PERFORMANCE ANALYSIS OF DESIGN-BUILD WATER AND WASTEWATER PROJECTS BY PAYMENT AND PROCUREMENT METHODS

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ABSTRACT: Water and wastewater facilities are essential to any country's development. According to the American Society of Civil Engineers' 2017 Infrastructure Report Card, about $271 billion will be required to repair and replace drinking water facilities over the next 25 years. It was found that the design-build projects have less cost and schedule growth compared to design-bid-build and construction manager at-risk projects. The main objective of this study is to see whether the cost and schedule performance of design-build water and wastewater projects were affected by the payment and procurement methods used in the DB projects. The data for this research was collected from the Design-Build-Institute of America website. This research shows that the average cost growth of design-build water wastewater projects is at a minimum for the sole source method (-8.44%) and at a maximum for a two-step qualifications-based method. However, the average schedule growth is maximum for the best value method (9.57%) and minimum for the two-step qualification-based method (-2.12%). Depending on the payment method, lump-sum projects observed low-cost growth (3.17%) and schedule growth (1.26%) and vice-versa in the case of guaranteed maximum price projects with high schedule growth (2.71%) and low-cost growth (3.62%). When the statistical tests were conducted, the differences were not found to be significant. This shows that the procurement and payment methods do not significantly affect the cost and schedule performance of the design-build water and wastewater projects. It is recommended that similar studies be conducted for design-build highways and building projects.

Keywords: Cost growth, schedule growth, lump-sum, design-build, guaranteed maximum price, best value, two-step qualifications-based, one-step qualifications-based, sole source.

1. INTRODUCTION

Municipal water and wastewater facilities are crucial to the country's infrastructure. The life expectancy of wastewater treatment facilities is 50 years, whereas that of water treatment facilities is 25 years, and the machinery utilized in these facilities has a lifespan of 15 to 25 years (Feghaly 2018; Shane et al. 2013). According to the American Water Works Association (AWWA), most of the water infrastructure is nearing the end of its useful life. It will likely need to be replaced within this decade. The strain on water and wastewater treatment systems increases as the number of people living in cities rises. Due to aging infrastructure, urban population expansion, environmental legislation, and a lack of sustainable management solutions, municipalities and industries face challenges. Owners are attempting to implement various project delivery methods to build new water and wastewater facilities, retrofit, and rehabilitate existing facilities. Design-bid-build (DBB) is the conventional delivery process that many agencies use. However, the owners are increasingly adopting a variety of alternative delivery methods, such as design-build (DB) and construction management at-risk (CM@R/CMAR), as a result of changes in procurement legislation and the advantages of these methods (Shane et al. 2013).

DBB, also called the traditional method, has two separate contracts with the designer and contractor, and the construction can only start after a detailed design is completed. Generally, in this type of project, the procurement method used is the lowest bid. Since there is no contractual relationship between the contractor and the designer, and the contractor is chosen based on price rather than qualifications, the

contractor is not permitted to participate in the design phase (Feghaly 2018). This may result in constructability issues that can delay projects and raise final project costs.

In the CMAR method, the owner hires a construction firm or manager early in the design phase to oversee the project design and construction. The construction management (CM) firm or manager advises the designer during the project design and planning phases and later acts as a general contractor to hire subcontractors to complete the required construction work. In this method, the construction firm negotiates a guaranteed maximum price (GMP), and the construction manager is responsible for any cost exceeding the agreed amount. The CM is selected based on the qualification and the bid (Feghaly 2018). Since the CM is selected in the early design phase, the chances of facing design-related issues are decreased, and project performance is increased compared to DBB.

In addition to CMAR, another alternate project delivery method is DB. DB is a method in which the owner signs one contract with the design-builder for both the design and construction. DB is awarded based on the qualifications and cost proposals of the design-builders. In DB projects, the design-builder completes the design and construction. This allows the design-builder opportunities for schedule compression, overlapping design and construction, saving time, and decreasing the chances of design-related disputes (Feghaly 2018; Shrestha et al. 2014). This approach suits owners wanting to shift the project risks to the design-builders. DB projects can be divided into two types: namely progressive design-build (PDB) and lump-sum design-build (LSDB).

Progressive Design-Build (PDB) uses a two-step qualifications-based selection process, requiring the owner agency and PDB team to progress the design together toward a final scope, schedule, and budget. This is best used for complex construction projects (WDBC 2025). Some of the benefits of PDB are ease of contracting, schedule expediency, elimination of change orders, collaborative working relationships among all parties, and transfer of risks from the owner to the design-builder. Lump sum design-build (LSDB) is a delivery method where the owner signs off a lump sum or fixed price for the entirety of the project (Gad et al., 2020). In this method, the owner transfers the risk to a design-builder; however, the cost will be uncertain during construction.

Procurement of a design-builder in DB projects is critical as the firm is responsible for the project's design and construction. Some of the procurement methods used to select the design-builder are best value (BV), one-step qualification-based selection (one-step QBS), two-step qualifications-based (two-step QBS), sole source (SS), etc. Most LSDB projects are selected using the BV or one-step qualification-based (QBS) procurement method. In most PDB projects, the design-builders are chosen using the two-step qualifications-based selection process. None of the research has investigated the cost and schedule performance differences in DB projects based on the procurement methods. This study has collected data from the Design-Build Institute of America (DBIA) to determine whether the procurement methods affect the cost and schedule performance of DB water and wastewater projects. In addition, this study investigates the impact of payment methods on the cost and schedule performance of DB water and wastewater projects. The payment methods used in the DB projects are fixed price or Guaranteed Maximum Price (GMP). This research focused on analyzing the performance of DB water and wastewater projects depending on the payment (LS or GMP) and the procurement methods. The main objectives of this study are:

- Compare the cost growth of DB water and wastewater projects using payment methods.
- Compare the schedule growth of DB water and wastewater projects using payment methods.
- Compare the cost growth of DB water and wastewater projects using procurement methods.
- Compare the schedule growth of DB water and wastewater projects using procurement methods.

2. LITERATURE REVIEW

Literature reviews showed that no other studies have been conducted to compare the cost and schedule performance of DB water and wastewater projects based on the payment and procurement methods. It was also found that this type of study was also not conducted in other types of DB projects, e.g., highways, buildings, and infrastructure projects. However, one study has been conducted to determine the cost and

schedule performance difference in DB and DBB water and wastewater projects based on payment methods. Bogus et al. (2010) prepared a questionnaire. They collected cost and schedule data from the owners who have completed water and wastewater projects in DB and DBB with a minimum project cost of $3 million. The cost and schedule data were collected for the design and construction phases of DBB projects, as DB project data consists of both phases. The data collected were then analyzed in several steps, such as cleaning raw data, summarizing descriptive analysis, and presenting inferential statistics for the data. The authors investigated the cost and schedule growth based on payment methods, irrespective of delivery methods used in water and wastewater projects. The results showed that the cost growth of lump-sum DB projects was significantly higher than that of GMP projects (4% vs. 1%). In addition, the schedule growth of lump-sum DB projects was higher than that of GMP projects (8% vs. 0%); however, the finding was not significant at alpha level 0.05.

As there was a lack of study on this topic, this section described mostly the literature related to cost and schedule growths of projects that were delivered using DBB, DB, and CMAR. Many studies have been conducted on the performance of delivery methods, such as DBB, DB, and CMAR, comparing the different sectors in construction, such as water and wastewater, highway, and building projects. The literature related to the use of DB in water and wastewater projects is summarized in this section. Shrestha et al. (2014) surveyed alternative project delivery methods to analyze the satisfaction levels of owners for water and wastewater projects. The APD methods used in the water and wastewater are DB and CMAR. The authors sent a questionnaire to measure owners' satisfaction levels with DB and CMAR methods in water and wastewater projects. The survey results show that most DB respondents were satisfied with the various advantages of these alternative delivery methods. The most popular procurement method used by the owners in the DB water and wastewater projects was the BV. Some owners used only qualifications, and some used only price to select the contractor in their APD projects. About two-thirds of respondents were involved in projects using the two-step qualifications-based procurement process, and about one-third were involved in one-step qualifications-based procurement methods. When the respondents were asked to rank the advantages of DB and CMAR use in their projects, schedule advantage, better quality, and cost advantages were ranked as the top three advantages.

Shane et al. (2013) conducted research in continuation with Bogus et al. (2010). Shane et al. (2013) collected more data for DB and DBB water and wastewater projects and compared the cost and schedule performance. The results show that the cost growth of DB projects was not significantly lower than that of DBB projects (1.6% vs. 3.6%). However, the study found that the schedule growth regarding months of DB projects was significantly lower than that of DBB projects (1 month vs. 2 months).

Fathi et al. (2019) researched design-build infrastructure projects to analyze the change order and schedule performances by comparing the highway, water, and wastewater projects. In this research, the authors defined performance metrics such as project duration, schedule growth, change order cost, change order percentage, and project intensity. They compared these metrics for both highway, water, and wastewater projects. They also conducted t-tests to find any significant differences between both types of projects. This research shows that the change orders in DB highway projects were about 2.5 times higher than those of the DB water and wastewater projects. In contrast, the DB water and wastewater projects take longer than the DB highway projects.

Shrestha (2023) has analyzed the cost and schedule performance of DB, DBB, and CMAR in water and wastewater projects. The author prepared a questionnaire and collected data all around the United States. The result of this research shows that the DB water and wastewater projects have less mean cost growth (0.72%) compared to DBB (0.81%) and CMAR (1.85%); however, the finding was not significant at alpha level 0.05. In contrast, the schedule growth of DB projects (6.76%) was significantly lower than that of DBB (33.34%) and CMAR (28.51%) projects. When the construction intensity of DB projects was compared to DBB and CMAR projects, no significant difference was detected.

Feghaly (2018) researched the performance of project delivery methods on water and wastewater projects. The author sent a questionnaire survey to collect the DBB, DB, and CMAR water and wastewater project performance data in this research. This survey consists of questions about the design cost, construction costs, start date, completion date, and substantial completion date. A total of 74 responses were collected

for data analysis. The performance metrics used in the research are design, construction, total construction cost growths and design, construction, total schedule growths, and project speed. The results show that there are no significant differences in the cost and schedule-related performances of DB compared to DBB and CMAR. However, it was found that the speed and intensity of the DB projects were significantly higher than those of the DBB and CMAR projects.

3. RESEARCH METHODOLOGY

The primary objective of this research is to determine whether the payment and procurement methods affect the cost and schedule performance of DB water and wastewater projects. Figure 1 shows the steps the authors followed during the study.

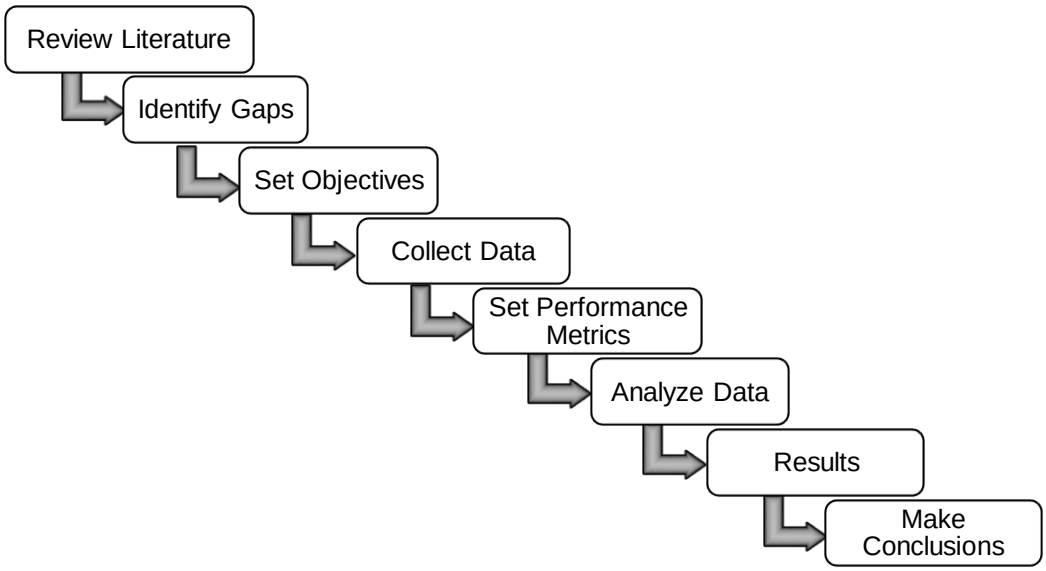

Figure 1: Flowchart of Research Process

3.1 Gaps in Literature Review

In the literature review section, the authors summarized the studies conducted on the performance comparison of DB water and wastewater projects with DBB and CMAR. Limited studies investigate the cost and schedule performance of DB water and wastewater projects based on payment methods. However, no studies have been done to determine whether procurement methods affect the cost and schedule growth of DB water and wastewater projects. Therefore, there is a research gap on this topic, and the authors collected data to determine whether the payment and procurement methods affect the cost and schedule growth of DB water and wastewater projects.

3.2 Data Collection:

The data was collected from the DBIA website. The collected data consists of the project name, city, state where the project was constructed, procurement methods, and payment methods. The performance data related to schedule, e.g., contract start date, contract completion date, actual start and completion date, and contract and actual durations of the project, were collected. The project's duration is the number of working days between a project's start and end dates. Both contract duration and actual duration of the data collected were calculated using the dates stated in the database and converting those dates into working days by considering that there are 22 working days in one month. The contract and actual completion costs were also collected to determine the cost growth metrics for these projects.

3.3 Performance Metrics:

Using the data collected, the following project performance parameters were defined and calculated:

- Schedule growth (percentage): This is calculated using Equation 1.

$$Schedule\ Growth = \frac{Actual\ Duration - Contract\ Duration}{Contract\ duration} * 100\% \quad \text{..... (1)}$$

- Cost growth (percentage): This is calculated using Equation 2.

$$Cost\ Growth = \frac{Actual\ cost - Contract\ cost}{Contract\ cost} * 100\% \quad \text{..... (2)}$$

3.4 Data Analysis

After the data were collected from the DBIA database, the authors converted the start and completion dates to the number of working days to accurately calculate the schedule growth metric. Similarly, the final cost of the projects was adjusted using the RS Means Cost Guide historical cost indices. The final cost of all the DB projects was adjusted to the base December 2024 cost. The DB projects collected for this study were completed between 2013 and 2024. Table 1 shows the RS Means Cost Indices used to convert the cost to base 2024 cost. The descriptive statistics were used to determine about whether the payment types and procurement methods affect the cost and schedule performance of DB water and wastewater projects.

Table 1: RS Means Cost Indices

Year	Cost Indices	Year	Cost Indices
2013	196.9	2019	227.3
2014	203.0	2020	234.3
2015	204.0	2021	238.3
2016	207.7	2022	276.9
2017	209.4	2023	299.4
2018	217.7	2024	295.6

4 RESULTS

The results are expressed in terms of descriptive statistics and the significance test results to make conclusions. The cost and schedule growths of DB water and wastewater projects were reported based on the payment and procurement methods. These results will help to determine whether the payment and procurement methods affect the cost and schedule growths in DB water and wastewater projects. The first section will discuss the descriptive statics of the contract and actual durations as well as the projects' adjusted cost and actual cost. The second section will discuss the cost and schedule growth statistics based on payment and procurement methods.

4.1 Descriptive Analysis

The DB water and wastewater project data collected from the DBIA database were from 21 states. Figure 2 shows project distribution across different states. There is a total of 78 DB projects, with the oldest project being completed in 2013 and the latest being in 2024. The highest number of DB water and wastewater projects were built in California (14) and Florida (14), followed by Georgia (9). This is because California, Florida, and Georgia had state legislatures that allowed DB delivery methods about a decade ago. This helps the state agencies to use DB methods while designing and constructing water and wastewater projects with taxpayers' money.

There are 25 types of water and wastewater projects, such as storage facilities, recycle stations, lift stations, pump stations, sewer crossings, water pipelines, storm drains, pollution control plants, water recycling, and many others. Figure 3 represents the percentage of types of DB water and wastewater projects. About 23% of the projects are water treatment plants, and about 12% of the projects are water reclamation facilities. About 11% of projects are wastewater treatment plants, followed by 9% of pump stations.

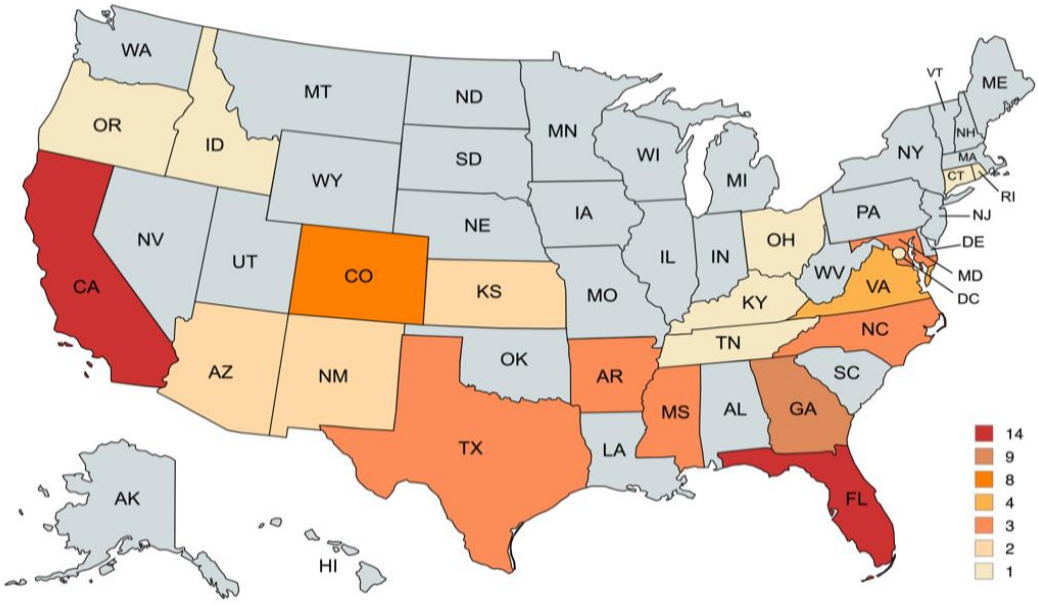

Figure 2: Map of Project Data Collected from Different US States

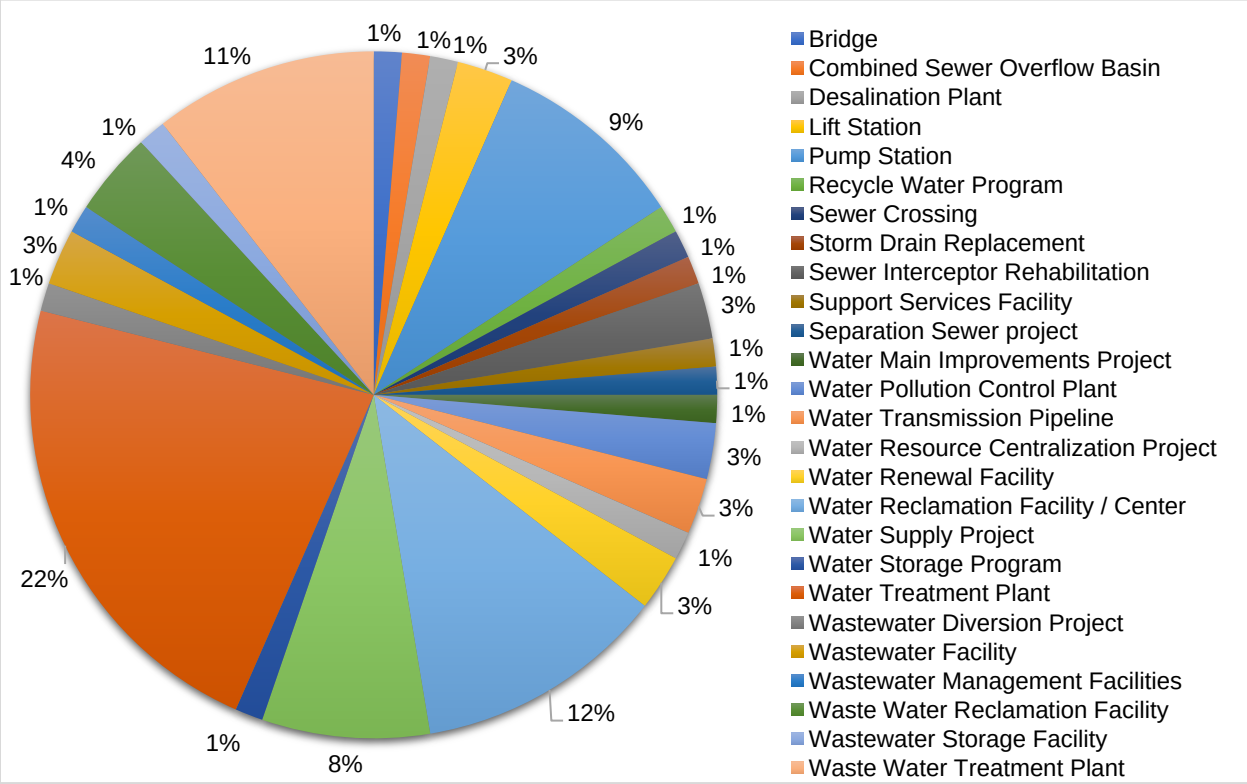

Figure 3: Representation of Types of Water and Wastewater Project Data Collected

Table 2 depicts the minimum, maximum, median, and mean values of the contract duration, actual duration, contract cost, and cost of DB water and wastewater projects. The average contract duration of these projects was 635 working days. Some projects were contracted to be completed in 112 working days, and some had a maximum duration of 1,270 working days. The average actual duration of these projects was 649 working days, and the range of actual completion days was from 113 to 1,272 working days. The contract cost of these projects ranged from $200,000 to $540 million. The average contract cost was found to be $56.43 million. The actual completion cost of these projects ranges from $750,000 to $540 million, with an average cost of $60.4 million. The cost and schedule data show that the sample comprises small and large projects.

Table 2: Mean, Median, Minimum, and Maximum of Actual and Contract Duration and Cost

Statistics	Contract Duration	Actual Duration	Contract Cost	Actual Cost
	Days	Days	Millions	Millions
Minimum	112	113	$0.2	$0.75
Maximum	1270	1272	$540	$540
Median	641	610	$28.5	$29.5
Mean	635	649	$56.43	$60.4

Table 3 shows the payment methods used in these DB water and wastewater projects. Generally, lump-sum and GMP payment methods are used in DB projects. Out of 78 DB projects, only 74 have stated the payment methods they used while executing the project. About 55% of the projects used lump-sum payment methods, and the rest used GMP.

Table 3: Number of Projects Depending on Payment Types

	# Projects	% of Projects
Lump- Sum	41	55%
Guaranteed Maximum Price	33	45%

Generally, four procurement methods are used to select the design-builder for these DB projects. Out of 78 projects, 74 have stated the types of procurement methods used to select the design-builder. Table 4 shows the distribution of the procurement methods used in these sample projects. The one-step qualifications-based procurement method was used in most of the projects (36%), followed by the two-step qualifications-based (30%) and best value (28%) procurement methods. Some projects used the sole source (6%) procurement method, in which the owner provided the contract to the design-builder without competitive bids. This type of procurement cannot be used in public projects that involve taxpayer money. However, the private owners can use this procurement method to select the design-builder for their DB projects.

Table 4: Number of Projects Depending on Procurement Methods

Procurement Methods	# Projects	% of Projects
Two-Step Qualifications-Based	27	36%
One-Step Qualifications-Based	22	30%
Best Value	21	28%
Sole Source (or negotiated)	4	6%

4.2 Cost Growth and Schedule Growth

The data was analyzed depending on the payment and procurement methods used in the projects, and the results are shown in Tables 5 and 6, respectively. The results include average cost growth and schedule growth along with median cost and schedule growth.

Table 5 shows the average and median cost and schedule growth values for the data collected depending on the payment method. Seventy-three (73) projects cost data were found, and the average cost growth for LS projects was 3.17% and 3.62% for GMP projects, indicating that projects using the GMP payment method have higher cost overruns than those that used the LS payment method. Similarly, the average schedule growth for LS projects was 1.26% and 2.71% for GMP projects, indicating that the LS projects observed a lower schedule growth than GMP projects. T-test was conducted to determine the difference between average cost and schedule growths based on payment methods. The results showed that there is no significant difference in cost and schedule growth based on the payment types.

Table 5: Cost and Schedule Growths of DB Water and Wastewater Projects by Payment Methods

Payment Method	Sample Size	Average Cost Growth	Average Schedule Growth	Median Cost Growth	Median Schedule Growth
LS-DB	40	3.17%	1.26%	0.20%	0.00%
GMP-DB	33	3.62%	2.71%	1.17%	0.00%

The variability of cost and schedule growths of DB water and wastewater projects can be depicted by calculating the standard deviation, maximum, and minimum values of the cost and schedule growths based on type of payment. Table 6 shows these values. The results shows that the highest variability of the data for cost growth was found to be in LS-DB compared to GMP-DB with standard deviation of 13.67%. Similarly, the schedule growth variability in LS-DB was also higher than that of GMP-DB (standard deviation of 8.55% vs. 7.99%).

Table 6: Variability of Cost and Schedule Growths of DB Water and Wastewater Projects by Payment Methods

Payment Type	Cost Growth			Schedule Growth		
	Maximum	Minimum	SD	Maximum	Minimum	SD
LS-DB	67.67%	-28.85%	13.67%	61.06%	-54.98%	8.55%
GMP-DB	52.52%	-17.22%	11.58%	75.07%	-28.61%	7.99%

Table 7 depicts the average cost and schedule growths of 73 DB water and wastewater projects based on various procurement methods. The results show that DB projects that used the one-step QBS method to select a design-builder have the highest cost growth of 5.93%, followed by two-step QBS (3.87%), BV (3.65%), and SS (-8.44%), respectively. This indicates that the DB projects using the SS procurement method are the best for lower-cost growth. However, public agencies cannot use this procurement method to select the design-builder. Therefore, for the public sector, the BV procurement method reduces the cost growth in the DB water and wastewater projects. It was also found that the average schedule growth DB projects using BV, SS, two-step QBS, and one-step QBS were 9.57%, 2.60%, -2.12%, and -1.58%, respectively. The results show that the two-step QBS is the best procurement method for selecting a contractor for lower schedule growth, and BV is the worst procurement method for selecting design-builders. The significant test was conducted to determine the cost and schedule growths differences based on procurement methods, both cost and schedule growths were found to be not significantly different based on procurement methods at alpha level 0.05.

Table 7: Cost and Schedule Growths of DB Water and Wastewater Projects by Procurement Methods

Procurement Method	Sample Size	Average Cost Growth	Average Schedule Growth	Median Cost Growth	Median Schedule Growth
Two-Step QBS	22	3.87%	-2.12%	0.20%	0.00%
One-Step QBS	27	5.93%	-1.58%	1.17%	0.00%
Best Value	20	3.65%	9.57%	3.42%	0.00%
Sole Source	4	-8.44%	2.60%	-2.46%	-0.13%

The standard deviation, maximum, and minimum values were calculated for cost and schedule growths of DB water and wastewater projects based on the procurement methods. Table 8 shows these values. The results shows that the highest variability of the cost growth data can be seen one-step QBS method, in which the maximum cost growth was 67.67% and lowest growth was -6.55% with a standard deviation of 15.83%. The lowest variability of cost growth data was found to be in BV method in which the standard deviation was 5.05% and the maximum and minimum cost growths were 14.68% and -3.57%, respectively. Interestingly, the DB water and wastewater projects that used SS has no positive cost growth indicating that all the projects were completed below or on the budget. Similarly, in schedule growth, the highest variability is found to be SS method, whereas the lowest variability is found to be in one-step QBS method

Table 8: Variability of Cost and Schedule Growths of DB Water and Wastewater Projects by Procurement Methods

Procurement Method	Cost Growth			Schedule Growth		
	Maximum	Minimum	SD	Maximum	Minimum	SD
Two-Step QBS	52.52%	-17.22%	13.67%	11.09%	-28.61%	8.55%
One-Step QBS	67.67%	-6.55%	15.83%	22.40%	-16.97%	7.99%
Best Value	14.68%	-3.57%	5.05%	75.70%	-48.23%	28.13%
Sole Source	0.0%	-28.58%	13.69%	58.56%	-54.98%	35.07%

5 CONCLUSIONS

This study analyzes the DB water and wastewater project costs and schedule growths based on payment and procurement methods to determine whether these methods affect performance. The data were collected from the DBIA database, and descriptive statistics and statistical tests were used to assess the effect of payment and procurement methods on DB project performance.

The database consists of DB water and wastewater projects from 21 states within the US, owned by private and public agencies. The size of the project in terms of cost ranges from $200,000 to $540 million. About 25 types of water and wastewater facilities were built, showing that the projects included in this study were diverse in terms of cost and type.

This research results conclude that the DB projects that used the LS payment method had the least cost growth compared to the GMP payment type; similar finding was detected for schedule growth. However, the statistical test does not show the significance difference. In terms of cost growth findings, this study's finding contradicts those of Shane et al. (2013). Shane et al. (2013) found that the cost and schedule growth were higher in LS projects than in GMP projects. It should be noted that the current study collected only DB water and wastewater project data; however, Shane et al. (2013) collected DB and DBB water and wastewater project data.

The study found that BV is the best procurement method for public DB water and wastewater projects to reduce cost growth. However, it was also found that DB projects selected based on the BV procurement method had the highest schedule growth compared to one-step QBS and two-step QBS. This study is the first to investigate the effect of procurement methods on DB water and wastewater project cost and schedule performance. The BV procurement method shows mixed results with cost advantages and schedule disadvantages. Also, the statistical test does not show the significant difference in cost growth based on procurement methods. Therefore, further studies must be conducted to verify these findings.

The authors would like to caution the readers that DB water and wastewater project costs and schedule performances can be affected by many other factors such as project management, types of projects, complexity of the projects, etc. Even the difference cost and schedule growths based on procurement and payment types were not found to be significant, the authors recommend conducting this research with similar types of DB water and wastewater projects involving public owners and similar sizes in terms of cost

to control the variability. If similar sizes of projects are compared, may the significant difference in cost and schedule growths based on procurement and payment methods could be detected.

6 REFERENCES:

Bogus, S. M., Shane, J. S., and Molenaar, K. R. 2010. Comparison of Water/Wastewater Project Performance by Project Delivery System and Payment Provision. *Construction Research Congress,* ASCE, Alberta, Canada, 859 – 868.

Fathi, M., Shrestha, P.P., and Shakya, B. 2019. Change Orders and Schedule Performance of Design-Build Infrastructure Projects: Comparison between Highway and Water and Wastewater Projects. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*. https://doi.org/10.1061/(ASCE)LA.1943-4170.0000353. 04519043-1.

Feghaly, J. 2018. *Project Delivery Method Performance Evaluation for Water and Wastewater Capital Projects.* Master Thesis, December 2018, Arizona State University, Tempe, AZ.

Gad, G. M., Davis, B., Shrestha, P.P., and Fathi, M. 2020. Legal and Contractual Issues in Lump-Sum Design-Build Implementation on Large-Scale Airport Projects. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction* 12(1). 05019011-1. https://doi.org/10.1061/(ASCE)LA.1943-4170.0000364.

Shane, J. S., Bogus, S. M., and Molenaar, K. R. 2013. Municipal Water/Wastewater Project Delivery Performance Comparison. *Journal of Management in Engineering* 29 (3): 251–58. https://doi.org/10.1061/(ASCE)ME.1943-5479.000013.

Shrestha, P. P., Maharjan, R., Shakya, B. and Batista., J. 2014. Alternative Project Delivery Methods for Water and Wastewater Projects: The Satisfaction Level of Owners. *Construction Research Congress,* ASCE, Tempe, AZ, 1733 – 1742.

Shrestha, S. 2023. *Performance Comparison of Design-Bid-Build (DBB), Design-Build Performance Comparison of Design-Bid-Build (DBB), Design-Build (DB) and Construction Management-At-Risk (CMAR) Methods, (DB) and Construction Management-At-Risk (CMAR) Methods, and Identification of Critical Success Factors for DB and CMAR in and Identification of Critical Success Factors for DB and CMAR in Water and Wastewater Projects Water and Wastewater Projects.*" Thesis, December 2023, University of Nevada, Las Vegas, Las Vegas, NV.

Water Design Build Council (WDBC). 2025. Progressive Design-Build (PDB). Access on February 6, 2025, < https://watercollaborativedelivery.org/glossary/>