop: Water Research Foundation Project #4685. Arizona State University. Tempe, AZ

Acknowledgements

- This work is funded by the Water Research Foundation (WRF) Project #4685 “*Project Delivery Performance Evaluation and Decision Support Tool for Water and Wastewater Capital Projects.*”



Acknowledgements



WATER DESIGN-BUILD COUNCIL
AN ASSOCIATION OF LEADING DESIGN BUILDERS



Thank you!

Any Questions?

