Report
on
SELECTING THE BEST PROJECT DELIVERY METHOD USING THE ANALYTICAL HIERARCHY PROCESS (AHP)

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CEM 520
Construction Contracting & Administration

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Abstract

Selecting a project delivery system that achieves quality, time, money and other key requirements is a critical task that owners should do to ensure project success. In this report, a set of traditional and innovative project delivery methods were examined and evaluated to determine which of the options would produce the best outcome to the owner. The selection criteria are determined by studying a number of factors. In addition, a decision-making methodology using the analytical hierarchy process is used to assist owners in selecting the best delivery method for their projects, based on their objectives. A case study application for selecting the best project delivery method is also provided.

1 January 2011

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INTRODUCTION:

This report discusses how should the owners choose the best method to deliver their projects and what are the factors that influence their judgment or choice? It is a challenging task that requires owner to make decision between many competing traditional and non-traditional or innovative methods such as design-bid-build and design-build. As a result, the analytical hierarchy process (AHP) developed by Saaty [1] is used to compare between the different methods of delivery systems so that the owner can easily define the proper selection. Many factors are involved that affect the selection of a project delivery method [3;4;8]. Some of the major factors are described in Appendix B.

The main objective of this report is to assist owners in selecting a project delivery method that satisfies their requirements and parameters. In order to achieve that goal, a decision-making methodology using the analytical hierarchy process is implemented.

The report begins with some of typical project delivery systems. This is followed by the factors affecting the selection of a project delivery method. Then, the approach and methodology of analytical hierarchy process (AHP) and a case study are discussed. Finally, a conclusion of the report summarizing the report objectives and key results are highlighted.

I. PROJECT DELIVERY METHOD (PDM)

A set of common project delivery alternatives that are currently used in the construction industry is identified in Appendix A. There are many methods to choose from. However, in this report, the most common project delivery methods are considered.

A. Traditional Method

This report presents three traditional contracting methods as follow:

1. Design-Bid-Build (DBB)

The DBB project delivery is the traditional and most popular method in which the owner enters into a contract with two separate entities, the architect/engineer (A/E) to do the design and a contractor to do the construction work. The A/E prepares the plans, specifications and contract documents that are then incorporated into a bid package. Contractors competitively bid the project based on these completed plans and specifications. The owner evaluates the bids received, awards the contract to the lowest bidder [3]. Figure 1 illustrates the method.

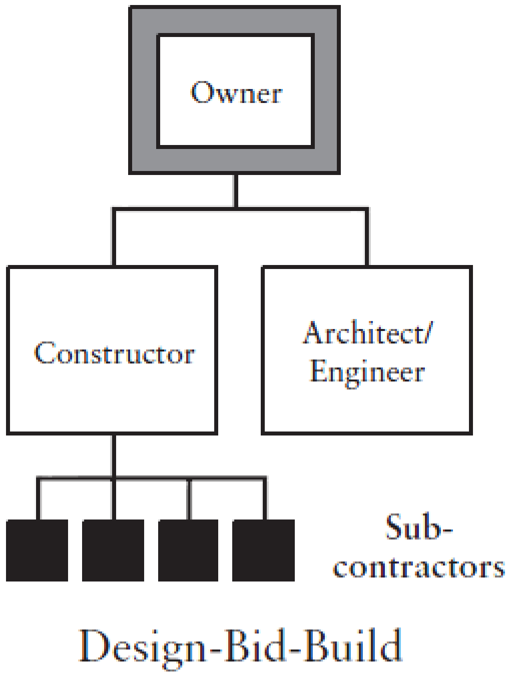

Figure 1, DBB method illustration [7].

2. Construction Manager (CM or CMA)

The CM project delivery is almost the same as DBB, except that a professional construction manager is added to the project team to manage the two separate design and construction contracts on the behalf of the owner [3].

The CM provides consulting and managerial functions. The CM is responsible for design constructability review, cost and scheduling information and control, as well as quality requirements. The CM is also responsible for managing the actual construction activities, including all construction operations normally associated with a contracting organization [4]. Figure 2 illustrates the method.

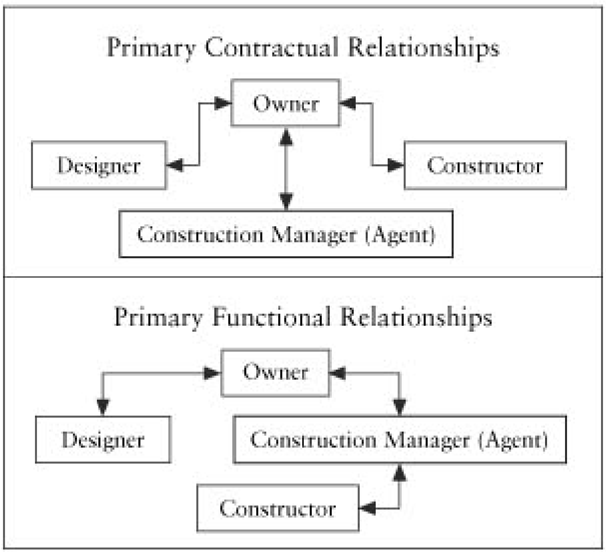

Figure 2, CMA method illustration [8].

3. Construction Manager at Risk (CMR)

The CM at Risk is a delivery method in which the construction contractor participates early during the project design phase to help the owner with managerial duties and also to increase the feasibility and constructability of the design. After a certain amount of design is complete, the CMR provides the construction services with obligation to deliver the project with a guaranteed maximum price [1;9]. Figure 3 illustrates the method.

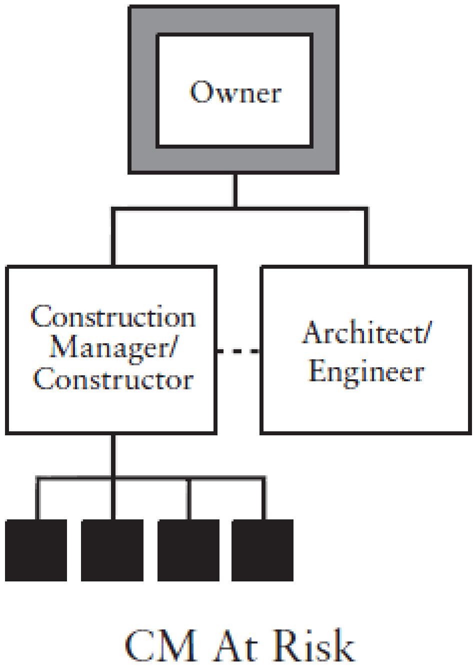

Figure 3, CMR method illustration [7].

B. Innovative Method

Several alternatives to the traditional PDM have been developed over the years, including design-build, cost-plus-time and warranties [5].

1. Design -Build (DB)

The DB project delivery is coming more popular in industry and considered the best option in large projects [4]. In DB method, the owner enters into a contract with single entity to perform both the design and construction work [3]. Recent studies have shown that DB method has significant less design and construction cost growth when compared to DBB [7]. Also, the overall time for project complementation can be reduced and design and construction expertise can be combined [8]. Figure 4 illustrates the method.

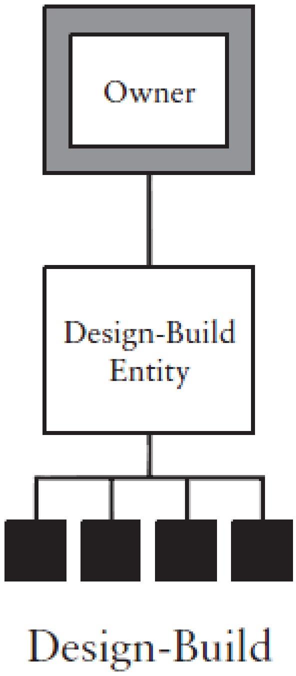

Figure 4, DB method illustration [7].

2. Cost-Plus-Time (A+B)

Cost-Plus-Time, also known as A+B bidding, is a contracting method that not only considers the initial construction cost in the bidding process, but also takes into account the time needed to complete the project. This procedure is intended to provide a motivation for the contractor to minimize delivery time for high priority work such as busy and congested roadways. This is achievable by offering the contractor bonus for early completion and assessing disincentives for late completion [5;10].

3. Warranty

The warranty project delivery method allows the owner to receive an assurance that the project will serve its purpose without failure for a specific period and if does not, it is the contractor's responsibility to repair or replace the defects. Performance bonds are used to guarantee that the materials and workmanship of the contractor will be satisfactory during the project completion and acceptance [5]. Warranty PDM motivates the contractor to do a better job than would be done without such assurance.

Warranties have a higher initial cost, but may result in lower life-cycle costs than those of PDM contracted projects. A warranty PDM may include other forms of contracting, such as DBB or DB [9;10].

II. FACTORS AFFECTING PDM SELECTION

The selection of a particular PDM will depend upon several factors. Some of the factors to consider when evaluating the appropriateness of a PDM are presented in Appendix B. The purpose of this selection is to get the maximum achievement of the owner’s project objectives and requirements. Therefore, for a project under consideration, the selection criteria should be based on the owner’s objectives for that project.

There are many factors that may influence the project delivery selection. Al Khalil [3] identified three main factors broken down into 12 sub factors as shown in Table 1.

Table 1. Factors affecting the selection of a project delivery method [3].

Project characteristics	Owner's needs	Owner's preferences
1.Scope definition	5.Constructability	10.Responsibility
2.Schedule	6.Value engineering	11.Design control
3.Price	7.Contract packaging	12.Involvement after award
4.Complexity	8.Budget estimates	
	9.Other needs	

Mahdi et al., [4] identified seven main factors broken down into 34 sub factors as shown in Table 2.

Table 2. Factors affecting the selection of a project delivery method [4].

Project characteristics	Owner characteristics	Design characteristics	Contractor characteristics	Regulatory	Risks	Claims & disputes
1.Define the project scope	8.Understanding the project scope	13.Design changes during construction	17.Availability of experience	24.Allowance for competitive bidding	31.Risk management improvement	33.Between design and builder/single point responsibility
2.Time reduction	9.Control over design	14.Design quality	18.Familiarity and establishment	25.Desired contractual relationship	32.Risk allocation	34.Conflict of interest
3.Precise cost estimate	10.Benefits from cost saving	15.Flexibility to redesign	19.Contractor input in design	26.Regulatory requirements		
4.Size and complexity	11.Involvement in project details	16.Constructability of the design	20.Experience needed for a particular delivery	27.Complexity of decision making		
5.Cost saving	12.Applicability		21.Construction quality	28.Reduction in administrative staff		
6.Project budget			22.Coordination &communications	29.Enough experience		
7.Tight project milestone or deadlines			23.Clarity of defined roles	30.Funding cycle		

CII [7] identified three main factors broken down into 20 sub factors as shown in Table 3.

Table 3. Factors affecting the selection of a project delivery method [8].

Cost related factors	**Schedule related factors**	**Other factors**	**Cont.**
1.Completion within budget	6.Completion within schedule	9.An above normal level of changes	16.Desire of minimal use of own resources
2. Minimal cost	7. Early completion	10.A below-normal level of changes	17.Project features are well-defined
3. Owner's cash flow	8. Early procurement of long-lead items	11.Confidentiality of business	18.Project features are not well defined
4.Early &reliable cost figures		12.Local conditions at project site	19.Prefer of minimal number of parties
5.Minimal financial risk		13.Desire of high degree of control	20. Project design is complex
		14.Desire of minimal level of control	
		15. Desire of substantial use of own resources	

As mentioned earlier, the process of choosing the best project delivery method is critical. First, owners should assess the relative importance of factors on which project delivery methods are to be evaluated. Second, owners should evaluate the attractiveness of each project delivery method. Finally, a combination of the factors into an overall assessment of each project delivery method is to be developed. The complete process can be modeled using the analytical hierarchy process (AHP) to arrive the best option [2].

III. ANALYTICAL HIERARCHY PROCESS (AHP)

The AHP is a powerful mathematical tool used for ranking alternatives and making decisions to choose the best option. The AHP uses a hierarchical model comprising a goal, factor, several levels of subfactors, and alternatives for each problem or decision [1].

A. AHP Methodology

First, a list of project delivery method selection factors to be identified and used in the AHP model. Al Khalil [3] identified three main factors. Each of these factors is further broken down into subfactors. For example, the project characteristics factor is broken down into four subfactors: scope definition, schedule, price and complexity as shown previously in Table 1. After all the factors and subfactors have been input into the AHP model (see Figure 5), comparison matrices are generated.

Second, the relative importance or preference between each pair of factors and subfactors is to be compared. For instance, for project characteristics, there are four preferences: scope definition versus schedule, scope definition versus price, scope definition versus complexity, schedule versus price, schedule versus complexity, and price versus complexity. Each preference is important not only to itself but also to the overall matrix that is developed [3].

After the subfactors matrices are completed, a final matrix, which compares all of the high-level PDM factors, is filled out. This matrix consists of a pair-to-pair comparison of each factor [2]. The matrix is used to get the owner responses for the importance of one factor versus another. A comparison can be made between each and every factor using a nine-point rating scale [1]. For example, the project characteristics are *more important* than the owner preferences. The even numbers can be used in the case of a tie between rating choices (see Table 4).

Table 4. The AHP comparison scale [1].

Weight	Definition
1	Equal importance
3	Weak importance of one over another
5	Essential or strong importance
7	Very strong importance
9	Absolute importance
2.4.6.8	Intermediate values between the two adjacent judgments
Riciprocals of above	If factor i has one of the above numbers assigned to it when compared to factor j, then j has the reciprocal value when compared with i

IV. AHP APPLICATIONS

In applying AHP to select PDM, software widely known as ‘‘Expert Choice’’ was used [1;2]. Expert Choice software is a decision making tool based on the AHP. AHP has been applied to a widerange of large-scale projects and current decision-making problems and issues [2]. In this section, two applications will be used to demonstrate how this procedure can be applied to select a project delivery method.

A. Case Study 1

Al khalil [3] applied the AHP to select the appropriate project delivery method among three options: the design-bid-build (DBB), design-build (DB) and construction management (CM). He constructed a hierarchy consisting of five levels to evaluate the appropriateness of a PDM based on several factors as shown in Figure 5.

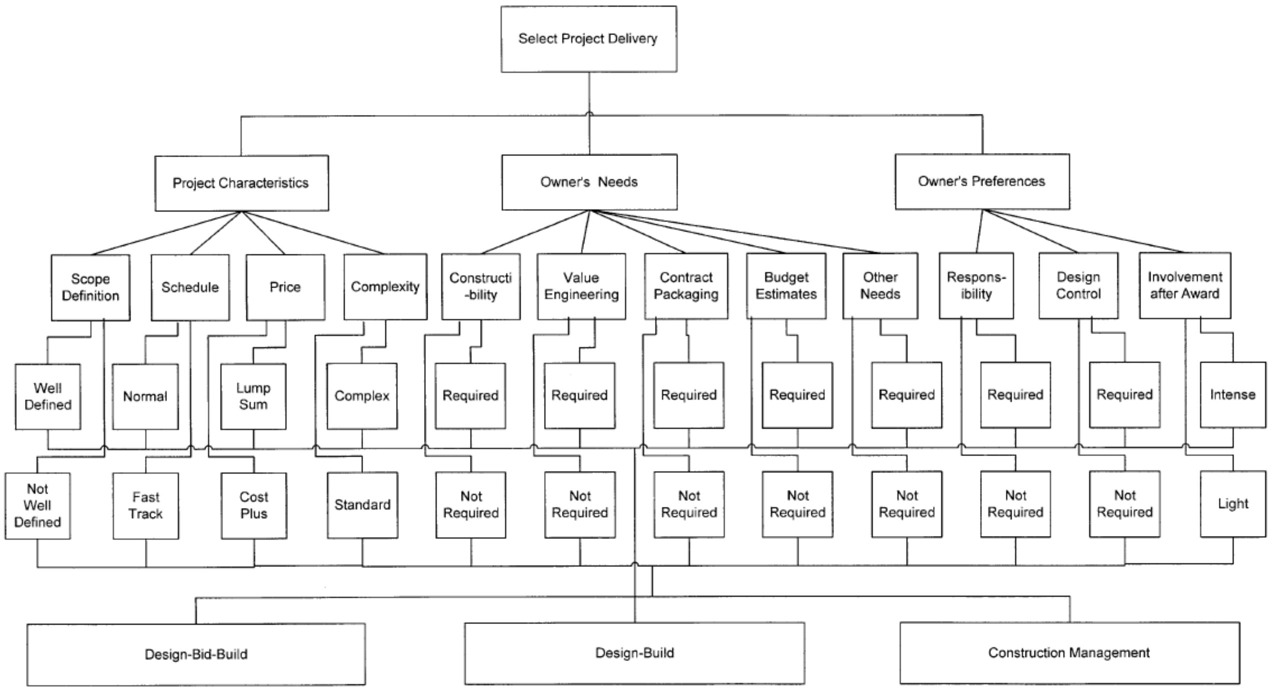

Figure 5, Hierarchy design for the project delivery method selection model [3].

These factors were discussed thoroughly in his study. Each of the factors was compared pair-wise with the other with respect to the overall goal of selecting the appropriate PDM. Ranking among the different factors was also done to find out the final priority of each PDM as shown in Figure 6.

	Final priorities
DBB	0.27
DB	0.39
CM	0.34

Figure 6, Final priorities ranking [3].

In conclusion, based on this final priorities, the appropriate PDM was selected which is DB in this case.

B. Case Study 2

Mahdi and Alreshaid [4] also used the AHP to select the proper PDM based on high degree of technical factors and low construction cost. In their study, the most common PDMs (DB, DBB, CMR and CMA) were evaluated. The evaluation procedure considered seven main factors and 34 sub factors as shown previously in Table 2. Then, the hierarchy structure was established and an overall priority was computed using the Expert Choice software based on the input given by the decision-maker. The analysis showed that DB was the most proper project delivery option if all the factors were considered as shown in Figure 7.

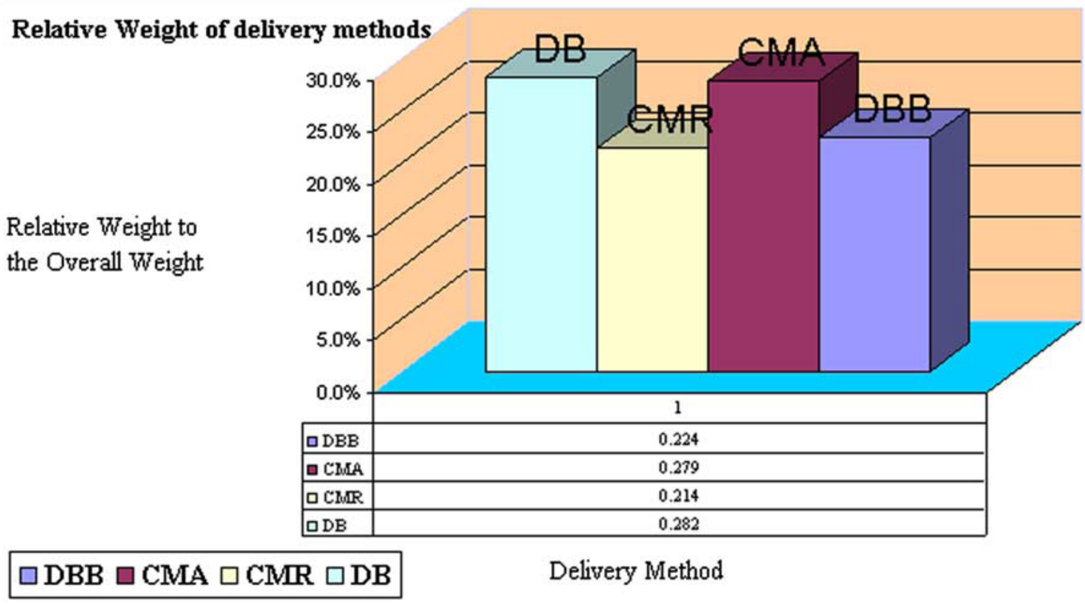

Figure 7, Relative weight of delivery methods [4].

In addition, a sensitive analysis was carried out to determine how the selection might change if the importance of the factors were changed. The authors claimed that increasing the importance of the factor "project characteristics" would result in this case that CMA to be the proper selection. Moreover, if one of the three factors "owner characteristics", "regulatory", "contractor characteristics" were considered only in the decision making analysis, DBB would be the best option.

CONCLUSION:

In conclusion, selecting the appropriate PDM that would result in significant savings is a complex task. The AHP approach is very helpful decision making tool used for prioritizing objectives and chooses the best. However, it is difficult to define a particular PDM for different projects because the factors that may influence the choice of a project delivery method could vary due to the decision-makers' different viewpoints.

In this report, a set of common project delivery methods were identified. The selection criteria were determined by studying a number of factors. Then, the AHP model was developed to assist owners ranking the PDM alternatives by considering both factors and owner's opinion. To illustrate this methodology, case studies were demonstrated.

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APPENDIX A

Project Delivery and Contract Strategies [8]

PDCS Number	PDCS Name	Description
PDCS 1	Traditional D-B-B	Serial sequence of design and construction phases; procurement begins with construction; owner contracts separately with designer and constructor.
PDCS 2	Traditional with early procurement	Serial sequence of design and construction phases; procurement begins during design; owner contracts separately with designer, constructor, and supplier.
PDCS 3	Traditional with PM	Serial sequence of design and construction phases; procurement begins with construction; owner contracts separately with designer and constructor; PM (Agent) assists owner in managing project.
PDCS 4	Traditional with CM	Serial sequence of design and construction phases; procurement begins with construction; owner contracts separately with designer and constructor; CM (Agent) assists owner in managing project.
PDCS 5	Traditional with early procurement and CM	Serial sequence of design and construction phases; procurement begins during design; owner contracts separately with designer, constructor and supplier; CM Agent assists owner in managing project.
PDCS 6	CM @ Risk	Overlapped sequence of design and construction phases; procurement begins during design; owner contracts separately with designer and CM @ Risk (constructor).
PDCS 7	Design-Build (or EPC)	Overlapped sequence of design and construction phases; procurement begins during design; owner contracts with Design-Build (or EPC) contractor.
PDCS 8	Multiple Design-Build	Overlapped sequence of design and construction phases; procurement begins during design; owner contracts with two Design-Build (or EPC) contractors, one for process and one for facilities.
PDCS 9	Parallel Primes	Overlapped sequence of design and construction phases; procurement begins during design; owner coordinates separate contracts with designer and multiple constructors (or D-B contractor(s)).
PDCS 10	Traditional with Staged Development	Multi-stage, serial sequence of design and construction phases; separate contracts for each stage; procurement begins with construction; Project Manager (Agent) assists owner with project management.
PDCS 11	Turnkey	Overlapped sequence of design and construction phases; procurement begins during design; owner contracts with Turnkey contractor.
PDCS 12	Fast Track	Overlapped sequence of design and construction phases; procurement begins during design; owner contracts separately with designer and constructor.

APPENDIX B

Selection Factors for PDMs [8]

Factor Number	Selection Factor	Factor Description for Comparing PDCS	Factor Action Statement
Cost-related factors			
1	Completion within original budget is critical to project success.	Project delivery and contract strategy facilitate control of cost growth.	Control cost growth.
2	Minimal cost is critical to project success.	Project delivery and contract strategy ensure lowest reasonable cost.	Ensure lowest cost.
3	Owner's cash flow for the project is constrained.	Project delivery and contract strategy delay or minimize rate of expenditures.	Delay or minimize expenditure rate.
4	Owner critically requires early (and reliable) cost figures to facilitate financial planning and business decisions.	Project delivery and contract strategy facilitate accurate early cost estimates.	Facilitate early cost estimates.
5	Owner assumes minimal financial risk on the project.	Project delivery and contract strategy reduce risks or transfer a high level of cost and schedule risks to the contractor(s).	Reduce risks or transfer risks to contractor(s).
Schedule-related factors			
6	Completion within schedule is highly critical to project success.	Project delivery and contract strategy facilitate control of time growth.	Control time growth.
7	Early completion is critical to project success.	Project delivery and contract strategy ensure shortest reasonable schedule.	Ensure shortest schedule.
8	Early procurement of long-lead equipment and/or materials is critical to project success.	Project delivery and contract strategy promote early design and purchase of long-lead equipment or materials.	Promote early procurement.

Factor Number	Selection Factor	Factor Description for Comparing PDCS	Factor Action Statement
Other factors			
9	An above-normal level of changes is anticipated in the execution of the project.	Project delivery and contract strategy promote ease of incorporating changes to the project scope during detailed design and construction.	Ease change incorporation.
10	A below-normal level of changes is anticipated in the execution of the project.	Project delivery and contract strategy capitalize on expected low levels of changes.	Capitalize on expected low levels of changes.
11	Confidentiality of business/ engineering details of the project is critical to project success.	Project delivery and contract strategy protect secrecy of business objectives and proprietary technology.	Protect confidentiality.
12	Local conditions at project site are favorable to project execution.	Project delivery and contract strategy capitalize on familiar project conditions.	Capitalize on familiar project conditions.
13	Owner desires a high degree of control/influence over project execution.	Project delivery and contract strategy increase owner's role in managing design and construction.	Maximize owner's controlling role.
14	Owner desires a minimal level of control/influence over project execution.	Project delivery and contract strategy minimize owner's role in managing design and construction.	Minimize owner's controlling role.
15	Owner desires a substantial use of own resources in the execution of the project.	Project delivery and contract strategy promote greater owner involvement in detailed design and construction.	Maximize owner's involvement.
16	Owner desires a minimal use of own resources in the execution of the project.	Project delivery and contract strategy minimize owner involvement in detailed design and construction.	Minimize owner's involvement.
17	Project features are well-defined at award of the design and/or construction contract.	Project delivery and contract strategy capitalize on well-defined project scope prior to award of design and/or construction.	Capitalize on well-defined scope.

Factor Number	Selection Factor	Factor Description for Comparing PDCS	Factor Action Statement
Other factors (continued)			
18	Project features are not well-defined at award of design and/or construction contract.	Project delivery and contract strategy efficiently utilize poorly defined project scope prior to award of design and/ or construction.	Efficiently utilize poorly defined scope.
19	Owner prefers minimal number of parties to be accountable for project performance.	Project delivery and contract strategy minimize the number of parties under contract directly with the owner.	Minimize number of contracted parties.
20	Project design/engineering or construction is complex, innovative, or non-standard.	Project delivery and contract strategy facilitate efficient coordination and management of non-standard project design/engineering and/or construction.	Efficiently coordinate project complexity or innovation.