THE ENGAGEMENT OF EXPERT OPINIONS IN THE MODELING OF MULTI-ATTRIBUTE DECISION MAKING FOR THE SELECTION OF PROJECT DELIVERY METHODS IN BUILDING CONSTRUCTION

by

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The Introduction, Literature Review, Conclusions, have been added to maintain the flow of the dissertation.

ABSTRACT

Choosing the most appropriate project delivery method (PDM) available is acknowledged as a crucial issue in the construction industry. Both the choice and application of an unsuitable PDM can result in project failure. Likewise, the selection of a suitable PDM can increase the chance for project success. A method of selecting from among the seven PDMs recognized by the Construction Specifications Institute (CSI) was created in an attempt to address this issue.

This research was comprised of three objectives. The first objective was to determine the influential factors needed to select the appropriate PDMs available to the US construction industry. The importance of each influential factor was also examined to determine whether or not significant differences exist between the following: both public and private sectors, project contractual parties, and various regions across the US. An empirical survey was conducted to gather this information throughout the US construction industry. The relative performance and suitability of PDMs for the different conditions involved in building constructions were evaluated as part of the second objective. Another empirical survey was conducted in the US construction industry to help with this evaluation. The performance and suitability of each PDM was examined with respect to 36 project criterion. The information was analyzed to create a decision support model for the PDM selection. This research used the early engagement of experts' opinions in the modeling of multi-attribute decision making (MADM). A decision support model was established by linking together the Conjunctive Satisficing Method and the TOPSIS decision making approach, and applying them to the PDM selection. The face validation method, with a subset of the surveyed professionals, was used to validate the model.

The results gathered from this research provide both the project owners and the decision makers with a framework that can be used to evaluate a project's priorities and delivery options. A practical tool was also created that utilizes the expertise needed to make critical decisions without the physical existence of an expert panel. Applying the provided MADM model to the selection of a PDM allows the decision maker to choose the best alternative promoting a building construction project's success.

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1. INTRODUCTION

1.1. BACKGROUND

This research investigates advantages and disadvantages of the seven project delivery methods (PDMs) recognized by the Construction Specifications Institute (CSI). A construction project delivery method is the manner in which one manages the design and construction process while coordinating and maintaining the relationship between all of the project contractual parties. Depending on the project requirements some PDMs will be more suitable than others. Choosing the most appropriate PDM available is acknowledged as a crucial issue in the construction industry. Both the choice and application of an unsuitable PDM can result in project failure. Likewise, the selection of a suitable PDM can increase the chance for project success. A method of selecting from among the seven PDMs recognized by the Construction Specifications Institute (CSI) was created in an attempt to address this issue.

The project owner typically selects the method he or she determines is most suitable to the project's features and conditions. Additional, contractual parties (e.g., Architecture/Engineer, contractor/subcontractors, construction manager/consultant) provide adjustments during the negotiation stage to establish a compromise agreement. The risks shared between the project's contractual parties are allocated by the PDM (e.g., cost, time, and performance risks). According to the Construction Specifications Institute (CSI), a construction project delivery can be conducted by adopting any one of the following procedures: Design-Bid-Build (DBB), Design-Negotiate-Build (DNB), Design-Build (DB), Construction Manager as agent or adviser (CMa), Construction Manager as contractor (CMc), Owner-Build (OB), and Integrated Project Delivery (IPD).

The project owner needs to select the most appropriate construction project delivery among the available alternatives. Doing so increases the chance of satisfying the project's goals while keeping everything within the cost budget. The project owner typically struggles to compare the available PDM options to one another because the influential factors (e.g., owner objectives [cost, time, quality, and so forth] and project features [type, extent, complexity, and so forth]) are quite diverse. Often, the various objectives (such as minimum cost, early project delivery, and high quality) cannot be achieved simultaneously. Therefore, the project owner encounters a problem in comparison between the advantages of a specific target against another.

The introduction to this dissertation presents the background (section 1.1), research objectives (section 1.2), research methods (section 1.3), and scientific research contribution (section 1.4) of this project. Furthermore, the organization of this dissertation is on the end (section 1.5).

1.2. RESEARCH OBJECTIVES

This research project was divided into three parts. The first part of this project was comprised of two research objectives. The first objective of the first part was to determine the influential factors needed to select appropriate PDMs in the US construction industry. The second research objective was to ascertain whether or not significant differences exist in the influential factors' importance between the following: the public and private sectors, project contractual parties, and regions in the US.

The research objective of the second part of this study was to evaluate the relative performance and suitability of project delivery approaches for the different conditions associated with building construction. Industry experts evaluated these performances with respect to: the owner's goals, and the project's objectives. The suitability of utilizing each PDM was determined with respect to: the project's features, the owner's capabilities and attitude, and market considerations.

The objective of the third part of this research project was to create and validate a model that can be used to select the most appropriate PDM for building construction purposes. This decision support model provides project owners with the ability to choose the best alternatives to promoting a project's success.

1.3. RESEARCH METHODS

The first part of the research project was approached survey conducted in the US to identify the influential factors importance for selecting appropriate PDMs. a comprehensive literature review (section 2) was conducted from which a total of 40 influential factors were chosen for consideration. A survey containing 23 questions (see Appendix I) was sent to 1088 professionals/experts in the US construction industry. A total of 186 responses were recorded, reflecting a 17% response rate. This sample included the following: either owners or owner's representatives, either contractors or sub-contractors, Architecture/Engineering (A/E), and construction managers/consultants.

The target sample population was the local construction experts and professionals who were registered in some professional originations. This population was estimated to be about 10,000 experts and professionals. The sample size was estimated based on Hogg and Tannis (2009) formula shown in Equation 1.

$$n = \frac{m}{1+\frac{(m-1)}{N}} \tag{1}$$

Where *n* is the required sample size, N is the size of available population, and *m* is calculated by Equation 2.

$$m = \frac{z^2 p(p-1)}{\varepsilon^2} \tag{2}$$

Where z is the confidence level statistic value (e.g., 2.575, 1.96, and 1.645, for 99%, 95%, and 90% confidence levels, respectively), p is the population value of the proportion which can be given ½ if nothing is known about it, and ε is the maximum error of the estimate.

For the sample size (*n*) of this survey, *z* was given 2.575 for 99% confidence level, *p* was given ½, and *ε* was given 0.10, then *m* = 166 rounded up to the closest integer. Thus, the required sample size (*n*) = 166/ (1+ ((166-1))/10,000) = 164, rounded up to the nearest integer. The number of invited participants out of the population needed to achieve the desired sample size was 1088, which was determined based on the expected response rate of 15% and rounded up to the nearest integer.

The survey study was designed to ensure that the findings were statistically relevant within the US construction industry. The survey respondents determined the influential factors' importance to select a PDM. A Likert scale was used to score responses along a five-point scale. Cronbach's alpha coefficient was applied to measure the Likert scale reliability. The Relative Importance Index (RII) was used to determine the each influential factor's relative importance (Kometa et al 1994). The Mann-Whitney U-test (also known as the Wilcoxon Rank sum Test) was used to identify significant differences between respondents' evaluations (Israel, 2008). The Shapiro-Wilks statistical test was used to investigate the non-normally distributed data. The Kruskal-Wallis H-Test was used to identify significant differences between respondents' evaluations across the four US regions examined (Sheskin, 2004).

An empirical survey conducted in the United States was also used in the second part of this research. The performance and suitability of project delivery approaches were determined for the different situations of building construction. This survey was launched during July-September 2013. Equation 1 and 2 were used to estimate the sample size (n) of this survey as well. The value of z was given 1.96 for 95% confidence level, p was given ½, and ε was given 0.10, then m = 97 rounded up to the closest integer. Thus, the minimum required sample size (*n*) = 97/ (1+ ((97-1))/10,000) = 96, rounded up to the nearest integer.

Participants were either experts or professionals within the field of either building construction engineering or management. A total of 594 participants were recorded. Exactly 137 completed the questionnaires, reflecting a 23% response rate. Survey data analysis was taken from 132 completed questionnaires. Each respondent had more than 10 years of experience in their respective fields. The survey contained 26 questions to address the research objective. The first 17 questions were focused on evaluating the performance and suitability of utilizing each PDM. The remaining nine questions were related to the participant's personal information (see Appendix II). A Likert scale was used to score responses along a 10-point scale. Cronbach's alpha coefficient was applied to measure the scale's reliability. The geometric mean of the experts' evaluation scores was utilized to aggregate the individual opinions of the experts into a single representative judgment (Saaty, 2008).

The model created as the third part of this project leveraged the data collected from the two surveys. The elicited expert opinions were engaged as parameters in multi-attribute decision making (MADM) model to establish the aimed decision support tool. The model was established by linking together the Conjunctive Satisficing Method (Yoon & Hwang, 1995) and the Technique for Order Preference by Similarity to Ideal Solution

(TOPSIS) decision making approach (Triantaphyllou, 2000), and applying them to the PDM selection in building construction management. The face validation technique was then used to validate the model (Lucko, 2009).

1.4. RESEARCH CONTRIBUTION

The initial contribution of this study provides a framework both the project's owner and the decision maker can use to evaluate a project's priorities and delivery options (first and second parts). The influential factors used when considering PDMs were identified and organized into six related categories. The relative performance and suitability of PDMs were determined for the different conditions associated with building construction. These relative performance and suitability indicators revealed by this research can be used as guidelines when evaluating PDMs.

This research presents the early engagement of expert opinions in the modeling of multi-attribute decision making (third part). A decision support model was established by linking together the Conjunctive Satisficing Method and the TOPSIS decision making approach, and applying them to project delivery method selection. Thus, this study provides a model that can be used to select an appropriate PDM that leverages experts' opinions without requiring these experts to be physically present. Decision makers within the building construction industry can use the MADM model to choose the best PDM available and thus a project's success.

1.5. RESEARCH OUTLINE

This dissertation is presented as a publication option form. Three journal papers are included and organized as sections. After the introduction and the literature review, sections 1 and 2, the first paper, "*Influential Factors for Selecting a Project Delivery Method in the US Construction Industry*", is followed by "*Performance and Suitability of Project Delivery Approaches for different Conditions of Building Constructions,*" and "*Engagement of Experts' Opinions in the Modeling of Multi-Attribute Decision Making for Project Delivery Method Selection of Building Construction*". Section 6 contains the conclusion.

2. LITERATURE REVIEW

The basis for writing the three articles is introduced in this brief literature review. Additional, more detailed literature reviews are presented within each individual manuscript.

Various definitions for project delivery appear throughout literature. Pishdad and Beliveau (2010) stated that the previous definitions of PDM gave a description of "how a project will be planned, designed, and built", and he defined it as "Procurement approach, financing strategy and a management system developed for accomplishing the project's objectives and tasks in order to deliver a project that is successful throughout its life cycle from concept to implementation, operation and maintenance." Mahdi (2005) defined a PDM as "A method for procurement by which the owner's assignment of delivery risk & performance for design & construction has been transferred to another party (parties)." The American Institute of Architects (2008) gave the following definition for a PDM as "the method selected to allocate roles, responsibilities, risks, and rewards among the parties accomplishing the design, preparation of construction documents, construction, and management of a construction project." According to the Construction Specifications Institute (2008), "Project delivery encompasses the contractual relationships necessary to establish a sequential process of design and construction activities that converts a conceptual idea into a completed and occupied facility".

Considerable efforts have been made throughout the previous three decades to recognize the criteria governing the selection of a PDM within the construction industry (Pishdad & Beliveau, 2010). Investigators have discovered that the most common factors related to a client's concerns include the following: time, cost, quality, responsibility, and involvement in the design work (Ambrose & Tucker 2000; Michell et al., 2007). Various studies have established criteria to formulate a basis for selecting the most relevant influential factors. These studies demonstrated differences regarding the numbers of recognized influential factors. A list of 40 influential factors were determined and organized into 6 categories (see Table 1 of paper I).

Chen et al. (2011) stated that a project's performance for various PDMs can be predicted as a basis for choosing the appropriate PDM. Rashid et al. (2006) studied the effect of PDMs on the performance of construction projects. They focused on the three parameters most critical to a project's performance (i.e., time, cost, and quality). They concluded that all influential factors must be carefully considered when selecting the most appropriate approach. A list of 36 factors was selected from the list of 40 influential factors mentioned above to evaluate the performance and suitability of construction PDMs. These factors were classified into five categories. The factors included in each category were related to (1) the owner's goals, (2) the project's objectives (3) the project's features, (4) the owner's capabilities and attitude, (5) and market considerations. The excluded factors belong to the cultural and regulations category. These factors included the following: both the institution and the society's culture, organizational constraints, regulation flexibility and constraints, and political concerns. These factors were excluded because they cannot be used to evaluate either the performance or suitability of construction PDMs. The effect of these factors should be considered on a case-by-case basis. For example, public and governmental agencies are frequently required to use PDMs that include competitive bidding to ensure that the taxpayers' revenue is utilized fairly for public facilities. Therefore, the design-Negotiate-build (DNB) method is rarely used for the public projects (CSI, 2008).

In the literature, a variety of decision tools and techniques for the selection of a project delivery method have been presented. Each procedure has its own distinctive features (see Appendix A of paper III). Reviewing the recent existing procedures for the selection of a project delivery method leads to the following remarks:

- The established approaches began with NEDO (1985) and have continued through Ding, et al. (2014) so far.
- Most approaches use different methodologies to solve the problem. These approaches can vary from simple (e.g., Skitmore & Marsden, 1988) to highly complex (e.g., Alhazmi & McCaffer, 2000).

- Each approach made an effort to cross-reference project attributes with project delivery methods.
- The current approaches ignore some important affecting factors and/or the consideration of limited alternatives of project delivery methods (e.g., Ambrose and Tucker, 2000; Cheung el at. 2001; Moshini and Botros, 1990; NEDO, 1985; Skitmore & Marsden,1988; Zhang and Wang, 2009)
- Special advanced math skills are needed to apply some methods. The decision maker, however, may not have these skills (e.g., Wang el at., 2008)
- The Analytical Hierarchy Process (AHP) was applied to several procedures so that could be selected the proper PDM (Al Khalil, 2002; Mahdi & Alreshaid, 2005; Mafakheri et al., 2007; Zhang & wang, 2009). These procedures become quite complicated if a large number of influential factors are used because they depend on the pairwise comparison matrix. Therefore, reduction and careful selection of influential factors is required to utilize these procedures which will negatively affect the accuracy of the results (Chen et al., 2011).
- Several applied the Multi-Attribute Utility Theory (MAUT) to select the proper PDM (Skitmore & Marsden, 1988; Chuang et al., 2001). Although these models are simple and easy to use, the project may not reach the anticipated objectives because the influential factor's utility values mostly fail to represent the actual project status, (Chen et al., 2011). Also, the lack of observations' compatibility among selection criteria's utility values is the main difficulty of the MAUT selection models (Chan et al., 2001).
- Mahdi (2005) concluded that, in order to select the most suitable PDM for an aimed project, an owner should first understand the available types of PDMs, the project's features, and his/her own abilities. In reality, this is not always possible.
- The proposed approaches assume that the decision maker has adequate knowledge on the performance of each construction PDM as related to the decision criteria. Pishdad and Beliveau (2010) concluded that most project owners lack sufficient knowledge to recognize the various aspects of project delivery. In these instances, the previously

suggested decision support models are nearly useless. Wang at al. (2008) reported that "the determination of the weight in the existing project delivery decision-making model relies on experts' knowledge and experience excessively, and the subjective factors play too big roles in the decision-making process."

This research is aimed to establish a practical and reliable PDM selection model to overcome some of previous procedures' disadvantages. This study incorporated the experts' opinions as a "*group*" for multi-attribute decision making (MADM) modeling to minimize the judgment subjective effect on the model's parameters. Also, the early engagement of expert opinions in MADM modeling provides a practical approach for utilizing expertise to make the best decision for a specified project without the physical existence of an expert panel during the decision making process.

I. Influential factors for selecting a project delivery method in the US construction industry

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Abstract

The purpose of this paper is to determine the influential factors involved in selecting appropriate project delivery methods in the US construction industry. Also, this paper investigates if there are significant differences in the influential factors' importance between the following groups: project contractual parties, among the public and private sectors, and between different United States regions. A survey was conducted among: owners, contractors, Architecture/Engineering, and consultants to measure influential factors importance within the US construction industry. The result from this study revealed that there are 40 influential factors. These factors were divided in the following six related categories: (1) the owner's goals, (2) the project's features, (3) the project's objectives, (4) the owner's capabilities and attitude, (5) market considerations, (6) and both culture and regulations. No significant differences were found in the importance of most of the influential factors between the public and private sectors, among the owners, contractors, consultants, and Architecture/ Engineering evaluations, and different regions within the United States. The results of this research provide attributes by which project owners can evaluate both a project's priorities and its delivery options to help ensure project success.

Keywords: US construction industry, construction project management, project delivery.

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1. Introduction

The American Institute of Architects (2008) defined a project delivery method as "the method selected to allocate roles, responsibilities, risks, and rewards among the parties accomplishing the design, preparation of construction documents, construction, and management of a construction project." (p. 1000). According to the Construction Specifications Institute (2008), construction project delivery can be conducted by adopting any one of the following seven procedures:

- Design-Bid-Build (DBB). As a part of the DBB process, the owners enter into a contractual arrangement with two or more different entities for each the project's design and construction. The project activities (including: design, bidding, and construction) taking place one after another in time (CSI, 2008).
- Design-Negotiate-Build (DNB). After the design stage is completed, the owner negotiates a construction contract with a contractor(s) without formal competitive bidding. The negotiation seeks to achieve a compromise arrangement for the benefit of all, and to minimize the risk for each party (CSI, 2008).
- Design-Build (DB). The owner enters into a contractual arrangement with one entity to provide all required project's design and construction services (CSI 2008). The owner provides the design-builder with the project performance requirements. The design-builder designs and builds the project to satisfy those requirements according to a combined contract for both design and construction (AGC, 2004).
- Construction manager as agent or adviser (CMa). The manager's role involves advising the owner on the project management, and sometimes he works as an owner representative as well. The owner contracts directly with the A/E and either a single-prime contractor or multiple prime contractors (CSI, 2008).
- Construction manager as contractor (CMc). The owner contracts with the construction manager to serve as a contractor (CSI, 2008). The CMc bears not only the performance risk but also the financial risk. Therefore, this method is known as "CM at-Risk" (AGC, 2004).

- Owner-Build (OB). The owner directly manages all of the project activities. The owner works as a contractor with separate entities who are typically A/E, subcontractors, and suppliers (CSI, 2008).
- Integrated Project Delivery (IPD). The American Institute of Architects (AIA, 2007) defined the IPD as follows:

> A project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction. (p. 1)

Both the choice and application of an unsuitable project delivery method could result in project failure (Luu et al. 2003). Likewise, the selection of a suitable procurement system could increase the client's chance for project success (Kumaraswamy and Dissanayaka 1998). Because of existence of large amount of uncertain information, the selection of suitable project delivery method is not easy task (Chen et al. 2011). According to Morledge et al. (2006), the choice of a suitable project delivery scheme involves two steps:

a) Analysis – Identify and establish priorities for designated project objectives while considering the owner's attitude toward risk.

b) Alternatives – Consider potential options, evaluating them according to determined priorities, and then choosing the option most appropriate for a particular project.

The primary objective of this study was to identify the influential factors of selecting the construction project delivery approach in the US construction industry. The result of this research provides an essential step toward evaluating project's priorities by the owner or the decision-maker. This study also sought to determine the differences in the importance of these influential factors between the public and private sectors, between the owners, contractors, consultants, and Architecture/ Engineering respondents, and between the different regions across United States. These investigations were conducted for generalizing of the objective results throughout the US construction industry.

2. Background

2.1. Cost, time, and quality importance

Determining a client's needs and then prioritizing them in a systematic manner are essential tasks when selecting the most appropriate construction project delivery approach available. These tasks can increase client satisfaction and, thus, project success likelihood. The contractual parties need to match the various established project delivery forms with the client's features, criteria, and priorities while also considering cost, time, and quality in order to achieve project success (Naoum, 1994).

Investigators have discovered that the most common influential factors related to clients' concerns are: time, cost, quality, responsibility, and involvement in the design work (Ambrose and Tucker, 2000, and Michell et al., 2007). Hashim et al. (2006) suggested that the Design-Bid-Build (DBB) method of a construction project delivery has the advantages of both cost and quality. Unfortunately this method increases in the required time for project completion. The Design-Build (DB) method has the advantages of both cost and time, though the level of quality is often decreased. The Construction-Management (CM) method has the advantages of both quality and time but it increases the cost. Fig. 1 illustrates the relationship between the three main construction project delivery systems and cost-time-quality priorities. This figure can be used as a simple guideline for understanding this relationship when looking for cost-time-quality priorities without considering additional factors.

2.2. Criteria for selecting a PDM in the construction field

Throughout the previous three decades, considerable efforts have been made to recognize the criteria governing the selection of a project delivery approach within the construction industry. The first acknowledged attempt discovered by these authors to identify these criteria in the literature was conducted by the National Economic Development Office (NEDO, 1985). Owners can use its established criteria to define the priorities of the project. NEDO (1985) identified eight influential factors most relevant for a project delivery method choice. These eight influential factors include the following:

- *Duration*: The importance of early completion.

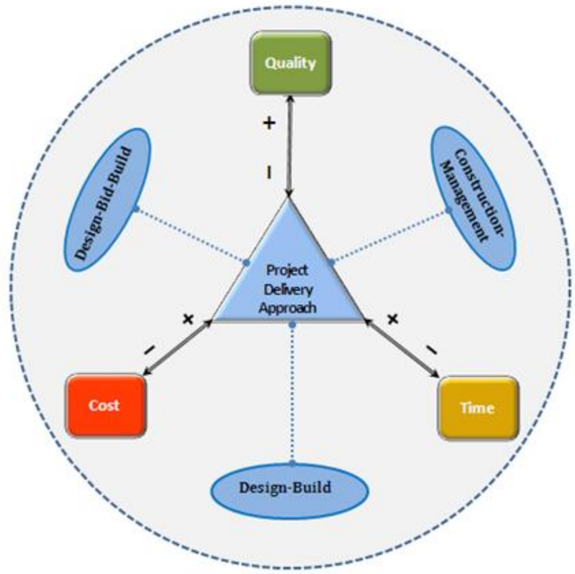

Fig. 1. The relationship between the three main PDMs and Cost-Time-Quality priorities

- *Tractability*: Flexibility after work has begun.
- *Complexity*: Complex technology and services.
- *Quality*: Design and workmanship quality level.
- *Certainty of Cost*: Firm price before commitment.
- *Competition*: Team selection by price competition.
- *Responsibility*: On either one or more parties.
- *Risk*: Avoidance of cost and time slippage risk.

Various other studies have established criteria to formulate a basis for selecting the most relevant influential factors. Hibberd and Djebarni (1996) focused on ten fundamentals for comparison criteria (see Table 1). They concluded that, although the selection criteria (influential factors) is crucial, many decisions of project delivery method selection are made based on general project features rather than the evaluation of predetermined criteria. Ambrose and Tucker (2000) identified a range of factors influencing the decision of which project delivery method to utilize. They concluded that the assessment of project delivery arrangements versus both the owner's objectives (such as minimum project cost) and the project features (such as project extent) is a crucial step in the selection process for assisting in project success.

Table 1. References used to formulate criteria for construction PDM selection

	Considered Influential Factors[$]	NEDO, 1985	Moshini and Botros, 1990	Hibberd and Djebarni, 1996	Dorsey, 1997	Kumaraswamy and Dissanayaka, 1998	Ambrose and Tucker, 2000	Ng et al., 2002	Cheung et al., 2001	Hashim et al, 2006	Morledge et al., 2006	CSI, 2008	QDPW, 2008	Pishdad and Beliveau, 2010	Chen et al., 2011	Thwala and Mathonsi, 2012	Al-Jawhar, and Rezouki, 2012
	First - Owner Goals Category																
	Cost-related factors:																
F1	Minimum cost	X	X					X	X	X			X	X			X
F2	Cost control					X	X	X	X		X	X			X		X
F3	Early budget estimation	X		X						X	X	X			X		
	Time-related factors:																
F4	Early project delivery	X	X	X	X			X	X	X	X	X	X	X	X	X	X
F5	Schedule control			X		X	X	X	X		X	X	X		X		X
F6	Early procurement			X	X						X	X					
	Quality-related factors:																
F7	High quality of the outcomes					X	X	X	X	X	X		X	X	X		X
F8	Construction quality control	X									X			X			
F9	High performance of O&M												X				X
	Risk-related factors:																
F10	Minimal financial risk	X					X				X		X				
F11	Minimal schedule risk	X					X				X		X				
F12	Minimal performance risk						X				X		X				
	Second - Project Features Category																
F13	Project subdivision type		X			X	X					X	X	X	X		X
F14	Project extent		X		X	X	X				X	X	X	X	X	X	X
F15	Complexity	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
F16	Uniqueness		X				X						X	X		X	X
F17	Workplace location		X			X					X			X			
F18	Workplace circumstances						X							X			
F19	Design completion stage		X	X	X	X	X				X			X			
F20	Possibility for changes	X						X	X	X	X			X	X		X
F21	Degree of risk of scope of work		X		X		X	X		X	X		X	X	X	X	
F22	Sustainability involved												X	X			
	Third - Project Objectives Category																
F23	Project life cycle				X					X			X	X		X	
F24	Pre-construction services				X				X		X						
F25	Project team relation			X		X	X		X					X	X		
F26	Safety					X								X			
F27	Security					X								X			
F28	Stakeholders' satisfaction					X							X	X			
	Fourth - Owner Capability and Attitude Category																
F29	Owner's experience			X	X	X				X	X	X	X			X	X
F30	Owner's degree of participation		X	X	X		X		X					X	X		X
F31	Owner's available resources				X									X	X	X	
F32	Owner's attitude towards risk		X	X					X					X	X		X
F33	Adequate number of contractual parties	X			X			X	X	X				X			X
	Fifth - Market Consideration Category																
F34	Availability of demanded service				X	X							X	X	X	X	X
F35	Accessibility of commodity				X	X							X	X			
F36	Economic status of the market					X	X				X		X	X	X	X	
	Sixth - Culture and Regulations Category																
F37	Society and institution's culture			X	X	X					X			X			
F38	Organizational constraints												X			X	
F39	Regulation flexibility and constraints		X		X	X		X		X	X		X	X	X	X	X
F40	Political concerns					X	X				X		X	X		X	
	Categories																
C1	Owner Goals Category		X				X								X		
C2	Project Features Category		X			X	X				X			X	X		
C3	Project Objectives Category													X			
C4	Owner Capability and Attitude Category					X								X	X		
C5	Market Consideration Category					X								X	X		
C6	Cultural and Regulations Category		X											X			

References[#]

\# Note: X symbol means that this factor (F) or categories (C) was considered in those references.

$ In case of there are different expressions with the same meaning of considered influential factors, then only one of them is chosen for the unification purposes.

Several studies have applied the eight NEDO influential factors as a basis for their established influential factors. Ng et al. (2002) suggested nine influential factors usually used by Australian owners: "speed, time certainty, price certainty, complexity, flexibility, responsibility, quality level, risk allocation, and price competition."

Hashim et al. (2006) found that the common influential factors for selecting a PDM included: "time, controllable variation, complexity, quality level, price certainty, competition, responsibility, risk avoidance, price completion, government policy, and client familiarity in a procurement method."

The Construction Specifications Institute (CSI, 2008) identified the influential factors affecting the quality of a project as: the owner's capability, the extent of the work, the time required for project completion, and the cost of the work. These factors influence which project delivery approach should be used. Previous studies demonstrated noticeable differences regarding their recognized influential factors (see Table 1). Therefore, a comprehensive list of influential factors should be established for the selection of an appropriate PDM. This paper demonstrates the results of a survey for the factors affecting the selection of an appropriate PDM in the US industry. The following sections describe the survey construction and deployment, analysis approach, survey results, and conclusion and future work.

3. Methodology

3.1. Empirical survey

A 23 questions empirical survey was created to better understand factors most influential to the selection of an appropriate PDM in the US construction industry. A total of 40 influential factors were considered and arranged into six related categories based on a broad literature review for the most relevant studies, as shown in Table 1.

This survey was conducted in the United States to ensure that the literature review findings were effectual within the US construction industry. Survey respondents were asked to evaluate the influential factors importance for selecting a project delivery approach. Their evaluations were established considering the environment of the US construction industry.

3.2. Survey deployment and data collection

An online survey was utilized to launch the questionnaires in 2012. Approximately 1088 specialists (or experts) within the construction industry were invited to participate in the survey. Those specialists were working in the US at the time of this study. Respondents were asked to evaluate the importance of both the 40 influential factors and the 6 categories related to the selection of construction PDM, as illustrated in Appendix A.

Respondents were also asked to provide some personal information related to their qualifications and positions in the second part questions. This information was collected to provide data for both statistical and comparative analyses. It also helped ensure that those answering questions were indeed qualified to participate. The requested information included the following: work experience in the construction field, education and qualifications, nature and location of the work; and organization or institution type, and so forth. When the online survey closed, a total of 186 responses were recorded, reflecting a 17% response rate.

3.3. Analysis approach

The Likert scale is widely used to format data collected in surveys. Typically, five-point response levels are used (Allen and Seaman, 2007). Thus, for the purpose of this study, a Likert scale was used to score responses along a five-point scale for evaluating the influential factors' importance, (as given in Appendix A). Cronbach's alpha coefficient was applied to measure the reliability of the Likert scale within the survey. This coefficient of reliability (or consistency) investigates the internal consistency of the respondents' results among the 40 influential factors.

The Relative Importance Index (RII) developed by (Kometa et al, 1994) was used to determine the relative importance of the 40 influential factors, investigated in the first part questions, according to the following formula:

$$Relative\ Importance\ Index\ (RII) = \frac{\sum_{i=1}^{A} w_i . n_i}{(A \times N)} \quad (1)$$

Where w_i, are given weights to the influential factors by the respondents, which ranges from 1 to 5. A is the highest possible Likert score point (i.e. 5 in this case). n_i is the number of respondents who selected an *i* score, where $i = 1, 2, \ldots, A$, and N is the total number of the respondents.

The Predictive Analytics Software (PASW Statistics 18.0) used for statistical analysis was utilized in this study. According to Israel (2008), the Mann–Whitney U-test (also known as the Wilcoxon Rank Sum Test) is a practical method that will identify significant differences between the median of the two groups where the following condition are satisfied: the data are assessed on an interval scale, and the satisfaction of normality assumptions relating to the sample groups do not acknowledged to be achieved. The data collected from this study, questions of the first part, met these two conditions.

The first part questions' data were structured as Likert response questions; therefore, the first Mann–Whitney U-test condition was satisfied. The non-normal distribution based on Shapiro-Wilks statistical test results indicated that $p\text{-value} < 0.05$ for all of the first part questions' data. Therefore, the second condition was satisfied. Thus, the Mann-Whitney U-test was used to determine the significant differences of respondents' evaluation between those who were working in the public and private sectors regarding the influential factors of selecting a project delivery approach.

The United States was divided into four regions for statistical comparison analysis (The United States were divided into four regions according to census regions of the US Census Bureau. DE, DC, MD, and WV states were relocated in NE region to get approximately the same number of states in each region for the study purpose). Each region has approximately the same number of states (as depicted in Fig. 2). The Northeast region is indicated in blue, the Midwest in green, the Western in red, and the Southern region in yellow.

Statistical comparison of the first part questions' results was conducted throughout the US four regions for generalization achievement. Sheskin (2004) suggested that the Kruskal-Wallis H-Test can be applied with ordinal (rank-order) data in a hypothesis testing condition when a pattern of two or more independent sample distributions exists. Thus, this test was used to identify significant differences between the four regions.

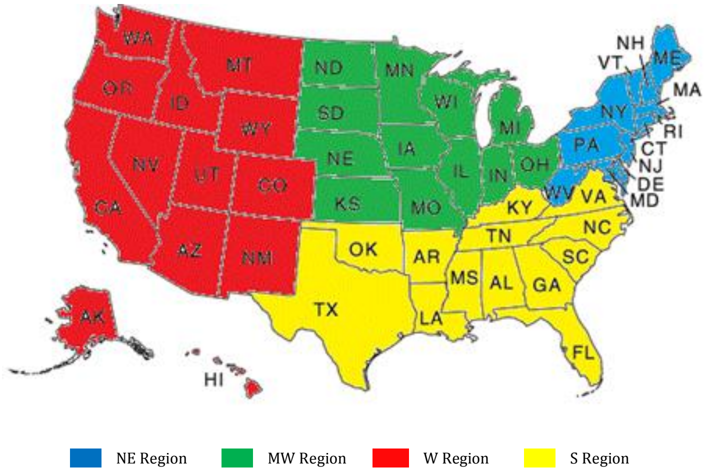

Fig. 2. The four divided regions as defined for the comparison study

4. Analysis of survey results

4.1. Respondents

Survey data was taken from 186 completed questionnaires. 97% of the respondents described themselves as having more than 10-years of experience in the construction field. 93% have academic degrees, including 31% with graduate degrees. 92% have at least one non-degree professional certificate in construction engineering and management field. The number of respondents who reported that they were familiar with different construction project types is illustrated in Fig. 3.

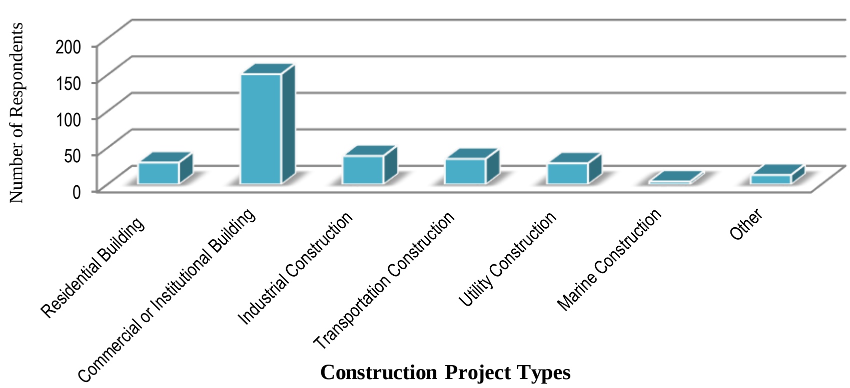

Fig. 3. Number of respondents familiar with different construction project types

An investigation into the nature of respondents' companies/institutions, through second part questions, revealed that 48% were consultant services, 20% were either contractors or sub-contractors, 19% were Architecture/Engineering (A/E), 11% were either owners or owner representatives, and 2% were governmental agencies. Approximately 20% were related to the public sector, 71% were related to the private sector, and 9% where related to the quasi-public (public and private) sector.

4.2. Influential factors importance

According to George and Mallery (2010), the recognized rule for observing internal consistency with the Cronbach alpha coefficient is "$\alpha > 0.9$ – Excellent, $\alpha > 0.8$ – Good, $\alpha > 0.7$ – Acceptable, $\alpha > 0.6$ – Questionable, $\alpha >0 .5$ – Poor, and $\alpha < 0.5$ – Unacceptable." In this study, the coefficient of reliability (the Cronbach alpha coefficient) was .887 considering the 40 factors affecting the selection of a PDM. This value ($\alpha = 0.887$) demonstrated that the five–point scale scoring devoted good internal consistency. Therefore the evaluation of the 40 factors is reliable for the purpose of this study.

The Relative Importance Indexes (RII), as shown in Eq. (1), were computed for each one of the 40 considered influential factors to distinguish the most important factors from the least important. They were then ranked according to these values (see Table 2). The 15 most important factors were identified based on the highest RII values, as shown in Table 3. The cost control factor (restraint cost growth), F2, was found to be the most important influential factor in the study (RII = 0.87). The lowest rated important factor by respondents was the sustainability involves, F22, with (RII = 0.58). The overall average evaluations of the considered influential factors were between median and critically important.

The rank of each of the six categories was determined by measuring the average value of the relative importance indexes of related influential factors: the higher the average value, the more important the category (as represented in Table 4). According to these rankings, the most important attributes are as follows:

- *Owner-related influential factors***.** The first and the second most important categories were owner-related categories. These included the owner capability and attitude

Table 2. Influential factors' relative importance index, and Mann Whitney U-test results

Influential factors#			Relative Importance Index (RII)						Mann Whitney U-test#		
Categories	Factors		Number of Responses (N)	Weighting Sum $\sum_{i=1}^{A}(w_i.n_i)$	Relative Importance Index (RII)		Rank		Mean Ranks Public Sector	Mean Ranks Private Sector	Exact Sig. (P-value)☼
C1: Owner Goals	F1	Minimum cost	186	706	0.76	RII (C1) = 0.80	23	Rank (C1) = 2	82	86	0.639
	F2	Cost control	186	806	0.87		**1**		80	87	0.377
	F3	Early budget estimation	186	760	0.82		12		72	89	**0.05**
	F4	Early project delivery	186	698	0.75		26		70	90	**0.018**
	F5	Schedule control	186	777	0.84		7		75	88	0.134
	F6	Early procurement	186	642	0.69		32		86	85	0.891
	F7	High quality	186	775	0.83		8		82	87	0.57
	F8	Construction quality control	185	756	0.82		11		82	86	0.657
	F9	High performance	185	749	0.81		14		83	85	0.818
	F10	Minimal financial risk	184	780	0.85		3		82	86	0.416
	F11	Minimal schedule risk	185	719	0.78		20		83	86	0.734
	F12	Minimal performance risk	185	733	0.79		18		87	84	0.759
C2: Project features	F13	Project subdivision type	183	660	0.72	RII (C2) = 0.72	30	Rank (C2) = 4	83	84	0.861
	F14	Project extent	185	656	0.71		31		88	84	0.717
	F15	Complexity	185	773	0.84		6		84	85	0.945
	F16	Uniqueness	183	699	0.76		22		78	86	0.368
	F17	Workplace location	184	546	0.59		39		87	84	0.706
	F18	Workplace circumstances	185	568	0.61		38		89	84	0.603
	F19	Design completion stage	185	728	0.79		19		88	84	0.635
	F20	Possibility of changes	184	733	0.80		17		87	84	0.662
	F21	Degree of risk	184	759	0.83		9		91	83	0.333
	F22	Sustainability involved	184	533	0.58		40		89	83	0.511
C3: Project objectives	F23	Project life cycle	185	595	0.64	RII (C3) = 0.75	35	Rank (C3) = 3	93	83	0.266
	F24	Pre-construction services	185	713	0.77		21		73	88	0.065
	F25	Project team relationship	185	775	0.84		5		79	87	0.406
	F26	Safety	180	659	0.73		28		94	79	0.073
	F27	Security	182	584	0.64		36		93	81	0.148
	F28	Stakeholders' satisfaction	185	781	0.84		4		88	84	0.638
C4: Owner's capability and attitude	F29	Owner's experience	186	749	0.81	RII (C4) = 0.82	15	Rank (C4) = 1	84	86	0.79
	F30	Owner's degree of participation	186	759	0.82		13		81	87	0.538
	F31	Owner's available resources	186	798	0.86		2		91	84	0.409
	F32	Owner's attitude towards risk	185	757	0.82		10		72	89	**0.045**
	F33	Adequate number of contractual parties	186	749	0.81		16		90	84	0.462
C5: Market State	F34	Availability of demanded service	185	699	0.76	RII = .72	25	Rank = 5	90	84	0.437
	F35	Accessibility of commodity	185	610	0.66		33		99	81	**0.042**
	F36	Economic status of the market	185	676	0.73		29		93	83	0.266
C6: Culture and Regulations	F37	Society and institution's culture	183	603	0.66	RII = 0.70	34	Rank = 6	80	85	0.536
	F38	Organizational constraints	185	678	0.73		27		90	84	0.475
	F39	Regulation flexibility and constraints	184	697	0.76		24		79	86	0.423
	F40	Political concerns	180	574	0.64		37		87	81	0.539

Notes: # Max. number of respondents: public sector = 33; and private sector = 137
☼ Exact Sig. (P-value): if p > 0.05; then no significant difference exists between public and private sectors

category (RII = 0.82) and the owner goals category (RII = 0.80). These categories included 11 of the 15 most important factors (as given in Table 3). These results provided an indication that the owner capabilities, attitudes, and goals play the primary roles in the decision making process for selecting an appropriate PDM in the US construction industry.

- *Project-related influential factors***.** The third and fourth most important categories were project-related ones. They included both the project objectives category (RII = 0.75) and the project features category (RII = 0.72). These categories comprised 4 of the 15 most important factors. These outcomes indicate that the project objectives and features play an important role in selection an appropriate project delivery method.
- *External environment-related categories.* The fifth and sixth ranked categories included the external environment-related categories. (i.e. the market state category [RII = 0.72], and the cultural and regulation category [RII = 0.70]). These categories did not include any factors from the 15 most important factors suggesting they have the smallest impact.

Table 3. 15 most important influential factors for selecting a project delivery method

	15 Most Important Influential Factors	RII	Rank	Factor Category
F2	Cost control (restraint cost growth)	0.867	1	Owner Goals
F31	Owner’s available resources (enough funding ahead of project time)	0.858	2	Owner Capability and Attitude
F10	Minimal financial risk	0.848	3	Owner Goals
F28	Stakeholders’ satisfaction	0.844	4	Project Objectives
F25	Project team relation (collaboration, integration, minimum disputes)	0.838	5	Project Objectives
F15	Complexity (composite deign and/or several distinct scope of works)	0.836	6	Project Features
F5	Schedule control (restraint time growth)	0.835	7	Owner Goals
F7	High quality (of the project outcomes)	0.833	8	Owner Goals
F21	Degree of risk (uncertainty of scope of work and/or outcomes)	0.825	9	Project Features
F32	Owner’s attitude towards risk (behavior towards risk taking)	0.818	10	Owner Capability and Attitude
F8	Construction quality control (during carrying out stage)	0.817	11	Owner Goals
F3	Early budget estimation (cost estimate for planning and business decisions)	0.817	12	Owner Goals
F30	Owner’s degree of participation (owner’s willingness to direct the project)	0.816	13	Owner Capability and Attitude
F9	High performance (of operation and maintains after project completion)	0.810	14	Owner Goals
F29	Owner’s experience	0.805	15	Owner Capability and Attitude

Table 4. Average RII and ranking of categories of influential factors

	Category of Related Factors	Number of Factors Included	RII	Rank
C4	Owner Capability and Attitude	5	0.82	1
C1	Owner Goals	12	0.80	2
C3	Project Objectives	6	0.75	3
C2	Project Features	10	0.72	4
C5	Market State	3	0.72	5
C6	Culture and Regulations	4	0.70	6

4.3. Public and private sectors comparison

The null hypothesis of Mann-Whitney U-Test test (Ho): there is no significant difference in the public and private sectors' respondent evaluation. The alternative hypothesis (H1): there are significant differences in the public and private sectors' respondent evaluation. The Mann-Whitney U-Test revealed no significant differences in the evaluation of the importance among the public sector and private sector, as indicated in Table 2 (If $p > 0.05$, then no significant difference existed). Four factors were found have a p-value < 0.05. Therefore, for the following influential factors of project delivery method selection: F3, F4, F32, and F35 there is significant differences in the public and private sectors. Those four influential factors were the cases of alternative hypothesis (H1). Thus, the more crucial factors for the private sector (rather than the public sector) included early budget estimation, early project delivery, and the owner's attitude toward risk; the accessibility of commodity providers was scored to be more important to the public sector. All other influential factors were found to share similar importance (or no significant differences in importance) between both public and private sectors.

4.4. Comparison of factors' evaluation between project contractual parties

The null hypothesis of Kruskal-Wallis H-Test (Ho): the median of the respondents' evaluation are the same for all project contractual parties groups. The alternative hypothesis (H1): there are at least two from the four groups represent responses with significantly different median values. The survey respondents were organized into four groups: owners/owner representatives, contractors/sub-contractors, consultant's services, and Architecture/ Engineering respondents. These groups had: 20, 38, 90, and 35 participants respectively. The Kruskal-Wallis H-Test was utilized to determine whether or not significant differences existed in attribute importance between the four groups, as shown in Appendix B. The results of this test revealed that no significant difference exists in 37 of the 40 influential factors evaluation between the four groups. The p-values for all 40 influential factors were greater than 0.05 with three exceptions, (if $p > 0.05$; then there was no significant difference). Significant differences were detected in the evaluation of three factors: F10, the minimum financial risk; F24, the pre-construction services; and F25, the project team relation (as shown in Appendix-C). Although all 40 influential factors were found to be considerably important, these three specified factors were given more importance by the contractors' group rather than the owners' group.

4.5. The four regions comparison

The null hypothesis of this test (Ho): the median of the respondents' evaluation are the same for all four regions. The alternative hypothesis (H1): there are at least two from the four regions represent responses with significant different median values. Survey responses were categorized according to the four geographic regions outlined in Fig. 2. The total number of respondents and corresponding states in each region is depicted in Table 5.

Table 5. Respondents from the four regions

	Northeast Region	Midwest Region	Southern Region	Western Region	Total
Number of states (and D.C.)	13	12	13	13	51
Maximum number of responses	32	44	51	59	186

Again, the Kruskal-Wallis H-Test was used to testify this hypothesis test. It indicates that the distribution of scores in each of the four regions were not significantly different for 36 of the 40 influential factors of project delivery method selection, as shown in

Appendix D. The p-values for all factors were greater than 0.05 with four exceptions, (if $p > 0.05$; then no significant difference existed). Significant differences were detected at F16, the uniqueness, F26, safety, F27, security, and F33, owner confidence. For example, the uniqueness factor was evaluated by Northeast Region respondents to have the highest importance (mean ranks = 108). Midwest Region respondents evaluated this as having the lowest importance (mean ranks = 72). None of these four factors belong to the 15 most important factors (see Table 3). The p-values for those factors were equal to 0.01, 0.03, 0.04, and 0.05, respectively. Thus, the null hypothesis (H_o) was rejected for those four influential factors. The null hypothesis (H_o) was acceptable, however, for the remaining 36 influential factors.

5. Conclusion and future research directions

Accomplishing construction projects with a low probable cost while achieving the highest performance within a definite time were found to be of considerable concern to the construction industry. This research reveals, however, that at least 40 observed influential factors should be considered during the selection of an appropriate construction PDM. These influential factors were ranked in importance from average to critical. The 15 most important factors were as follows:

1) Cost control (restraint cost growth)
2) The owner’s available resources
3) Financial risk (to maintain within a certain cost budget, tender, and estimates)
4) Stakeholders’ satisfaction
5) The project-team relationship
6) The project’s complexity
7) Schedule control (restraint time growth)
8) The project outcome’s quality
9) Uncertainty in the scope of the work
10) The owner’s attitude toward risk
11) Construction quality control
12) Early budget estimation

13) The owner's desired degree of participation

14) Performance of operation and maintains after project completion

15) Owner's experience regarding the construction project delivery procedures

The influential factors were organized in the following six categories: the owner's goals, project features, project objectives, owner's capability and attitude, market consideration, and both of culture and regulations. Based on the results of this study, the importance of the influential factors impacting the selection of a construction project delivery system can be classified as follows:

- Owner-related influential factors. The most important influential factors were included in both the owner capability and attitude category and the owner goals category (cost, time, quality, and risk related factors). Owner capability, attitude, and goals play the primary role in the decision making process for selecting an appropriate project delivery method in the US construction industry.
- Project-related influential factors**.** Important influential factors were included in the project objectives and features categories. The project objectives and features influential factors have an important effect in the selection of appropriate project delivery method.
- External environment-related influential factors. Attributes with less importance were included in both the market state and the cultural and regulation categories. Influential factors related to these categories are considered to have a smaller impact in the selection of appropriate project delivery methods than many others in this study.

Studying the influential factors governing the selection of an appropriate project delivery approach in the US Construction Industry revealed that, in general, no significant differences were identified in the importance evaluation among the following:

- Public and private sectors. No significant differences were detected in the most cases except 4 factors. The factors of early budget estimation, early project delivery, and owners' behavior towards risk were found to be more important to private sector respondents than they were to public sector respondents. The availability of commodity providers was more important for the public sector than the private sector.

- Owners, contractors, consultants, and A/E evaluations. No significant differences were detected in the most cases except 3 factors. The minimum financial risk, pre-construction services, and project team relationship factors were given more importance by the contractors group rather than the owners group.
- The different United States regions. No significant differences were detected in the most cases except 4 factors. Uniqueness, safety, security, owner's confidence (towards the number of contracting parties) and market consideration were found to have significant differences. The highest important evaluation was given by the northeast region respondents for the uniqueness, and by southern region respondents for the other three factors. The Midwest region respondents valued all four of these factors as having the least amount of impact.

This study provides a framework for evaluating a project's priorities and delivery options by the project's owner or the decision maker to help ensure project success. Further research is suggested to better understand the reasons behind the difference in importance for specific influential factors. Additionally, future research is suggested to evaluate the relative performance of each PDM with respect to the influential factors that revealed by this study.

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Appendix A. First part questions of the survey questionnaire

Question 1. What is the important score of each criterion for the selection of suitable construction project delivery method?

	Influential factors	**Important Score** [#]					
		1	2	3	4	5	N/A
	First - Owner Goals Category						
	Cost-related factors:						
F1	Minimum cost *(lowest price)*	○	○	○	○	○	○
F2	Cost control *(restraint cost growth)*	○	○	○	○	○	○
F3	Early budget estimation *(early cost estimate to help planning and business decisions)*	○	○	○	○	○	○
	Time-related factors:						
F4	Early project delivery *(shortest period of time for completion)*	○	○	○	○	○	○
F5	Schedule control *(restraint time growth)*	○	○	○	○	○	○
F6	Early procurement *(encourage early design, and materials or equipment's acquisition)*	○	○	○	○	○	○
	Quality-related factors:						
F7	High quality *(of the project outcomes)*	○	○	○	○	○	○
F8	Construction quality control *(during carrying out stage)*	○	○	○	○	○	○
F9	High performance *(of operation and maintains after project completion)*	○	○	○	○	○	○
	Risk-related factors:						
F10	Minimal financial risk *(to maintain within a certain cost budget, tender, and estimates)*	○	○	○	○	○	○
F11	Minimal schedule risk *(to keep in a certain time for design creation, constructing and occupancy)*	○	○	○	○	○	○
F12	Minimal performance risk *(to satisfy the needed technical standards for quality, expected performance, and environment conservation)*	○	○	○	○	○	○
	Second - Project Feature Category						
F13	Project subdivision type (*building construction, utility systems, highway, bridge …)*	○	○	○	○	○	○
F14	Project extent *(the size or physical magnitude of the project)*	○	○	○	○	○	○
F15	Complexity *(the project has composite deign and/or several distinct scope of works)*	○	○	○	○	○	○
F16	Uniqueness *(the project has unique characteristics, or technological advancement)*	○	○	○	○	○	○
F17	Workplace location *(distance from the required resources for construction activities)*	○	○	○	○	○	○
F18	Workplace circumstances *(flexibility for managing the constr. activities and supplies)*	○	○	○	○	○	○
F19	Design completion stage *(of drawing before construction commences)*	○	○	○	○	○	○
F20	Possibility for changes *(in the design, specifications, or scope of work)*	○	○	○	○	○	○
F21	Degree of risk *(uncertainty of scope of work and/or outcomes)*	○	○	○	○	○	○
F22	Sustainability involved*(needs to incorporate green or sustainable features)*	○	○	○	○	○	○
	Third - Project Objectives Category						
F23	Project life cycle *(planning, execution, closing, O&M, destruction)*	○	○	○	○	○	○
F24	Pre-construction services *(value engineering, constructability, cost reduction)*	○	○	○	○	○	○
F25	Project team relationship *(collaboration, coordination, integration, min. disputes)*	○	○	○	○	○	○
F26	Safety *(people and/or properties safety)*	○	○	○	○	○	○
F27	Security *(protect secret project's documents/information/technological development)*	○	○	○	○	○	○
F28	Stakeholders' satisfaction	○	○	○	○	○	○
	Fourth - Owner Capability and Attitude Category						
F29	Owner's experience *(project delivery and contract strategy)*	○	○	○	○	○	○
F30	Owner's degree of participation *(owner's willingness to direct the project)*	○	○	○	○	○	○
F31	Owner's available resources *(enough funding at ahead of project time)*	○	○	○	○	○	○
F32	Owner's attitude towards risk *(behavior towards risk taking)*	○	○	○	○	○	○
F33	Owner's confidence on adequate number of contractual parties *(parties of responsibility)*	○	○	○	○	○	○
	Fifth - Market Consideration Category						
F34	Availability of demanded service *(contractor or company for perform project works)*	○	○	○	○	○	○
F35	Accessibility of commodity *(availability of articles of commerce)*	○	○	○	○	○	○
F36	the economic status of the market *(inflation, interest rate, and other economic indexes)*	○	○	○	○	○	○
	Sixth - Culture and Regulations Category						
F37	Society and institution's culture	○	○	○	○	○	○
F38	Organizational constraints	○	○	○	○	○	○
F39	Regulation flexibility and constraints	○	○	○	○	○	○
F40	Political concerns	○	○	○	○	○	○

[#] Note: Influential factors' importance: 1 = not import; 2 = slightly import; 3 = median import; 4 = very import; and 5 = critically import.

Appendix B. Kruskal-Wallis H-test for the influential factors vs. the respondents' institution or company types

	Influential factors	No. of Cases Ownr❶	No. of Cases Cont.❶	No. of Cases Consult❶	No. of Cases A/E ❶	Total No. of Cases	Mean Ranks Ownr	Mean Ranks Cont.	Mean Ranks Consult	Mean Ranks (A/E)	Asymp. Sig. (P-Value)
F1	Minimum cost	20	38	90	35	183	79	93	89	106	0.20
F2	Cost control	20	38	90	35	183	77	86	96	98	0.28
F3	Early budget estimation	20	38	90	35	183	75	95	92	98	0.41
F4	Early project delivery	20	38	90	35	183	77	92	98	85	0.27
F5	Schedule control	20	38	90	35	183	85	91	94	92	0.88
F6	Early procurement	20	38	90	35	183	85	107	88	89	0.25
F7	High quality of the outcomes	20	38	90	35	183	85	95	93	90	0.88
F8	Construction quality control	20	38	89	35	182	88	94	92	89	0.96
F9	High performance of O&M	20	38	89	35	182	103	87	91	92	0.71
F10	Minimal financial risk	20	37	90	34	181	65	99	96	85	**0.04**
F11	Minimal schedule risk	20	37	90	35	182	97	93	93	82	0.60
F12	Minimal performance risk	20	37	90	35	182	97	94	92	85	0.78
F13	Project subdivision type	20	37	88	35	180	91	91	87	99	0.69
F14	Project extent	20	38	89	35	182	106	79	90	99	0.19
F15	Complexity	20	38	89	35	182	104	88	88	96	0.56
F16	Uniqueness	20	38	88	34	180	106	96	86	86	0.34
F17	Workplace location	20	38	88	35	181	87	92	90	95	0.92
F18	Workplace circumstances	20	38	89	35	182	108	86	89	95	0.40
F19	Design completion stage	20	38	89	35	182	73	96	92	98	0.29
F20	Possibility for changes	20	37	89	35	181	93	95	90	89	0.94
F21	Degree of risk of scope of work	20	38	89	34	181	96	103	87	86	0.32
F22	Sustainability involved	20	37	89	35	181	92	86	92	95	0.89
F23	Project life cycle	20	38	89	35	182	105	86	92	89	0.58
F24	Pre-construction services	20	38	89	35	182	75	112	87	89	**0.02**
F25	Project team relationship	20	38	89	35	182	65	105	89	98	**0.02**
F26	Safety	20	37	87	33	177	99	82	93	80	0.34
F27	Security	20	38	87	34	179	83	92	90	90	0.92
F28	Stakeholders' satisfaction	20	38	89	35	182	90	98	86	99	0.42
F29	Owner's experience	20	38	90	35	183	82	94	93	93	0.80
F30	Owner's degree of participation	20	38	90	35	183	100	101	88	88	0.44
F31	Owner's available resources	20	38	90	35	183	84	93	88	106	0.27
F32	Owner's attitude towards risk	20	37	90	35	182	77	101	91	91	0.33
F33	Adequate number of contractual parties	20	38	90	35	183	81	97	86	108	0.09
F34	Availability of demanded service	20	37	90	35	182	86	87	92	99	0.71
F35	Accessibility of commodity	20	37	90	35	182	94	89	90	96	0.92
F36	Economic status of the market	20	37	90	35	182	89	94	92	88	0.96
F37	Society and institution's culture	20	38	89	33	180	94	91	90	87	0.97
F38	Organizational constraints	20	38	89	35	182	118	92	90	80	0.06
F39	Regulation and constraints	20	38	89	34	181	104	85	92	86	0.53
F40	Political concerns	20	37	88	32	177	87	87	91	89	0.98

❶ Note: Respondents' institution types: Ownr = Owner/Owner Rep. , Cont. = Contractor/Sub-Cont., Consult = Consultant Services, A/E = Architecture/Engineering

Appendix C. Kruskal-Wallis H-test for the influential factors vs. the US four regions

Influential factors		No. of Cases (NR) ❶	No. of Cases (MWR) ❶	No. of Cases (SR) ❶	No. of Cases (WR) ❶	Total No. of Cases	Mean Ranks (NR)	Mean Ranks (MWR)	Mean Ranks (SR)	Mean Ranks (WR)	Asymp. Sig. (P-Value)
F1	Minimum cost	32	44	51	59	186	98	89	95	93	0.88
F2	Cost control	32	44	51	59	186	86	93	100	93	0.65
F3	Early budget estimation	32	44	51	59	186	104	87	93	93	0.53
F4	Early project delivery	32	44	51	59	186	89	92	87	103	0.36
F5	Schedule control	32	44	51	59	186	83	92	99	96	0.52
F6	Early procurement	32	44	51	59	186	83	89	94	102	0.37
F7	High quality of the outcomes	32	44	51	59	186	95	89	95	95	0.92
F8	Construction quality control	32	44	51	58	185	101	84	96	93	0.48
F9	High performance of O&M	32	44	51	58	185	104	94	98	82	0.19
F10	Minimal financial risk	31	44	50	59	184	94	100	93	86	0.54
F11	Minimal schedule risk	31	44	51	59	185	96	88	92	96	0.85
F12	Minimal performance risk	31	44	51	59	185	98	94	90	92	0.90
F13	Project subdivision type	32	44	50	57	183	88	90	93	94	0.95
F14	Project extent	32	44	51	58	185	97	75	97	101	0.06
F15	Complexity	32	44	51	58	185	98	79	98	96	0.21
F16	Uniqueness	30	44	51	58	183	108	72	97	94	0.01
F17	Workplace location	32	44	51	57	184	87	89	103	89	0.37
F18	Workplace circumstances	32	44	51	58	185	92	87	99	93	0.72
F19	Design completion stage	32	44	51	58	185	83	98	86	101	0.22
F20	Possibility for changes	32	44	51	57	184	79	90	97	98	0.33
F21	Degree of risk of scope of work	32	43	51	58	184	97	78	95	99	0.16
F22	Sustainability involved	32	44	51	57	184	101	83	98	90	0.38
F23	Project life cycle	32	44	51	58	185	99	79	104	90	0.11
F24	Pre-construction services	32	44	51	58	185	105	88	88	94	0.39
F25	Project team relationship	32	44	51	58	185	93	91	100	88	0.67
F26	Safety	32	43	49	56	180	95	78	107	84	0.03
F27	Security	32	42	50	58	182	93	78	107	87	0.04
F28	Stakeholders' satisfaction	32	44	51	58	185	93	93	100	86	0.51
F29	Owner's experience	32	44	51	59	186	99	85	102	89	0.26
F30	Owner's degree of participation	32	44	51	59	186	102	86	91	97	0.47
F31	Owner's available resources	32	44	51	59	186	86	90	104	91	0.30
F32	Owner's attitude towards risk	32	44	50	59	185	93	85	105	88	0.18
F33	Adequate number of contractual parties	32	44	51	59	186	85	82	108	94	0.05
F34	Availability of demanded service	32	44	51	58	185	85	90	105	89	0.25
F35	Accessibility of commodity	32	44	51	58	185	91	80	102	95	0.20
F36	Economic status of the market	32	44	51	58	185	93	84	100	94	0.50
F37	Society and institution's culture	31	43	50	59	183	106	83	92	91	0.28
F38	Organizational constraints	32	44	50	59	185	105	87	90	93	0.45
F39	Regulation and constraints	32	43	50	59	184	101	88	93	91	0.73
F40	Political concerns	32	41	49	58	180	104	84	93	85	0.29

❶ Note: US Four Regions: NR = Northeast Region , MWR = Midwest Region, SR = South Region, WR = West Region

II. Performance and Suitability of Project Delivery Methods for Various Conditions of Building Constructions

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Abstract

The objective of this paper is to evaluate the performance and suitability of project delivery approaches used in various building construction situations. An empirical survey was conducted in the US construction industry that considered the seven project delivery methods recognized by the Construction Specifications Institute (CSI 2008). The performance and suitability of these methods were examined with respect to 36 influential factors which are categorized into five groups. The performances were evaluated with respect to the owner's goals, and the project's objectives. The suitability of utilizing each project delivery method was also investigated with respect to the project's features, the owner's capabilities and attitude, and the market's conditions. The results of this study reveal that no project delivery method can simultaneously achieved all probable owner goals and project objectives. Moreover, no project delivery method was suitable for all project features, owner's capabilities and attitudes, and market conditions. Each project delivery approach had both strengths and weaknesses. The relative performance and suitability indicators revealed in this study could be used as guidelines toward a rational decision for the selection of an appropriate project delivery method.

Keywords: US Construction Industry, Construction Performance, Construction Project Management, Project Delivery Method.

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1. Introduction

This study was focused on evaluating the performance and suitability of project delivery methods (PDMs) for different building construction conditions in the US construction industry. This industry demands that a number of functions be met, including the origination of development, design, cost planning, contracting, and subcontracting. These functions may be executed by different entities (i.e., project contractual parties), at different stages, as a part of the project delivery process (Collier, 1987). According to the Construction Specifications Institute (2008), "Project delivery encompasses the contractual relationships necessary to establish a sequential process of design and construction activities that converts a conceptual idea into a completed and occupied facility." Project delivery can be conducted by adopting any one of the following methods:

- Design-Bid-Build (DBB)
- Design-Negotiate-Build (DNB)
- Design-Build (DB)
- Construction Manager as agent or adviser (CMa)
- Construction Manager as contractor (CMc)
- Owner-Build (OB)
- Integrated Project Delivery (IPD).

Each project delivery approach has both advantages and disadvantages with regard to practical applications. (For more details on these seven project delivery methods, please refer to Appendix A.)

Typically, either the project's owner or the owner representative chooses the method most suited to the project. The other project contractual parties may also provide some accommodations to establish a compromise contractual scheme. The project owner needs to select the most appropriate construction PDM from among the available alternatives to increase the chance of meeting the project's objectives (e.g., maintaining a budget and/or schedule). Therefore, this study was conducted in an attempt to evaluate the performance of PDMs with respect to the owner's goals and the project's objectives. It was also used to evaluate the suitability of PDMs with respect to project's features, the owner's capabilities and attitudes, and the market's conditions. The following sections include a literature review, an empirical survey, survey data analysis methodology, survey results, and conclusion.

2. Literature Review

Performance is the act of completing something successfully with available resources. Projects are created to achieve client's objectives. Consequently, project success is assessed in terms of how well the intended objectives have been attained. The successful of a construction project should satisfy the client's goals (Takim and Adnan, 2008).

The performance of PDMs was assessed by several studies on the basis of the comparison of observed data from a number of completed projects (e.g., Konchar & Sanvido, 1998; Rojas & Kell, 2008; Korkmaz et al., 2010; Shane et al., 2012; Minchin et al., 2013; and El Asmar et al., 2013).

Konchar and Sanvido (1998) compared in an empirical manner the cost, time, and quality performances of the three principal PDMs used in the US which were: design-bid-build, design-build, and construction management at risk. Their study used specific data from 351 building projects. Konchar and Sanvido (1998) did not, however, explain how to utilize their results when selecting PDMs.

Rojas and Kell (2008) studied 297 projects that were completed at Pacific Northwest public schools. In this study, they investigated the cost performance of CMc and DBB project delivery methods. No statistically significant differences were discovered in construction change order costs between projects using CMc and DBB methods, and the average cost growth of projects using CMc was more than projects using DBB method. These results were traditionally expected for the CMR delivery method.

Korkmaz et al. (2010) studied 12 sustainable high performance buildings projects to investigate the project performance outcomes as result of using DBB, DB, and CMc project delivery methods. More than 100 variables in the green project delivery method were examined to identify important metrics. Korkmaz et al. (2010) found that projects that utilized either CMc or DB project delivery methods tends to outperform DBB projects.

Shane et al. (2012) examined data that was collected from 31 DB projects and 69 DBB projects to investigate several aspects of their performance. They found that the time increase for DBB projects was twice that of DB projects; more DB projects were completed at or below budget. They noted that projects utilized both DB and DBB methods had similar qualities.

Minchin et al. (2013) recently studied data collected from highway and bridge construction projects in Florida to compare cost and time performance of DB and DBB delivery methods. They found that projects utilizing the DBB method had a significantly better cost performance than did projects utilizing the DB method.

El Asmar et al. (2013) investigated 35 completed projects to compare the performance of projects the used the integrated project delivery (IPD) method, the design-bid-build (DBB) method, the design-build (DB) method, and the construction management at-risk (CMr) method. They concluded that IPD performed better in terms of quality, time, project changes, collaboration, environmental factors, and financial resources than did the other project delivery methods examined.

Ward et al. (1991) suggested that, regardless of the project delivery methods being compared, all comparisons done must be between like things. In the construction industry, however, such comparisons are difficult. For example, even if the projects' designs and the owners' objectives are identical, the environmental factors, work contractors, and laborers are quite different. Comparisons between projects' final outcomes are inadequate because like comparisons can be problematic. Therefore, this study introduced the elicitation of experts' opinions to evaluate the relative performance and suitability of project delivery approaches used in various building construction conditions.

Chen et al. (2011) stated that project performance for various project delivery methods can be predicted as a basis for choosing a PDM. Rashid et al. (2006) studied the effect of project delivery methods on a construction project's performance. Their investigation was focused on the three critical parameters of project performance: time, cost, and quality. They concluded that all influential factors must be considered when one is selecting the most appropriate project delivery approach. Thus, a list of 36 factors was compiled, through a comprehensive review of literature, to evaluate the performance and suitability of construction project delivery methods. These factors were objectively classified under five categories for the purpose of this study. These factors included the following: the owner's goals, the project's objectives, the project's features, the owner's capabilities and attitudes, and market considerations. A more detailed definition of each of these factors is given in Table 1.

Table 1. Influential Factors for the Evaluation of Construction Project Delivery Methods*

Category	Factor
Owner Goals	Minimum cost *(lowest price)* Cost control *(restraint cost growth)* Early budget estimation *(early cost estimate to help planning and business decisions)* Early project delivery *(shortest period of time for completion)* Schedule control *(restraint time growth)* Early procurement *(encourage early design and equipment or materials acquisition)* High quality *(of the project outcomes)* Construction quality control *(during construction stage)* High performance *(of operation and maintains after project completion)* Minimal financial risk *(to maintain within a certain cost budget, tender, and estimates)* Minimal schedule risk *(to keep in a certain time for design creation, constructing and occupancy)* Minimal performance risk *(to satisfy the needed technical standards for quality, expected performance, and environment conservation)*
Project objectives	Project life- cycle *(planning, execution, closing, O&M, destruction)* Pre-construction services *(value engineering, constructability, cost reduction)* Project team relation *(collaboration, coordination, integration, minimum disputes)* Safety *(people and/or property safety)* Security *(protect secret project's documents/information/technological development)* Stakeholders' satisfaction
Project features	Project subdivision type (*such as building construction, utility systems, highway, bridge)* Project extent *(the size or physical magnitude of the project)* Complexity *(the project has composite design and/or several distinct scope of works)* Uniqueness *(the project has unique characteristics, or technological advancement)* Workplace location *(distance from the required resources for construction activities)* Workplace circumstances *(flexibility for managing the construction activities and supplies)* Design completion stage *(of drawing before construction commences)* Possibility for changes *(in the design, specifications, or scope of work)* Degree of risk *(uncertainty of scope of work and/or outcomes)* Sustainability involved *(needs to incorporate either green or sustainable features)*
Owner's capability and attitude	Owner's experience *(project delivery and contract strategy)* Owner's degree of participation *(owner's willingness to direct the project)* Owner's available resources *(enough funding at ahead of project time)* Owner's attitude towards risk *(behavior towards risk taking)* Owner's confidence on adequate number of contractual parties *(parties of responsibility)*
Market State	Availability of demanded service *(contractor or company for perform project works)* Accessibility of commodity *(availability of articles of commerce)* The economic status of the market *(inflation, interest rate, and other economic indexes)*

* Literature: NEDO, 1985; Moshini & Botros, 1990; Flanagan & Norman, 1993; Hibberd & Djebarni, 1996; Dorsey, 1997; Kumaraswamy & Dissanayaka, 1998; Ambrose & Tucker, 2000; Cheung et al., 2001; Ng et al., 2002; Hashim et al., 2006; Morledge et al., 2006; CSI, 2008; Pishdad & Beliveau, 2010; Chen et al., 2011; Thwala & Mathonsi, 2012; and Al-Jawhar & Rezouki, 2012.

3. Empirical Survey

3.1. Survey Questionnaire

An empirical survey was conducted in the United States between July 2013 and September 2013 to evaluate the performance and suitability of various project delivery methods. The seven project delivery methods recognized by the Construction Specifications Institute (2008) were considered. Thirty-six influential factors (attributes) divided into five categories were used to evaluate the performance and suitability of each PDM, as listed in Table 1. Survey participants were asked to evaluate the relative performance of project delivery approaches with respect to the following categories: the owner's goals and project's objectives. They were also asked to evaluate the relative suitability of each project delivery method with respect to the project's features, the owner's capabilities and attitudes, and the market's state.

An online survey comprised of 26 questions was created. The first 17 questions were focused on evaluating the relative performance and suitability of each PDM with regard to the 36 influential factors previously discussed. A Likert scale was used to score responses along a ten-point scale. The scoring evaluation scale consisted of scores from 0 to 10, where 0 = no satisfaction at all, 5 = average satisfaction, and 10 = highest satisfaction (see Appendix-B).

Last nine questions were demographic questions. The survey participants were either experts or professionals in the field of building construction engineering or management. Each was to have had no less than 10 years of experience in his/her respective field. These questions asked respondents to provide personal information related to their qualifications, experiences, and positions as well as both the nature and the location of their works. All of the participants were working in the US at the time of this study.

3.2. Analysis Method

Cronbach's alpha coefficient was applied to measure the reliability of the Likert scale responses within the survey. This coefficient of reliability (or consistency) investigated the internal consistency of the results between the evaluation of relative performance and suitability of the seven CSI project delivery methods regarding the 36 influential factors.

The Predictive Analytics Software (PASW Statistics 18.0) for statistical analysis was used to determine Cronbach's alpha coefficient of reliability.

Each project delivery approach's relative performance and suitability was determined with regard to the established 36 criteria. The respondents were likely to hold different attitudes toward each evaluation criterion. Therefore, the expert's individual opinions were aggregated into one particular judgments standing for the entire group. Saaty (2008) demonstrated that the geometric mean (the mean of n numbers expressed as the n^{th} root of their product), not the often used arithmetic mean, is the only method available to do so. Therefore, the geometric mean was used to aggregate the individual opinions of the expert's group into a single judgment standing for the entire group. Microsoft Excel was used for this purpose.

4. Analysis of Survey Results

4.1. Respondent Demographics

The online survey was closed October 2013. A total of 594 participants were recorded with 137 complete questionnaires, reflecting a 23% response rate. The survey data analysis was taken from only those respondents with more than 10 years of experience in the field of building construction engineering or management. Thus, results were only collected from 132 surveys. A total of 58% of the respondents described themselves as having more than 30 years of experience, as illustrated in Figure 1.

Approximately 85% of the survey respondents had college degrees. Approximately 20% had graduate degrees. A total of 92% had at least one non-degree professional certificate in the construction engineering and management field. Respondents were familiar with most construction project types, particularly building construction projects. They were also familiar with the different project delivery approaches examined in this study. Survey respondents were employed as follows: 37.1% were Architecture/Engineering (A/E), 11.4 % were either owners or owner representatives. 10.6% were consultant services, 9% were either contractors or sub-contractors, 5% were in construction and project management, 16% were more than one type, and 11% indicated themselves to be "others".

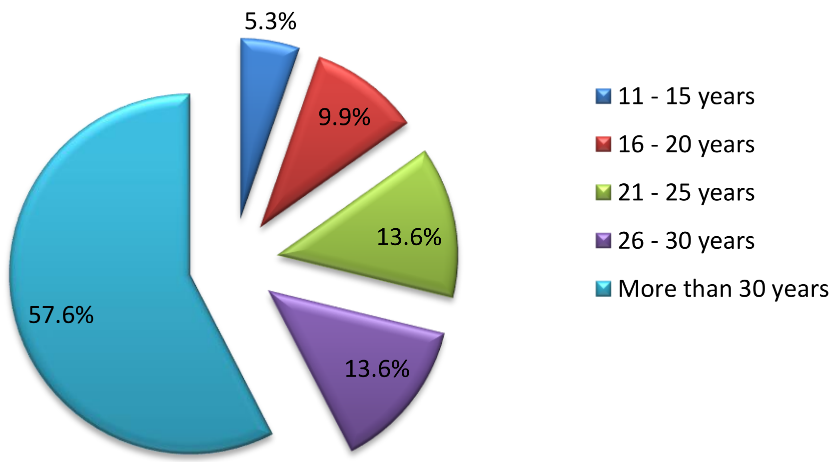

Figure 1. Survey respondents' experience

Furthermore, approximately 16% were related to the public sector, 67% were related to the private sector, And 12% were related to the quasi-public (public and private) sector, as illustrated in Appendix-C.

The survey data collected indicated that the coefficient of reliability (the Cronbach alpha Coefficient) was 0.821 for the evaluation of relative performance and suitability of using each project delivery method regarding considered 36 influential factors. According to George and Mallery (2010), the recognized rule for observing internal consistency with the Cronbach alpha Coefficient is: "$\alpha > 0.9$ – Excellent, $\alpha > 0.8$ – Good, $\alpha > 0.7$ – Acceptable, $\alpha > 0.6$ – Questionable, $\alpha >0 .5$ – Poor, and $\alpha < 0.5$ – Unacceptable". The value $\alpha = 0.821$ demonstrates that the ten–point scale offered good internal consistency. Therefore, the collected evaluations are reliable for the purpose of this study.

4.2. Performance and Suitability Evaluations of PDMs

The performance and suitability of project delivery approaches with respect to 36 influential factors as determined by the survey respondents are aggregated in Table 2. They have been ranked in the following subsections.

Table 2. The evaluations of Relative Performance and Suitability of PDMs vs. Considering Influential Factors

Influential factors			Project Delivery Approaches*						
Categories		Factors	DBB	DNB	DB	CMa	CMc	OB	IPD
Owner Goals	Performance with respect to how well it assists in …	Minimizing project cost (lowest price)	5.92	6.05	5.84	4.38	4.92	4.99	5.42
Owner Goals	Performance with respect to how well it assists in …	Controlling project cost (restraint cost growth)	4.58	6.03	6.41	4.90	5.47	5.05	5.52
Owner Goals	Performance with respect to how well it assists in …	Early project budget estimation (early cost approximation to help planning and business decisions)	3.38	5.13	6.13	5.26	5.54	4.63	5.90
Owner Goals	Performance with respect to how well it assists in …	Early project delivery (shortest period of time for completion)	3.87	5.24	7.20	4.93	5.62	5.26	5.65
Owner Goals	Performance with respect to how well it assists in …	Project schedule control (restraint time growth)	4.40	5.63	6.66	5.15	5.73	5.09	5.54
Owner Goals	Performance with respect to how well it assists in …	Early project procurement (encourages early design and material or equipment's acquisition)	3.07	4.57	6.68	4.75	5.54	5.76	6.00
Owner Goals	Performance with respect to how well it assists in …	Achieving high quality of the project outcomes	4.84	5.96	5.46	5.12	5.23	5.61	5.96
Owner Goals	Performance with respect to how well it assists in …	Controlling construction quality (during carrying out stage)	4.62	5.66	5.39	5.10	5.26	5.62	5.80
Owner Goals	Performance with respect to how well it assists in …	Achieving high quality of operation and maintenance (O&M) after accomplishing	4.50	5.31	5.24	4.95	5.08	5.95	5.89
Owner Goals	Performance with respect to how well it assists in …	Minimizing financial risk (to maintain within a certain cost budget, tender, and estimates)	4.93	5.95	6.33	4.92	5.44	5.22	5.53
Owner Goals	Performance with respect to how well it assists in …	Assists in minimizing schedule risk (a certain time for design creation, constructing and occupancy)	4.58	5.82	6.41	5.03	5.65	5.21	5.73
Owner Goals	Performance with respect to how well it assists in …	Minimizing quality risk (technical standards, expected performance, and environment conservation)	4.22	5.59	5.17	5.01	5.14	5.70	5.94
Project objectives	Performance with respect to how well it assists in …	Considering project life cycle (planning, execution, closing, operation and maintenance, destruction)	4.29	5.42	5.63	5.16	5.08	5.33	6.31
Project objectives	Performance with respect to how well it assists in …	Pre-construction services (value engineering, constructability, cost reduction	2.99	5.11	6.07	5.44	5.62	4.79	6.18
Project objectives	Performance with respect to how well it assists in …	Project team relation (collaboration, coordination, integration, min. disputes)	3.05	4.83	5.96	4.97	4.94	4.70	6.50
Project objectives	Performance with respect to how well it assists in …	Safety (people and/or properties safety)	5.22	5.85	5.74	5.68	5.88	4.63	5.54
Project objectives	Performance with respect to how well it assists in …	Security (protect secret project's documents/information/technological development).	3.74	5.01	5.61	4.91	5.10	6.58	5.34
Project objectives	Performance with respect to how well it assists in …	Stakeholders' satisfaction	4.47	5.66	5.77	5.19	5.11	5.97	6.15
Project features	Suitability for (or when) …	Residential building construction	4.93	6.80	5.49	3.01	3.82	5.34	3.68
Project features	Suitability for (or when) …	Non-residential building construction	6.75	7.20	6.86	5.80	6.18	4.61	6.30
Project features	Suitability for (or when) …	Large extent projects (the size or physical magnitude of the project is big)	5.91	6.61	6.09	6.06	6.18	3.48	6.20
Project features	Suitability for (or when) …	Complex projects (the project have composite deign and/or several distinct scope of works)	5.21	6.41	5.84	6.14	6.23	3.46	6.35
Project features	Suitability for (or when) …	Unique projects (the project has unique characteristics or technological advancement)	4.66	6.35	6.07	5.61	5.61	3.63	6.38
Project features	Suitability for (or when) …	Far location projects (workplace is far from the required resources for construction activities)	4.89	5.95	5.56	5.56	5.72	3.98	5.68
Project features	Suitability for (or when) …	Confined project's workplace (difficult for handling construction activities and supplies)	4.55	5.73	6.09	5.57	5.93	4.21	5.75
Project features	Suitability for (or when) …	Design stage completion projects (when design of drawings before construction commences is completed)	5.17	6.39	5.89	5.44	5.62	5.25	5.79
Project features	Suitability for (or when) …	Project changes (high possibility for changes in the project's designs, specifications, or scope of work)	3.17	4.49	5.42	5.02	5.11	5.44	5.45
Project features	Suitability for (or when) …	Projects with uncertainty (high degree of uncertainty of project's scope of work and/or outcomes)	2.51	4.11	4.55	4.79	4.69	4.91	5.16
Project features	Suitability for (or when) …	Sustainability involvement (needs to incorporate green or sustainable features)	5.76	6.48	6.19	5.94	5.85	5.47	6.47
Owner's capability and attitude	Suitability for (or when) …	Project owner who is highly experienced in project delivery and contract strategy	6.03	7.15	6.71	4.87	5.76	7.85	6.36
Owner's capability and attitude	Suitability for (or when) …	Project owner who has available resources (existing of enough funding at ahead of project time)	5.89	6.71	6.75	5.60	5.57	7.11	6.16
Owner's capability and attitude	Suitability for (or when) …	High degree of participation of the project's owner (to direct the project)	4.91	6.10	5.30	4.93	5.07	8.14	5.83
Owner's capability and attitude	Suitability for (or when) …	Project's owner risk avoidance (project's owner has negative attitude towards risk taking)	5.24	5.93	5.77	5.13	5.44	3.93	5.15
Owner's capability and attitude	Suitability for (or when) …	Few numbers of contracting parties (the project's owner looks for single or few parties of responsibility)	5.75	6.52	7.52	4.33	5.66	4.56	4.71
Market State	Suitability for (or when) …	There is availability of demanded service (contractor or company for perform project works)	6.61	6.86	6.56	5.64	5.71	5.01	5.65
Market State	Suitability for (or when) …	There is accessibility of commodity (availability of articles of commerce)	6.85	6.79	6.50	5.75	6.08	5.82	5.60
Market State	Suitability for (or when) …	The economic status of the market is good (inflation, interest rate, and other economic indexes)	6.79	6.82	6.47	5.51	5.90	5.84	5.80
Average			4.82	5.90	6.04	5.18	5.47	5.25	5.77

* **Project Delivery Approaches:** (DBB) = Design-Bid-Build, (DNB) = Design-Negotiate-Build, (DB) = Design-Build, (CMa) = Construction manager as agent or adviser, (CMc) = Construction manager as contractor, (OB) = Owner-Build, (IPD) = Integrated Project Delivery.

* The green highlighted cells include most effective project delivery approach to achieve this factor, and the yellow highlighted cells include the lowest values.

* Factors are on a Likert scale form: 0 (no satisfaction) to 10 (highest satisfaction) based on survey results.

4.2.1. Design-Build (DB)

The Design-Build method (DB) was the first PDM that was capable of producing intended results, in general*, because it had the highest average of relative performance and suitability (Avg. = 6.04). The DB was evaluated to have the best performance for the following seven owner goals and project objectives.

- Controlling a project's expense (restraining the cost growth)
- Estimating the budget at an early stage (early cost approximation to help with planning and business decisions)
- Completing project deliveries early (shortest period of time for completion)
- Controlling the project's schedule (restraining the time growth)
- Procuring projects at an early stage (early design, material, and equipment acquisition)
- Minimizing the financial risk
- Helping minimize the schedule risk

The results of this research indicate that the DB method obtains either acceptable or good outcomes for all but 1 of 36 factors examined. Projects with a high degree of uncertainty were less suitable for DB method. The DB method was evaluated to be the most suitable PDM in the following situations:

- The project is taking place in a confined workplace that cannot adequately handle the required construction activities and supplies.
- The owner prefers a limited number of contracting parties. (The project's owner desires few parties of responsibility).

4.2.2. Design-Negotiate-Build (DNB)

In general, the Design-Negotiate-Build (DNB) was the second PDM capable of producing intended results; its average was equal to 5.90. This method was also evaluated

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* "*In general*" means that all influential factors were given the same priority. In reality, each project should have its particular criterion priorities. The selection of a suitable PDM depends on those priorities.

to be the best PDM for minimizing a project's cost. Finally, DNB was evaluated to be the most suitable PDM for the following 10 influential factors:

- Residential building construction
- Non-residential building construction
- Large extent projects
- Complex projects
- Remote locations
- A project with a completed design stage
- Sustainability requirements
- Risk avoidance
- Projects going with available services to complete the project works
- Positive economic market status

The DNB was not suitable when the project contained a high degree of uncertainty.

4.2.3. Integrated Project Delivery (IPD)

The Integrated Project Delivery (IPD) method was the third project delivery method, in general, capable of producing intended results. It held an average that was equal to 5.77. The IPD was identified as the best method for achieving the following seven objectives:

- Reaching high quality project outcomes
- Controlling construction quality during the executive stage
- Minimizing quality risk
- Adapting to the project's life-cycle (e.g., planning, executing, closing, operating and maintaining, and destructing)
- Considering pre-construction services (e.g., value engineering, constructability, and cost reduction)
- Establishing quality project team relationships (e.g., collaboration, coordination, integration, and minimum disputes)
- Meeting stakeholders' satisfaction

IPD was also evaluated to be the most suitable for the following three project features:

- Unique projects (the project has either unique characteristics or unique technological advancements)
- Project changes (the project's designs, specifications, and/or scope of work are quite likely to change)
- Projects with uncertainty (a high degree of uncertainty of project's scope of work and/or outcomes)

The IPD method was also found to be more suitable for non-residential building construction than it was for the residential building construction; it was deemed less appropriate for the owner who prefers a smaller numbers of contracting parties.

4.2.4. Construction Manager as Contractor (CMc)

The Construction Manager as contractor (CMc) method was evaluated to be the fourth project delivery method that could produce the intended results. It had an average of 5.47. The CMc was the best method to use when safety is a priority. In contrast, it was not preferred for residential building construction projects.

4.2.5. Owner-Build (OB)

The Owner-Build (OB) was the fifth project delivery method, in general, capable of producing intended results. It had an average that was equal to 5.25. It was evaluated as obtaining the best performance in the following areas:

- Achieving a high quality of operation and maintenance (O&M) after the project was complete
- Maintaining an acceptable level of security (e.g., protecting the confidentiality of project document/proprietary technology)

The OB method was evaluated to be the most suitable project delivery approach for the following three influential factors (as related to the owner's capabilities and attitudes):

- A project owner who has a great deal of experience with project delivery and contract strategies
- A project owner who has the necessary resources available
- A project owner who actively participates in the project

In contrast**,** OB was identified as inadequate in helping maintain safety. It was also evaluated to be unsuitable for non-residential building construction projects, large extent projects, complex projects, unique projects, remote locations, and confined workspaces. Finally, it was determined that it was not suitable when the project owner has a negative attitude toward risk.

4.2.6. Construction Manager as Agent (CMa)

The Construction Manager as agent (CMa) was the sixth project delivery method, in general, capable of producing intended results. It had an average of 5.25. This method was not ranked first in any of the 36 attributes examined. The CMa method achieved the lowest ranks when the owner was focused on minimizing either the project's cost (lowest price) or the financial risk. The CMa was evaluated to be inappropriate for residential building construction. It was also evaluated to have the lowest relative suitability for the following three attributes:

- A project owner who is highly experienced in project delivery and contract strategies
- A project owner who prefers a limited number of contracting parties
- A good economic market

4.2.7. Design-Bid-Build (DBB)

The Design-Bid-Build (DBB) method was least able to produce any of the intended results. Although it has been used for more than 100 years (making it the oldest method available) and it is the most widely recognized approach, DBB had the lowest evaluation average score (4.82). It was evaluated to have the lowest relative performance for nearly all of the owner's goals except minimizing project cost and financial risk. It was also evaluated to have the lowest relative performance for all of the project's objectives except safety.

The DBB was the best method when various commodities (raw materials and/or products) were accessible. It was, however, inappropriate under the following conditions:

- The design stage is complete.
- The project's designs, specifications, and/or scope of work are likely to change
- The project's scope of work and/or outcomes are uncertain
- The project owner has a high degree of control over the project

5. Validating of the Research Results

According to Lucko (2009), "validation is a challenge to all researchers, but especially so to those working in interdisciplinary fields such as construction engineering and management." The effective way to conduct face validity is by engaging domain experts throughout the study. Such involvement may range from consolatory to active collaboration. Therefore, the Face Validation procedure was conducted as a part of this research. This procedure is a subjective assessment of non-statistical characteristics. The results were presented to several experts in this field. They were asked if they think that the study outcomes will provide assistance to the decision maker and/or get correct results. The research results were then validated by a subset of these experts who hold either a PhD or a master degrees and have at least 25 years of experience within their respective fields.

6. Conclusions

The relative performance and suitability of project delivery approaches used in various building construction conditions were identified as a part of this research. The results reveal that no PDM can simultaneously achieve all probable owner goals and project objectives. Additionally, there is no a single PDM is perfect for all project features, owner's capabilities and attitudes, and market states.

Each project delivery approach had both some weak points and incentives for a particular practical application. The most appropriate PDM should be chosen after considering the owner's goals, project objectives, project features, owner's capabilities and attitudes, and the market state. The relative performance and suitability indicators revealed in this study should be given careful consideration during this process. The results from this study can be used to establish a framework so that both the project's owner and the decision maker can evaluate a project's priorities and delivery options. These results can also be used to establish a multi-attribute decision support tool, based on a quantitative selection process, to select an appropriate project delivery method.

The success of a construction project is significantly affected by the implemented PDM chosen. Additional factors (not discussed here) related to both the internal and the external project environment may, however, also influence a project's success. Therefore, the failure (or low performance) of a construction project may not correctly indicate the suitability of the implemented project delivery method. This paper studied only the PDMs recognized by the Construction Specifications Institute (2008). Other PDMs and more influential factors should be investigated in a future research.

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Appendix–A. Common Characteristics, Advantages, and Disadvantages of Project Delivery Methods (PDMs)

PDMs	Characteristics	Advantages	Disadvantages	Ref.
Design-Bid-Build (DBB)	• This method is traditional, standard contractual relationship, and the owner plays the role of coordinator between the designer and contractor. • This approach is used for more than 100 years and widely recognized. • The owner determines both the performance and quality demands prior bidding. • Competitive construction bidding occurs after the design is completed. • The owner selects the constructor solely on the basis of a low lump sum price. • The owner assumes the risk of errors in the contract documents. • The suitable contract strategy for DBB is a fixed price contract.	• This process makes it possible to know the cost of the project before construction is begun. • Competitive construction bidding may lead to lower construction prices. • Project schedules are easier to establish because no overlap phases exist. • Both public and governmental agencies typically require competitive bidding to ensure a fair price. That precondition encourages to use DBB method. • Construction activity costs are fixed at the time of tender.	• The owner holds more risk. • A "bid-day surprise" sometimes occurs when all received bids exceed the owner's project budget. • Both drawings and specifications should be free of error before the bidding takes place. Otherwise, change orders are expected and may be costly. • The DBB reliance on restrictive contract language, audit, inspection, and legal system. • The DBB has limited opportunities for schedule/cost optimization, and it lacks constructability reviews and value engineering analysis. • The owner typically cannot give directions to the contractor who is managing the project's construction. This situation tends to make the owner and the contractor oppose one another because of opposite financial concerns. This opposition can lead to disputes.	(CSI 2008), (AGC 2004), (Dorsey 1997).
Design-Negotiate-Build (DNB)	• The DNB is similar to DBB but not include formal competitive bidding. • The contractor is selected according to his qualifications after the project's scope of work and cost have been negotiated. • The A/E provides the design and construction contract administration services. • The contractor manages the project's construction. • The owner is allowed to participate in the subcontractors/suppliers selection if he wants to do so. • The DNB is rarely used for public projects.	• The scope of the work can be refined according to available funds before the construction documents are prepared. • The contractor is selected according to his qualifications and history that probably leads to better results. • The contractor's early participation contributes to facilitating the work based on his experience and advices. • The DNB encourages the project team to utilize "value analysis" and "constructability" to reduce construction time and/or cost.	• The lowest possible cost may not be realized due to the absence of competitive bidding. • The possibility of change orders may leads to claims and disputes. • Conflicts between contractual parties may occur as a consequence of cost overruns because the negotiated price was arrived at as a result of incomplete information. • The owner carries the risk of not knowing the project's final total cost until the contract is almost complete.	
Design-Build (DB)	• The owner enters into a contractual arrangement directly with a design-builder. • The design-builder is selected, primarily, according to his qualifications, though price may be considered as well. • A single entity provides both the project design and the construction services. • Schematic designs (or "bridging documents") can be prepared first so that they become the basis of the contract between the owner and a D-B entity. • The owner provides the project performance requirements to the design-builder.	• The risk is transferred from the owner to the design-builder. • The DB provides the owner single part of responsibility and early cost estimation. • Fast-track planning is an available alternative that may accelerate project delivery. • The DB method makes easier management of change orders. • Design errors, as well as conflicts between specifications and drawings, are not the owner's responsibility. • The DB provides benefits from the expertise during the project's design and construction, which maximize the value of the project.	• A third party may be required to help the owner prepare the project's description if the owner is not familiar with the project's scope of work. • No balance will exist between the design and contractor's interests. Special builder interest may drive the design. • The design must be suspended in the early stages because of construction overlap. • Design errors are omitted. • The design-builder will perform few services that are not required by the owner's project description.	

Cont. Appendix–A

PDMs	Characteristics	Advantages	Disadvantages	Ref.
Construction manager as agent or adviser (CMa)	• The CMa serves as an advisor to provide assistance/expertise on project delivery. • The CMa may represent the owner. • The owner contracts directly with the A/E and either a single-prime contractor or multiple subcontractors. • The CMa does not bear any financial risk.	• The CMa manages the owner's risk. • The CMa is appropriate to involve multiple contracts • This method provides opportunity to engage the construction entity much earlier in the design process and to involve the value engineering analysis. • An early construction start date may lead to either an early partial occupancy or a rapid project completion. • The cost of using CMa and the several contracts mostly will be substituted by the additional A/E fees and costs for developing bid documents.	• The owner carries the risk. • Most of the CMa benefits occur when the CMa is contributed early within the project's cycle. • The CMa is not suitable for projects that are small and simple in scope. • The CMa may not be suitable for owners that require single-source responsibility. • The owner will pay most of the significant professional fees. • The CMa leads to additional level of authority which can be time consuming and expensive for both of the A/E and contractor(s).	(CSI 2008), (AIA 2007), (AGC 2004), (Dorsey 1997).
Construction manager as contractor (CMc)	• The owner contracts with the construction manager to serve as both a consultant and a contractor. Various criteria (qualification-based-selection) is used to select the CMc. • The CMc consults with both the A/E and the owner to prepare of project's documents. • The CMc executes the construction as a contractor. • The CMc bears not only the financial risk but also the performance risk. Therefore, it is known as "CM at-Risk." • The Guaranteed Maximum Price (GMP) is a significant part of this project delivery method.	• The CMc provides information on the expected project's costs and the products' availability and performance. • The CMc assists to reduce the change orders and the cost over budget. • Many CMc entities are staffed with various professionals who are engaged in the design and project construction process. • The CMc may increase the construction progress schedules accuracy. • The CM's obligation for complying with the budget provides some assurance that the A/E will not perform a costly design.	• The owner must be experienced in assessing the guaranteed maximum price (GMP). • Conflicts are possible when the CMc is both advising the owner and constructing the project. • The CMc may be disinclined to become involved in changes that will directly reduce its profitability. • The scope of work is not clearly defined if the CMc selection takes place early in the design phase • The owner's review and audit rights are subject to limits to those determined in the contract documents.	
Owner-Build (OB)	• The owner acts as a general contractor and owner. • The owner participates in all of the component of the project's construction contract. • The owner should be experienced and have qualified staff to manage the construction work. • The A/E may be utilized to perform the design and contract administration services.	• The owner may achieve entire cost saving. • The owner controls over the project activities which facilitates any changes to the work. • The OB provides flexibility and control over the outcomes of the project.	• The owner carries almost all the involved risks. • When the owner performs the design work in-house, design errors and discrepancies are omitted from the construction documents. • The owner is the prime contractor so the owner is responsible for occupational health and safety, in addition to the responsibility for insurance and performance bonds during construction.	
Integrated Project Delivery (IPD).	• The IPD is Integrated and collaborative approach • The IPD provides early engagement of design consultants, constructors, and trade constructors. • This procedure proceeds design decisions forward in time as far as possible. • The IPD focuses on the project outcomes instead of participants' individual goals.	• The IPD aids to achieve an effective design and provides high project's performance. • The IPD is more beneficial for design alternative evaluation, and it improves the visual image of the facility before it becomes a project. • The IPD helps for perception and resolution of conflicts between construction elements. • The IPD achieves maximum efficiency of site utilization and reduces construction waste	• The IPD is a new approach so most of the project's participants do not familiar with it that may limit its utilization. • It is most suitable for extensive and complicated in structure projects.	

Appendix-B. The first Part of the Questionnaire for the Evaluation of PDMs

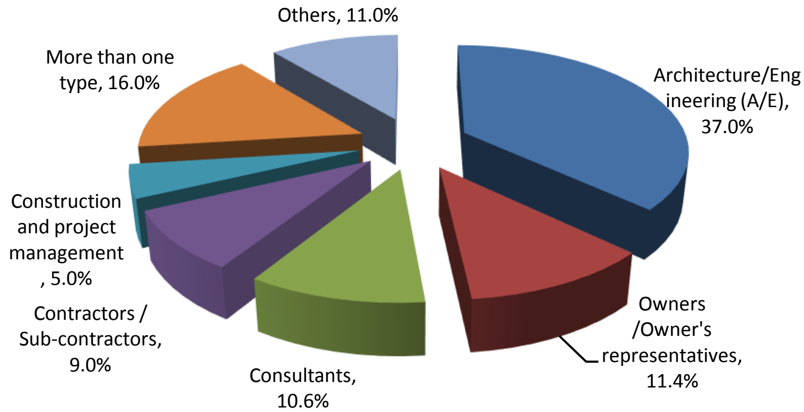
Q: evaluate the performance or suitability of each project delivery method with respect to the following influential factors? #
Note: the score evaluation should be: 0 = No Satisfaction at all, 5 = Average Satisfaction, 10 = Highest Satisfaction, and so on

Influential factors (Considered Categories and Related Factors)	**PDMs*** DBB	DNB	DB	CMa	CMc	OB	IPD
Owner Goals Category: Performance with respect to how well it assists in …							
Minimizing project cost (lowest price)	○	○	○	○	○	○	○
Controlling project cost (restraint cost growth)	○	○	○	○	○	○	○
Early project budget estimation (early cost approximation to help planning and business decisions)	○	○	○	○	○	○	○
Early project delivery (shortest period of time for completion)	○	○	○	○	○	○	○
Project schedule control (restraint time growth)	○	○	○	○	○	○	○
Early project procurement (encourages early design and material or equipment's acquisition)	○	○	○	○	○	○	○
Achieving high quality of the project outcomes	○	○	○	○	○	○	○
Controlling construction quality (during carrying out stage)	○	○	○	○	○	○	○
Achieving high quality of operation and maintenance (O&M) after accomplishing	○	○	○	○	○	○	○
Minimizing financial risk (to maintain within a certain cost budget, tender, and estimates)	○	○	○	○	○	○	○
Assists in minimizing schedule risk (a certain time for design creation, constructing and occupancy)	○	○	○	○	○	○	○
Minimizing quality risk (technical standards, expected performance, and environment conservation)	○	○	○	○	○	○	○
Project objectives Category: Performance with respect to how well it assists in …							
Considering project life cycle (planning, execution, closing, operation and maintenance, destruction)	○	○	○	○	○	○	○
Pre-construction services (value engineering, constructability, cost reduction	○	○	○	○	○	○	○
Project team relation (collaboration, coordination, integration, min. disputes)	○	○	○	○	○	○	○
Safety (people and/or properties safety)	○	○	○	○	○	○	○
Security (protect secret project's documents/information/technological development).	○	○	○	○	○	○	○
Stakeholders' satisfaction	○	○	○	○	○	○	○
Project features Category: Suitability for …							
Residential building construction	○	○	○	○	○	○	○
Non-residential building construction	○	○	○	○	○	○	○
Large extent projects (the size or physical magnitude of the project is big)	○	○	○	○	○	○	○
Complex projects (the project have composite deign and/or several distinct scope of works)	○	○	○	○	○	○	○
Unique projects (the project has unique characteristics or technological advancement)	○	○	○	○	○	○	○
Far location projects (workplace is far from the required resources for construction activities)	○	○	○	○	○	○	○
Confined project's workplace (difficult for handling construction activities and supplies)	○	○	○	○	○	○	○
Completion of design stage (when design of drawings before construction commences is completed)	○	○	○	○	○	○	○
Project changes (high possibility for changes in the project's designs, specifications, or scope of work)	○	○	○	○	○	○	○
Projects with uncertainty (high degree of uncertainty of project's scope of work and/or outcomes)	○	○	○	○	○	○	○
Sustainability involved (needs to incorporate green or sustainable features)	○	○	○	○	○	○	○
Owner's capability and attitude Category: Suitability for …							
Project owner who is highly experienced in project delivery and contract strategy	○	○	○	○	○	○	○
Project owner who has available resources (existing of enough funding at ahead of project time)	○	○	○	○	○	○	○
High degree of participation of the project's owner (for control over the project)	○	○	○	○	○	○	○
Project's owner risk avoidance (project's owner has negative attitude towards risk taking)	○	○	○	○	○	○	○
Few numbers of contracting parties (project's owner looks for single or few parties of responsibility)	○	○	○	○	○	○	○
Market State Category: Suitability for …							
There is availability of demanded service (contractor or company for perform project works	○	○	○	○	○	○	○
There is accessibility of commodity (availability of articles of commerce)	○	○	○	○	○	○	○
The economic status of the market is good (inflation, interest rate, and other economic indexes)	○	○	○	○	○	○	○

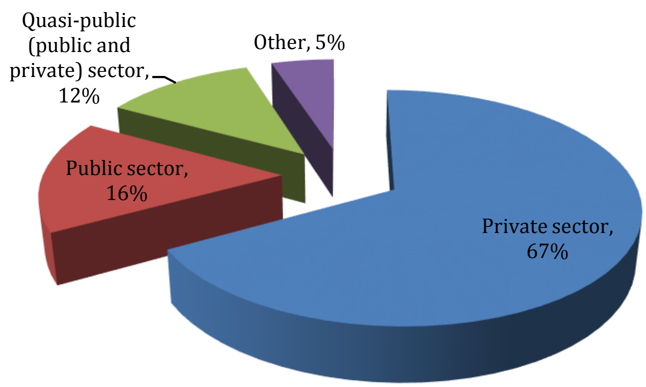
Hint: the performance should be evaluated considering only one specific attribute each time regardless of the others (for example: when you consider "minimizing project cost attribute" do not look for the other influential factors such as "controlling project cost" or "early project budget estimation". That means the evaluation of each project delivery method should be done according to the achievement of "lowest price" only.

* **Project delivery method (PDMs):** (DBB) = Design-Bid-Build, (DNB) = Design-Negotiate-Build, (DB) = Design-Build, (CMa) = Construction manager as agent or adviser, (CMc) = Construction manager as contractor, (OB) = Owner-Build, (IPD) = Integrated Project Delivery.

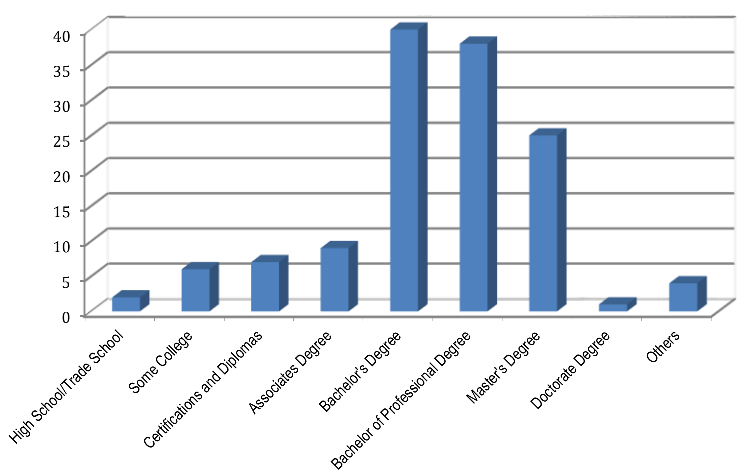
Appendix - C. Illustration of the Survey Participants' Characteristics



The nature of respondents' institutions or companies



The types of respondents' institutions or companies



The respondents' highest education degrees

III Engagement of Expert Opinions in the Modeling of Multi-Attribute Decision Making for the Project Delivery Method Selection of Building Construction

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Abstract

This paper presents the early engagement of expert opinions in the modeling of multi-attribute decision making (MADM). This study was conducted by linking together the Conjunctive Satisficing Method (CSM) with the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) decision making approach and applies them to project delivery method selection in building construction management. An empirical survey study was conducted to elicit experts' opinions for the evaluation of construction project delivery options with respect to determined influential factors. The seven project delivery approaches recognized by the Construction Specifications Institute were considered. Both performance and suitability of project delivery methods were examined with respect to 36 criterion factors categorized within 5 groups. The relative performances were evaluated by the experts with respect to the owner goals and the project objectives. The relative suitability of utilizing each project delivery method was also evaluated with respect to the project features, the owner's capabilities and attitudes, and market conditions. The elicited experts' opinions were engaged in the modeling of multi-attribute decision making as model parameters to establish the aimed decision support tool. This study provided a practical tool to utilize the expertise of experts to make a suitable decision without the physical existence of an expert panel. Applying the provided MADM model for the selection of a project delivery method of building construction helps the decision maker choose the best alternative available to ensure project success.

Keywords: US construction industry; Construction management; Multi-attribute decision making; Project delivery; Expert opinions.

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1. Introduction

The objective of this paper was to create and validate a model that can be used to select the most appropriate project delivery method (PDM) for building construction purposes. A construction PDM is the manner in which one manages the design and construction activities while coordinating and maintaining relationship between all of the project contractual parties. PDMs of construction projects are diverse, as are the titles and terms applied to them. To understand such arrangements, it is not enough to look only at the titles; one must also examine the roles and functions and who bears which risks (Collier, 1987). Each type of PDM has its characteristics, advantages, disadvantages and incentives for application. The decision maker encounters a problem when comparing the advantages of one specific method against the advantages of choosing another. Choosing the most appropriate construction project delivery procedure is not an easy task for a number of reasons, including the following:

- Diverse influential factors (e.g. owner objectives, project features, economy, regulations)
- Uncertainty of project outcomes (e.g., completion time and budget)
- Conflicting objectives (e.g., minimum cost, minimum completion time, and highest quality). Very often these objectives cannot be achieved simultaneously.
- Differentiation in the advantages and disadvantages of project delivery methods
- Project risks shared between the contractual parties (the owner, designer, consultant, and contractor) are determined mainly by the selected project delivery method.

Pishdad and Beliveau (2010) concluded that most project owners lack sufficient knowledge to recognize the various aspects of project delivery. In these instances, the previously suggested decision support models are nearly useless. Wang at al. (2008) reported that “the determination of the weight in the existing project delivery decision-making model relies on experts’ knowledge and experience excessively, and the subjective factors play too big roles in the decision-making process.” Thus, this research utilized incorporating the experts’ opinions as a “*group”* for multi-attribute decision making (MADM) modeling to minimize the judgment subjective effect on the model’s parameters. The engagement of expert opinions in MADM modeling provides a practical approach for utilizing expertise to make the best decision for a specified project without the physical existence of an expert panel during the decision making process.

2. Literature review

Both academic and industrial entities have proposed a variety of decision support tools and technics for the selection of a PDM (see Appendix A). Each procedure has its own distinctive features. Reviewing the recent existing procedures for the selection of a project delivery method leads to the following remarks:

- The established approaches began with NEDO (1985) and have continued through Ding, et al. (2014) so far.
- Most approaches use different methodologies to solve the problem. These approaches can vary from simple (e.g., Skitmore & Marsden, 1988) to highly complex (e.g., Alhazmi & McCaffer, 2000).
- Each approach made an effort to cross-reference project attributes with PDMs.
- The current approaches ignore some important factors and/or the consideration of limited alternatives of project delivery methods (e.g., Ambrose and Tucker, 2000; Cheung el at. 2001; Moshini and Botros, 1990; NEDO, 1985; Skitmore & Marsden,1988; Zhang and Wang, 2009)
- Special advanced math skills are needed to apply some methods. The decision maker, however, may not have these skills (e.g., Wang el at., 2008)
- The proposed approaches assume that the decision maker has adequate knowledge on the performance of each construction PDM as related to the decision criteria.
- The Analytical Hierarchy Process (AHP) was applied to several procedures so that the proper PDM could be selected (Al Khalil, 2002. Mahdi & Alreshaid, 2005. Mafakheri et al., 2007. Zhang, 2009). These procedures become quite complicated if a large number of influential factors are used because they depend on the pairwise comparison matrix. Therefore, reduction and careful selection of influential factors is

required to utilize these procedures which will negatively affect the accuracy of the results (Chen et al., 2011).

- Several applied the Multi-Attribute Utility Theory (MAUT) to select the proper PDM (Skitmore & Marsden, 1988. Chuang et al., 2001). Difficulties come out when it is implemented to mixing different properties, and accordingly dissimilar units, so the additive utility hypothesis is violated and the outcome is such as "*adding apples and oranges"* (Triantaphyllou, 2000). The lack of compatibility of observations amongst the utility values of the selection criteria is the main difficulty of the MAUT selection models, (Chan et al., 2001). Although these models are simple and easy to use, the project may not reach the anticipated objectives because the influential factor's utility values mostly fail to represent the actual project status (Chen et al., 2011).
- Mahdi (2005) concluded that, in order to select the most suitable PDM for an aimed project, an owner should first understand the available types of PDMs, the project's features, and his/her own abilities. In reality, this is not always possible.

The objective of this research is to establish a practical and reliable PDM selection model to overcome previous procedures' disadvantages.

3. Research methodology

Multi-criteria decision making (MCDM) is a subdivision of the decision making discipline. Triantaphyllou (2000) noted that MCDM is divided into two parts: multi-objective decision making (MODM) and multi-attribute decision making (MADM). In MODM the decision space is "*continuous"*. In these types of studies, the set of decision alternatives is undetermined. In MADM the decision space is "*discrete",* or predetermined. Often, the alternatives (or the options) represent the different choices of action available to the decision maker. Typically, each MCDM problem is linked to some attributes. These attributes are also known as either "decision criteria" or "goals." The distinct dimensions from which the options can be viewed are represent by the decision criteria. According to Triantaphyllou (2000), any decision making technique use three steps as follows.

1. Identify both the related attributes and the applicable options.
2. Assign numerical measures to not only the relative importance of the attributes but also the consequence of the applicable options on these attributes.
3. Perform the numerical evaluation to calculate a rating for each option.

This research utilized the early engagement of expert opinions in modeling MADM. These opinions were incorporated into an MADM model for the selection of a suitable project delivery method. A decision support model (DSM) was established by coupling the Conjunctive Satisficing Method (CSM) with the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) decision making approach to improve its outcomes.

This study focused on establishing a decision making model to evaluate and rank the performance of commonly used construction project delivery methods with respect to related decision criteria without the need for an experienced decision maker. This approach is established by engaging experts' opinions early on the decision support model in terms of model parameters. It should still be assumed that the decision maker is able to express his/her opinion of the priority of each decision criterion for a specific project based on both the project owner goals and the project's characteristics. This requirement is expected to be known by any project's owner (or owner representative). The following steps describe the procedure this research method utilized:

3.1. Define the alternatives of project delivery methods

The first step in this study involved listing alternatives to building construction project delivery methods. Several alternatives were considered. Each method has its own features in addition to both advantages and disadvantages. Those PDMs most commonly used in the US industry were used in this study because their results are dependent on the best practices of various experts in this field. Therefore, the seven project delivery approaches recognized by the Construction Specifications Institute (CSI, 2008) were considered. These project delivery methods included:

- Design-Bid-Build (DBB). DBB is the traditional method of PDM. The project's owner enter into a contractual arrangement with separate entities for both the project design and construction. The owner plays the role of coordinator between the designer and contractor. The project activities (including: design, bidding, and construction) taking place one after another in time (CSI, 2008).
- Design-Negotiate-Build (DNB). The contractor(s) is selected based on his qualifications after the design stage is completed, and both project scope of work and cost is negotiated without formal competitive bidding. The negotiation seeks to achieve a compromise arrangement for the benefit of all, and to minimize the risk for each party (CSI, 2008).
- Design-Build (DB). A single entity provides both of project design and construction services (CSI 2008). The design-builder is selected mostly on the basis of qualification, price may be considered as well. The owner provides the design-builder with the project performance requirements. The design-builder designs and builds the project to satisfy those requirements according to a single contract for both design and construction (AGC, 2004).
- Construction manager as agent or adviser (CMa). The construction manager provides assistance/expertise on project delivery process as advisor, and sometimes he works as an owner representative as well. The owner contracts directly with the A/E and either a single-prime contractor or multiple prime contractors (CSI, 2008). The CMa does not bears financial risk.
- Construction manager as contractor (CMc). The owner contracts with the construction manager to serve as a consultant and a contractor (CSI, 2008). CMc is selected by criteria (qualification-based-selection). The CMc bears not only the performance risk but also the financial risk. Therefore, this method is known as "CM at-Risk" (AGC, 2004). The Guaranteed Maximum Price (GMP) is a significant part of this project delivery system.
- Owner-Build (OB). The owner is participated in all the component of construction contracts for the project and directly manages all of the project activities. The owner works as a contractor with separate entities who are typically A/E, subcontractors,

and suppliers (CSI, 2008). Owner should be experienced and have qualified staff to manage the construction work.

- Integrated Project Delivery (IPD). It is integrated and collaborative approach based on early engagement of design consultants, constructors, and suppliers. IPD focuses on the project outcomes instead of participants' individual goals. The American Institute of Architects (AIA, 2007) defined the IPD as follows:

> A project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction. (p. 1).

3.2. Specify influential factors for evaluating construction project delivery methods

Influential factors are sometimes described by words such as "criteria" or "attributes." A broad literature review was conducted to help identify 36 influential factors (i.e. decision criteria) that can be used to select a suitable project delivery method. These factors were divided into five categories as shown in Table 1. In case of there are different expressions with the same meaning of considered influential factors, then only one of them was chosen for the unification purposes.

3.3. Evaluation of project delivery methods

An empirical survey was conducted between July 2013 and September 2013 in the US construction industry to evaluate both the relative performance and suitability of various project delivery approaches. This online survey included 26 questions. The first 17 questions are summarized in Appendix B. Participants (experts) were asked to evaluate the relative performance of project delivery approaches with respect to not only to the owner's goals but also the project's objectives. They were also asked to determine the relative suitability of utilizing each project delivery method with respect to the project's features, the owner's capabilities and attitudes, and the market.

Table 1
List of considered influential factors for construction PDM selection

Category			Influential Factors[$] (decision criteria)	References[#]																
				a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q
Owner Goals	Cost-related	C1	Minimum cost *(lowest price)*	√	√					√	√	√			√	√			√	√
		C2	Cost control *(restraint cost growth)*					√	√	√	√		√	√			√		√	√
		C3	Early budget estimation *(early cost estimate to help planning and business decisions)*	√		√						√	√	√			√			
	Time-related	C4	Early project delivery *(shortest period of time for completion)*	√	√	√	√			√	√	√	√	√	√	√	√	√	√	
		C5	Schedule control *(restraint time growth)*			√		√	√	√	√		√	√	√		√		√	√
		C6	Early procurement *(encourage early materials or equipment's acquisition)*			√	√						√	√						
	Quality-related	C7	High quality *(of the project outcomes)*					√	√	√	√	√	√		√	√	√		√	
		C8	Construction quality control *(during carrying out stage)*	√									√			√				√
		C9	High performance *(of operation and maintains (O&M) after accomplishing)*												√				√	
	Risk-related	C10	Financial risk *(to maintain within a certain cost budget, tender, and estimates)*	√					√				√		√					
		C11	Schedule risk *(to keep in a certain time for design, constructing and occupancy)*	√					√				√		√					
		C12	Performance risk *(quality, expected performance, and environment conservation)*						√				√		√					
Project Objectives Category		C13	Project life cycle *(planning, execution, closing, O&M, destruction)*				√					√			√	√		√		
		C14	Pre-construction services *(value engineering, constructability, cost reduction)*				√				√		√							
		C15	Project team relation *(collaboration, coordination, integration, min. disputes)*			√		√	√		√					√	√			
		C16	Safety *(people and/or properties safety)*					√								√				
		C17	Security *(protect secret project's documents/information/technological development)*					√								√				
		C18	Stakeholders' satisfaction					√							√	√				
Project Features Category		C19	Project subdivision type (*building construction, utility systems, highway, bridge*)		√			√	√					√	√	√	√		√	√
		C20	Project extent *(project size or physical magnitude), high score for large extent)*		√		√	√	√				√	√	√	√	√	√	√	√
		C21	Complexity *(project has composite deign and/or several distinct scope of works)*	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√
		C22	Uniqueness *(the project has unique characteristics, or technological advancement)*		√				√						√	√		√	√	
		C23	Site location (distance from the required resources for the construction activities)		√			√					√			√				
		C24	workplace circumstances (for handling construction activities and supplies)						√							√				√
		C25	Design completion stage *(of drawing before construction commences)*		√	√	√	√	√				√			√				√
		C26	Possibility for changes *(in the design, specifications, or scope of work)*	√						√	√	√	√			√	√		√	
		C27	Degree of risk *(uncertainty of scope of work and/or outcomes)*		√		√		√	√		√	√		√	√	√	√		√
		C28	Sustainability involved *(needs to incorporate green or sustainable features)*												√	√				
Owner Capability and Attitude		C29	Owner's experience *(project delivery and contract strategy)*			√	√	√				√	√	√	√			√	√	√
		C30	Owner's available resources (enough funding at ahead of project time)		√	√	√		√		√					√	√		√	
		C31	Owner's degree of participation (Owner's willingness to direct the project)				√									√	√	√		√
		C32	Owner's attitude towards risk *(project's owner attitude towards risk taking)*		√	√					√					√	√		√	√
		C33	Owner's willingness on a single contractual party *(few parties of responsibility)*	√			√			√	√	√				√			√	√
Market Consideration		C34	Availability of demanded service *(contractor or company for perform project works)*				√	√							√	√	√	√	√	√
		C35	Accessibility of commodity *(availability of articles of commerce)*				√	√							√	√				√
		C36	The market economic status *(inflation and interest rate, and other economic indexes)*					√	√				√		√	√	√	√		√

\# **Note:** a = NEDO (1985); b = Moshini and Botros (1990); c = Hibberd and Djebarni (1996); d = Dorsey (1997); e = Kumaraswamy and Dissanayaka (1998); f = Ambrose and Tucker (2000); g = Ng et al. (2002); h = Cheung et al. (2001); I = Hashim et al. (2006); j = Morledge et al. (2006); k = CSI (2008); l = QDPW (2008); m = Pishdad and Beliveau (2010); n = Chen et al. (2011); o = Thwala and Mathonsi (2012); p = Al-Jawhar, and Rezouki (2012); q = Zho and Ke (2013). √ = Symbol means that the factor (C) was considered in those references.

A Likert scale was used to score responses along a ten-point scale. The evaluation scale contained interval scores from 0 to 10 (e.g., 0 = no satisfaction at all, 5 = average satisfaction, and 10 = highest satisfaction). These evaluations expressed the domain expert's preferences, revealing which options were preferred for each criterion.

The participants in this survey were either experts or professionals who had no less than 10 years' experience in the field of either construction engineering or management. Therefore, respondents were asked to provide information related to their qualifications, experiences, and positions to ensure they were qualified to participate.

These experts were expected to hold differing attitudes with regard to each evaluation criterion. They were also expected to express these opposing views. As a result, the issue of aggregating the individual opinions into a single representative judgment for the entire group needed to be addressed. It has been demonstrated that the geometric mean (the mean of n numbers expressed as the n^{th} root of their product), not the often used arithmetic mean, is the only available manner to do so (Saaty, 2008). Microsoft Excel was used to determine the geometric mean of the experts' evaluation scores (opinions).

Group decision making is an opportunity to gather a number of opinions and expertise. The decision maker can choose the most suitable option when groups of experts' opinions are incorporated together in a decision support model. That decision contains more credible value than a decision made by one individual.

3.4. Establishing multi-attribute decision support model

A multi-attribute decision support model was established by linking together the Conjunctive Satisficing Method (CSM) and the TOPSIS decision making approach to improve its outcomes, and then applying them to project delivery method selection in building construction management. The basic concepts of each method can be concluded as follows.

3.4.1. Conjunctive Satisficing Method (CSM)

Yoon and Hwang (1995) suggested that CSM should not be applied to a select alternative. Instead, it should be divided into acceptable/unacceptable categories. Each alternative will be acceptable as long as it meets the minimum designated limits. Consequently, an alternative (A_i) can be classified as an acceptable alternative only if

$$x_{ij} \geq x_j^0, \quad j = 1 \; and \; 2 \ldots and \; n$$

Where x_j^0 is the minimum acceptable level of the *j*th attribute.

The decision maker (DM) plays a key role in discarding non-contender options. If the cutoff values given by the DM are greater than the normal levels, no alternative may remain. In this case, the DM can reduce the minimum acceptable levels of one or more influential factors and thus resume the evaluation. According to Linkov et al. (2005), "These simple screening rules can be used to select a subset of alternatives for analysis by other, more complex decision-making tools". Thus, this method can be connected to the TOPSIS method to improve the decision making process by satisficing the decision maker's requirements. Doing so guarantees decision maker's satisfaction with regard to the option will be selected in the next stage (by TOPSIS).

3.4.2. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS is a technique for order preference by similarity to ideal solution. Its conception was founded based on the idea that the preferred option should have the nearest distance from the positive ideal solution, and the farthest distance from the negative-ideal solution. The ideal solution is defined by this method as an aggregation of ideal levels (or evaluations) in all considered criteria. The TOPSIS method then selects an option that is most similar to the positive-ideal solution. Both Triantaphyllou (2000) and Yoon and Hwang (1995) suggested that the basic concepts of the TOPSIS method can be explained in the following steps.

Step 1: *Decision matrix (D) conceptualization*

The TOPSIS method is used to evaluate a decision matrix that is formulated as follows.

$$DM = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{matrix} C_1 & C_2 & \cdots & C_n \end{matrix} \\ \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \end{array} \qquad (1)$$

$$W = [w_1 \quad w_2 \quad \ldots \quad w_n] \quad .$$

where A_1, A_2, …, A_m are the possible alternatives (project delivery methods in this study), C_1, C_2, … , C_n are the evaluation criteria (36 influential factors in this study), x_{ij} are the performance evaluations for the alternative (A_i) with respect to the criterion (C_j), and W is a set of weights assigned by the decision maker (criterion priorities), where w_j is the weight of the criterion C_j, ($\sum w_j = 1$).

The Conjunctive Satisficing Method (CSM) is suggested to be linked to after finishing the previous step, decision matrix (D) conceptualization. The decision maker should identify the minimum, acceptable, required performance level for each decision criterion. Each alternative will be considered acceptable if and only if

$$x_{ij} \geq x_j^0, \qquad j = 1 \text{ and } 2 \ldots \text{and } n$$

Where x_j^0 is the minimum acceptable level of the *j*th attribute

Step 2: *Calculate the normalized decision matrix (R)*

$$R_{ij} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}, \quad \text{where:} \quad r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \quad i = 1, 2\ldots m \quad \text{and} \quad j = 1, 2\ldots n. \qquad (2)$$

Step 3: *Calculate the weighted decision matrix (V)*

$$V_{ij} = \begin{bmatrix} v_{11} & v_{12} & \cdots & v_{1n} \\ v_{21} & v_{22} & \cdots & v_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ v_{m1} & v_{m2} & \cdots & v_{mn} \end{bmatrix}, \text{ where: } \quad v_{ij} = w_j \times r_{ij}, \quad i = 1, 2\ldots m \quad \text{and} \quad j = 1, 2\ldots n. \qquad (3)$$

Step 4: *Identify both the positive-ideal (A^*) and the negative-ideal (A^-) solutions*

$$A^* = \{v_1^*, v_2^*, ..., v_j^*, ..., v_n^*\} = \left\{(\max_i v_{ij} \,\middle|\, j \in J_1), (\min_i v_{ij} \,|\, j \in J_2\right\}, \; i = 1, 2\ldots m \qquad (4a)$$

$$A^- = \{v_1^-, v_2^-, ..., v_j^-, ..., v_n^-\} = \left\{(\min_i v_{ij} \,\middle|\, j \in J_1), (\max_i v_{ij} \,|\, j \in J_2\right\}, \; i = 1, 2\ldots m \qquad (4b)$$

Where J_1 is a set of benefit criteria, and J_2 is a set of cost/loss criteria. It is assumed that the decision-maker requires both the maximum value among the options for the benefit criteria and the minimum values among the options for the cost/loss criteria.

Step 5: *Calculate the separation measures*

Let S_i^* = the distance of each options from the positive-ideal solution (A^*). This distance can be determined by applying the n-dimensional Euclidean distance method. Then,

$$S_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2}, \; for \quad i = 1, \; 2\ldots m \qquad (5a)$$

Similarly, let S_i^- = the distance of each alternative from the negative-ideal solution (A^-). Then,

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}, \; for \quad i = 1, \; 2\ldots m \qquad (5b)$$

Step 6: *Calculate the similarities to the positive-ideal solution*

The relative closeness (C_i^*) of an option (A*i*) regarding the positive-ideal solution (A^*) can be determined as follows:

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*}, i = 1, 2, 3, \ldots m, 0 \le C_i^* \le 1 \qquad (6)$$

Note that when $A_i = A^-$, then C_i^* =0. Additionally when $A_i = A^*$, then C_i^* = 1.

Step 7: *Rank the preference order*

The most preferable option should be the one that has the shortest distance from the positive-ideal solution. Therefore, the best alternative is the alternative that has the higher value of (C_i^*), and so on.

4. Research findings and results

4.1. Survey results

Approximately 594 participants in the survey were recorded. 137 questionnaires were completed reflecting a response rate of 23%. The survey data was collected from 132 completed questionnaires as their respondents had more than the desired 10 years of experience. The participants were from varies fields including: Architecture/Engineering (A/E), either owners or owners representatives, consultants, either contractors or sub-contractors, construction and project management, and more. (For a complete illustration see Appendix C).

Each participant evaluated the relative performance of the 7 considered project delivery methods with respect to the owner goals and project objectives criteria. They also evaluated the relative suitability of utilizing each project delivery method with respect to the project features, owner's capabilities and attitudes, and market criteria. The evaluation scores were between 0 and 10. The elicited experts' opinions were examined, aggregated, as show in Table 2, and then incorporated in the process of multi-attribute decision making as model parameters to establish the aimed decision support tool.

Table 2

The geometric means of the experts' evaluation scores of relative performance and suitability of PDMs

Influential factors				Project Delivery Approaches						
Categories	Factors			DBB	DNB	DB	CMa	CMc	OB	IPD
Owner Goals	Performance with respect to how well it assists in …	C1	Minimizing project cost (lowest price)	5.92	6.05	5.84	4.38	4.92	4.99	5.42
		C2	Controlling project cost (restraint cost growth)	4.58	6.03	6.41	4.90	5.47	5.05	5.52
		C3	Early project budget estimation (early cost approximation to help planning and business	3.38	5.13	6.13	5.26	5.54	4.63	5.90
		C4	Early project delivery (shortest period of time for completion)	3.87	5.24	7.20	4.93	5.62	5.26	5.65
		C5	Project schedule control (restraint time growth)	4.40	5.63	6.66	5.15	5.73	5.09	5.54
		C6	Early project procurement (encourages early design and material or equipment's acquisition)	3.07	4.57	6.68	4.75	5.54	5.76	6.00
		C7	Achieving high quality of the project outcomes	4.84	5.96	5.46	5.12	5.23	5.61	5.96
		C8	Controlling construction quality (during carrying out stage)	4.62	5.66	5.39	5.10	5.26	5.62	5.80
		C9	Achieving high quality of operation and maintenance (O&M) after accomplishing	4.50	5.31	5.24	4.95	5.08	5.95	5.89
		C10	Minimal financial risk (to maintain within a certain cost budget, tender, and estimates)	4.93	5.95	6.33	4.92	5.44	5.22	5.53
		C11	Minimal schedule risk (to keep in a certain time for design, constructing and occupancy)	4.58	5.82	6.41	5.03	5.65	5.21	5.73
		C12	Minimal performance risk (quality, expected performance, and environment conservation)	4.22	5.59	5.17	5.01	5.14	5.70	5.94
Project objectives		C13	Considering project life cycle (planning, execution, closing, operation and maintenance,	4.29	5.42	5.63	5.16	5.08	5.33	6.31
		C14	Pre-construction services (value engineering, constructability, cost reduction	2.99	5.11	6.07	5.44	5.62	4.79	6.18
		C15	Project team relation (collaboration, coordination, integration, min. disputes)	3.05	4.83	5.96	4.97	4.94	4.70	6.50
		C16	Safety (people and/or properties safety)	5.22	5.85	5.74	5.68	5.88	4.63	5.54
		C17	Security (protect secret project's documents/information/technological development).	3.74	5.01	5.61	4.91	5.10	6.58	5.34
		C18	Stakeholders' satisfaction	4.47	5.66	5.77	5.19	5.11	5.97	6.15
Project features	Suitability for (or when) …	C19a	Residential building construction	4.93	6.80	5.49	3.01	3.82	5.34	3.68
		C19b	Non-residential building construction	6.75	7.20	6.86	5.80	6.18	4.61	6.30
		C20	Large extent projects (the size or physical magnitude of the project is big)	5.91	6.61	6.09	6.06	6.18	3.48	6.20
		C21	Complex projects (the project have composite deign and/or several distinct scope of works)	5.21	6.41	5.84	6.14	6.23	3.46	6.35
		C22	Unique projects (the project has unique characteristics or technological advancement)	4.66	6.35	6.07	5.61	5.61	3.63	6.38
		C23	Far location projects (workplace is far from the required resources for construction activities)	4.89	5.95	5.56	5.56	5.72	3.98	5.68
		C24	Confined project's workplace (difficult for handling construction activities and supplies)	4.55	5.73	6.09	5.57	5.93	4.21	5.75
		C25	Design stage completion projects (when design of drawings before construction commences is	5.17	6.39	5.89	5.44	5.62	5.25	5.79
		C26	Possibility for changes (in the design, specifications, or scope of work)	3.17	4.49	5.42	5.02	5.11	5.44	5.45
		C27	Degree of risk (uncertainty of scope of work and/or outcomes)	2.51	4.11	4.55	4.79	4.69	4.91	5.16
		C28	Sustainability involved (needs to incorporate green or sustainable features)	5.76	6.48	6.19	5.94	5.85	5.47	6.47
Owner's capability and attitude		C29	Project owner who is highly experienced in project delivery and contract strategy	6.03	7.15	6.71	4.87	5.76	7.85	6.36
		C30	Project owner who has available resources (existing of enough funding at ahead of project	5.89	6.71	6.75	5.60	5.57	7.11	6.16
		C31	High degree of participation of the project's owner (for control over the project)	4.91	6.10	5.30	4.93	5.07	8.14	5.83
		C32	Project's owner risk avoidance (project's owner has negative attitude towards risk taking)	5.24	5.93	5.77	5.13	5.44	3.93	5.15
		C33	Few numbers of contracting parties (the project's owner looks for single or few parties of	5.75	6.52	7.52	4.33	5.66	4.56	4.71
Market State		C34	There is availability of demanded service (contractor or company for perform project works	6.61	6.86	6.56	5.64	5.71	5.01	5.65
		C35	There is accessibility of commodity (availability of articles of commerce)	6.85	6.79	6.50	5.75	6.08	5.82	5.60
		C36	The economic status of the market is good (inflation, interest rate, and other economic	6.79	6.82	6.47	5.51	5.90	5.84	5.80

4.2. Multi-attribute decision support model for PDM selection

A Decision Matrix (DM) is formulated based on the identified PDM, decision criteria, and the experts' evaluation for the relative performance and suitability of alternatives (A_i) with respect to criterion (C_j). Microsoft Excel was used to determine the geometric mean of the experts' evaluation scores (x_{ij}). The results are given in Table 3.

Table 3
Decision matrix conceptualization

DM =

Criteria	Alternatives (project delivery methods) A1 (DBB)	A2 (DNB)	A3 (DB)	A4 (CMa)	A5 (CMc)	A6 (OB)	A7 (IPD)
C1	5.92	6.05	5.84	4.38	4.92	4.99	5.42
C2	4.58	6.03	6.41	4.90	5.47	5.05	5.52
C3	3.38	5.13	6.13	5.26	5.54	4.63	5.90
C4	3.87	5.24	7.20	4.93	5.62	5.26	5.65
C5	4.40	5.63	6.66	5.15	5.73	5.09	5.54
C6	3.07	4.57	6.68	4.75	5.54	5.76	6.00
C7	4.84	5.96	5.46	5.12	5.23	5.61	5.96
C8	4.62	5.66	5.39	5.10	5.26	5.62	5.80
C9	4.50	5.31	5.24	4.95	5.08	5.95	5.89
C10	4.93	5.95	6.33	4.92	5.44	5.22	5.53
C11	4.58	5.82	6.41	5.03	5.65	5.21	5.73
C12	4.22	5.59	5.17	5.01	5.14	5.70	5.94
C13	4.29	5.42	5.63	5.16	5.08	5.33	6.31
C14	2.99	5.11	6.07	5.44	5.62	4.79	6.18
C15	3.05	4.83	5.96	4.97	4.94	4.70	6.50
C16	5.22	5.85	5.74	5.68	5.88	4.63	5.54
C17	3.74	5.01	5.61	4.91	5.10	6.58	5.34
C18	4.47	5.66	5.77	5.19	5.11	5.97	6.15
C19a	4.93	6.80	5.49	3.01	3.82	5.34	3.68
C19b	6.75	7.20	6.86	5.80	6.18	4.61	6.30
C20	5.91	6.61	6.09	6.06	6.18	3.48	6.20
C21	5.21	6.41	5.84	6.14	6.23	3.46	6.35
C22	4.66	6.35	6.07	5.61	5.61	3.63	6.38
C23	4.89	5.95	5.56	5.56	5.72	3.98	5.68
C24	4.55	5.73	6.09	5.57	5.93	4.21	5.75
C25	5.17	6.39	5.89	5.44	5.62	5.25	5.79
C26	3.17	4.49	5.42	5.02	5.11	5.44	5.45
C27	2.51	4.11	4.55	4.79	4.69	4.91	5.16
C28	5.76	6.48	6.19	5.94	5.85	5.47	6.47
C29	6.03	7.15	6.71	4.87	5.76	7.85	6.36
C30	5.89	6.71	6.75	5.60	5.57	7.11	6.16
C31	4.91	6.10	5.30	4.93	5.07	8.14	5.83
C32	5.24	5.93	5.77	5.13	5.44	3.93	5.15
C33	5.75	6.52	7.52	4.33	5.66	4.56	4.71
C34	6.61	6.86	6.56	5.64	5.71	5.01	5.65
C35	6.85	6.79	6.50	5.75	6.08	5.82	5.60
C36	6.79	6.82	6.47	5.51	5.90	5.84	5.80

The Normalized Decision Matrix (R) was calculated. The values of r_{ij} were determined by applying formula (2). The normalization decision matrix (R) can be formulated as shown in Table 4.

Table 4
The normalized decision matrix

R =

Criteria	A1 (DBB)	A2 (DNB)	A3 (DB)	A4 (CMa)	A5 (CMc)	A6 (OB)	A7 (IPD)
	Alternatives (project delivery methods)						
C1	0.415	0.424	0.409	0.307	0.345	0.350	0.380
C2	0.317	0.418	0.444	0.340	0.379	0.350	0.382
C3	0.245	0.372	0.444	0.382	0.402	0.336	0.428
C4	0.267	0.362	0.497	0.340	0.388	0.363	0.390
C5	0.302	0.387	0.458	0.354	0.394	0.350	0.381
C6	0.218	0.325	0.476	0.338	0.395	0.410	0.427
C7	0.334	0.412	0.378	0.354	0.361	0.388	0.412
C8	0.326	0.399	0.380	0.359	0.371	0.396	0.409
C9	0.321	0.379	0.374	0.353	0.362	0.425	0.421
C10	0.339	0.409	0.435	0.338	0.374	0.359	0.380
C11	0.314	0.399	0.439	0.345	0.387	0.357	0.392
C12	0.302	0.400	0.370	0.359	0.368	0.408	0.425
C13	0.303	0.383	0.398	0.365	0.359	0.376	0.446
C14	0.214	0.367	0.436	0.390	0.403	0.344	0.443
C15	0.226	0.358	0.442	0.369	0.367	0.349	0.482
C16	0.358	0.400	0.393	0.389	0.402	0.317	0.379
C17	0.269	0.361	0.405	0.354	0.368	0.474	0.385
C18	0.307	0.389	0.396	0.357	0.351	0.410	0.423
C19a	0.382	0.527	0.426	0.233	0.296	0.414	0.285
C19b	0.406	0.433	0.412	0.348	0.371	0.277	0.378
C20	0.380	0.426	0.392	0.390	0.398	0.224	0.400
C21	0.343	0.422	0.384	0.404	0.410	0.228	0.418
C22	0.317	0.432	0.413	0.382	0.382	0.247	0.435
C23	0.344	0.419	0.391	0.391	0.402	0.280	0.400
C24	0.316	0.398	0.422	0.387	0.412	0.292	0.399
C25	0.345	0.427	0.393	0.363	0.375	0.350	0.386
C26	0.243	0.344	0.415	0.385	0.391	0.417	0.418
C27	0.213	0.348	0.385	0.405	0.397	0.415	0.437
C28	0.361	0.406	0.388	0.372	0.367	0.343	0.405
C29	0.353	0.419	0.393	0.285	0.337	0.460	0.372
C30	0.354	0.404	0.406	0.337	0.335	0.428	0.371
C31	0.317	0.394	0.342	0.319	0.327	0.526	0.376
C32	0.376	0.426	0.415	0.368	0.391	0.282	0.370
C33	0.383	0.434	0.500	0.288	0.377	0.303	0.313
C34	0.414	0.430	0.411	0.353	0.357	0.314	0.353
C35	0.417	0.413	0.395	0.350	0.370	0.354	0.340
C36	0.415	0.417	0.396	0.337	0.361	0.357	0.355

The provided matrices can be used to both rank and select the appropriate project delivery method for any building construction project, as shown in Fig. 1.

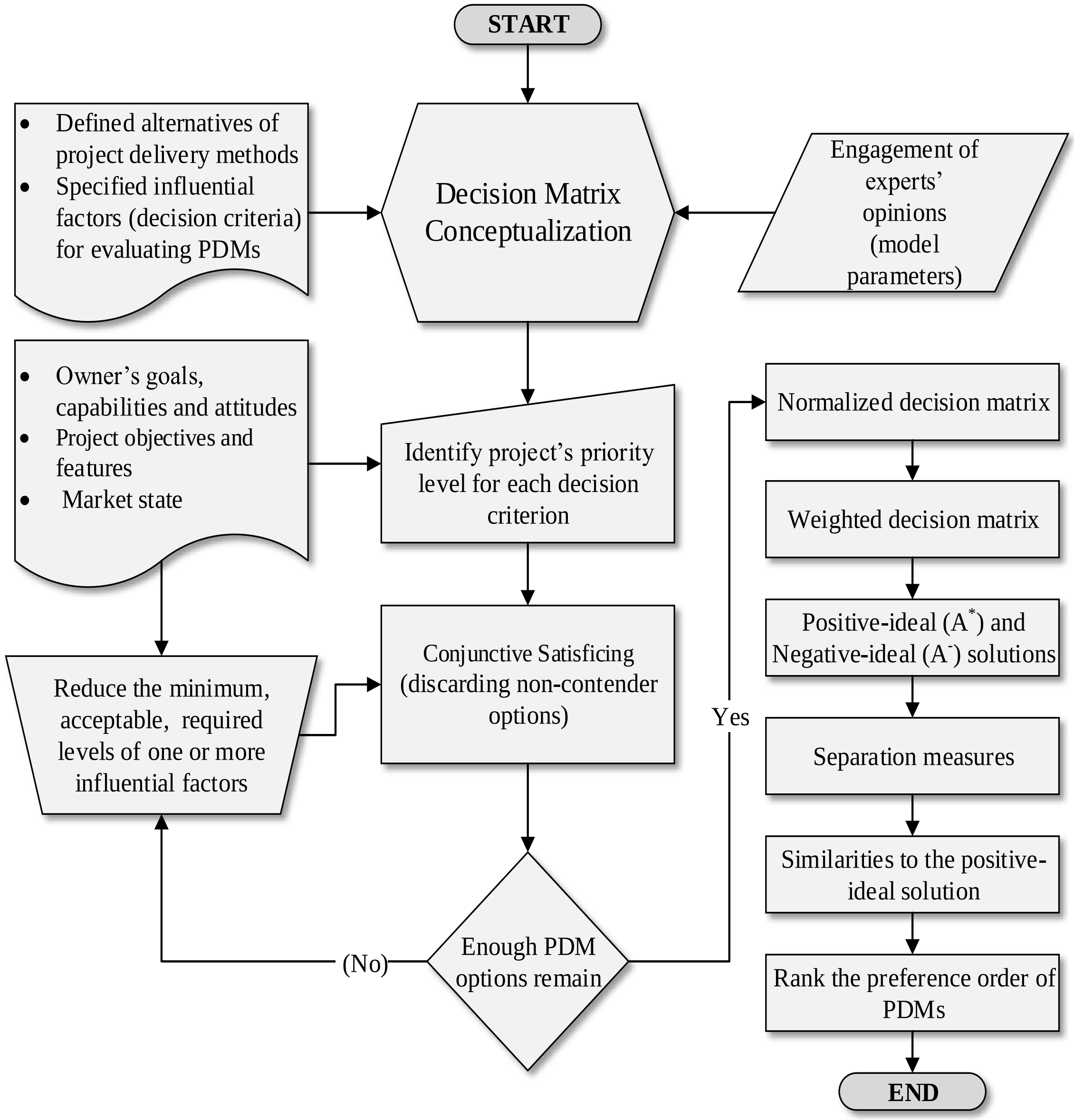

Fig. 1. Process flowchart of the PDMs selection model

A set of weights (W) for each project should be assigned by the decision maker (owner) to calculate the Weighted Decision Matrix (V). This set of weights reflect the criterion priorities for that project, where w_j is the weight of criterion C_j, ($\sum w_j = 1$). Both the Positive-Ideal (A*) and the Negative-Ideal (A-) Solutions can be identified by using formulas (4a) and (4b). Respectively, the separation measures can then be calculated according to equations (5a) and (5b). Next, the similarities to the Positive-Ideal Solution for each considered project delivery method can be determined with equation (6). The most preferable project delivery method should be the one with the highest value of (C_i^*). Because this decision support tool includes a large number of parameters, an Excel spreadsheet is provided to facilitate its calculations, as shown in Tables 5, 6, and 7.

Table 5

An example for assigning decision criteria priority scores for the considered project

Category		Criterion Factor	Priority
Assign project priority scores for the for the following decision criterion (e.g., Min. Score = 0, Average 5, Max. Score = 10)			
Owner Goals		**Cost-related factors:**	
	C1	Minimum cost *(lowest price)*	**7**
	C2	Cost control *(restraint cost growth)*	**8**
	C3	Early budget estimation *(early cost estimate to help planning and business decisions)*	**5**
		Time-related factors:	
	C4	Early project delivery *(shortest period of time for completion)*	**6**
	C5	Schedule control *(restraint time growth)*	**7**
	C6	Early procurement *(encourage early materials or equipment's acquisition)*	**4**
		Quality-related factors:	
	C7	High quality *(of the project outcomes)*	**8**
	C8	Construction quality control *(during carrying out stage)*	**5**
	C9	High performance *(of operation and maintains (O&M) after accomplishing)*	**7**
		Risk-related factors:	
	C10	Minimal financial risk *(to maintain within a certain cost budget, tender, and estimates)*	**7**
	C11	Minimal schedule risk *(to keep in a certain time for design, constructing and occupancy)*	**5**
	C12	Minimal performance risk *(quality, expected performance, and environment conservation)*	**7**
Project objectives	**C13**	Project life cycle *(planning, execution, closing, O&M, destruction)*	**5**
	C14	Pre-construction services *(value engineering, constructability, cost reduction)*	**4**
	C15	Project team relation *(collaboration, coordination, integration, min. disputes)*	**5**
	C16	Safety *(people and/or properties safety)*	**6**
	C17	Security *(protect secret project's documents/information/technological development)*	**5**
	C18	Stakeholders' satisfaction	**6**
Assign scores for each project's feature or condition of the following decision criterion (Min. Score = 0, Average 5, Max. Score = 10)			
Project features	**C19a**	In case of residential building construction; score = 10, otherwise = 0	**0**
	C19b	In case of non-residential building construction; score = 10, otherwise = 0	**10**
	C20	Project extent *(project size or physical magnitude), high score for large extent)*	**7**
	C21	Complexity *(project has composite deign and/or several distinct scope of works)*	**8**
	C22	Uniqueness *(the project has unique characteristics, or technological advancement)*	**7**
	C23	Far location (workplace is far from the required resources for the construction activities)	**0**
	C24	Confined workplace (difficult for handling construction activities and supplies)	**5**
	C25	Design completion stage *(of drawing before construction commences)*	**2**
	C26	Possibility for changes *(in the design, specifications, or scope of work)*	**5**
	C27	Degree of risk *(uncertainty of scope of work and/or outcomes)*	**5**
	C28	Sustainability involved *(needs to incorporate green or sustainable features)*	**0**
Owner's capability and attitude	**C29**	Owner's experience *(project delivery and contract strategy)*	**1**
	C30	Owner's available resources (enough funding at ahead of project time)	**7**
	C31	Owner's degree of participation (Owner's willingness to direct the project)	**2**
	C32	Owner's attitude towards risk *(project's owner has negative attitude towards risk taking)*	**8**
	C33	Owner's willingness on a single contracting party *(single or few parties of responsibility)*	**6**
Market State	**C34**	Availability of demanded service *(contractor or company for perform project works)*	**5**
	C35	Accessibility of commodity *(availability of articles of commerce)*	**5**
	C36	The market economic status *(inflation and interest rate, and other economic indexes)*	**5**

Table 6

An example for determining appropriate PDMs

Considered Project Delivery Methods *	Yes/No
Design-Bid-Build (DBB)	Yes
Design-Negotiate-Build (DNB)	Yes
Design-Build (DB)	Yes
Construction manager as agent or adviser (CMa)	Yes
Construction manager as contractor (CMc)	Yes
Owner-Build (OB)	No
Integrated Project Delivery (IPD).	Yes

* In case of few appropriate or non-applicable project delivery methods; then one or some of priority scores of the criterion factors should be decreased to get more applicable PDMs.

Table 7

An example for preferable rank of considered PDMs

Appropriate Project Delivery Methods	RPI#	Rank
Design-Bid-Build (DBB)	0.23	6
Design-Negotiate-Build (DNB)	0.65	3
Design-Build (DB)	0.81	1
Construction manager as agent/adviser (CMa)	0.42	5
Construction manager as contractor (CMc)	0.55	4
Integrated Project Delivery (IPD).	0.65	2

(RPI) = Relative Preferable Index
The best alternative is the method has the higher value of RPI
$0 \leq (RPI) \leq 1$

4.3.Reliability and validity of the research results

Lucko (2009) noted that "validation is a challenge to all researchers, but especially so to those working in interdisciplinary fields such as construction engineering and management." MADM models are often difficult to test because there is no standard procedure for determining which option is best. Lucko (2009) indicated that the effective way to establish face validity is through the engagement of domain experts either before, during, and after the study. Such involvement can range from consultatory to active collaboration. Therefore, in this research the following procedures were conducted.

- **Content Validation** The non-statistical method focuses on determining whether or not the research content represents reality in a reasonable manner (Lucko, 2009). Accordingly, both the assumptions and the procedure were examined for reasonability and acceptability. For example, the list of criteria was complete (nothing was omitted), there was no overlap between criteria, and it was as simple as possible to get valid scores or weights based on the research procedure.

- **Experts' Group** The validity of these results was highly dependent on the experts' qualifications. Therefore, the participants in this study were experts or professionals with experience not less than 10 years in the field of construction engineering or management. Appendix-C illustrates participants' characteristics.

- **Coefficient of reliability (or internal consistency)** Cronbach's alpha coefficient was applied to measure the reliability of the Likert scale used within this survey. This coefficient of reliability investigated the internal consistency of the results between the evaluation of relative performance and the suitability of the studied project delivery methods. The Predictive Analytics Software (PASW Statistics 18.0) for statistical analysis was utilized to determine the Cronbach's alpha coefficient of reliability. For this study (α) was equal to 0.821. If $\alpha > 0.8$, good internal consistency was maintained (George and Mallery, 2010). Thus, the evaluation of both the relative performance and suitability of the considered project delivery methods, with respect to the defined influential factors, were reliable for the purpose of this study.

- **Face Validation** Face validation is a subjective assessment of non-statistical characteristics. The results of this study were given to several experts in the field. These experts were asked if they think this research results will provide assistance to the decision maker and/or get correct results. The research results were validated by subset of 13 experts who have either Ph.D. or M.Sc. degree and at least 25 years of experience.

5. Conclusions

This research presents the early engagement of experts opinions in the modeling of multi-attribute decision-making (MADM). It was conducted by linking together the Conjunctive Satisficing Method and the TOPSIS decision making approach and then applying them to a project delivery method selection within building construction management. A decision support tool was established based on the experts' opinions in the field of project and construction management within the US construction industry. This study demonstrates that expert group opinions can be incorporated into multi-attribute decision making analysis. Doing so provides an invaluable tool that can utilize this expertise to make a more suitable project delivery method selection without the physical existence of an expert panel. The decision support model provided by this research can be adopted by decision makers as a guiding basis for comparison between the various methods of construction project delivery systems. The research results help to rationalize decisions and ensuring success of the building construction projects deliveries.

Acknowledgment

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Appendix A. Review of literature on the procedures of selecting construction PDMs

Authors	Procedure Description
NEDO (1985)	NEDO (1985) conducted a study that was the first acknowledged attempt made to identify the criteria governing the selection of a PDM within the construction industry. A procurement path decision chart was used to identify the eight priorities most relevant to a project delivery track choice. The provided decision chart is intended to be used as a primer for discussing with a principal consultant.
Skitmore and Marsden (1988)	Skitmore and Marsden (1988) described two approaches that can be used to choose the appropriate PDM. The first approach was developed from the National Economic Development Office's decision chart (NEDO, 1985). This approach used a multi-attribute utility analysis with both a weighting of the owner's priorities and a rating approach. The second approach was developed by means of a discriminant analysis. This approach uses three discriminant functions to provide consistent predictions.
Moshini and Botros (1990)	Moshini and Botros (1990) created an expert system, PASCON. This matches the influential factors with several conditions that the variable of a PDM can assume. The results can be used to select a appropriate PDM.
Gordon (1994)	Gordon (1994) studied the characteristic of various construction PDMs with particular clients and projects. Contracting methods were defined to comprise four parts: scope, organization, contract, and award. Guidelines were provided to help the owner choose the project delivery and contract type most suitable to the considered project.
Griffith and Headley (1997)	Griffith and Headley (1997) proposed a weighted score model that can be used to select a PDM for small building projects. This procedure utilizes weightings to evaluate criteria and project delivery options that are limited in either size or scope. This model is neither complicated nor difficult.
Kumaraswamy and Dissanayaka (1998)	Kumaraswamy and Dissanayaka (1998) developed a model that links PDM variables to the project's outcomes. Both the project's participants and features were integrated as intervening variables in the model. The rank agreement factor used to weight the priorities and arrange them in a sequence of ranks.
Ambrose and Tucker (2000)	Ambrose and Tucker (2000) created a procedure that can be used to determine PDM's performance within a considered project. The interactions that occur between project delivery characteristics and a range of influential factors are considered. This model is based on MAUA (which considers three dimensions). Unfortunately, it has complicated structure.

Alhamzi and McCaffer (2000)	Alhamzi and McCaffer (2000) created a PDM selection model. This model incorporated both the analytic hierarchy process (AHP) and the value engineering techniques of the Parker's judging alternative into multi-criteria and multi-screening procedures. This method allows users to choose from a cut down number of dictated alternatives and schemes. It is quite a complex system.
Chan et al. (2001)	Chan et al. (2001) created a multi-attribute model by using Delphi method in the selection of PDMs. This method asking the decision maker to weight a set of attribute to be multiplied by the utility rating of limited PDMs.
Cheung et al. (2001)	Cheung et al. (2001) used both the analytical hierarchy process (AHP) and a multi-attribute utility theory to develop a PDM selection procedure. The NEDO attributes were used. Utility factors that represent various PDMs were demonstrated. The AHP was used to assess the proportional weightings of the selection criteria. The selection of an appropriate project delivery method was based on the highest derived utility value of the considered options.
Al Khalil (2002)	Al Khalil (2002) used the analytical hierarchy process (AHP) to develope a model for choosing a suitable project delivery method. The priority of PDM determined by pairwise comparison matrix. Three PDMs were considered: DBB, DB, and CM. Various influential factors were considered relevant to PDM selection. These factors were used to rank the PDMs.
Mahdi and Alreshaid (2005)	Mahdi and Alreshaid (2005) applied the analytical hierarchy process (AHP) for developing a multi-criterion decision making procedure. This procedure proposed to aid the decision-maker for deciding which the proper delivery method should be used for a project. A pairwise comparison matrix was used to prioritize the PDMs.
Luu et al. (2006)	Luu et al. (2006) suggested indicators by applying the case-based reasoning (CBR). Collection of facts from previous cases (i.e. projects) are captured and reused for PDM decision making. Both characteristics of project and client and external environment were each taken into consideration. The cases have similarity with the goal are retrieved by determine the similarity matrix. This is assessed by computing the linearly similarity of various indicators.
Oyetunji and Anderson (2006)	Oyetunji and Anderson (2006) applied the simple multi-attribute rating approach with swing weights for selecting PDMs. They Linked project delivery methods with the contractual arrangements. The objectives are scored by this method then the most critical measurements of the system are ranked. Limited alternatives and criteria. Limited for the suggested PDMs and contracting procedures.

Mafakheri et al. (2007)	Mafakheri et al. (2007) presented a decision assistance model by the application of interval Analytical Hierarchy Process (AHP) joined with rough estimate conception. The rough estimate concepts were developed to fully rank the options and help decision makers. The full ranking relies upon a high risk that increases the chance of obtaining inaccurate results.
Wang at al. (2008)	Wang at al. (2008) used the “entropy weight” theory to not only adjust the subjective weight but also make the decision maker’s comprehensive weights. A multi-attribute fuzzy model was demonstrated to rank the options. This method applied the technique for order preference by similarity to ideal solution.
Zhang and Wang (2009)	Zhang and Wang (2009) adopted the fuzzy analytical hierarchy process (FAHP) to select a suitable construction PDM. They considered some related factors. The priority of PDM was determined by a pairwise comparison matrix. Sensitivity analysis was used to determine the selection’s influence various key factors were considered.
Chen et al. (2011)	Chen et al. (2011) developed a PDM selection model that project owners can use to make a decision. The project’s similarity matrix was identified between the database and the project’s target. A Data Envelopment Analysis - Bound Variable (DEA-BND) model was used to examine and modified the influential factors values. The Artificial Neural Network (ANN) model was used to predict a proper PDM for the target project.
Wang et al. (2013)	Wang et al. (2013) studied the selection of PDMs between DB and DBB methods by a way of assessing the Value-Added. Project transaction element was used to analysis the Value-Added of DB vs. DBB with respect to the primary influential factors. Estimated expressions for the parameters with respect to the Value-Added were established as a contribution to scientific decision-making analysis, but the authors mentioned that: “the analysis of estimating relevant parameters for each Value-Added way is very difficult, or even impossible to achieve.”
Cui and Chen (2014)	Cui and Chen (2014) suggested using the Relational Case-based Reasoning (RCBR) approach for PDMs selection. Both the project structural and feature similarity were considered. A framework for factors governing PDM selection was identified but the authors did not give details how their method can be utilized for various PDMs.
Ding, et al. (2014).	Ding, et al. (2014) investigated the effect of complexity, governance strength, and market environment on the project owner’s decision for PDMs selection. They established a multi-agent experimental model, which shows that the project’s owners mostly select DB method for complex projects and when the possible contractors get up quickly. This study was limited to DBB and DB methods only.

Appendix B. The first part questions of the survey for the evaluation of PDMs

Evaluate the performance or the Suitability of each project delivery method with respect to the following influential factors? #

Note: the score evaluation should be: 0 = No Satisfaction at all, 5 = Average Satisfaction, 10 = Highest Satisfaction, and so on

Influential factors (Considered Categories and Related Factors)	**Project Delivery Methods*** DBB	DNB	DB	CMa	CMc	OB	IPD
Owner Goals Category: Performance with respect to how well it assists in …							
Minimizing project cost (lowest price)	□	□	□	□	□	□	□
Controlling project cost (restraint cost growth)	□	□	□	□	□	□	□
Early project budget estimation (early cost approximation to help planning and business decisions)	□	□	□	□	□	□	□
Early project delivery (shortest period of time for completion)	□	□	□	□	□	□	□
Project schedule control (restraint time growth)	□	□	□	□	□	□	□
Early project procurement (encourages early design and material or equipment's acquisition)	□	□	□	□	□	□	□
Achieving high quality of the project outcomes	□	□	□	□	□	□	□
Controlling construction quality (during carrying out stage)	□	□	□	□	□	□	□
Achieving high quality of operation and maintenance (O&M) after accomplishing	□	□	□	□	□	□	□
Minimal financial risk (to maintain within a certain cost budget, tender, and estimates)	□	□	□	□	□	□	□
Minimal schedule risk (to keep in a certain time for design, constructing and occupancy)	□	□	□	□	□	□	□
Minimal performance risk (quality, expected performance, and environment conservation)	□	□	□	□	□	□	□
Project objectives Category: Performance with respect to how well it assists in …							
Considering project life cycle (planning, execution, closing, operation and maintenance, destruction)	□	□	□	□	□	□	□
Pre-construction services (value engineering, constructability, cost reduction	□	□	□	□	□	□	□
Project team relation (collaboration, coordination, integration, min. disputes)	□	□	□	□	□	□	□
Safety (people and/or properties safety)	□	□	□	□	□	□	□
Security (protect secret project's documents/information/technological development).	□	□	□	□	□	□	□
Stakeholders' satisfaction	□	□	□	□	□	□	□
Project features Category: Suitability for …							
Residential building construction	□	□	□	□	□	□	□
Non-residential building construction	□	□	□	□	□	□	□
Large extent projects (the size or physical magnitude of the project is big)	□	□	□	□	□	□	□
Complex projects (the project have composite deign and/or several distinct scope of works)	□	□	□	□	□	□	□
Unique projects (the project has unique characteristics or technological advancement)	□	□	□	□	□	□	□
Far location projects (workplace is far from the required resources for construction activities)	□	□	□	□	□	□	□
Confined project's workplace (difficult for handling construction activities and supplies)	□	□	□	□	□	□	□
Completion of design stage (design of drawings before construction commences is completed)	□	□	□	□	□	□	□
Possibility for changes (in the design, specifications, or scope of work)	□	□	□	□	□	□	□
Degree of risk (uncertainty of scope of work and/or outcomes)	□	□	□	□	□	□	□
Sustainability involved (needs to incorporate green or sustainable features)	□	□	□	□	□	□	□
Owner's capabilities and attitudes Category: Suitability for …							
Project owner who is highly experienced in project delivery and contract strategy	□	□	□	□	□	□	□
Project owner who has available resources (existing of enough funding at ahead of project time)	□	□	□	□	□	□	□
High degree of participation of the project's owner (for control over the project)	□	□	□	□	□	□	□
Project's owner risk avoidance (project's owner has negative attitude towards risk taking)	□	□	□	□	□	□	□
Few numbers of contracting parties (the project's owner looks for few parties of responsibility)	□	□	□	□	□	□	□
Market State Category: Suitability for …							
There is availability of demanded service (contractor or company for perform project works	□	□	□	□	□	□	□
There is accessibility of commodity (availability of articles of commerce)	□	□	□	□	□	□	□
The economic status of the market is good (inflation, interest rate, and other economic indexes)	□	□	□	□	□	□	□

Hint: the performance should be evaluated considering only one specific attribute each time regardless of the others (for example: when you consider "minimizing project cost attribute" do not look for the other influential factors such as "controlling project cost" or "early project budget estimation". That means the evaluation of each project delivery method should be done according to the achievement of "lowest price" only.

* **Project Delivery Approaches:** (DBB) = Design-Bid-Build, (DNB) = Design-Negotiate-Build, (DB) = Design-Build, (CMa) = Construction manager as agent or adviser, (CMc) = Construction manager as contractor, (OB) = Owner-Build, (IPD) = Integrated Project Delivery.

Appendix C. Illustration of the survey participants' characteristics

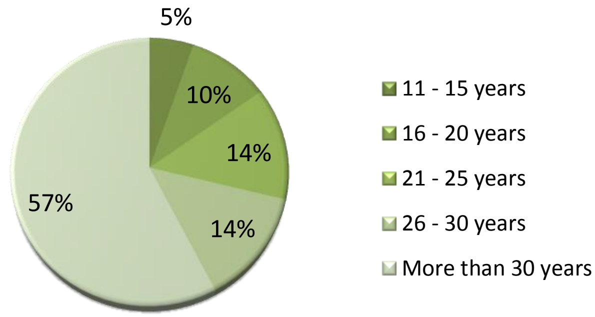

Fig. C.1. Experience in the field of building construction engineering or management

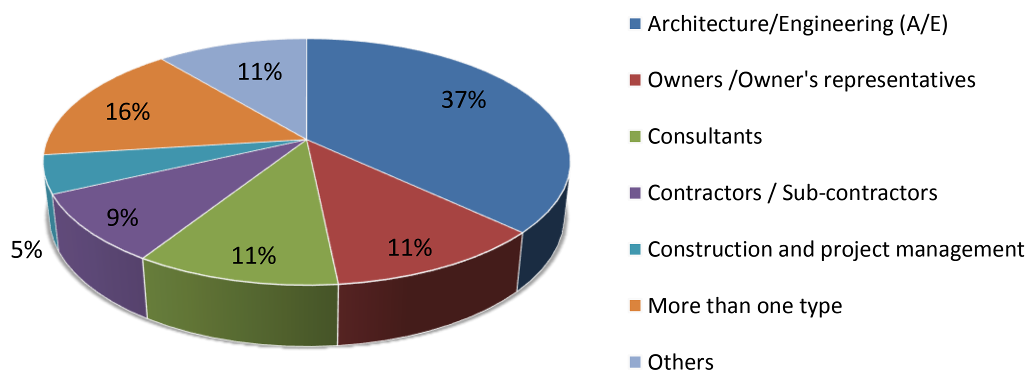

Fig. C.2. The natures of respondents' institutions or companies

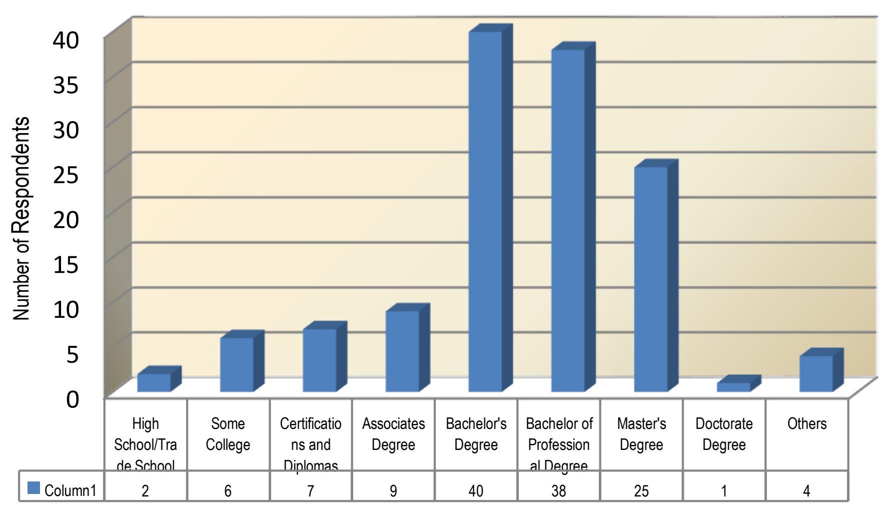

Fig. C.3. The respondents' highest education degrees

6. CONCLUSIONS

6.1. SUMMARY

Accomplishing construction projects at a low probable cost and a high quality performance, within a definite time, is considerable concern to the construction industry. The outcomes of this research reveal that 40 observed influential factors should be considered when selecting an appropriate construction project delivery approach. These factors were found to vary between average and critically important. The 15 most important factors were as follows:

16) Cost control (restraint cost growth)
17) The owner's available resources
18) Financial risk (to maintain within a certain cost budget, tender, and estimates)
19) Stakeholders' satisfaction
20) The project-team relationship
21) The project's complexity
22) Schedule control (restraint time growth)
23) The project outcome's quality
24) Uncertainty in the scope of the work
25) The owner's attitude toward risk
26) Construction quality control
27) Early budget estimation
28) The owner's desired degree of participation
29) Performance of operation and maintains after project completion
30) Owner's experience regarding the construction project delivery procedures

The relative performance and suitability of project delivery approaches in different situations within the building construction industry were identified in this study. It was determined that no project delivery method can achieve simultaneously all of the probable goals and objectives. Additionally, no project delivery method was perfect for all of project's features, the owner's capabilities and attitude, and the market states.

Each project delivery approach has both advantages and disadvantages. The most appropriate PDM should be chosen after the following have been considered: the owner's goals, the project's objectives, the project's features, the owner's capabilities and attitude, and the market states. The relative performance and suitability indicators revealed by this study should be given a careful consideration as guidelines when selecting an appropriate PDM.

The success of a construction project is strongly affected by the implemented project delivery method. Additional factors related to the internal and the external project's environment may affect the project success. Therefore, a construction project's low performance/failure may not be a good indication of whether or not the implemented PDM was successful.

The early engagement of experts' opinions was used in this study to model multi-attribute decision making (MADM). The Conjunctive Satisficing Method was linked with the TOPSIS decision making approach, and then applies them to PDM selection in building construction management. Experts opinions gathered from the fields of project and construction management in the US construction industry were used to establish a decision making tool. These opinions were incorporated into multi-attribute decision making analysis. That provides a tool to utilize the expertise in this field to make the suitable decision to select PDMs. The provided decision support model can be used without the physical existence of an expert panel during the process of PDM selection. This model can be adopted by decision makers as a guiding basis for comparing the various methods of construction PDMs. Doing so will help them rationalize their decisions better while ensuring project delivery success.

6.2. FUTURE RESEARCH

Additional research should be conducted to better understand the differences in the importance of some influential factors of PDM selection between the following: the public and private sectors, project contractual parties, and various regions across the United States.

APPENDIX A

SURVEY (I) QUESTIONNAIRE

Survey I – Investigation of Influential Factors for Selecting Suitable Project Delivery Methods for Construction projects

Welcome to My Survey

Introduction

In the field of contracting for construction projects there are several methods acknowledged for construction project deliveries. In the United States the main project delivery types used in the construction field are:

• Design-Bid-Build (DBB) method;
• Design-Build (DB) method;
• Construction Management (CM) method

Each type has its advantages, disadvantages and incentives for application. The project's owner usually selects the method suitable for the project nature. Also the contractor may provide some adjustments during negotiation stage to establish a compromise agreement.

Survey Objective

This questionnaire investigates the importance of several factors affecting the selection of project delivery methods construction projects. These criteria have been established based on a literature review, and categorized in the following groups:

• Owner goals;
• Project features;
• Project objectives;
• Owner characteristics;
• Market condition;
• Culture and Regulations;

Based on your knowledge and experience in the field of construction engineering, please give us your ideas about the following inquiries:

Your feedback is important.

Page 1 - Question 1 - Rating Scale - Matrix [Mandatory]

What is the important score of each criterion (factor) in regard to the selection of suitable project delivery methods for construction projects?
First - Owner Goals Category Cost-related factors: Scoring scale will be five numbers as follows:

	not important 1	slightly important 2	median important 3	very important 4	critically important 5	N/A
Prerequisite of: minimum cost (lowest price)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A
Cost control (restraint cost growth)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A
Early budget estimation (early cost assessment to help planning and business decisions)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A

Page 1 - Question 2 - Rating Scale - Matrix [Mandatory]

Time-related factors:

Prerequisite of: early project delivery (shortest period of time for completion)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A
Schedule control (restraint time growth)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A
Early procurement (encourage early design, and materials or equipment's acquisition)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A

Page 1 - Question 3 - Rating Scale - Matrix [Mandatory]

Quality-related factors:

	label	label	label	label	label	N/A
Prerequisite of: high quality (of the project outcomes)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A
Construction quality control (during carrying out stage)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A
High performance (of operation and maintains after project completion)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A

Page 1 - Question 4 - Rating Scale - Matrix [Mandatory]

Risk-related factors:

	label	label	label	label	label	N/A
Prerequisite of: minimal financial risk	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A
Minimal schedule risk	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A
Minimal performance risk	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A

Page 2 - Question 5 - Rating Scale - Matrix [Mandatory]

Second - Project characteristics Category

	not important	slightly important	median important	very important	critically important	N/A
Project type (a subdivision of particular kind of construction such as building construction [residential or nonresidential], utility systems, street, highway, and bridge construction)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A
Project extent (the size or physical magnitude of the project)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A
Project complexity (the project has composite deign and/or several distinct scope of works)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A
Uniqueness (the project has unique characteristics, or technological advancement)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A
Site location (distance from the required resources for construction activities)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A
Workplace circumstances (flexibility for managing the construction activities and supplies)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A
Design completion stage (of drawings before construction commences)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A
Possibility for changes (in the design, specifications, or scope of work)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A

Degree of risk (uncertainty of scope of work and/or outcomes)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A
Sustainability (incorporate green or sustainable features).	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A

Page 3 - Question 6 - Rating Scale - Matrix [Mandatory]

Third - Project objectives Category

	not important	slightly important	median important	very important	critically important	N/A
Project life cycle ((initiation, planning, execution, closing, operation and maintenance, destruction)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A
Pre-construction services (value engineering, constructability, cost reduction)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A
Project team relation (collaboration, integration, minimum disputes)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A
Safety (people and/or properties safety)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A
Security (protect secret project's documents/information/technological development)	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A
Stakeholders' satisfaction	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A

Page 4 - Question 7 - Rating Scale - Matrix [Mandatory]

Fourth - Owner's characteristics Category

	not important	slightly important	median important	very important	critically important	N/A
Owner's experience to determine which project delivery make attractive or acceptable	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A
Level of involvement (owner's willingness to	❍ 1	❍ 2	❍ 3	❍ 4	❍ 5	❍ N/A

direct the project)						
Owner's available resources (enough funding ahead of project time)	○ 1	○ 2	○ 3	○ 4	○ 5	○ N/A
Owner's behavior towards risk (behavior towards risk taking)	○ 1	○ 2	○ 3	○ 4	○ 5	○ N/A
Owner's confidence on adequate number of contractual parties (few parties of responsibility)	○ 1	○ 2	○ 3	○ 4	○ 5	○ N/A

Page 5 - Question 8 - Rating Scale - Matrix [Mandatory]

Fifth - Market condition Category

	not important	slightly important	median important	very important	critically important	N/A
Availability of demanded service (contractor or company that performs the works called for)	○ 1	○ 2	○ 3	○ 4	○ 5	○ N/A
Availability of commodity providers	○ 1	○ 2	○ 3	○ 4	○ 5	○ N/A
Economic state of the market (inflation rate, interest rate, other economic indexes)	○ 1	○ 2	○ 3	○ 4	○ 5	○ N/A

Page 5 - Question 9 - Rating Scale - Matrix [Mandatory]

Sixth - Cultural and Regulations Category

	label	label	label	label	label	N/A
Society and institution's culture	○ 1	○ 2	○ 3	○ 4	○ 5	○ N/A
Organizational constraints	○ 1	○ 2	○ 3	○ 4	○ 5	○ N/A
Regulation flexibility and constraints	○ 1	○ 2	○ 3	○ 4	○ 5	○ N/A
Political concerns	○ 1	○ 2	○ 3	○ 4	○ 5	○ N/A

Page 6 - Question 10 - Rating Scale - Matrix [Mandatory]

Base on your opinion, could you please score the importance of each category of affecting factors in regard to decision making for selecting the suitable project delivery methods and contracting strategies of construction projects

	not important 1	slightly important 2	median important 3	very important 4	critically important 5	N/A
Owner goals	❍	❍	❍	❍	❍	❍
Project features	❍	❍	❍	❍	❍	❍
Project objectives	❍	❍	❍	❍	❍	❍
Owner characteristics	❍	❍	❍	❍	❍	❍
Market condition	❍	❍	❍	❍	❍	❍
Culture and regulations	❍	❍	❍	❍	❍	❍

Page 6 - Question 11 - Rating Scale - One Answer (Horizontal)

Are you agreeing with the concept of categorizing the affecting factors in the previous categories?

Strongly Disagree	Disagree	Average	Agree	Strongly Agree
❍ 1	❍ 2	❍ 3	❍ 4	❍ 5

Page 6 - Question 12 - Open Ended - Comments Box

Any additional or formation for previous categories

Page 7 - Question 13 - Choice - One Answer (Bullets) [Mandatory]

Based on your opinion, do you think that there are any other factors affecting selection?

❍ Yes
❍ No
❍ If yes, could you please explain?

Page 7 - Question 14 - Choice - One Answer (Bullets)

Would you like to add any additional comments about the topic?

- Yes
- No
- If yes, could you please explain?

Page 8 - Question 15 - Name and Address (U.S)

Finally - The following section is about some of your personal information which will be used for the research purposes only, and your privacy will kept private (not revealed) all the time. Optional:

- Name
- Company
- Address 1
- Address 2
- City
- State
- Zip
- Job Title

Page 8 - Question 16 - Choice - Multiple Answers (Bullets) [Mandatory]

What is the nature of your company or institution?

- Main Contractor
- Sub-Contractor
- Consultant services
- Supplier
- Client
- Other, please specify

Page 8 - Question 17 - Choice - One Answer (Bullets) [Mandatory] [Up To 4 Answers]

What is the type of your company or institution?

- ❍ Public Sector
- ❍ Private Sector
- ❍ Quasi-Public
- ❍ Other, please specify

Page 8 - Question 18 - Choice - Multiple Answers (Bullets) [Mandatory]

What is the type of most your clients?

- ❑ Public Clients
- ❑ Private Clients
- ❑ Quasi-Public Clients
- ❑ Other, please specify

Page 8 - Question 19 - Choice - One Answer (Bullets) [Mandatory]

What is your highest education degree?

- ❍ Bachelor
- ❍ Master
- ❍ Doctor
- ❍ Other, please specify

Page 8 - Question 20 - Choice - Multiple Answers (Bullets) [Mandatory]

Do you have other non-degree certifications or qualifications?

- ❑ Fundamentals of Engineering (FE) written examination ,Engineering Intern (EI) , or Engineer-In-Training (EIT),
- ❑ Principles and Practice of Engineering exam, or Professional Engineer (PE)
- ❑ Other, please specify

Page 8 - Question 21 - Choice - One Answer (Bullets) [Mandatory]

How many years of experience that you have in the field of construction management?

- ❍ 1 -5 years
- ❍ 6 - 10 years
- ❍ 11 - 15 years
- ❍ 16 - 20 years
- ❍ 21 - 25 years
- ❍ 26 - 30 years
- ❍ more than 30 years
- ❍ Other, please specify

Page 8 - Question 22 - Choice - Multiple Answers (Bullets) [Mandatory]

What are your most familiar project types?

- ❑ Building constructions (residential)
- ❑ Building constructions (non-residential: commercial or institutional)
- ❑ Industrial constructions (manufacturing facilities, energy generation, ...)
- ❑ Transportation constructions (streets, highways, bridges, airports...)
- ❑ Utility construction (water supply, wastewater treatment, ...)
- ❑ Marine constructions (seaports...)
- ❑ Other, please specify

....

Page 8 - Question 23 - Choice - One Answer (Bullets)

Would you like to add any additional information or discussion?

- ❍ Yes
- ❍ No
- ❍ If yes, could you please explain?

Thank You Page

Survey Closed Page

Standard

APPENDIX B

SURVEY (II) QUESTIONNAIRE

Survey II - Construction Project Delivery Methods Evaluation

Introduction

The objective of this survey is to determine the relative performance of seven different project delivery methods with respect to: (1) owner goals, (2) project features, (3) and project objectives. In addition to investigate the relative suitability of utilizing each project delivery method with respect to: (4) owner's capability and attitude, (5) and Market consideration attributes. Based on your knowledge and experience in the field of building construction engineering, please complete the following survey. Your contribution is important and very much appreciated.

Project Delivery Method Nomenclature

According to the Construction Specifications Institute (CSI 2008), the construction project delivery can be conducted by adopting any one of the following procedures:

1. Design-Bid-Build (DBB)

In DBB; the project activities taking place in the following sequence: project conception, design, bidding and construction documents, competitive bidding, and finely the construction.

2. Design-Negotiate-Build (DNB)

DNB is in a close manner to the DBB, but the owner and the contractor negotiate a construction contract. The aim is to achieve mutual benefits to each party, and to avoid the risk. An owner can negotiate a project with several contractors and then select the preferred one.

3. Design-Build (DB)

In DB, the owner contracts with a single entity to provide all demanding design and construction services for the project.

4. Construction Management (CM)

There are two variations of CM:

a) *Construction manager as agent or adviser (CMa);* its role is to advise the owner on the management of the design and construction of the project, and may have the official permission to represent and act on behalf of the owner. The owner directly contracts with the A/E and either a single-prime contractor, or multiple-prime contractors.

b) *Construction manager as contractor (CMc);* the construction manager serves as a contractor, and bears the financial risk.

5. Owner-Build (OB)

In OB, the owner (usually some private companies that have expertise and qualified on-staff professionals may construct projects) does not employ another entity (contractor or construction manager) to provide construction services. The owner is involved in each and every aspect of construction contracting for the project. The construction contracts are accomplished directly between the owner and companies that are traditionally specialty subcontractors and material suppliers.

6. Integrated Project Delivery (IPD).

IPD was proposed by the AIA California Council and defined as:

"Integrated Project Delivery (IPD) is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction." [AIA, A Working Definition—Integrated Project Delivery, Version 2, June 2007]

Short name / Alias: Experience, Variable name: Y/N

The participants of this survey are supposed to have some experience in the field of building construction engineering or management.

Do you have experience in the field of building construction engineering or management (residential or Non-residential building construction)?*

○ Yes

○ No

Comments:

Page exit logic: Page Logic **IF:** Question "Do you have experience in the field of building construction engineering or management (residential or Non-residential building construction)?" is not exactly equal to ("Yes") **THEN:** Disqualify and display: "Thank you for your time; however, you are not the target audience for this survey."

First – Evaluation of the performance of each project delivery method with respect to the 12 attributes of the owner goals category.

Could you please evaluate the performance **(satisfaction)** of each project delivery method with respect to the following attributes (owner goals evaluation factors)?

Hint: the performance should be evaluated considering only one specific attribute each time regardless of the others (for example: when you consider "minimizing project cost attribute" do not look for the other attributes such as "controlling project cost" or "early project budget estimation". That means the evaluation of each project delivery method should be done according to the achievement of "lowest price" only.

Short name / Alias: Cost-related factors, Variable name: F.1.2.3.

1) Considering Cost-related factors:*

Note for the star ranting evaluation: (**no stars** = 0/10 = No performance (or satisfaction) at all, **five stars** = 5/10 = Average performance (or satisfaction), **ten stars** = 10/10 = Highest performance (or satisfaction) and so on ...

	With respect to how well it aids in minimizing project cost (lowest price)	With respect to how well it assists in controlling project cost (restraint cost growth)	With respect to how well it helps in early project budget estimation (early cost approximation to help planning and business decisions)
Design-Bid-Build	☐	☐	☐
Design-Negotiate-Build	☐	☐	☐
Design-Build	☐	☐	☐
Construction Manager as agent or adviser	☐	☐	☐
Construction Manager as contractor	☐	☐	☐
Owner-Build	☐	☐	☐
Integrated Project Delivery	☐	☐	☐

Comments:

Owner Goals Category

Short name / Alias: Time-related factors, Variable name: F.4.5.6.

2) Considering Time-related factors: *

	With respect to how well it aids in early project delivery (shortest period of time for completion)	With respect to how well it assists in project schedule control (restraint time growth)	With respect to how well it helps in early project procurement (encourages early design and material or equipment's acquisition)
Design-Bid-Build	□	□	□
Design-Negotiate-Build	□	□	□
Design-Build	□	□	□
Construction Manager as agent or adviser	□	□	□
Construction Manager as contractor	□	□	□
Owner-Build	□	□	□
Integrated Project Delivery	□	□	□

Comments:

Owner Goals Category

Short name / Alias: Quality-related factors, Variable name: F.7.8.9.

3) Considering Quality-related factors:*****

	With respect to how well it aids in achieving high quality of the project outcomes	With respect to how well it assists in controlling construction quality (during carrying out stage)	with respect to how well it helps in achieving high quality of operation and maintenance (O&M) after accomplishing
Design-Bid-Build	☐	☐	☐
Design-Negotiate-Build	☐	☐	☐
Design-Build	☐	☐	☐
Construction Manager as agent or adviser	☐	☐	☐
Construction Manager as contractor	☐	☐	☐
Owner-Build	☐	☐	☐
Integrated Project Delivery	☐	☐	☐

Comments:

Owner Goals Category

Short name / Alias: Risk-related factors, Variable name: F.10.11.12.

4) Considering Risk-related factors:*

	With respect to how well it aids in minimizing financial risk	With respect to how well it assists in minimizing schedule risk	With respect to how well it helps in minimizing quality risk
Design-Bid-Build	☐	☐	☐
Design-Negotiate-Build	☐	☐	☐
Design-Build	☐	☐	☐
Construction Manager as agent or adviser	☐	☐	☐
Construction Manager as contractor	☐	☐	☐
Owner-Build	☐	☐	☐
Integrated Project Delivery	☐	☐	☐

Comments:

Second – Evaluation of the suitability of each project delivery method with respect to the 11 attributes of the project feature category:

Could you please evaluate the **suitability** of each project delivery method with respect to the following attributes (project feature evaluation factors)?

Short name / Alias: Project subdivision type, Variable name: F.13.a.b.

5) Considering Project subdivision type (residential and non-residential building construction)*

	Suitability for residential building construction	Suitability for Non-residential building construction
Design-Bid-Build	☐	☐
Design-Negotiate-Build	☐	☐
Design-Build	☐	☐
Construction Manager as agent or adviser	☐	☐
Construction Manager as contractor	☐	☐
Owner-Build	☐	☐
Integrated Project Delivery	☐	☐

Comments:

Project feature Category

Short name / Alias: Project extent, complex, and unique, Variable name: F.14.15.16.

6) Considering Project features of (Extent, Complexity, and Uniqueness)*

	Suitability for large extent projects (the size or physical magnitude of the project is big)	Suitability for complex projects (the project have composite deign and/or several distinct scope of works)	Suitability for unique projects (the project has unique characteristics or technological advancement)
Design-Bid-Build	☐	☐	☐
Design-Negotiate-Build	☐	☐	☐
Design-Build	☐	☐	☐
Construction Manager as agent or adviser	☐	☐	☐
Construction Manager as contractor	☐	☐	☐
Owner-Build	☐	☐	☐
Integrated Project Delivery	☐	☐	☐

Comments:

Project feature Category

Short name / Alias: Project workplace, Variable name: F.17.18.

7) Considering Project features of (Workplace location and Workplace circumstances)*

	Suitability for far location projects (workplace is far from the required resources for construction activities)	Suitability for confined project's workplace (not free to move about condition, so difficult for managing the construction activities and supplies)
Design-Bid-Build	☐	☐
Design-Negotiate-Build	☐	☐
Design-Build	☐	☐
Construction Manager as agent or adviser	☐	☐
Construction Manager as contractor	☐	☐
Owner-Build	☐	☐
Integrated Project Delivery	☐	☐

Comments:

Project feature Category

Short name / Alias: Design completion/changes, Variable name: F.19.20.

8) Considering Project features of (Design completion stage and Possibility for changes)*

	Suitability for design completion stage projects (when design of drawings before construction commences is completed)	Suitability for project changes (high possibility for changes in the project's designs, specifications, or scope of work)
Design-Bid-Build	☐	☐
Design-Negotiate-Build	☐	☐
Design-Build	☐	☐
Construction Manager as agent or adviser	☐	☐
Construction Manager as contractor	☐	☐
Owner-Build	☐	☐
Integrated Project Delivery	☐	☐

Comments:

Project feature Category

Short name / Alias: Risk / Sustainability, Variable name: F.21.22.

9) Considering Project features of (degree of risk of scope of work and sustainability involves)*

	Suitability for projects with uncertainty (high degree of uncertainty of project's scope of work and/or outcome)	Suitability for sustainability involvement (needs to incorporate green or sustainable features)
Design-Bid-Build	☐	☐
Design-Negotiate-Build	☐	☐
Design-Build	☐	☐
Construction Manager as agent or adviser	☐	☐
Construction Manager as contractor	☐	☐
Owner-Build	☐	☐
Integrated Project Delivery	☐	☐

Comments:

Third – Evaluation of the performance of each project delivery method with respect to the 6 attributes of the project objectives category.

Could you please evaluate the performance **(satisfaction)** of each project delivery method with respect to the following attributes (project objectives evaluation factors)?

Short name / Alias: life cycle/pre-construction/team relation, Variable name: F.23.25.

10) Considering project objectives of (project life cycle, pre-construction services, and project team relation)*

	With respect to how well it aids in considering project life cycle (planning, execution, closing, operation and maintenance, destruction)	With respect to how well it aids in pre-construction services (value engineering, constructability, cost reduction	With respect to how well it aids in project team relation (collaboration, coordination, integration, min. disputes)
Design-Bid-Build	☐	☐	☐
Design-Negotiate-Build	☐	☐	☐
Design-Build	☐	☐	☐
Construction Manager as agent or adviser	☐	☐	☐
Construction Manager as contractor	☐	☐	☐
Owner-Build	☐	☐	☐
Integrated Project Delivery	☐	☐	☐

Comments:

Project objectives Category

Short name / Alias: Safety/security/satisfaction, Variable name: F.26.28.

11) Considering project objectives of (safety, security, and stakeholders' satisfaction)*

	With respect to how well it aids in safety (people and/or properties safety)	With respect to how well it aids in security (protect secret project's documents/information/technological development).	With respect to how well it aids in stakeholders' satisfaction
Design-Bid-Build	☐	☐	☐
Design-Negotiate-Build	☐	☐	☐
Design-Build	☐	☐	☐
Construction Manager as agent or adviser	☐	☐	☐
Construction Manager as contractor	☐	☐	☐
Owner-Build	☐	☐	☐
Integrated Project Delivery	☐	☐	☐

Comments:

Fourth – Evaluation of the suitability of each project delivery method with respect to the 5 attributes of the Owner's capability and attitude Category:

Could you please evaluate the suitability of each project delivery method with respect to the following attributes (Owner's capability and attitude evaluation factors)?

Short name / Alias: Experience/Resources, Variable name: F.29.30.

12) Considering project Owner's capability (experience, and availability of resources)*

	Suitability for the project owner who is highly experienced in project delivery and contract strategy	Suitability for the project owner who has available resources (existing of enough funding at ahead of project time)
Design-Bid-Build	☐	☐
Design-Negotiate-Build	☐	☐
Design-Build	☐	☐
Construction Manager as agent or adviser	☐	☐
Construction Manager as contractor	☐	☐
Owner-Build	☐	☐
Integrated Project Delivery	☐	☐

Comments:

Owner’s capability and attitude Category

Short name / Alias: participation/risk/contracting, Variable name: F.31.33.

13) Considering project Owner’s attitude (participation, risk avoidance, and numbers of contracting parties)*

	Suitability for high degree of participation of the project’s owner (to direct the project)	Suitability for project’s owner risk avoidance (project’s owner has negative attitude towards risk taking)	Suitability for few numbers of contracting parties (the project’s owner looks for single or few parties of responsibility)
Design-Bid-Build	☐	☐	☐
Design-Negotiate-Build	☐	☐	☐
Design-Build	☐	☐	☐
Construction Manager as agent or adviser	☐	☐	☐
Construction Manager as contractor	☐	☐	☐
Owner-Build	☐	☐	☐
Integrated Project Delivery	☐	☐	☐

Comments:

Fifth – Evaluation of the suitability of each project delivery method with respect to the 3 attributes of the Market consideration Category:

Could you please evaluate the suitability of each project delivery method with respect to the following attributes (Market evaluation factors)?

Short name / Alias: Market, Variable name: F.34.36.

14) Considering Market evaluation factors*

	Suitability when there is availability of demanded service (contractor or company for perform project works	Suitability when there is accessibility of commodity (availability of articles of commerce)	Suitability when the economic status of the market is good (inflation, interest rate, and other economic indexes)
Design-Bid-Build	☐	☐	☐
Design-Negotiate-Build	☐	☐	☐
Design-Build	☐	☐	☐
Construction Manager as agent or adviser	☐	☐	☐
Construction Manager as contractor	☐	☐	☐
Owner-Build	☐	☐	☐
Integrated Project Delivery	☐	☐	☐

Comments:

Sixth – Evaluation of Attributes' Categories:

Short name / Alias: Categories, Variable name: C.

15) Could you please score the relative importance of each affecting factors category with respect to how much it should be considered for the decision making of selecting the suitable project delivery methods of building construction?*

Owner Goals Category	0	________________________[__]____________________________	100
Project features Category	0	________________________[__]____________________________	100
Project objectives Category	0	________________________[__]____________________________	100
Owner's capability and attitude Category	0	________________________[__]____________________________	100
Market consideration Category	0	________________________[__]____________________________	100

Comments:

Short name / Alias: Additional Comments -1, Variable name: AC1.

16) The main part of this survey is completed. Would you like to add any additional comments about the topic so far? Your personal opinions will be valuable and will be given careful consideration.

Personal Information

The following section is designed to collect some of your personal information which will be used for some statistical analysis for the research purposes only, and will be kept private (not revealed).

Short name / Alias: Contact information, Variable name: CI.

17) Please provide us your contact information (all textboxes are optional – you can skip anyone except the State name which is required please)

First Name:

Last Name:

Title:

Company Name:

Street Address:

Apt/Suite/Office:

City:

State*:

Zip:

Email Address:

Phone Number:

Company or Institution Nature

Short name / Alias: Institution Nature, Variable name: IN.

18) What is the nature of your company or institution?*

- Owner, Owner representative, or Client
- Main Contractor or Sub-Contractor
- Architecture or Engineering
- Consultant services, Specifications Consultant, or Government agency
- Construction, Program, or Project Management
- More than one, please specify …: ____________ *
- Others please specify …: ____________ *

Company or Institution Type

Short name / Alias: Institution type , Variable name: IT.

19) What is the type of your company or institution?*

- Public Sector
- Private Sector
- Quasi-Public (Public & Private)
- Other, please specify…: ____________ *

Clients Type

Short name / Alias: Clients type, Variable name: CT.

20) What is the type of the most of your clients?*

- Public Clients
- Private Clients
- Quasi-Public (Public & Private) Clients
- Others please specify…: ______ *
- Not Applicable | NA | na

Education Degree

Short name / Alias: Education degree, Variable name: ED.

21) What is your highest education degree?*

- High School/Trade School
- Some College
- Certifications and Diplomas
- Associates Degree
- Bachelor's Degree
- Bachelor of Professional Degree
- Master's Degree
- Doctorate Degree
- Others, please specify…: ______ *

Certificates or Credentials

Short name / Alias: Certificate/ Credential, Variable name: CC.

22) Do you have any non-degree certificate or credential?

- ☐ Fundamentals of Engineering (FE) Exam, (EI), or (EIT)
- ☐ Professional Engineer (PE)
- ☐ Registered, Licensed Architect, or AIA member
- ☐ Any of CSI's Certificates: CDT, CCS, CCCA, and CCPR
- ☐ Any of DBIA's Certificates: Associate DBIA, Professional DBIA
- ☐ Any of PMP's Certificates: CAPM, PMP, PgMP, PMI-ACP, PMI-RMP, or PMI-SP
- ☐ Any of CMAA's Certificates: CCM
- ☐ Any of AIC's Certificates: AC, or CPC
- ☐ Any of USGBC's Certificates: LEED …
- ☐ Others, please specify…: ________ *
- ☐ Non

Practical Experience

Short name / Alias: Experience, Variable name: Ex.

23) How many years of experience you have in the field of building construction?*

- Non
- 1 -5 years
- 6 -10 years
- 11 -15 years
- 16 -20 years
- 21 -25 years
- 26 -30 years
- More than 30 years
- Others, please specify…: ______ *

Familiarity with Different Project Types

Short name / Alias: project types familiarity, Variable name: PTF.

24) What is your familiarity with the following project types?

	Not familiar at all	Slight familiarity	Moderate familiarity	Good familiarity	Extreme familiarity
Building constructions (residential)	○	○	○	○	○
Building constructions (non-residential: commercial or institutional)	○	○	○	○	○
Industrial constructions (manufacturing facilities, energy generation ...)	○	○	○	○	○
Transportation constructions (streets, highways, bridges, airports...)	○	○	○	○	○
Utility construction (water supply, wastewater treatment ...)	○	○	○	○	○
Marine constructions (seaports...)	○	○	○	○	○

Comments:

Familiarity with Different Project Delivery Methods

Short name / Alias: Project delivery methods familiarity, Variable name: PDF.

25) What is your familiarity with the following project delivery methods?

	Not familiar at all	Slight familiarity	Moderate familiarity	Good familiarity	Extreme familiarity
Design-Bid-Build (DBB)	○	○	○	○	○
Design-Negotiate-Build (DNB)	○	○	○	○	○
Design-Build (DB)	○	○	○	○	○
Owner-Build (OB)	○	○	○	○	○
Construction Management as agent or adviser (CMa)	○	○	○	○	○
Construction Management as contractor (CMc)	○	○	○	○	○
Integrated Project Delivery (IPD)	○	○	○	○	○

Comments:

Additional Comments

Short name / Alias: Additional Comments -2, Variable name: AD2.

26) This survey is completed. Would you like to add any additional comments?

Thank You!

Thank you for taking our survey. Your response is very important to us. Thanks for your time.

Best regards

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