State of Practice on Project Delivery Decision-Support Models for Water and Wastewater Capital Projects

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Abstract
The construction industry is rapidly evolving and pushing for innovative ways of project delivery. Despite traditional Design-Bid-Build (DBB) project delivery still prevailing, owners are now opting for alternative project delivery methods (APDM) such as through Design-Build (DB) and Construction Management at Risk (CMAR). APDM have been gaining popularity across numerous sectors, notably in the transportation sector; however it is not yet as widely adopted in the water infrastructure sector. Several agencies and organizations within the transportation and education sector have generated decision-support models to aid owners in selecting the best project delivery method (PDM) for their projects, based on maneuvering within a certain framework containing key PDM selection factors. Five decision-support models currently utilized in the airports, transit, transportation and education sectors will be evaluated in this paper. This overview will detect all key project delivery selection factors within each framework and reveal commonalities across all of them, aiming to combine the strengths of all models under one optimized decision-support tool to be later used for the water infrastructure sector.

Keywords

Alternative Project Delivery Method, Project Delivery Selection Factor, Decision-Support Models

1. Introduction

There is a growing need to renovate and upgrade existing aging water and wastewater treatment plants across the United States. According to the American Society of Civil Engineers (ASCE), the existing U.S. water and wastewater infrastructure systems received low grades of "D" and "D+", respectively on the 2017 ASCE Infrastructure Report Card (ASCE 2017). With a significant drop in federal funding from $16 Billion USD in 1976 to $4.4 billion USD in 2014, the problem of deteriorating infrastructure has fallen under the responsibility of individual States and municipalities (CBO 2015). Therefore, it is vital for water infrastructure sector leaders to choose project delivery methods that will maximize their financial investments, ensure efficient engineering design, and complete projects on time and within budget.

A project delivery method (PDM) can be termed as the process that will be utilized by the owner over agreements with other stakeholders and entities to commence with the planning, financing, design, construction, start-up and operation of a construction project. PDMs are known to be recognized by two fundamental characteristics: (1) contractual relationships between project stakeholders and (2) their timing of engagement in the project (Konchar and Salvido 1998; Molenaar et al. 1999; El Asmar et al. 2013).

Different PDMs have their own particular advantages and disadvantages depending on several unique project related factors. Despite traditional Design-Bid-Build (DBB) prevailing as the most applied PDM, owners are now opting for alternative project delivery methods (APDM) such as through Design-Build (DB) and Construction Manager at Risk (CMAR). In DBB, the contractor is typically not involved in the design phase and will only be included once 100% design has been completed. However, with APDMs such as CMAR, the construction team is involved with the design phase early on, and in DB the contractor is involved during around 20% of design completion (El Asmar et. al. 2013).

This overview will detect key project delivery selection factors of five PDM frameworks and reveal commonalities across the different models, aiming to combine all models under one optimized decision-support tool to be subsequently used in the water infrastructure sector.

2. State of Practice

It is essential for water and wastewater decision-makers to possess a tool to allow them to screen and evaluate their project delivery options. The Airport Cooperative Research Program (ACRP), Transit Cooperative Research Program (TCRP), Colorado Department of Transportation (CDOT), Washington State Department of Transportation (WSDOT) and the Alaska Department of Education and Early Development (ADEED) PDM decision-support models are reviewed and serve as a preliminary study for the implementation of a water infrastructure specific project delivery selection tool. A nonexhaustive sample of these models are presented in Table 1.

Table 1: Existing Project Delivery Section Decision-Support Models

Organization	Year	Application Sector	Title
ACRP	2009	Airports	A Guidebook for Selecting Airport Capital Project Delivery Methods
TCRP	2009	Transit	A Guidebook for the Evaluation of Project Delivery Methods
CDOT	2014	Transportation	Project Delivery Selection Matrix
WSDOT	2016	Transportation	Project Delivery Method Selection Guidance
ADEED	2017	Education	Project Delivery Method Handbook

In the following section, the project delivery selection decision-making models presented in Table 1 are briefly summarized and the major selection factors of each project delivery method identified.

2.1 ACRP – "A Guidebook for Selecting Airport Capital Project Delivery Methods"

The ACRP (2009) provides a two-tier system for project delivery selection, allowing airport capital projects owners and decision-makers to evaluate the advantages and disadvantages of certain PDMs such as the DBB, CMAR, and DB methods. Tier 1 is known as the *Analytical Delivery Decision Approach* and offers a straightforward six-step approach shown in Figure 1, allowing decision-makers to comprehend the elements and characteristics of each project delivery method.

Figure 1: ACRP Tier 1 Six-Step Approach (2009)

It is important during Step 5 of the Tier 1 process to review the advantages/disadvantages of each PDM individually against certain selection factors. 19 selection factors or project level issues are identified in Figure 2 and are categorized by the four major pertinent issues (based on surveys and research conducted by the ACRP) that influence PDM selection:

Project-Level Issues
1. *Project size/complexity* 2. *Schedule compression* 3. *Schedule growth control* 4. *Early cost precision* 5. *Cost control* 6. *Risk management/allocation* 7. *Lifecycle costs* 8. *Maintainability*

Airport-Level Issues
9. *Airport experience/staff capability* 10. *Airport control of project* 11. *Security* 12. *Control of impact on passengers and operations* 13. *Third-party stakeholder input to design and construction*

Public Policy/Regulatory Issues
14. *Competition and local talent* 15. *DBE/small business impacts* 16. *Legal and statutory constraints* 17. *Sustainability and LEED certification*

Other Issues
18. *Adversarial relationships* 19. *Construction claims*

Figure 2: ACRP Selection Factors or Project Level Issues for Airport Projects (2009)

Tier 2 utilizes a weighted-matrix delivery decision approach for PDM selection, established on the basis of prioritizing project objectives and calculates a score corresponding to each PDM. The Tier 2 *Weight-Matrix Delivery Decision Approach* consists of five distinct steps presented in Figure 3.

Figure 3: ACRP Tier 2 Five-Step Approach (2009)

The main intent of Step 1 of the Tier 2 approach is to reduce the 19 PDM selection factors of the Tier 1 approach to a maximum of 7 prominent factors to remain in use. Step 2 consists of ranking these remianing factors and obtaining their factored weight, allocating points to each factor based on importance. Step 3 provides a project delivery scoring scale that is to be multiplied with the factored weight from Step 2 to obtain the weighted score of each PDM. The PDM with the highest total score will be chosen as the most appropriate for a project. The two-tier system forces decision-makers to document the entire PDM selection process, serving as a reference for owners to make decisions for future projects.

2.2 TCRP – "A Guidebook for the Evaluation of Project Delivery Methods"

As an extension on the ACRP's (2009) two-tier approach, the TCRP's (2009) framework provides a third tier consisting of a risk analysis section for project delivery selection, allowing transit project owners to evaluate the pros and cons of different PDMs, comprising of the DBB, CMAR, DB and design-build-operate-maintain (DBOM) methods. The 24 PDM selection factors in this guidebook are identified in Figure 4.

Project-Level Issues
1. *Project size* 2. *Cost* 3. *Schedule* 4. *Risk management* 5. *Risk allocation* 6. *LEED certification*
Agency-Level Issues
7. *Agency experience* 8. *Staffing required* 9. *Staff capability* 10. *Agency goals and objectives*
11. *Agency control of project* 12. *Third-party agreements*
Public Policy/Regulatory Issues
13. *Competition* 14. *DBE/small business impacts* 15. *Labor unions* 16. *Federal/State/Local laws*
17. *FTA/EPA regulations* 18. *Stakeholder/Community input*
Lifecycle Issues
19. *Lifecycle costs* 20. *Maintainability* 21. *Sustainable design goals* 22. *Sustainable construction goals*
Other Issues
23. *Construction claims* 24. *Adversarial relationships*

Figure 4: TCRP Selection Factors or Project Level Issues for Transit Projects (2009)

Unlike the ACRP's framework, if a PDM is not selected by the end of Tier 2, decision-makers will then move to a two-phased Tier 3 optimal-risk based approach. The first phase involves a qualitative analysis and requires owners to develop a risk-allocation matrix containing a maximum of two PDMs. The second phase of Tier 3 is a quantitative approach and analyzes each PDM against project schedule and cost and allows owners to chose the most advantageous PDM.

2.3 CDOT – "Project Delivery Selection Matrix"

Simillary to the TCRP's (2009) framework, the Colorado Department of Transportation's (CDOT) "Project Delivery Selection Matrix" also suggests an extensive three-staged process which offers a structured approach for facilitating transit decision-makers in selecting the appropriate PDM. The PDMs in this matrix are the DBB, DB, and the Construction Manager / General Contractor (CM/GC) or what is also known as CMAR. Stage 1 consists of documenting project attributes, goals, and constraints. Stage 2 involves assessing 5 primary PDM selection factors. Finally, Stage 3 comprises of evaluating 3 secondary PDM selection factors. The three-staged decision-making process of CDOT's decision-support model is illustrated in Figure 5.

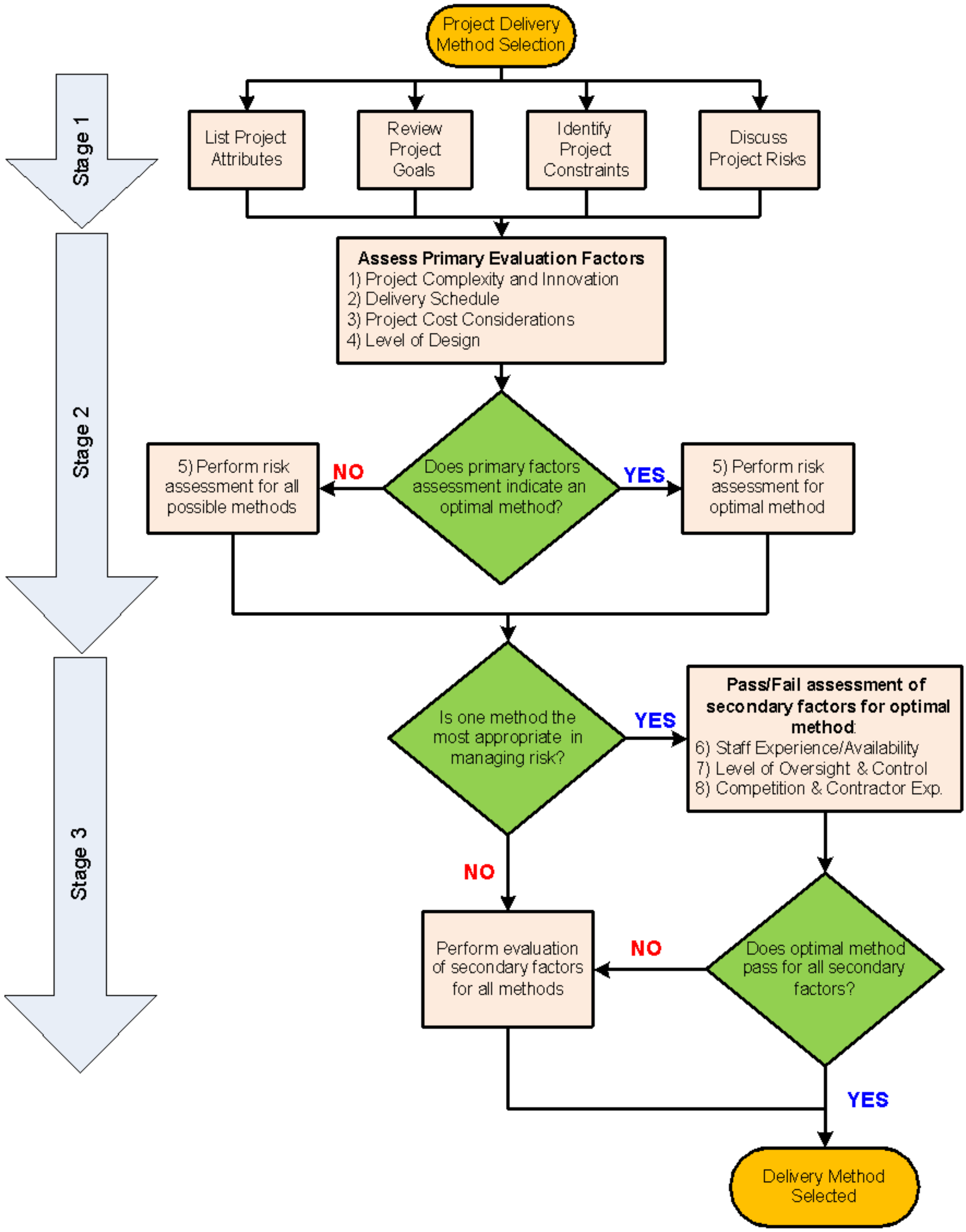

Figure 5: CDOT PDM Selection 3-Stage Approach (2014)

2.4 WSDOT – "Project Delivery Method Selection Guidance"

The Washington State Department of Transportation (WSDOT) adopted the CDOT's PDM selection approach and developed their own two-stage personalized PDM guide. Stage 1 is the probable PDM determination process and its first step is to document project attributes, goals, and constraints. It successively checks if a project has a project cost of $25 Million USD or more, if the cost is above that threshold it will direct the decision-makers to complete a selection matrix which compares PDMs with 10 selection factors presented in Figure 6.

Selection Factors
1. *Project delivery schedule* 2. *Funding limitations* 3. *Project cost* 4. *Third-party agreements*
5. *Owner's involvement and control* 6. *Lifecycle costs* 7. *Minimizing facility operations disturbance*
8. *Encourage room for innovation* 9. *Minimizing owner risk* 10. *Minimizing impact on local businesses*

Figure 6: WSDOT PDM Selection Factors (2016)

However, if project cost is under $25 Million USD it will direct owners to a selection checklist. This process will eventually lead decision-makers to the determination of a probable PDM. After the completion of Stage 1, Stage 2 consists of selecting a final PDM by undertaking an extensive validation and revision process of the probable PDM obtained in the earlier stage.

2.5 ADEED – "Project Delivery Method Handbook"

With the same amount of selection factors as the WSDOT's decision-support model, the ADEED handbook establishes a framework to aid owners in the education sector in selecting the appropriate PDM. ADEED identifies 6 need factors and 4 success factors, and assesses these factors against each PDM. The 10 key factors and need factors are identified in Figure 7.

Need Selection Factors
1. *Project delivery schedule* 2. *Amount of overlapping design/construction* 3. *Scope definition*
4. *Potential for change during construction* 5. *Need/Desire for contractors' input in design*
6. *Flexibility to make changes after construction completion*
Success Selection Factors
7. *Owner's ability to manage design* 8. *Owner's ability to eliminate disputes between parties*
9. *Regulatory and statutory requirements* 10. *State budget and funding cycles*

Figure 7: ADEED Need and Success PDM Selection Factors (2017)

3. Synthesis of the Models and the Factros

Inherently, each PDM decision-support framework was developed to cater to the needs, concerns, and objectives of individual sectors. However, after compiling the selection factors across the five models as demonstrated in Table 2, it can be observed that all models shared common PDM selection factors. These major selection factors are essential across various PDM selection frameworks and are to be used to design an optimized decision-support tool to be potentially utilized within the water infrastructure sector.

Table 2: PDM Selection Factors Across the Decision-Support Models

PDM Selection Factors	ACRP (2009)	TCRP (2009)	CDOT (2014)	WSDOT (2016)	ADEED (2017)	TOTAL
Project Delivery Schedule	X	X	X	X	X	**5**
Owner Involvement & Control	X	X	X	X	X	**5**
Risk Management & Allocation	X	X	X	X		**4**
Project Cost Control	X		X	X		**3**
Lifecycle Costs	X	X		X		**3**
Third-Party Involvement	X	X		X		**3**
Competition	X	X	X			**3**
Disadvantaged Business Enterprise	X	X		X		**3**
Legislation & Regulation	X	X			X	**3**
Adversarial Relationships	X	X			X	**3**
Staffing Requirements & Capabilities	X	X	X			**3**
Project Size	X	X				**2**
Early Cost Estimates & Precision	X	X				**2**
Maintainability	X	X				**2**
Owner Experience	X	X				**2**
Impact on Existing Facility Operations	X			X		**2**
Sustainability Goals	X	X				**2**
Community/Stakeholder Input		X	X			**2**
Project Complexity & Innovation			X	X		**2**
Funding				X	X	**2**
Construction Claims	X	X				**2**
Safety	X					**1**
Owner Goals & Objectives		X				**1**
Labor Unions		X				**1**
Level of Design			X			**1**
Contractor Experience			X			**1**
Amount of Overlapping Design & Construction					X	**1**
Scope Definition					X	**1**

Potential for Change During/After Construction					X	**1**
Need for Contractor's Input in Design					X	**1**

Committing to a *project delivery schedule* is typically the most significant challenge within construction projects; hence it is not unexpected to see this PDM selection factor present within all explored frameworks. Moreover, *owner involvement and control* is identified in all five decision-support models as it is crucial for the owner to define their capabilities and role within the construction project team, this in turn can dictate the best suited form of project delivery.

Other selection factors are addressed to accommodate for a concern of a specific sector a certain framework is serving. For example, the *impact on existing facility operations* selection factor is mentioned within the ACRP framework, as new airport construction projects should take into consideration existing airport operations and traffic. Another sector-specific concern example would be *funding* within the ADEED decision-support model, as educational institutions are generally financed and dependent on federal or local budget cycles and funding.

Additionally, ADEED's framework is the most recent decision-support model between the five frameworks; implying that its developers have had more experience and insight into the recent alternative project delivery market. Hence, its unique additional selection factors such as *contractor's input in design, scope definition, amount of overlapping design and construction, and potential for change during and after construction completion,* are arguably emerging selection factors in the field of PDM selection.

The five models have collectively produced 30 PDM selection factors, which are all respectively worth delving into further and considering when producing an optimized decision-support tool aimed at the water infrastructure sector.

4. Conclusion and Next Steps

This paper explored existing PDM decision-support models currently being used within the airports, transit, transportation and education sectors in the United States with the aim of compiling data for the creation of an optimized PDM selection framework to serve the water infrastructure sector. The key selection factors across the five decision-support models were identified and then ranked in order of appearance and repetition; leading to a collection of 30 distinctive project delivery selection factors. These 30 selection factors will be further explored and potentially utilized when creating a decision-support tool to serve the water infrastructure sector in the future. A limitation of this paper is the lack of quantity and variety of sector-driven PDM decision-support models in this study, as there are several potentially significant PDM selection factors and frameworks currently overlooked. Future research will aim to accumulate further comprehensive data by exploring additional models and increase significance on compiled PDM selection factors.

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