

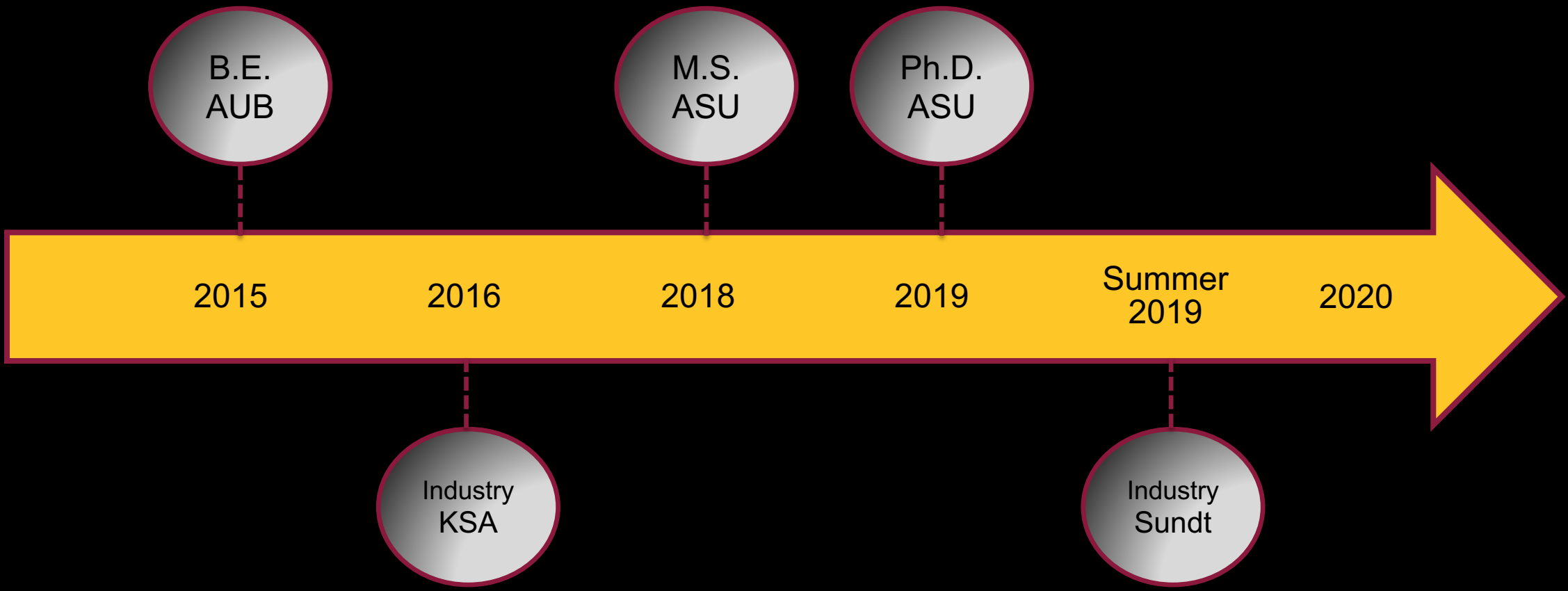
Innovative Delivery of Water Infrastructure Projects

PhD Dissertation Defense

by
Jeffrey Feghaly

Committee Members:
Dr. Mounir El Asmar, Co-Chair
Dr. Samuel Ariaratnam, Co-Chair
Dr. Wylie Bearup







2017

INFRASTRUCTURE REPORT CARD

2017 INFRASTRUCTURE REPORT CARD

AVIATION D	PARKS & RECREATION D+
BRIDGES C+	PORTS C+
DAMS D	RAIL B
DRINKING WATER D	ROADS D
ENERGY D+	SCHOOLS D+
HAZARDOUS WASTE D+	SOLID WASTE C+
INLAND WATERWAYS D	TRANSIT D-
LEVEES D	WASTEWATER D+

ASCE (2017)

Problem Statement

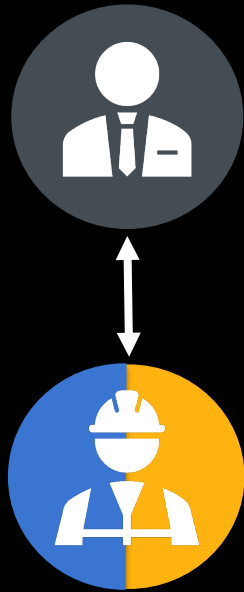
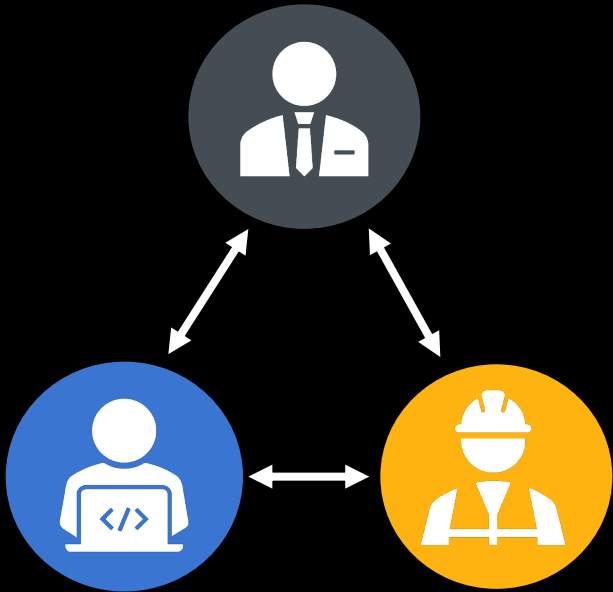
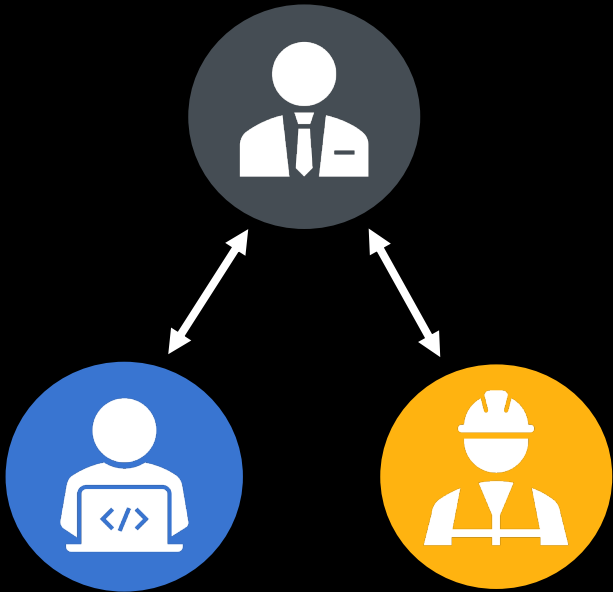
APDM presents an **opportunity** for water utilities

There is a **need** to understand **when**, **why**, and **how** different delivery methods can add value to water infrastructure projects

DBB

CMAR

DB



RESEARCH PHASES



RESEARCH PHASES



Literature Review

	DBB	CMAR	DB	Procurement	Execution	Speed	Intensity
Molenaar et al. (2004)	✗	✗	✓	✓	✓	✗	✗
Rao (2009)	✗	✓	✗	✓	✗	✗	✗
Bogus et al. (2010)	✓	✗	✓	✓	✗	✗	✗
Bogus et al. (2013)	✓	✗	✓	✓	✗	✗	✗
Francom et al. (2016)	✓	✓	✓	✓	✗	✗	✗
Shrestha et al. (2016)	✗	✓	✓	✓	✗	✗	✗
Shrestha et al. (2018)	✗	✓	✓	✓	✗	✗	✗
Feghaly (2020)	✓	✓	✓	✓	✓	✓	✓

Research Objectives #1 and #2

1. Assess the APDM **state of practice** during the procurement and execution of water infrastructure projects
2. Quantitatively assess the **performance impact** of APDM on water/wastewater treatment plant projects

Research Method

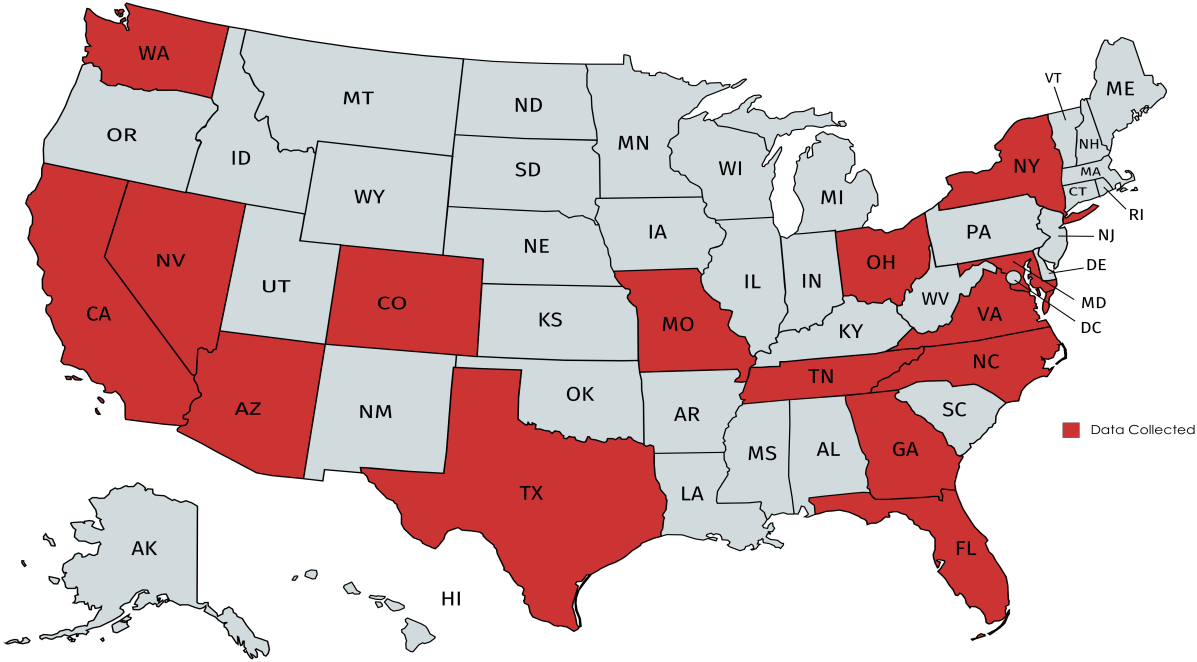
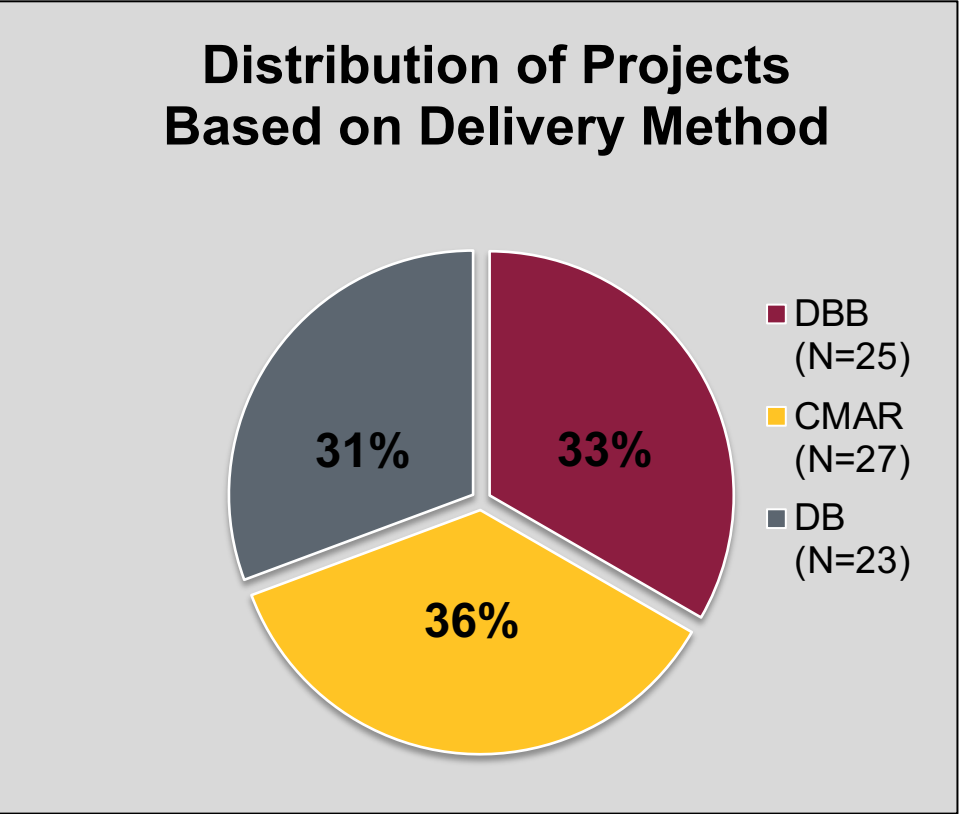
1. Review of Literature

2. Development of Data Collection
Survey & Industry Workshops

3. National Data Collection

4. Data Analysis

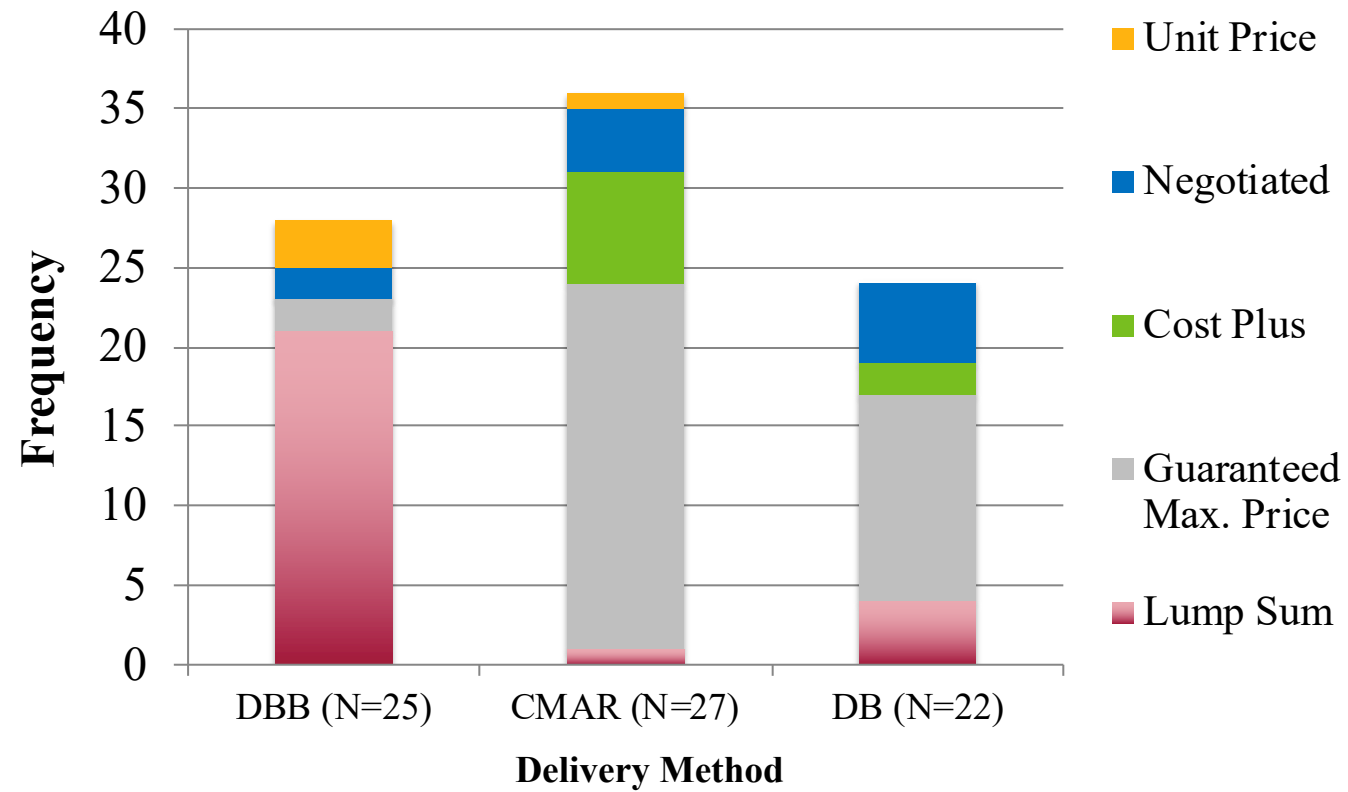
Data Characteristics



Created with mapchart.net ©

State of Practice: Results

Compensation Type



State of Practice: Results

Category	Delivery Method	Mean Value (Scale 1 to 5)	Median Value (Scale 1 to 5)
Utility Experience with Delivery Method	DBB	4.92	5
	CMAR	2.89	3
	DB	2.70	2
Utility Involvement in Design	DBB	4.56	5
	CMAR	4.44	5
	DB	3.83	4

H_0 = utility experience is the same for the delivery methods

H_1 = utility experience is not the same the delivery methods

State of Practice: Results

Duration between RFP and Contract Award	DBB (N=23)	CMAR (N=19)	DB (N=23)
1 to 2 Months	4 (17%)	3 (16%)	3 (13%)
3 to 4 Months	6 (26%)	6 (32%)	9 (39%)
5 to 6 Months	8 (35%)	5 (26%)	7 (31%)
Greater than 6 Months	5 (22%)	5 (26%)	4 (17%)

**statistically significant when p-value<0.05*

Performance: Results

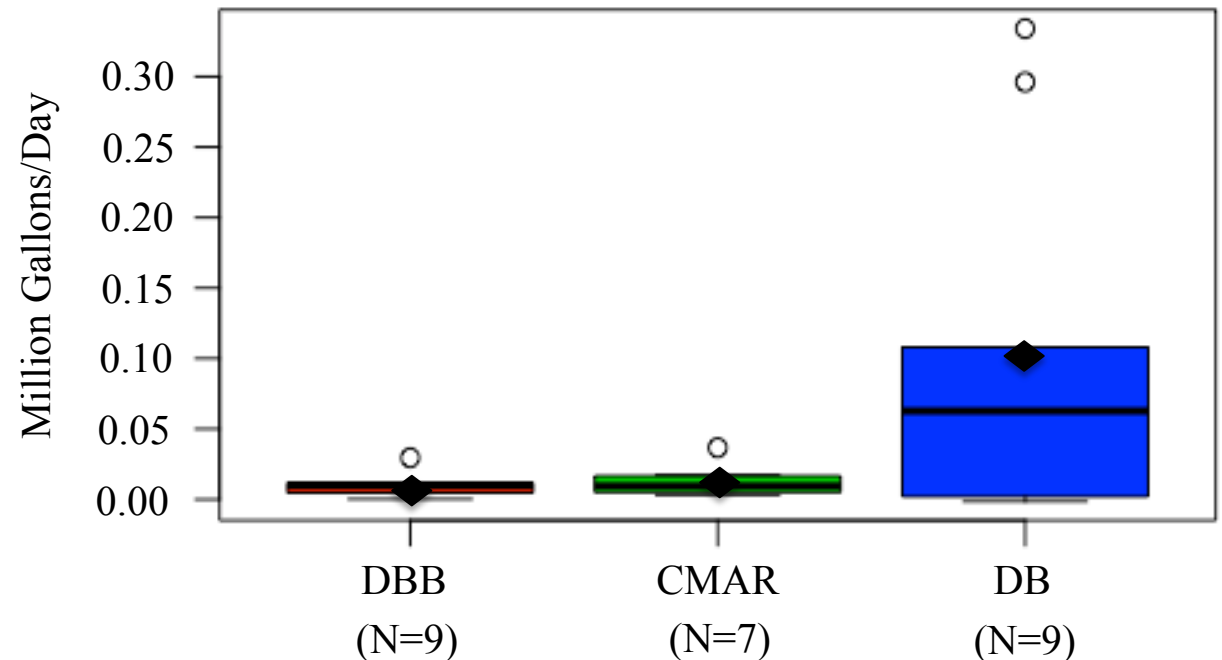
$$\text{Speed} = \frac{\text{Increased Plant Capacity (Million Gallons)}}{\text{Total Project Duration (Days)}}$$

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

p-value = 0.026*

Sample Size (N) = 22

Speed vs. Delivery Method



Performance: Results

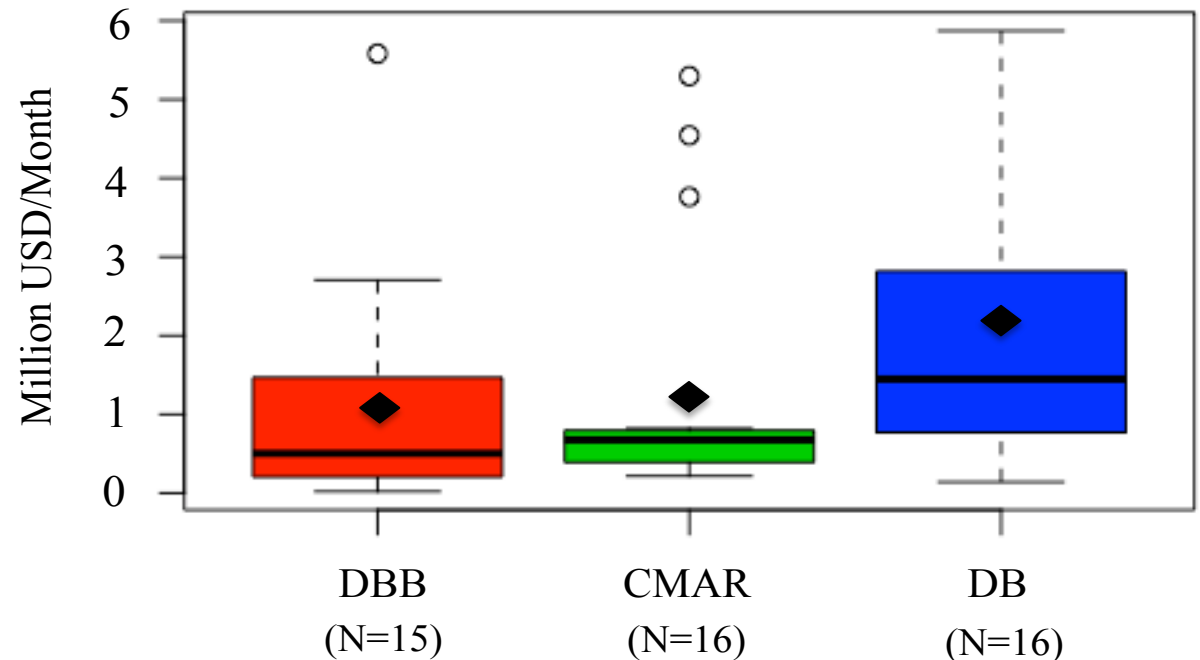
$$\text{Intensity} = \frac{\text{Total Project Cost (\$Million)}}{\text{Total Project Duration (Months)}}$$

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

p-value = 0.008*

Sample Size (N) = 43

Intensity vs. Delivery Method



RESEARCH PHASES

1

State of Professional Practice for Water Infrastructure Project Delivery



2

A Comparison of Project Delivery Method Performance for Water Infrastructure Capital Projects



3

Exploring Impacts on Unit Cost Performance for Water Infrastructure Project Delivery



4

Design-Build Project Administration Practices for the Water Industry



5

Selecting Project Delivery Methods for Water Infrastructure Projects



Resulted in a journal paper submitted to the ASCE Practice Periodical on Structural Design and Construction

Status: Accepted & In-Press

RESEARCH PHASES

1

State of Professional Practice for Water Infrastructure Project Delivery



2

A Comparison of Project Delivery Method Performance for Water Infrastructure Capital Projects



3

Exploring Impacts on Unit Cost Performance for Water Infrastructure Project Delivery



4

Design-Build Project Administration Practices for the Water Industry



5

Selecting Project Delivery Methods for Water Infrastructure Projects



Resulted in a journal paper submitted to the Canadian Journal of Civil Engineering

Status: Under Review

RESEARCH PHASES



Literature Review

	GMP	Experience	Involvement	Complexity	Chemistry	Size	Treatment Plants
Molenaar and Franz (2018)	✓	✓	✓	✓	✓	✓	✗
Molenaar and Songer (1998)		✓		✓	✓	✓	✓
Mafakheri et al. (2007)	✓	✓		✓		✓	✗
Shane et al. (2013)	✓		✓				✓
Tran et al. (2016)		✓	✓	✓			✗
Abi Shdid et al. (2018)			✓				✓
Feghaly (2020)	✓	✓	✓	✓	✓	✓	✓

Research Objective #3

To develop **exploratory** mathematical models that can observe the impact of project-specific factors and attributes on a water infrastructure project's **unit cost** performance

Research Method

- Analyzed the data using 75 completed treatment plant projects

$$\text{Unit Cost} = \frac{\text{Total Project Cost (Million USD)}}{\text{Increased Plant Capacity (Million Gallons Per Day)}}$$

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k + \varepsilon$$




$$\text{Unit Cost} = \text{Constant} + \underline{\text{Variable}_1 X_1} - \underline{\text{Variable}_2 X_2} + \dots$$



Cohen et al. (2003)

Variable No.	Factor/Attribute	Definition
V1	Use of GMP on Project	1=Yes; 0=No
V2	Project Team Experience with Delivery Method	1 to 15 (summation of owner, designer and constructor experience); - Owner Experience: 1=no experience; 5=highly experienced; - Designer Experience: 1=no experience; 5=highly experienced; - Constructor Experience: 1=no experience; 5=highly experienced
V3	Level of Design Completed Before Constructor Engagement	0% to 100% of design completion
V4	Project Complexity	Score ranging from 0 to 16 (summation of all applicable complexity issues on respondent's project)
V5	Project Team Chemistry/Communication	1=Very low; 5=Very high
V6	Project Size	In million gallons per day (MGD)

Multiple Linear Regression

Independent Variable	β (\$M/MGD)	<i>p</i> -value
Constant	14.913	0.031*
Use of GMP on Project	 -1.437	0.502
Project Team Experience with Delivery Method	-0.250	0.609
Level of Design Completed before Constructor Engagement	 0.039	0.322
Project Complexity	0.828	0.059
Project Team Chemistry/Communication	 -3.56	0.007*
Project Size	-0.016	0.193

*Statistical significance at p -value < 0.05

$R^2 = 0.846$
F-statistic: 5.475
p-value: 0.029*

RESEARCH PHASES

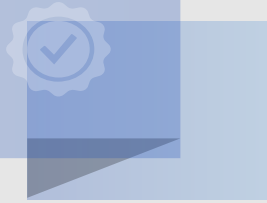
1

State of Professional Practice for Water Infrastructure Project Delivery



2

A Comparison of Project Delivery Method Performance for Water Infrastructure Capital Projects



3

Exploring Impacts on Unit Cost Performance for Water Infrastructure Project Delivery



4

Design-Build Project Administration Practices for the Water Industry



5

Selecting Project Delivery Methods for Water Infrastructure Projects



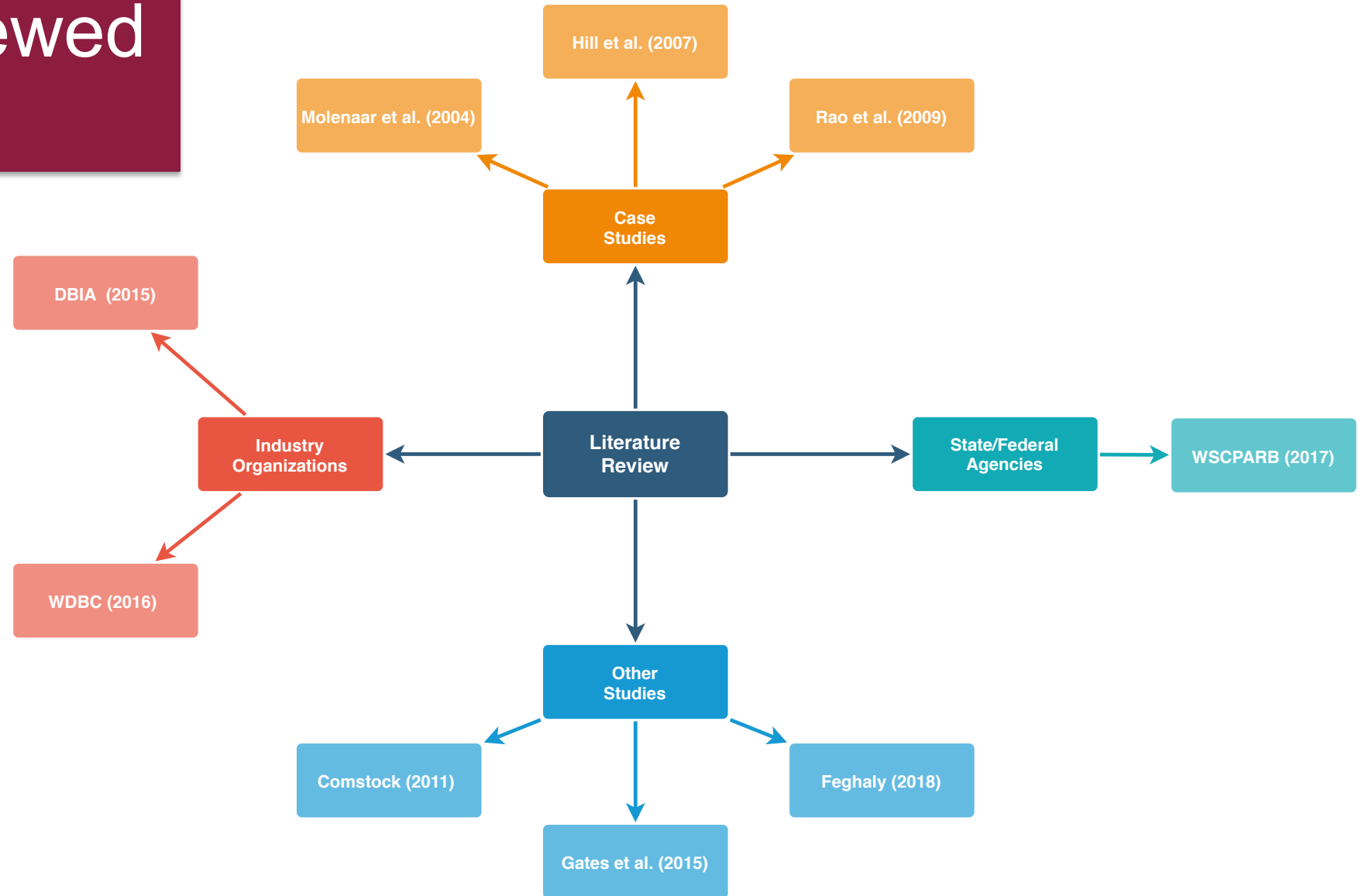
Resulted in a journal paper to be submitted to the Journal of Construction Engineering and Management

Status: In preparation

RESEARCH PHASES



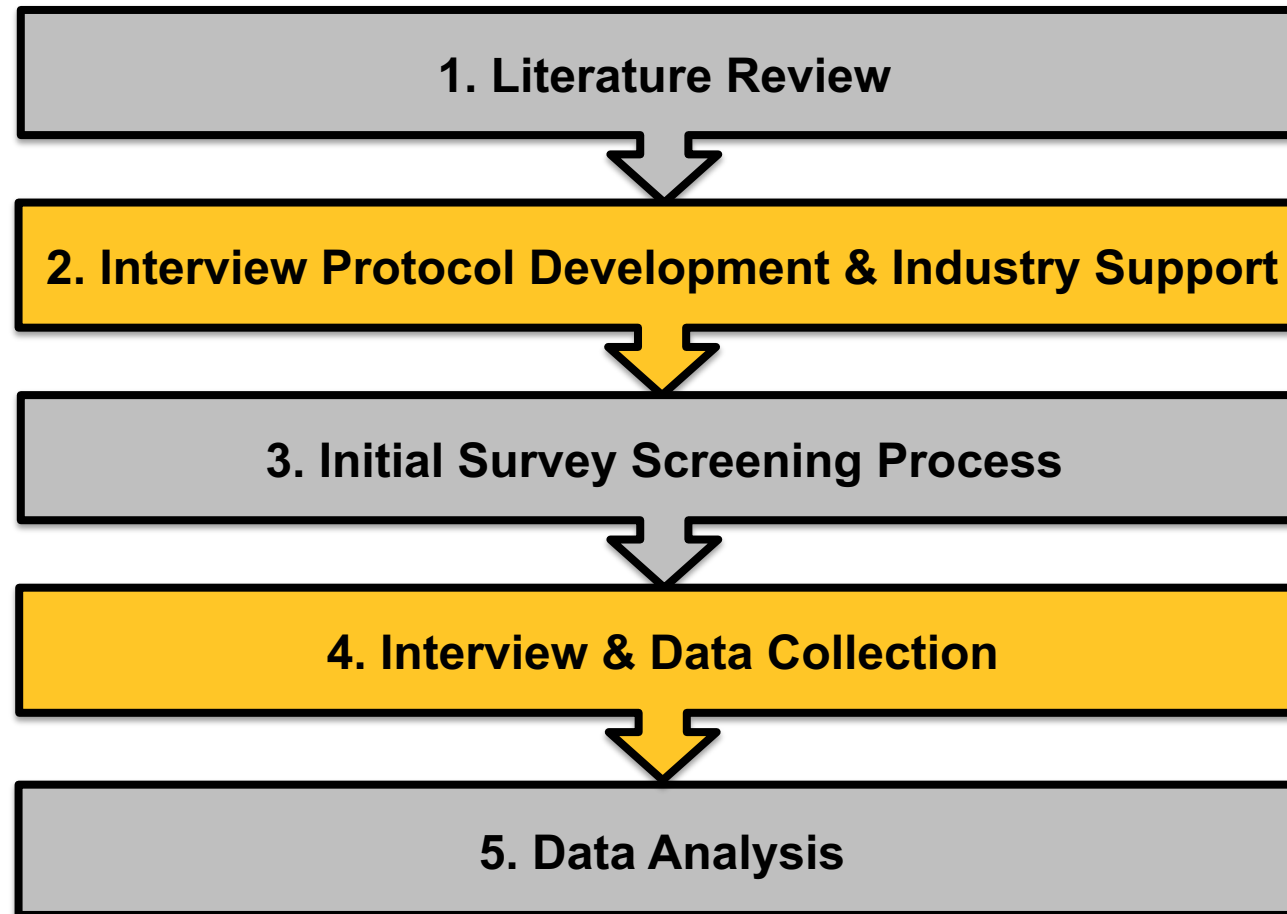
Sample of Reviewed Literature



Research Objective #4

To benchmark **successful practices** that help water utilities in administering **DB** projects

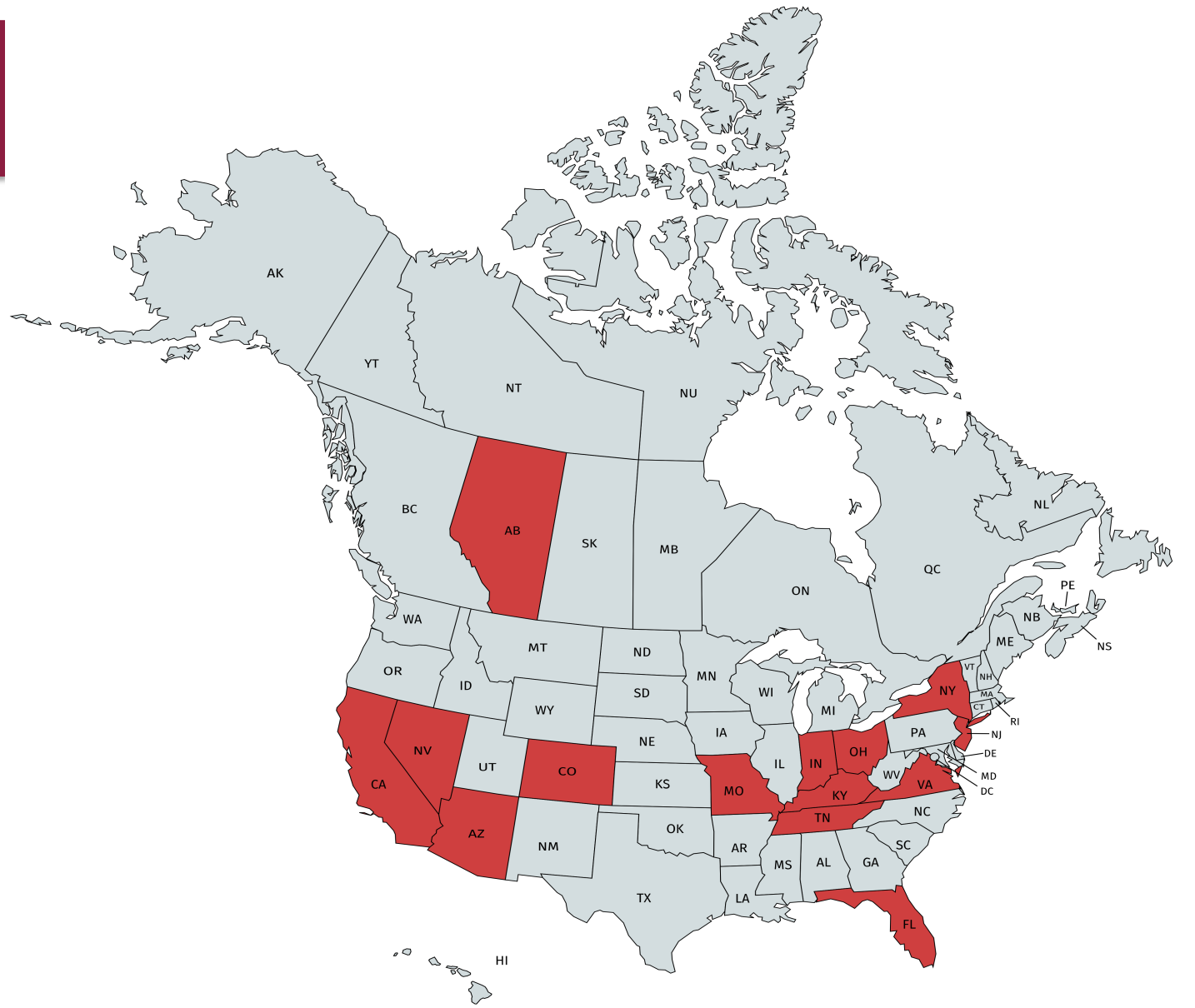
Research Methodology



Interview Protocol

No.	Key Category	Subcategories of Interest	No. of Questions
1	Procurement	<ul style="list-style-type: none"> In-house design completion Percentage of total costs allocated for design Proposal evaluation 	16
2	DB Roles & Responsibilities	<ul style="list-style-type: none"> Project team size and roles Owner level of involvement & control Public relations & permitting 	11
3	Risk & Quality Management	<ul style="list-style-type: none"> Risk register Quality assurance and quality control 	7
4	Design	<ul style="list-style-type: none"> Scope validation Geotechnical and environmental investigations 	9
5	Design Review & Submittal Review	<ul style="list-style-type: none"> Design review schedule and meetings Operations & maintenance team involvement RFI & submittal review process 	10
6	Cost & Schedule Estimates	<ul style="list-style-type: none"> Schedule development Guaranteed maximum price (GMP) 	6
7	Communication & Information Flow	<ul style="list-style-type: none"> Stakeholder collaboration Minimizing impact on existing operations 	8

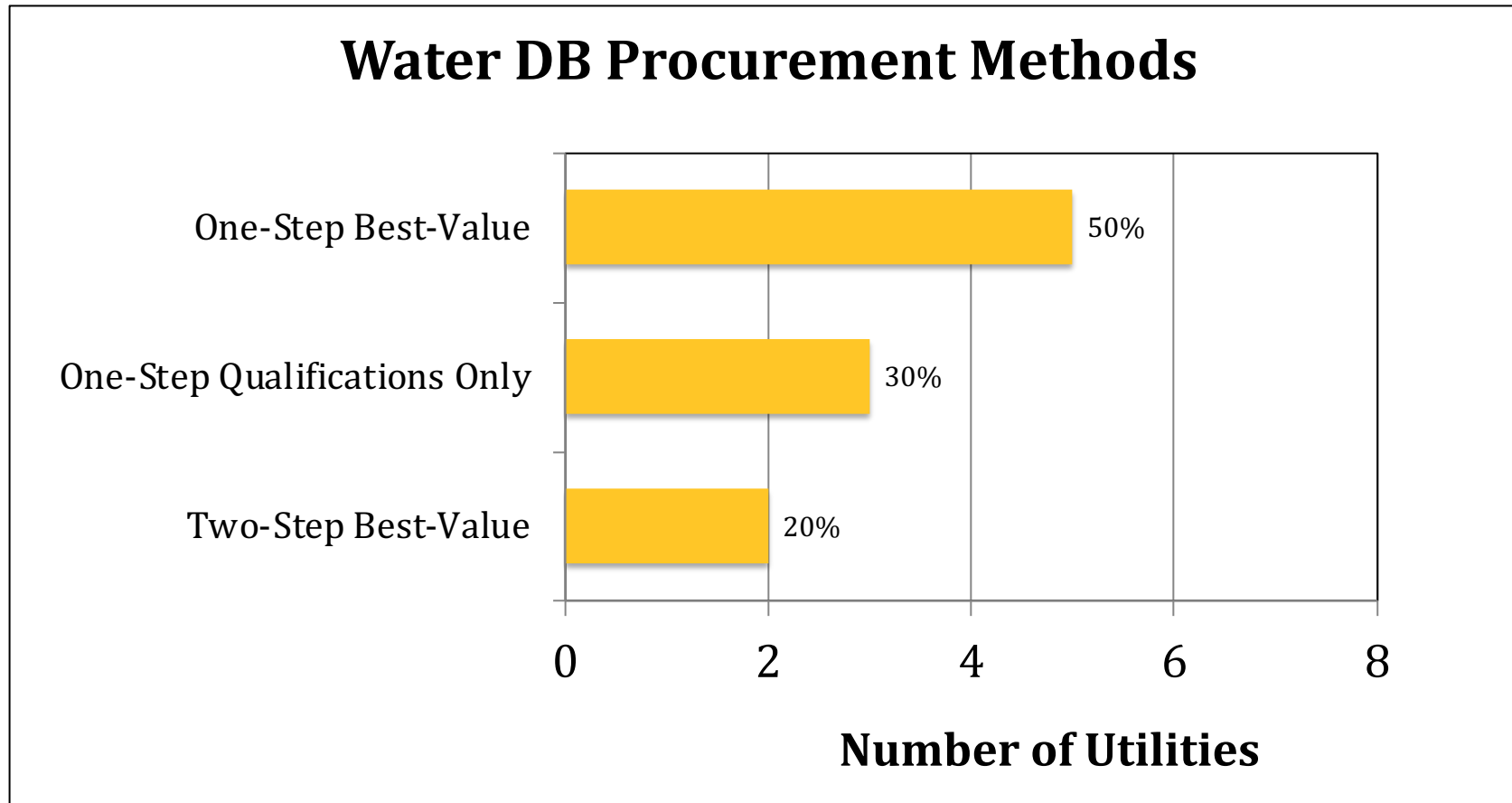
Data Characteristics



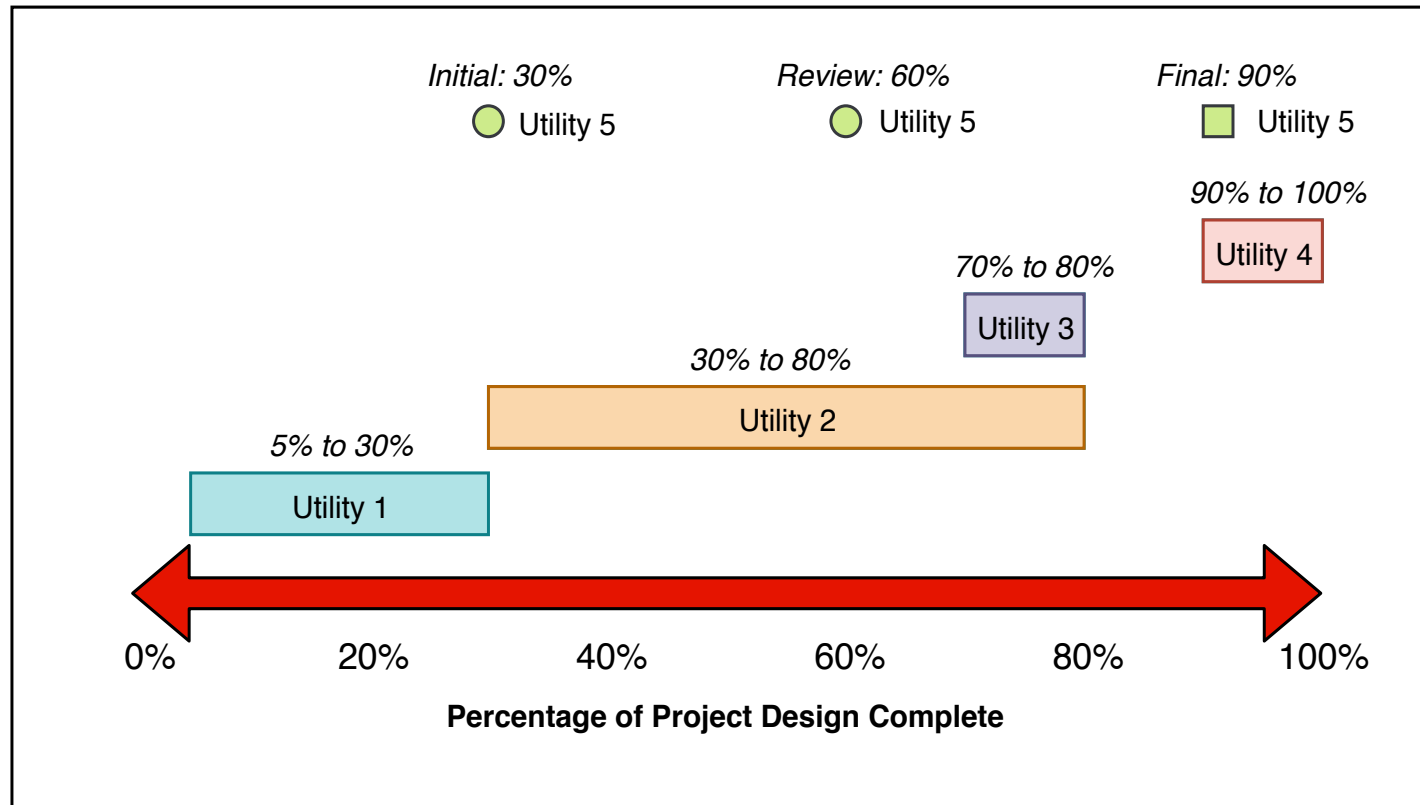
DB Practices: Results

No.	Key Category	No. of identified DB Practices
1	Procurement	7
2	DB Roles & Responsibilities	3
3	Risk & Quality Management	6
4	Design	3
5	Design Review & Submittal Review	3
6	Cost & Schedule Estimates	3
7	Communication & Information Flow	3
Total		28

DB Practices: Results



DB Practices: Results



RESEARCH PHASES

1

State of Professional Practice for Water Infrastructure Project Delivery



2

A Comparison of Project Delivery Method Performance for Water Infrastructure Capital Projects



3

Exploring Impacts on Unit Cost Performance for Water Infrastructure Project Delivery



4

Design-Build Project Administration Practices for the Water Industry



5

Selecting Project Delivery Methods for Water Infrastructure Projects



1. Resulted in a journal paper submitted to the ASCE Journal of Pipeline Systems Engineering and Practice

Status: Under Review

2. Resulted in a conference paper submitted to the ASCE Pipelines 2019 Conference

Status: Published

RESEARCH PHASES



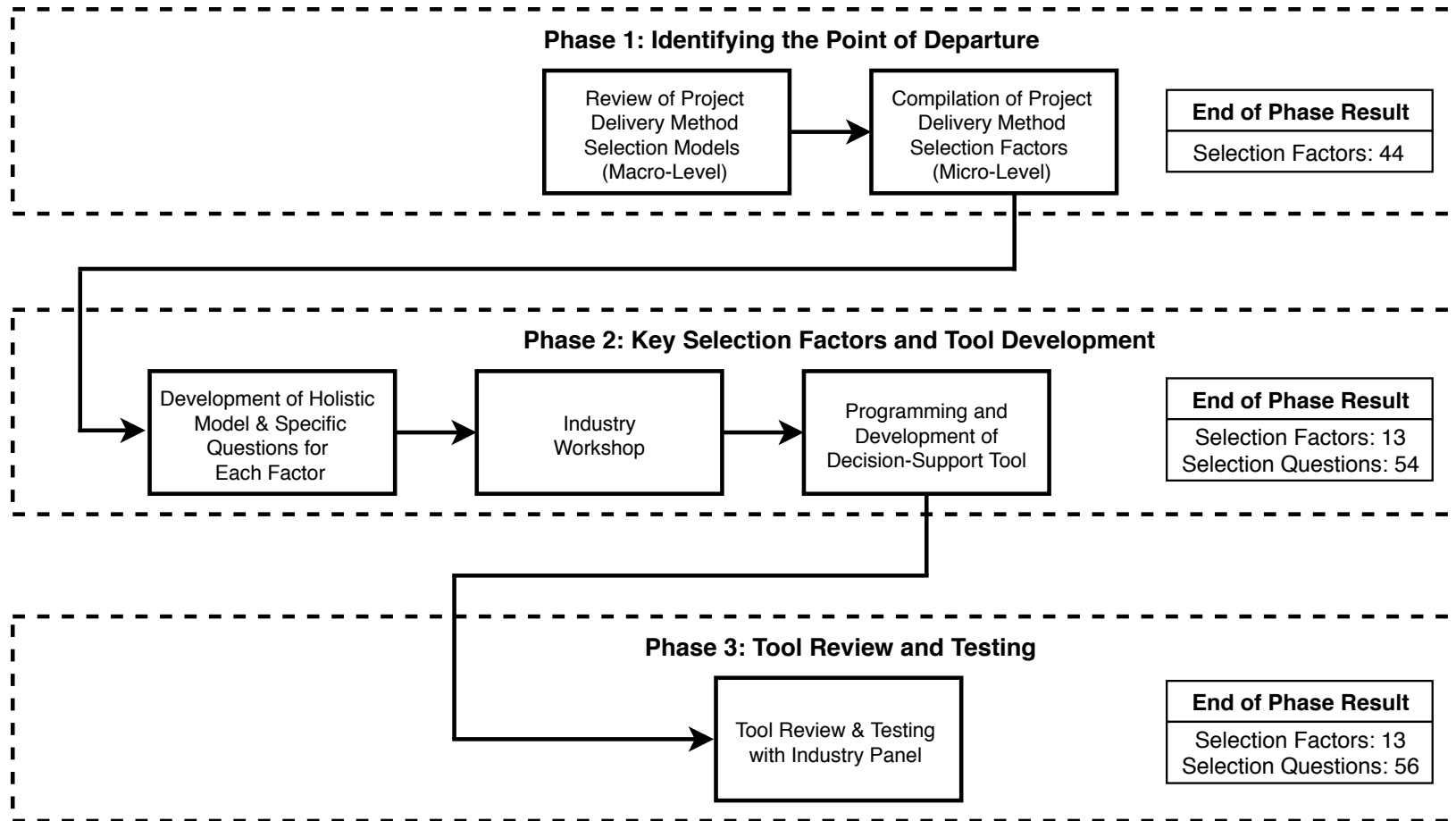
Literature Review

	Industry	No. of Factors	Water Industry	Web-Based
ACRP (2009)	Airports	19	✗	✗
TCRP (2009)	Transit	24	✗	✗
CDOT (2014)	Transportation	8	✗	✗
WSDOT (2016)	Transportation	20	✗	✗
ADEED (2017)	Education	10	✗	✗
TWDB (2002)	Water	-	✓	✗
WDBC (2016)	Water	-	✓	✗
Feghaly (2020)	Water	✓	✓	✓

Research Objective #5

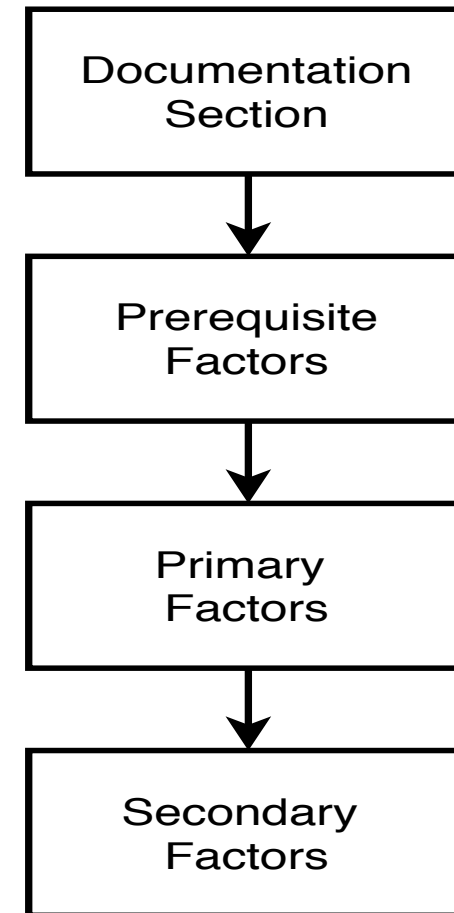
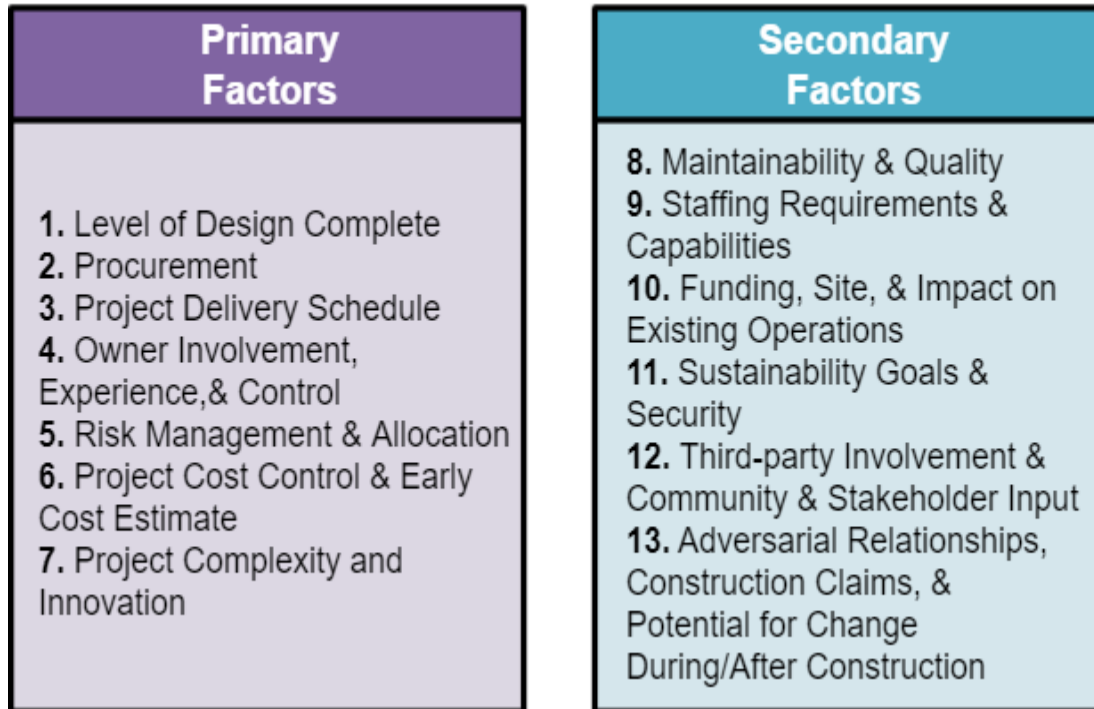
To identify key project delivery method **selection factors** and develop a **project delivery selection model** for the water industry

Research Methodology



Selection Factors	Comstock (2011)	Culp (2011)	Meszaros (2011)	Touran (2011)	ACI-NA, ACC, AGC (2012)	CMAA (2012)	AIA, AGC (2012)	Shorney-Darby (2012)	Tran (2013)	Benson et al. (2013)	CDOT (2014)	AWWA (2014)	Liu et al. (2014)	DBIA (2015)	King (2015)	Gates et al. (2015)	Giachino et al. (2015)	Canon and Hidebrand (2015)	WSDOT (2016)	WDBC (2016)	Fredell et al. (2016)	Mogerman (2016)	OCPWD (2017)	Jaime Partners Staff (2017)	ADEED (2017)	MnDOT (n.d.)	Post-2010 Total	All-time Total		
Schedule/Speed		x	x	x		x	x			x	x		x	x	x	x	x	x	x	x	x		x	x	x	x	19	42		
Risk Avoidance/Strategy		x		x	x	x	x				x		x	x		x	x	x	x			x		x		x	x	15	33	
Size/Budget					x	x	x	x			x			x		x	x	x	x	x	x	x					x	x	16	25
Scope/Clarity				x	x	x		x	x	x	x							x	x	x			x			x	x	13	24	
Quality	x	x								x		x				x	x	x				x						8	23	
Permitting/Regulatory Issues				x	x	x	x	x	x						x	x	x		x				x			x	x	13	23	
Owner Involvement					x	x				x			x	x		x	x	x		x			x		x	x	x	12	22	
Responsibility			x						x				x		x		x	x					x					7	20	
Complexity/Innovation	x			x				x	x		x							x	x					x			x	9	20	
Flexibility															x								x					2	16	
Certainty/Room for Change					x														x							x		4	16	
Contractor Needs/Capabilities/Input				x	x				x		x					x	x									x	x	8	16	
Project Characteristics	x	x			x	x			x			x	x						x									8	15	
Capital Costs	x	x			x					x						x	x			x			x					9	14	
Owner Experience			x	x	x					x								x						x	x			7	13	
Lifecycle Costs				x	x											x			x				x					5	13	
Communication		x														x	x	x		x	x							6	12	
Funding/Financial Issues																			x				x				x	x	4	12
Characteristics of Owner or Contractor					x						x		x													x	x	5	11	
Dispute Resolution/Minimalization				x						x																x		3	11	
Contract Pricing															x													1	10	
Market Attributes/Knowledge				x		x																						2	7	
Design Control/Interaction													x						x									2	6	
Value Engineering																						x						2	6	
Competition											x																x	x	3	5
Pre-construction Issues																	x											1	4	
Sustainability Goals					x																						x	2	4	
Third-Party Agreements																			x								x	2	4	
Impact on Existing Facility/Operations					x														x									2	3	
Efficient Decision-making																												0	3	
Client Satisfaction																												0	2	
Disadvantaged Business Enterprise																												0	2	
Maintainability																												0	2	
Community & Stakeholders Input																								x				1	2	
Environmental Constraints																			x									1	1	
Labor Unions																												0	1	
Constructability						x																						1	1	
Technological Capabilities						x																						1	1	
Commissioning																												0	1	
Safety Concerns																											x	1	1	
Overlap of Desing/Construction																											x	1	1	
Culture																												0	1	
Project Type																												1	1	
Utility Relocation																												1	1	

APDM Selection: Results



APDM Selection: Results

34%

Procurement



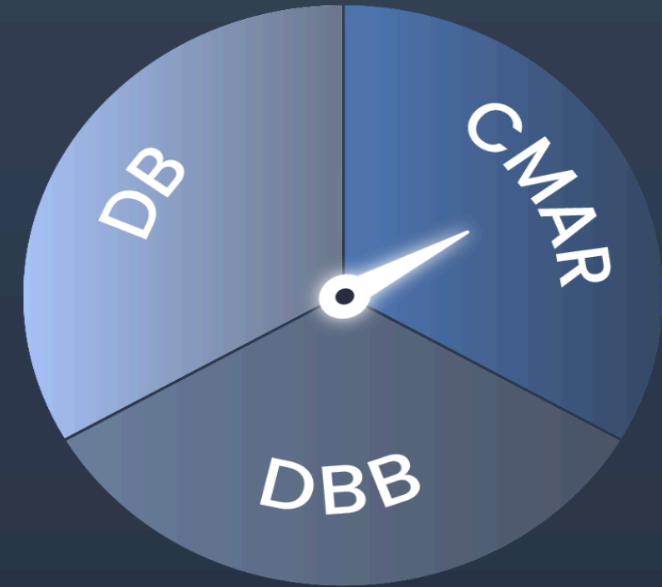
Is the utility allowed to, and is it seeking to include the construction team's qualifications as part of the procurement selection factors?



Yes



No



[Back](#) [Section](#) [Next](#)

APDM Selection: Results

63%

Please refer to the gauge to obtain the most favorable delivery method(s) recommended for your project based on the evaluation of the primary factors. The score is reflected under the gauge as a percentage out of a maximum 100% for each project delivery method. The delivery method with the highest percentage is the most favorable method for your project. If your team is satisfied with the recommendation, you may stop the evaluation process at this time by printing the results and closing this window. Alternatively, if you would like to continue and evaluate secondary factors that may influence your decision, you can simply click next.



DBB CMAR DB
37% 63% 78%

Back

Section

Next

Print

RESEARCH PHASES

1

State of Professional Practice for Water Infrastructure Project Delivery



2

A Comparison of Project Delivery Method Performance for Water Infrastructure Capital Projects



3

Exploring Impacts on Unit Cost Performance for Water Infrastructure Project Delivery



4

Design-Build Project Administration Practices for the Water Industry



5

Selecting Project Delivery Methods for Water Infrastructure Projects



1. Resulted in a journal paper submitted to the Journal of Engineering, Construction, and Architectural Management

Status: Published

2. Resulted in a conference paper submitted to the ASCE CRC 2020 Conference

Status: Accepted & In-Press

Problem Statement

There is a **need** to understand **when**, **why**, and **how** different delivery methods can add value to water infrastructure projects

RESEARCH CONTRIBUTIONS

1

State of Professional Practice for Water Infrastructure Project Delivery

- GMP is the preferred compensation type for APDM projects
- Utilities statistically have the lowest experience in delivering DB water projects



2

A Comparison of Project Delivery Method Performance for Water Projects

- DB statistically outperforming DBB in project speed and intensity performance



3

Exploring Impacts on Unit Cost Performance for Water Infrastructure Delivery

- Explored the impact of seven project-specific factors and attributes on unit cost performance
- Project team chemistry and communication has the highest impact on unit cost



4

Design-Build Project Administration Practices for the Water Industry

- Identified effective DB project administration practices, from a reasonably large geographically dispersed sample, under key seven categories across a project's delivery timeline



5

Selecting Project Delivery Methods for Water Infrastructure Projects

- Identified 13 key project delivery method selection factors for the water industry
- Developed EXPRSS-TP, a pioneering web-based delivery method decision-support tool



Future Work and Next Steps

- Future research can build on the work of this study:
 - Increase sample sizes to improve accuracy of results
 - Develop predictive performance models
 - Explore other APDM such as job order contracting (JOC) or integrated project delivery (IPD)
 - Build a similar decision-support tool for other industries (e.g., pipeline, energy)
- Continue collaborating with ASU to produce high quality research by bringing in my industry perspective

Journal Papers

- **Feghaly, J.**, El Asmar, M., Ariaratnam, S., and Bearup, W. (2019). “Selecting Project Delivery Methods for Treatment Plant Projects.” *Engineering, Construction, and Architectural Management*. Vol. ahead-of-print, No. ahead-of-print, doi: 10.1108/ECAM-06-2019-0308
- **Feghaly, J.**, El Asmar, M., and Ariaratnam, S. (2020). “State of Professional Practice for Water Infrastructure Project Delivery.” *Practice Periodical on Structural Design and Construction*, American Society of Civil Engineers (*in press*)
- **Feghaly, J.**, El Asmar, M., and Ariaratnam, S. (2020). “A Comparison of Project Delivery Method Performance For Water Infrastructure Capital Projects.” *Canadian Journal of Civil Engineering*, Canadian Society of Civil Engineers (*under review*)
- **Feghaly, J.**, El Asmar, M., Ariaratnam, S., and Bearup, W. (2020). “Design-Build Project Administration for the Water Industry.” *Journal of Pipeline Systems Engineering and Practice*, American Society of Civil Engineers (*under review*)
- **Feghaly, J.**, El Asmar, M., and Ariaratnam, S. (2020). “Exploring Impacts on Unit Cost Performance for Water Infrastructure Project Delivery.” *Journal of Construction Engineering and Management*, American Society of Civil Engineers (*in preparation*)

Conference Papers & National Reports

- **Feghaly, J.**, El Asmar, M., and Ariaratnam, S. (2019). “Design-Build Project Administration: Case Studies from Water Utilities in the US Southwest/Pacific Region.” *American Society of Civil Engineers 2019 Pipelines Conference*, Nashville, Tennessee, doi:10.1061/9780784482490.049
- **Feghaly, J.**, Ayer, S., and El Asmar, M. (2020). “Assessing the Impact of Building Information Modeling and Alternative Project Delivery Methods.” *American Society of Civil Engineers CRC 2020*, Tempe, Arizona (*in press*)
- **Feghaly, J.**, El Asmar, M., and Ariaratnam, S. (2020). “Identifying Key Factors that Inform Project Delivery Method Selection in the Water Industry.” *American Society of Civil Engineers CRC 2020*, Tempe, Arizona (*in press*)
- Ariaratnam, S., El Asmar, M., and **Feghaly, J.** (2019). “WRF Project#4685: Analyzing the Current Performance Impacts of Alternative Project Delivery in the Water and Wastewater Industry.” Water Research Foundation, Denver, Colorado
- El Asmar, M., Ariaratnam, S., and **Feghaly J.** (2019). “WRF Project #4753: Design-Build Project Administration.” Water Research Foundation, Denver, Colorado

Research Posters

- **Feghaly, J.**, Ayer, S.K., and El Asmar M. (2020). *Assessing the Impact of Utilizing Building Information Modeling for Alternative Project Delivery Method Projects*. ASCE CRC 2020, Tempe, Arizona (Finalist)
- **Feghaly, J.**, El Asmar, M., and Ariaratnam, S. (2019). *Delivery of Water Infrastructure Projects*. North American Society of Trenchless Technology 2019 No-Dig. Chicago, Illinois (1st Place Award)
- **Feghaly, J.**, El Asmar, M., and Ariaratnam, S. (2019). *Delivery of Water Infrastructure Projects*. 90th Annual Arizona Water Conference and Exhibition. Phoenix, Arizona (2nd Place Award)
- **Feghaly, J.**, El Asmar, M., and Ariaratnam, S. (2019). *Delivery of Water Infrastructure Projects*. 9th Annual SSEBE Graduate Research Poster Symposium, Tempe, Arizona (3rd Place Award)
- **Feghaly, J.**, El Asmar, M., and Ariaratnam, S. (2018). *State of Practice on Project Delivery Decision-Support Models for Water and Wastewater Capital Projects*. 8th Annual SSEBE Graduate Research Poster Symposium, Tempe, Arizona

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*” and Project #4753 “*Design-Build Project Administration for the Los Angeles Department of Water and Power.*” The research team would also like to thank the ASU Decision Theater Network for their support.



Acknowledgements



Thank you!

Any Questions?

