

AUS Repository

Decision Support Model for Selecting the Project Delivery Method for Sustainable Construction Projects

Item Type	Dissertation
Authors	Ahmed, Salma Nasser Korany Megahed
Download date	2026-03-16 06:02:24
Link to Item	http://hdl.handle.net/11073/25402

DECISION SUPPORT MODEL FOR SELECTING THE PROJECT DELIVERY
METHOD FOR SUSTAINABLE CONSTRUCTION PROJECTS

by

Salma Nasser Korany Megahed Ahmed

A Dissertation presented to the Faculty of the
American University of Sharjah
College of Engineering
In Partial Fulfilment
of the Requirements
for the Degree of

PhD in
Engineering Systems Management

Sharjah, United Arab Emirates

(March 2023)

Declaration of Authorship

I declare that this dissertation is my own work and, to the best of my knowledge and belief, it does not contain material published or written by a third party, except where permission has been obtained and/or appropriately cited through full and accurate referencing.

Signed.....Salma Nasser Korany Megahed Ahmed.....

Date.....28/03/2023.....

The Author controls copyright for this report.

Material should not be reused without the consent of the author. Due acknowledgement should be made where appropriate.

© Year 2023

Salma Nasser Korany Megahed Ahmed

ALL RIGHTS RESERVED

Approvals

We, the undersigned, approve the PhD Dissertation written by: Salma Nasser Korany
Megahed Ahmed

Dissertation Title: Decision Support Model for Selecting the Project Delivery Method
for Sustainable Construction Projects

Date of Defense: 15/03/2023

Name, Title and Affiliation

Dr. Sameh El-Sayegh
Professor
Department of Civil Engineering
Dissertation Advisor

Dr. Vian Ahmed
Professor
Department of Industrial Engineering
Dissertation Committee Member

Dr. Salwa Beheiry
Professor
Department of Civil Engineering
Dissertation Committee Member

Dr. Ghassan Abu-Lebdeh
Professor
Department of Civil Engineering
Dissertation Examiner

Dr. Ghaleb Sweis
Professor
Department of Civil Engineering
Dissertation Examiner

Accepted by:
Dr. Mohamed El-Tarhuni
Vice Provost for Research and Graduate Studies
Office of Research and Graduate Studies

Acknowledgements

First of all, I would like to thank Allah Almighty for blessing me with this milestone of my life.

Special thanks to my sole advisor and mentor Dr. Sameh El-Sayegh, to whom I am utterly grateful for his continuous support and assistance throughout this dissertation. His powerful knowledge of construction management paved the path for me to successfully complete this research. Not to mention, his inclusive scope and pioneering vision which helped develop innovative tools to enhance the delivery of sustainable construction projects. I truly appreciate the graduate teaching assistantship provided to me by the American University of Sharjah to be able to fulfil my PhD degree.

I genuinely appreciate the support from my family. My parents, Ms. Maha Mahmoud and Mr. Nasser Megahed, whose prayers blessed me and nurtured my whole being. My husband and support system, Eng. Mohamed Hassan, thanks for always being by my side and helping me succeed in every possible way. Finally, my sisters and best friends, Mai and Menna, thanks for pushing me to be the best version of myself always.

Dedication

To my beloved mother,

Without whom I wouldn't make it up to here

Abstract

As the demand for sustainable construction increases, the need to update project management practices in order to satisfy the objectives of sustainability becomes more significant. Project delivery method is a crucial decision in project management that impacts the success of construction projects. The extensive literature review conducted identified several gaps such as the lack of a comprehensive criteria list to select project delivery methods in sustainable construction projects and a lack of selection model that comprises that comprehensive criteria list. This research bridges the gaps in literature by developing a comprehensive decision support model that will provide decision-makers with a justified rationale for choosing the most appropriate delivery method for their sustainable construction projects. In order to achieve this, the underlying challenges of sustainable construction delivery were first categorized using factor analysed. These were then used to derive relevant sustainability -specific criteria which consisted of five groups: level of integration, green liability, green team, green criteria, and technology and innovation. Structural Equation Modelling was then used to predict the significance of these sustainability-specific selection criteria to the achievement of project success criteria such as efficiency, impact on client, team effectiveness and sustainability. Moreover, Analytical Hierarchy Process was used to calculate the relative weights of the traditional and sustainability-specific criteria as well as the effectiveness values of the three most common delivery methods in achieving the comprehensive criteria. The outputs of all these statistical procedures were then used to develop two decision support models that incorporate a comprehensive selection criteria list of both traditional and sustainability-specific criteria and the three most common delivery methods. Moreover, a customizable prototype software of the decision model was developed where the unfamiliar operations required in the adopted technique would be transparent to the end-users. A case-study that was administered in the end clearly indicates that DBB is outmatched by the unique requirements of sustainable construction. While, CMR and DB are both potentially competitive candidates that can enhance the success rate of sustainable construction projects.

Keywords: Project Delivery Methods, Sustainable Construction, Selection Criteria, Decision Support Models

Table of Contents

Abstract	6
List of Figures	10
List of Tables	12
Chapter 1. Introduction	14
1.1. Introduction	14
1.2. Overview	14
1.3. Problem Statement	16
1.4. Aim and Objectives	17
1.5. Research Questions	18
1.6. Research Significance	19
1.7. Content of the Dissertation	19
Chapter 2. Background and Literature Review	21
2.1. Project Delivery Methods	21
2.2. Selection Criteria for Project Delivery Methods	25
2.3. Selection Methods of Project Delivery Methods	27
2.4. Research Gaps	30
Chapter 3. Methodology	32
3.1. Research Philosophy and Approach	32
3.2. Research Strategy	33
3.3. Methods	34
3.4. Time Horizons	41
3.5. Data Collection Techniques	41
3.6. Sampling Techniques	42
3.7. Data Analysis Techniques	43
3.8. Ethics	44
3.9. Validity and Reliability	44
Chapter 4. Challenges and Selection Criteria of Sustainable Construction Projects Delivery	46
4.1. Challenges of Sustainable Construction	46

4.2.	Factor Analysis Results	49
4.3.	Discussions of Factor Analysis Results	53
4.3.1.	Financial Challenges	53
4.3.2.	Sustainable Materials and Technology	53
4.3.3.	Contractual	54
4.3.4.	Design	54
4.3.5.	Lack of Experience	55
4.3.6.	Regulations	55
4.3.7.	Limited Organizational Awareness	56
4.4.	Selection Criteria	56
4.4.1.	Traditional Selection Criteria	56
4.4.2.	Sustainability-Specific Selection Criteria	59
4.5.	Project Success Criteria	63
4.6.	Theoretical Framework	65
4.7.	PLS-SEM Final Results	69
4.7.1.	Traditional Selection Criteria Structural Model	69
4.7.2.	Sustainability-Specific Selection Criteria Structural Model	72
4.8.	Discussions of the PLS-SEM Results	75
4.9.	Summary and Conclusions	77
Chapter 5.	Assessment of Criteria Weights and Effectiveness of Project Delivery	
Methods		80
5.1.	Identified Selection Criteria	80
5.2.	Assessment of Selection Criteria Weights	82
5.3.	Discussions of Selection Criteria Weights	87
5.4.	Effectiveness of Project Delivery Methods	89
5.4.1.	PDM Effectiveness- Traditional Selection Criteria	92
5.4.2.	PDM Effectiveness- Sustainability-Specific Selection Criteria	95
5.5.	Summary and Conclusions	98
Chapter 6.	Decision Support Models	100
6.1.	Model A	100
6.2.	Model B	102
6.3.	Case Study- Model A	103

6.4.	Sensitivity and Scenario Analysis	107
6.5.	Conclusions	110
Chapter 7.	Summary and Conclusions	111
7.1.	Summary	111
7.2.	Conclusions	112
7.3.	Future Recommendations	114
References		116
Appendix A		137
	<i>Survey 1</i>	137
	<i>Survey 2</i>	141
	<i>Survey 3</i>	152
	<i>Survey 4</i>	159
Vita		170

List of Figures

Figure 1. Research Strategy	33
Figure 2. Sample of Pairwise Comparisons	36
Figure 3. Research Methodology Mapping	44
Figure 4. Final Path Diagram of the seven challenges clusters	52
Figure 5. Green Guarantee Model	61
Figure 6. Traditional Selection Criteria Theoretical Framework	67
Figure 7. Sustainability-Specific Selection Criteria Theoretical Framework	68
Figure 8. Traditional and Sustainability-Specific Selection Criteria	81
Figure 9. Cost-Related Criteria	93
Figure 10. Time-Related Criteria	94
Figure 11. Scope-Related Criteria	94
Figure 12. Owner and Contractor's Characteristics	94
Figure 13. Project's Characteristics Criteria	95
Figure 14. Level of Integration Criteria	96
Figure 15. Green Liability Criteria	97
Figure 16. Green Team Criteria	97
Figure 17. Green Contract Criteria	97
Figure 18. Technology & Innovation Criteria	98
Figure 19. Model A	101
Figure 20. Model B	103
Figure 21. Graphical User Interface Form	105
Figure 22. Screenshot of Case Study Model A on Excel Software	106
Figure 23. Tornado Graph for CMR Aggregate Scores	107
Figure 24. Tornado Graph for DB Aggregate Scores	108

Figure 25. Percentage Change in DB and CMR Aggregate Scores.....108

List of Tables

Table 1. Overview of Selection Criteria	26
Table 2. Overview of Selection Methods	30
Table 3. AHP Saaty Scale [125]	37
Table 4. Respondent's Profile for the Four Surveys	38
Table 5. Research Questions and Objectives with Data Collection Methods.....	41
Table 6. Challenges of Sustainable Construction Projects Delivery	48
Table 7. KMO, Bartlett's test of sphericity and Cronbach's alpha.....	50
Table 8. Communalities of the thirty-three challenges	51
Table 9. Traditional Selection Criteria Groups and Tags	58
Table 10. Sustainability-Specific Criteria.....	62
Table 11. Project Success Criteria	64
Table 12. CR, AVE and Cronbach's alpha of Traditional Selection Criteria Latent Variables	70
Table 13. Factor Loadings	70
Table 14. Path Values	71
Table 15. AVE, CR and Cronbach's alpha of Sustainability-Specific Selection Criteria Latent Variables	72
Table 16. Factor Loadings	73
Table 17. Path Values	74
Table 18. Traditional Selection Criteria Local and Global Weights	83
Table 19. Sustainability-Specific Selection Criteria Local and Global Weights.....	84
Table 20. Calculation of Normalized Traditional Criteria Groups Weights.....	85
Table 21. Calculation of Normalized Sustainability-Specific Criteria Groups Weights	86
Table 22. Top 10 Selection Criteria.....	86

Table 23. Effectiveness of Project Delivery Methods	90
Table 24. The Ten Selected Criteria with Their Normalized Weights	104
Table 25. Scenario Analysis	109

Chapter 1. Introduction

1.1. Introduction

This chapter presents a brief background on sustainable construction, its significance and the challenges that it encounters as well as the different rating systems available in practice. This chapter also introduces aspects of one of the main project management decisions that impact the success of sustainable construction; the selection of project delivery method. Problem statement, research significance, aim and objectives of this dissertation are also presented in this chapter. Finally, general organization of the thesis is presented.

1.2. Overview

Sustainable construction is a topic that has been gaining a lot of attention over the past years. Looking back at the 1970's, the earliest definition of sustainability was developed, it only focused on the environmental aspect [1]. As time passed, this definition has evolved and the notion of sustainability in the construction sector has become widely defined as striking a balance between the three pillars; economic, environmental and social into construction business practices and strategies to promote social involvement, motivate economic growth and reduce environmental impacts [2]. This definition will be adopted in this research as the mindset of the authors matches the focus of the report. In fact, each one of these three pillars have their own unique set of indicators. For instance, the indicators related to the economical pillar include but not limited to financial risks, lifecycle costs and benefits as well as the budget of the project [3]. While for the environmental pillar, the indicators include air and water pollution, energy consumption, ecological system disruption and land use [4]. Whereas, for the social pillar, the indicators include the availability of employment opportunities, professional code of ethics, and perseverance of cultural heritage [5].

This shift towards sustainable construction has been motivated by the fact that the construction industry consumes natural resources in tremendous amounts and produces a significant quantity of construction demolition waste [6]. For instance, Hao et al. [7] claims that in China the construction demolition waste has reached an estimate of 1.55 to 2.4 billion tons. Alarming percentages in natural resources and energy consumption as well as carbon dioxide emissions were also found in the United States, which are as

big as 40% [8]. Moreover, some of the highest carbon dioxide emissions per capita have been witnessed in the Gulf Corporation Council (GCC) countries due to extensive construction activities, where in the UAE for example 75% of the waste produced emerges solely from construction activities [9]. Aside from the environmental benefits of sustainable construction, it also has a positive effect of the health and wellbeing of people as studies have revealed that the materials used in sustainable building construction are healthier and cleaner for the occupants. Moreover, the productivity of occupants has shown to be around 11% higher in sustainable buildings with thermal control devices than in traditional buildings [10]. Furthermore, sustainable construction also helps combat economic issues such as the increase in energy prices and the costs of the traditional building materials [11].

The current leaders in environmental rating system are BREEAM in the UK and LEED developed in the US that awards points to residential and commercial construction developments in order to achieve one of the four certification levels: Certified, Silver, Gold and Platinum [12]. Similarly, other countries around the world have been developing their own sustainable initiatives. Among which is the UAE, where Estidama's Pearl System has been launched in Abu Dhabi in order to localize the definition of sustainability and set some local sustainable development criteria to complement the cultural, climatic and financial circumstances of the region [13]. Other initiatives in the country include the Masdar Institute in Abu Dhabi which is a technology cluster powered by renewable energy as well as the sustainable building initiative introduced by Dubai Municipality in 2014 to enforce sustainable construction on all buildings [14].

Nevertheless, sustainable construction faces a lot of complicated challenges that are different from the ones encountered in traditional construction. For instance, the higher upfront cost due to sustainable products, the gap between policy formulation and actual project delivery as well as lack of legislation to impose the adoption of sustainable procurement are some of the challenges that hinder the implementation of sustainable construction [15]. Moreover, lack of awareness, resistance to change and the absence of government support are also other significant barriers [16, 17]. Furthermore, Lam et al. [18] also highlighted a critical barrier by focusing on the limited availability of competent suppliers. Not only this but, Djokoto et al. [19] also stated that the key

barriers to sustainable construction include the lack of demand and lack of strategy to promote sustainable construction. Additionally, the delays and longer time during preconstruction phase as well as the difficulty of selecting experience and skilled contractors and subcontractors are other barriers that hinder the progress of sustainable construction [20].

In light of the aforementioned challenges, stakeholders are required to modify their project management practices to match the requirements of sustainable construction [11]. Among the crucial decisions that affect the success of construction projects is the choice of project delivery method as it has a direct effect on key performance indicators such as cost, schedule and quality [21]. Delivery method is defined as “The assignment of responsibilities to the different parties involved in a project in order to establish a framework of the entire design, procurement and construction process.”[22]. In fact, there are several delivery methods available in practice. Such as the traditional design bid build (DBB) where the owner issues separate contracts for the consultant in the design phase and for the contractor during project execution [23]. Moreover, other alternative methods include design build (DB) and construction manager at risk (CMR) where DB represents a single entity that hires both contractor and consultant under one contract [24]. While CMR recruits a construction manager during the design phase to act as both a project coordinator and general contractor [25]. Furthermore, other delivery methods that have emerged recently are collaborative delivery methods such as integrated project delivery, alliancing and partnering that have been developed based on features that emphasize collaboration, trust and commitment [26].

A closer look into literature has shown that it is very rich in providing guidelines and decision support models to select the appropriate delivery methods in traditional construction industry. However, research in the field of project delivery selection in sustainable construction falls short which creates a gap that needs to be bridged. Therefore, the aim of this research study is to construct a decision support model that will assist project managers in choosing the optimum delivery method for sustainable construction projects.

1.3. Problem Statement

Currently, the shift towards sustainable construction is gaining momentum as part of the national response with regards to the global concern of natural resource depletion

and the pollution generated from the tremendous amount of construction demolition waste produced during construction activities. Nevertheless, sustainable construction brings along with it complicated challenges that are different from the ones encountered in traditional construction and makes them vulnerable to obstacles that might impede the fulfilment of the project's target objectives. Indeed, sustainable construction also has an interactive multidisciplinary nature with integrated technology. In light of this, project managers are required to modify their project management practices in order to match the needs of sustainable construction. In fact, among the crucial decisions in project management that affect the outcomes and success of any construction project is the choice of the project delivery method. An unsuitable project delivery method can result in problems that jeopardize the overall success rate of sustainable construction projects such as cost over runs, delays and poor schedule performance.

However, a closer look into literature has revealed that there is a gap in providing guidelines and decision support models for selecting the most appropriate delivery method for sustainable construction projects. In fact, available literature only focuses on traditional selection criteria of project delivery methods. These criteria, while important, may not address the challenges associated with sustainable construction projects delivery and their relative weights might also be different in sustainable construction projects as compared to their traditional counterparts. Therefore, it follows from the above discussion that there is a need to first develop sustainability-specific criteria that are relevant to overcome the challenges faced in the delivery of sustainable construction projects. Re-assessment of the relative weights of the traditional criteria with respect to the comprehensive criteria list is also crucial as well as the evaluation of the effectiveness of the most common delivery methods such as DBB, DB and CMR in achieving those sustainability-specific and traditional criteria. Lastly, a decision support model needs to be constructed that will assist project managers in the decision-making process of choosing the most appropriate delivery method to successfully accomplish sustainable construction projects.

1.4. Aim and Objectives

This research aims to develop a decision support model to assist decision makers in selecting the appropriate delivery method for sustainable construction projects. In order to achieve this aim, the following detailed objectives have to be met:

- Identify the criteria required to overcome the challenges faced in the delivery of sustainable construction projects. The challenges encountered in sustainable construction projects delivery are different from traditional ones and determining them is essential to develop the criteria required to improve the success rate of sustainable construction projects delivery.
- Determine the relationship between the identified criteria for the selection of project delivery methods and the success of sustainable construction projects. The significance of each criterion developed in objective 1 with regards to the success of sustainable construction project delivery will be tested.
- Evaluate the effectiveness of project delivery methods in achieving the traditional and the sustainability-specific criteria set. The traditional criteria such as risks, cost, quality, safety, schedule and cost growth will be integrated with the new criteria from objective 1 and 2 to examine the relationship between the most common project delivery methods and their ability to achieve the comprehensive selection criteria list. This will help in the decision-making process of selecting the optimum delivery method for sustainable construction projects.
- Develop a decision support model to assist clients in selecting the appropriate project delivery based on the traditional criteria and sustainability-specific criteria. The model will be a comprehensive approach combining the results of objective 1 to 3 to optimize between traditional and sustainability-specific criteria. The model will provide aggregate scores for each delivery method which is a function of the weight and the pre-determined effectiveness values and will be the basis to choose the most optimum project delivery method.
- Develop a prototype customizable tool that assists clients in using the developed model. The prototype will be used to simulate the characteristics of the decision support model developed in objective 4. It will also provide the decision makers with a defensible rationale for project delivery method selection.

1.5. Research Questions

This dissertation will focus on answering four consolidated research questions as follows:

1. What are the challenges and selection criteria associated with the delivery of sustainable construction projects?
2. What is the relationship between the sustainability-specific criteria and the success of sustainable construction projects?
3. What are the most common types of project delivery methods and their effectiveness in relation to sustainable construction project performance?
4. What is the most appropriate project delivery method in relation to the identified comprehensive list of selection criteria?

1.6. Research Significance

This research is significant for owners and decision makers in the construction industry. By employing the outputs of this dissertation, a decision support model will be presented to assist decision makers in selecting the appropriate delivery method for sustainable construction projects. Case study will also be presented at the end to demonstrate the applicability of the model. Not only this but, this model will also expand the set project delivery methods selection criteria that are available to owners in the decision- making process. Moreover, this model will also provide a more reliable technique to select the appropriate delivery method instead of relying on informal assessments, incomprehensive list of selection criteria and owner's preferences. Furthermore, the decision support model provides a defensible rationale for owners to justify their project delivery method selection. Additionally, if deemed feasible, the outcomes of this research can improve the success rate of sustainable construction projects which will encourage contractors to pursue sustainability practices and bid for more sustainable projects in their portfolio. Accordingly, this will also be beneficial to the society as a whole since more projects that support sustainable development will be promoted.

1.7. Content of the Dissertation

The proposed dissertation includes 7 chapters. A summary of each chapter is summarized below:

Chapter 1- Introduction

This chapter describes a background of the topic, problem statement, aims and objectives as well as the research significance.

Chapter 2- Literature Review

This chapter describes the literature related to the background relevant to this research. It explains the several project delivery methods available in practice and then it turns the discussion and focuses on the selection criteria that are used to choose the project delivery methods. Moreover, this chapter will also study the different techniques of project delivery methods selection.

Chapter 3- Research Methodology

This chapter describes the research methodology, it presents the philosophical stance as well as the research approach and strategy. It also describes the proposed data collection and analysis techniques.

Chapter 4- Challenges and Selection Criteria of Sustainable Construction Projects Delivery

This chapter describes the most cited challenges in sustainable construction projects and their categorization into different groups. Moreover, the chapter presents the selection criteria required to overcome these challenges and tests their significance with regards to the success of sustainable construction projects.

Chapter 5- Effectiveness of Project Delivery Methods and Weights of Selection Criteria

This chapter illustrates the effectiveness of the most common project delivery methods with regards to a comprehensive list of selection criteria. Furthermore, the chapter also reports the relative importance and the weights of the traditional and sustainability-specific criteria in order to establish priority amongst the criteria for clients of sustainable construction projects.

Chapter 6- Decision Support Models

This chapter presents the final outcome of this dissertation which is the decision support models that the user can use in order to select the most appropriate delivery method for sustainable construction projects.

Chapter 7- Summary and Conclusions

This Chapter shows summary, conclusion and recommendations deduced from the dissertation.

Chapter 2. Background and Literature Review

This chapter aims to develop an understanding of the different project delivery methods available in practice and the evolution that happened over the years to go from traditional project delivery methods towards collaboratives ones. This chapter also provides an overview of the traditional selection criteria of project delivery methods and highlights the lack of literature base on critical factors needed for non-traditional sustainable construction projects. Furthermore, the chapter also sheds the light on the selection methods of project delivery methods that are currently used and emphasizes the gaps that need to be addressed to be able to develop a decision support model to appropriately select the delivery method that will enhance the success rate of sustainable construction projects.

It is worth mentioning that the sections (2.1, 2.2 and 2.3) below are extracted from the article “Critical Review of the Evolution of Project Delivery Methods in the Construction Industry” by Salma Ahmed and Sameh El-Sayegh [27].

2.1. Project Delivery Methods

Selecting the appropriate project delivery method is one of the most important managerial decisions as it has a direct impact on the success of the project since it affects key performance indicators such as cost, quality, schedule and safety. Indeed, project delivery methods have evolved over the years and there have been many variations and alternatives introduced in the construction industry to meet various consumer demands.

To begin with, up until 1990, the traditional delivery system, design-bid-build (DBB) was considered the dominant method. Where professionals were endorsing and standardizing its features throughout almost all construction projects [28]. DBB, also known as the conventional method which follows a linear fragmented approach to go over the different design, bid and build phases of the construction project. The owner issues two separate contracts, one with the consultant for the design phase and the second contract is with a construction professional for the execution of the project. Usually, the architect develops completed plans and specifications that are tailored to the owner’s requirements for the construction of the project. The owner then uses these documents as the foundation to initiate bidding and eventually issue a separate contract

with the contractor. This disconnection however, has led to numerous procurement steps and a prolonged nature of design and construction as well as adversarial relationships between the key project players that have resulted in several disputes and an increase in the number of claims and change orders which ultimately lead to cost and time overruns [29]. In fact, this delivery method is usually associated with the single fixed price or the lump sum contract strategy. Where the contractor performs a specified work load for a specific amount of money. Such a contract removes the risk of any changes to the final cost for the owner [30].

As the demand for heavy engineering projects increased, it became difficult to precisely quantify the required work, making the lump sum contract incapable of achieving project's objective. Therefore, unit price contract strategy was developed, where the owner divides the work into bid items with an estimated quantity of work for each item. After that, the contractor bids the direct cost of each item and has to account for overhead, profit and other project expenses [31]. Moreover, as the 20th century progressed, and with the increase in the complexity of buildings, the need for more coordination between stakeholders emerged which urged the need for alternative delivery systems. This is when design build (DB) started gaining popularity in the construction industry. Where the project delivery culture was significantly transformed as the project owner's contracts for both design and construction from a single entity called DB. Indeed, the shift was challenging and owners were reluctant in the beginning as they feared that they would no longer have contractual advocacy and the quality of construction projects would be compromised [32]. However, as the process evolved, these fears vanished as DB has proved to provide benefits such as collaborative construction effort since the designer and contractor work as one entity. As distinct from DBB, the owner has minimal control and influence over the project in DB and it also eliminates the tension in the relationship between the parties Moreover, DB also allows fast track alternative where some portion of construction can be started while design is still ongoing, therefore, this can result in cost and time savings, reduction in work variations, better progress monitoring records and greater allocation of risks to contractors [33].

Over the years there have been other variations to design build including bridging, novation DB, package deals, direct DB, develop and construct, turnkey method and

build operate transfer. Each one of these variations are designed to meet diverse scenarios of construction settings [34, 35]. Another delivery system that emerged around the same time as DB was construction management (CM), where the owner hires both a design firm and a construction project firm early in the pre-construction phase of the project. The construction manager would then advise the owner in matters regarding design and managing construction activities. Although it is true that this method leads to high level of collaboration between project participants, it also requires high owner involvement which dictates the need for a sophisticated owner [36]. A derivative of construction management that has been around for more than forty years is the construction management at risk (CM@R) approach. In fact, it is very similar to DBB as the owner still issues two separate contracts, one for the contractor and one for the consultant. However, the role of the construction manager shifts from being an advisor to a vendor where they will act as both a project coordinator and general contractor to execute the construction activities. This in turn mimics the benefits of DB as it allows for preconstruction services as well as the overlapping of design and construction that can ultimately result in cost and schedule compression. This method is associated with guaranteed maximum price contract which is an advantage to the owners [25]. Additionally, CMR is usually associated with competitive qualification-based procurement which helps ensure the owner that the contractor has the required skills and experience which are essential for project success. It also leads to decreased change order and increased cost certainty as well as superiority in product and service quality levels when compared to traditional DBB delivery method [37, 38].

Nonetheless, it can be seen that these delivery methods were developed to target specific objectives with restricted focus which leads to fragmented approaches as the improvement of the overall delivery system is yet to be achieved in the construction industry [39]. Researchers argue that the recent development of Integrated Project Delivery (IPD) systems is the solution to this problem [40]. IPD is defined as a “method that integrates people, systems, business structures and practices into a process that collaboratively harness the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication and construction” [41]. Moreover, Azhar et al. [42] listed six features that characterize IPD. These include early involvement of key participants, shared risk and reward, multiparty contract, collaborative decision making and control, liability waivers among participants as well

as jointly developed project goals. Furthermore, a need for more integration in delivering construction projects is critical to cover the limitations of traditional DBB method which leads to the development of various cultures that results in severe inefficiency and high costs of inadequate interoperability as well as high levels of data and team fragmentation that even CM and CM@R methods were not able to overcome [43-46]. Indeed, these traditional delivery approaches have historically resulted in a profound number of claims, high risks, delayed schedule and over-priced projects [47]. It is about time that integration is taken to another level in these delivery methods where project members are engaged in a much faster way that allows for real time monitoring through intuitive interfaces with the help of the technological innovations that transformed the construction industry [48-51]. In fact, Demetracopoulou et al. [52] confirmed that there is a strong positive correlation between the characteristics that lead to innovation opportunities and the level of integration between designer and contractor.

Among other efforts to increase collaboration in projects delivery methods is the introduction of lean delivery methods. Where lean delivery consists of 4 phases. The first phase is the project definition phase which deals with determining the needs and value of the client. While the second phase is the lean design phase where decisions regarding product and process are made simultaneously to create a conceptual design. Furthermore, the third phase is the lean supply phase which consists of transforming the conceptual design to detailed engineering documents such as components fabrication and logistics of deliveries. The last phase is the lean assembly phase which begins by the delivery of materials, tools, labour or other components till the project is finished and handed over to the client [53]. Under the umbrella of collaborative delivery methods also comes alliances and partnering. Where project alliancing is a delivery method that allows the owner and other participants to work together as an integrated and collaborative team with faith and trust to manage risks jointly and share the project outcome in the end. While partnering is a method used by two organizations who share mutual goals to reach specific business objectives. It constitutes of an agreed upon method to solve conflicts with an aim of continuous improvement [54]. Next section will provide an overview of the traditional selection criteria of project delivery methods.

2.2. Selection Criteria for Project Delivery Methods

Owners are presented with various options for their project delivery process from traditional DBB to DB or CMR. Ideally, project delivery selection would be based on which success factors offer the greatest likelihood of achieving the desired success criteria of a project. Over the years, there have been many changes in the construction industry which have caused frequent updates to the list of success factors either by adding more factors or prioritizing some factors over the others.

To begin with, up until the 1970s and 1980s, the delivery method was selected mainly on a cost-oriented basis. However, beyond the 1980s, the customers' demands have evolved where they were looking for more integration and mutual cooperation between project members [55]. As the interaction increased, the owners realized that this decreased disputes and change orders which ultimately reduced delay in schedules and rise in costs. Hence this caused factors such as communication, cost and schedule growth to be included in the selection criteria list as they lead to more efficient selection of project delivery [56]. Furthermore, around this period, the construction industry witnessed the age of information technology which brought advances in engineering software. For instance, the application of BIM technology in each of the different delivery systems to integrate various disciplines during design and construction phases [57]. This technological boom that the construction industry endorsed has further emphasized the significance of the communication selection criteria.

Moreover, around the year 1987, the concept of sustainability invaded the construction industry. Although the literature does represent some papers that discuss the effect of sustainability on project delivery such as Korkmaz et al. [58] who presented evaluation metrics for sustainable project delivery, the research in this field still doesn't suffice. Indeed, this area of study is still in its embryonic stage and more digging is required about the inclusion of sustainability goals in the selection criteria list for the various project delivery methods selection. Unfortunately, this shows that even though the construction industry has witnessed the move towards sustainability a long time ago, project management is still struggling to incorporate sustainability in the selection criteria list for project delivery selection. This proves that there is a lag between the rate of evolution of the construction industry and the rate at which the selection criteria list is being updated, indicating that there is still a lot of room for improvement.

At the start of the 21st century, more criteria were included in the selection set. Among those criteria was quality as customers have started paying more attention to the quality of the delivered project rather than just economic and transaction specific measures [59, 60]. Besides, Analysis of literature review has revealed that more papers in the 21st century were directed towards studying risk as a selection factor upon which the project delivery method would be selected [61-64]. Furthermore, Grasberg et al. [65] claimed that even though, all of these selection criteria are relevant, the owner’s characteristics and his experience on how to handle disputes as well as his willingness to take risk affects all other factors and therefore, should play a major role in selecting the most appropriate project delivery method. Additionally, health and wellbeing of the workers in the construction industry is another selection criterion that has been the centre of attention in recent papers [66, 67]. Not only this but, around the year 2011, there has been a huge digital transformation in the construction industry where drones, laser technologies and artificial intelligence started being used in the construction process [68]. However, there is very little research on the contribution of these technological advances to the list of criteria used to select the most appropriate delivery method which creates a gap that needs to be bridged in future research. Table 1 below summarizes an overview of selection criteria.

Table 1. Overview of Selection Criteria

Criteria	Sources	#
Quality	[56], [69], [61], [70], [71], [72], [73], [74], [75], [76], [77], [78]	12
Owner Involvement	[61], [79], [72], [80], [81], [76], [82], [83]	8
Time/Delivery Speed	[55], [84], [71], [82], [77]	5
Project Cost	[71], [73], [85], [86], [76], [82], [87]	7
Cost Growth	[22], [61], [80], [73], [88], [76], [89]	7
Project Type	[55], [56], [80], [89], [82], [77], [90]	7
Project Manager’s Characteristics	[56], [61], [91], [92], [93], [94], [95], [96], [97], [90]	10
Schedule Growth	[22], [55], [61], [91], [98], [80], [73], [76], [89], [77], [83], [90]	12
Market Competitiveness	[91], [99], [74], [100], [81], [75], [101]	7
Contractor’s Abilities	[61], [102], [74], [76], [103], [104]	6

Sustainability Goals	[105], [106], [72], [76], [107], [108]	6
Technological Innovations	[109], [110], [100], [111], [101]	5
Risk	[22], [74], [61], [112], [80], [113], [114], [115], [116], [72], [73], [117], [76], [82]	14
Complexity	[61], [80], [118], [72], [81], [74], [76], [101], [77]	9
Communication	[119], [120]	2

The above discussion highlights how the literature review is very rich in providing guidelines on the traditional selection criteria of project delivery methods. But there is a lack of a solid literature base on the critical criteria needed for the selection of project delivery methods in non-traditional sustainable construction projects. The next section will summarize the evolution witnessed in the selection methods of project delivery methods over the years. This will help determine the gap that needs to be fulfilled to develop a decision support model that can assist decision makers in selecting the most appropriate delivery methods in sustainable construction projects.

2.3. Selection Methods of Project Delivery Methods

Selecting the most suitable project delivery method is a complex and a lengthy process that demands a comprehensive analysis of various success factors and criteria and it does not follow a one size fits all approach [121]. Traditionally, project managers relied on their gut feelings and the delivery methods they are most familiar with to help them choose. However, with increasing complexity and evolution of the construction projects, project managers realized that there was a need for a structured mechanism or models to assist them in choosing the most suitable delivery method for a specific construction project [98]

Typically, a decision support model is constructed to help decision-makers evaluate the consequences of different alternatives. However, a decision support model is most useful when information about uncertainties related to each decision option are incorporated [122]. These models usually derive their data from either first-hand data, expert knowledge or pre-existing models. Expert knowledge is used when the estimates of relationships cannot be obtained directly. Sensitivity analysis is usually done with expert assessment to study the variance estimates around the model parameters [123]. In the case of this research, expert knowledge with sensitivity analysis will be used as

it is not feasible to get first-hand data on sustainable construction projects and there are no pre-existing models due to the novelty of this research.

The history of decision support-models in project delivery method selection began by a simplified version of a scoring and decision chart where each project delivery method was assigned a score using a numerical scale which measured its ability to fulfil a specific criterion. After that the evaluation criteria were weighed to identify the relative significance of each of the selected criteria. The overall score of each project delivery was then calculated by adding up all the scores from each criterion and then finally the project delivery with the highest score was identified as the most appropriate alternative [71]. However, as the age of information technology arrived by the year 1975, the decision-making tools grew more sophisticated with the introduction of multi attribute utility theory (MAUT) and analytical hierarchy process (AHP) to help improve the objectivity of the selection process and make it less subjective.

In MAUT, the project manager initially identifies a utility function for each criterion. These functions are later used to compute the utility score of each project delivery method with regards to different criteria. Similar to the weighted sum approach, weights are assigned to each criterion individually to indicate their relative significance. After that, the utility scores for all the various criteria are weighted and summed to calculate a global utility score for a specific delivery method. Finally, the project delivery method with the highest global utility score is selected [124]. While in AHP, the first step in the process is identifying the different project delivery methods and developing a hierarchy of the selected criteria. The main step in the process is the conduction of pair-wise comparison of project delivery methods where project managers are to compare all methods with reference to the evaluation criteria respectively. Ratio scales are then used to measure the manager's comparative preferences and integrated to compute an overall weight for each project delivery method [80].

After introducing AHP in the early 1980's, Saaty [125] introduced the analytic network process (ANP) around 1996 which was considered as the general form of AHP. It was used in order to overcome the limitations underlying the assumption of independence between criteria. Where ANP model allowed for complicated interrelations between various criteria elements. Furthermore, with the introduction of selection criteria such as quality, flexibility and speed by the beginning of the 21st century, it was challenging

to measure them using numerical values. This is when the method referred to as the fuzzy logic approach was introduced in the construction industry to select the project delivery method. Ng et al. [91] explained the fuzzy approach where the integral function in this method was the membership function. These functions were used to assign a criterion in a fuzzy set to either 0 or 1 where 1 indicated a member and 0 indicated otherwise. This helped in conversion of linguistic terms such as low, medium or high into numerical values. However, there is no evidence in literature that the current methods are fit to quantify other selection criteria that have been added due to the evolution of the construction industry such as the parameters of sustainability for instance. This in turn creates a gap that the selection methods have not evolved or matured enough to catch up with the pace of the construction industry's evolution.

In addition to new embellishments in the criteria elements list, the digital transformation that invaded the construction industry has also brought along with it some changes in the selection methods used to choose the project delivery method. For instance, the development of Monte Carlo simulation algorithm, which is a technique used to randomly generate input variables from statistical distributions to model a stochastic process [126]. The outputs of the simulation then result from conducting a large number of iterations to account for risk and uncertainty. Some project managers also opt to use a mix of methods to help them in the decision-making process of selecting the most appropriate delivery method such as combining both ANP and Monte Carlo simulation to reach optimum results. Furthermore, over the years there have been several advances in decision making tools such as tools that formally separate project characteristics from project goals to assist decision makers in selecting an optimum delivery method based on their institutional needs and requirements [127]. Although there has been a lot of sophistication in the selection methods over the years, there are still some limitations that need to be covered. For instance, the development of selection models that consider the interdependencies between different projects which basically defines the construction industry of today where all projects are interconnected in one way or the other. Another limitation that needs to be fulfilled is the development of an optimization model that considers different scenarios of time and cost trade-offs in order to satisfy the new selection criteria presented in the previous section [128]. Table 2 summarizes an overview of project delivery selection methods.

Table 2. Overview of Selection Methods

No	Method	Source	Total
1	Weighted Sum Approach	[71], [129], [130]	3
2	AHP	[56], [61], [98], [80], [92], [70], [131]	7
3	ANP	[126],[132], [83], [133]	4
4	Multi-Attribute Decision Models	[22], [98], [124], [129], [134] , [135], [75], [94]	8
5	Fuzzy Approach	[110], [131], [136], [137] , [138], [139], [140],[141], [142], [143], [111]	11
6	Simulation Decision Models	[144], [101], [145], [146]	4
7	ANN	[147], [148], [149], [150]	4
8	Web Based Approach	[72], [151], [127]	3
9	Case-Based Reasoning	[109],[110], [152], [93], [153], [154]	6
10	Risk Based Approach	[155], [156]	2

In light of the above discussion, it can be concluded that the selection methods available in practice mainly focus on the selection of project delivery methods in traditional construction projects. Although there has been a lot of improvement and sophistication over the years in the selection methods of project delivery methods, these advancements have not yet captured critical sustainability-specific criteria that need to be integrated into decision support models to be able to choose the most appropriate delivery method for non-traditional sustainable construction projects. Therefore, there is a need to develop a comprehensive multi-criteria decision support model that integrates both traditional and sustainability-specific criteria in order to assist decision makers in selecting the delivery method that will enhance the success rate of sustainable construction projects.

2.4. Research Gaps

The concluded literature review confirms the below research gaps as follows:

- The gap in interpreting the underlying latent variables of sustainable construction delivery challenges.
- The gap in identifying sustainability-specific significant criteria required for the selection of project delivery methods in sustainable construction projects.

- The gap in determining the effectiveness of the most common project delivery methods available in practice (DBB, DB, CMR) in achieving the identified comprehensive criteria list of both traditional and sustainability-specific.
- The gap in developing a decision support model to select the most appropriate project delivery method for sustainable construction projects using a comprehensive criteria list.

Accordingly, this dissertation aims to develop a decision support model to assist decision makers in selecting the most appropriate delivery method for sustainable construction projects which comprises of the three most common delivery methods (DBB, DB and CMR) and a comprehensive criteria list that combines both traditional and sustainability-specific selection criteria.

Chapter 3. Methodology

The selection of project delivery methods is a critical decision that impacts the success rate of construction projects. Based on the literature review conducted, where the significance of sustainable construction was stressed and the lack of a comprehensive criteria list for the selection of project delivery methods for sustainable construction projects was emphasized, it has been highlighted that there is a need to develop a new decision support model that comprises a comprehensive selection criteria list that will assist clients in selecting the optimum delivery method for sustainable construction projects and help bridge this gap. In order to achieve this, the aforementioned five objectives in chapter 1 should be fulfilled successfully. The sections below represent the philosophy, approach, strategy, data collection and analysis techniques that will be adopted in this research in order to accomplish the aim and objectives of this study.

3.1. Research Philosophy and Approach

This research adopts a pragmatic philosophical stance that employs both positivist and interpretivist. This is due to the fact that both qualitative and quantitative data collection methods will be used to answer the research questions in this dissertation. As it would be unrealistic to answer via one or the other only. For instance, qualitative data collection methods will be needed to research the challenges and the selection criteria for sustainable projects delivery, where literature should be extensively reviewed and the opinions of construction professionals should be gathered. Moreover, quantitative data collection methods will also be needed to rank and prioritize these challenges and selection criteria as well as predict the significance of the relationship between the selection criteria and the success criteria of sustainable construction projects. Furthermore, the effectiveness of the delivery methods with regards to the selection criteria will be assessed using quantitative methods in order to finally propose a decision model that allows clients to choose the most optimum delivery method for sustainable construction projects. Additionally, this research follows an abductive approach which includes both inductive (theory building) and deductive (theory testing) approaches. This is due to the fact that initially, sustainability-specific selection criteria will be induced through theory building and then after that the relationship between these criteria and project delivery methods as well as the success of sustainable construction projects will be deduced through theory testing in order to build the final

decision support model. This will be explained in more detail in the next sections of this chapter.

3.2. Research Strategy

A mixed method that combines both exploratory and explanatory approaches will be adopted in this research. The exploratory part of the research will be conducted through literature review, and surveys in order to identify the challenges of sustainable construction, the project delivery methods and their selection criteria available in practice as well as the criteria of success for sustainable construction projects. On the other hand, the explanatory part of the research will aim to find causal relationships between the sustainable selection criteria of the project delivery methods and the success of sustainable construction projects as well as the relationship between the effectiveness of project delivery methods and the relative importance of the selection criteria with the help of mathematical and statistical tools in order to build the final decision support model to select the optimum delivery method for sustainable construction projects. This model will then be validated through a case study to ensure the practicality of the model in assisting clients to choose the optimum delivery method for their sustainable construction projects. Figure 1 further illustrates this research strategy.

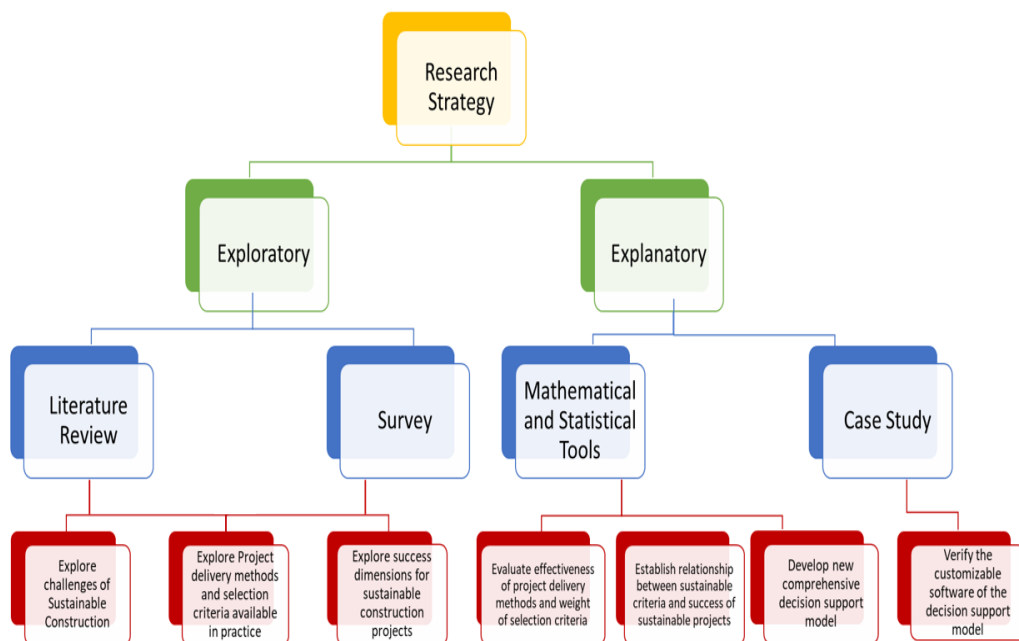


Figure 1. Research Strategy

3.3. Methods

This section illustrates the steps required to achieve the aforementioned objectives of the research. The first objective is to identify the criteria required to overcome the challenges faced in the delivery of sustainable construction projects following the below steps:

- Step 1: Conduct a comprehensive literature review on the challenges of sustainable construction delivery.
- Step 2: Extract a list of the most cited challenges for sustainable construction projects in literature.
- Step 3: Conduct the first questionnaire survey (see Appendix A p. 137) for this research (five-point Likert Scale) to rank the extracted challenges
- Step 4: Conduct exploratory factor analysis to measure and interpret the latent variables of the sustainable construction delivery challenges
- Step 5: Assess the suitability of the data using Kaiser-Meyer-Olkin and Bartlett's test of sphericity
- Step 6: Extract the factors using principal component analysis to provide a simple solution with the minimum number of factors needed to explain so much variance in the original data set
- Step 7: Use varimax rotation to rotate the factors and provide a clear picture of the clusters extracted
- Step 8: Interpret the clusters using theoretical background and previous studies
- Step 9: Develop sustainability-specific criteria required to address the identified latent variables from factor analysis in order to improve the delivery of sustainable construction projects.

Eighty-two responses were collected from the first survey and used for analysis. The respondents' profile for this survey is shown in table 4.

The second objective is to determine the relationship between the identified criteria for the selection of project delivery methods and the success of sustainable construction projects. Accordingly, the below steps are to be followed:

- Step 1: Conduct literature review to determine the selection criteria of project delivery methods and success criteria for sustainable construction projects

- Step 2: Combine the criteria developed in objective 1 with the results extracted from literature in step 1 to develop a comprehensive criteria list that incorporates both traditional and sustainability-specific criteria
- Step 3: Develop two reflective theoretical frameworks: traditional selection criteria and sustainability-specific selection criteria with arrows representing the directions of the predicted hypothesized influences in the structural model.
- Step 4: Conduct the second questionnaire survey (see Appendix A p. 141) for this research using the inputs from the theoretical frameworks developed in order to rate the significance of the selection criteria and project success criteria using a Likert Scale (1-5)
- Step 5: Analyse the data using partial least square structural equation modelling (PLS-SEM) to appraise the impact of the traditional and sustainability-specific selection criteria of project delivery methods on achieving the criteria of project success.
- Step 6: Create the measurement model that relates the exogenous variables (selection and success criteria) to the latent variables (criteria groups) and the structural model that relates latent variables to each other
- Step 7: Assess and refine the measured construct models of traditional criteria, sustainability-specific criteria and sustainable projects success criteria in order to eliminate variables that are not significant from the model with the help of the factor loads perspective.
- Step 8: Evaluate the measurement model using confirmatory factor analysis to check the validity, reliability and appropriateness of the model using average variance extract test (AVE) and composite reliability (CR) as well as Cronbach's Alpha.
- Step 9: Evaluate the structural model using bootstrapping technique to predict the significance of the path coefficients.
- Step 10: Conduct PLS-SEM using Smart-PLS software to predict the significance of the traditional and sustainability-specific criteria on the success criteria of sustainable construction projects

The PLS-SEM was adopted in this research as it has features that match the objectives and sample size of this research in order to estimate associations between a number of variables [157]. Hundred and ten responses were collected and used for this analysis

and the results of the respondent's profile for this survey is shown in table 4. Indeed, SEM has been widely used in construction management by researchers worldwide. For instance, Watfa et al. [158] used SEM to assess the impact of sustainability management on the success of construction projects where they investigated 37 technical attributes across 12 confirmatory factors and concluded in the end that there was a significant relationship between project sustainability management and project success. Additionally, Baki [159] used a hybrid approach of SEM and fuzzy additive ratio assessment (ARAS) to rank suitable sustainable suppliers. The author identified 8 criteria and 27 sub-criteria and then administered a questionnaire and analysed the responses using SEM in the first phase.

The third objective is to evaluate the effectiveness of project delivery methods in achieving the traditional and the sustainability-specific criteria by following the steps below:

- Step 1: Conduct comprehensive literature review to formulate the most common project delivery methods (PDM) alternatives available in practice.
- Step 2: Develop a comprehensive criteria list by combining the traditional criteria extracted from literature and the sustainability-specific criteria developed in objective 1 and validated through objective 2
- Step 3: Use AHP to measure the relative importance of the selection criteria through a questionnaire (survey 3 (see Appendix A p.152)) distributed to construction professionals in the UAE with the help of attainment levels expressed on the prescribed 1 to 9 Saaty ratio scale (Table 3) and validated through expert judgement. A sample of pair-wise comparisons between two criteria groups is shown in Figure 2. The respondent first has to determine which group is more significant and then determine the level of intensity of that significance accordingly.

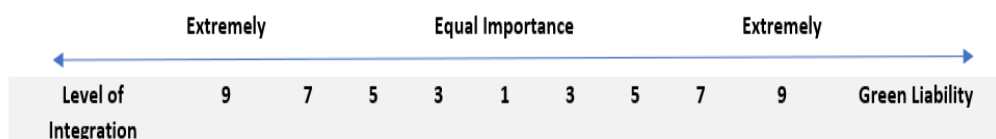


Figure 2. Sample of Pairwise Comparisons

Table 3. AHP Saaty Scale [125]

AHP Scale of Importance for Comparison of Pairs	Numeric Rating
Extremely More Important	9
Very Strongly More Important	7
Strongly More Important	5
Moderately More Important	3
Equally Important	1

- Step 4: Establish priority amongst criteria using Pairwise comparison and check for consistency.
- Step 5: Analyse the results using Excel software, to calculate the local and global priorities of each criterion within each group in the traditional and sustainability-specific criteria. Plus, perform pairwise comparisons between the overall sustainability-specific criteria list and the overall traditional criteria list in the same manner.
- Step 6: Develop a questionnaire survey (survey 4 (see Appendix A p. 159)) to conduct pairwise comparisons between the three most common project delivery methods (DBB, DB and CMR) in order to assess their effectiveness in achieving the pre-identified selection criteria list.
- Step 7: Calculate the geometric mean score using Excel software and use it to produce a scoring chart that yields aggregated values to evaluate the effectiveness of the alternative project delivery methods in relation to achieving the identified comprehensive criteria

In fact, AHP has been used extensively in literature to assess the weights of the selection criteria of project delivery methods. Indeed, AHP is a highly preferred approach as it is an objective tool that helps organize factors within a hierarchy structure and provides solutions to unorganized problems which are all important features for any decision-making problem [160]. A total of thirty and twenty-six responses were collected for survey 3 and 4 respectively and used for the analysis. The respondents' profile of survey 3 and 4 are shown in Table 4.

Table 4. Respondent's Profile for the Four Surveys

Category		Survey 1: Respondents (Total 82) %	Survey 2: Respondents (Total 110) %	Survey 3: Respondents (Total 30) %	Survey 4: Respondents (Total 26)
Years of Experience	> 20 years	12.2	11.8	6.7	11.5
	11-20 years	19.5	10.9	6.7	30.8
	5-10 years	41.5	49.1	33.3	38.5
	<5 years	26.8	28.2	53.3	19.2
Company	Local	61	48.2	53.3	53.8
	International	39	51.8	46.7	46.1
Project Type/ Expertise	Buildings	48.8	50.9	50	61.5
	Infrastructure	37.8	33.6	46.7	30.8
	Others	13.4	15.5	3.3	7.7
Role	Owner	11	4.5	10	3.8
	Consultant	39	39.1	30	26.9
	Contractor	36.6	41.8	50	57.7
	Construction/ Project Management Firm	13.4	14.5	10	11.5
Average Project Size	< 50 (Million AED)	24.4	11.8	13.3	11.5
	50 – 200 (Million AED)	28	37.3	33.3	34.6
	201 – 500 (Million AED)	15.9	17.3	13.3	11.5
	> 500 (Million AED)	31.7	33.6	40	42.3

The fourth objective is to develop a decision support model to assist clients in selecting the appropriate project delivery based on the traditional criteria and sustainability-specific criteria, in this research 2 models will be developed (Model A and Model B) according to the steps below:

Model A

- Consists of a multicriteria decision making process organized as a Microsoft Excel-based decision support tool that is composed of the three common project delivery alternatives (DBB, DB, CMR) and the comprehensive criteria list developed in the earlier objectives
- The effectiveness levels of the three project delivery alternatives with respect to each criterion were predetermined using AHP from objective #3
- The weights of the selection criteria were predetermined using AHP from objective #3
- The user can opt to use all of the selection criteria in the model or can choose only the required selection criteria as per the objectives of their sustainable construction project
- The spreadsheet tables will then normalize the weights of all chosen required selection criteria and calculate the sum product of the required selection criteria weights and the effectiveness values of the three PDMs.
- Aggregate scores will then be calculated to rank the three PDMs using a built-in macro function and the project delivery method with the highest aggregate score will then be the most appropriate alternative.

Model B

- Consists of a multicriteria decision making process organized as a Microsoft Excel-based decision support tool that is composed of the 3 most common project delivery alternatives (DBB, DB, CM@R) and the comprehensive criteria list developed in the earlier objectives
- The user will then be asked to choose up to ten selection criteria that are best aligned with the objectives of their sustainable construction projects
- The user would then rank the criteria as per their relevance from 1 to 10 accordingly

- The user would then assign preference scores to the ten criteria selected, where 100 would be assigned to the most important criterion ranked as 1 in the previous stage and then the other criteria would be ranked less than 100 based on their relative importance to the first-ranked criteria
- Spreadsheet tables would then automatically compute the relative weights of the ten selected criteria
- The sum product of the relative weights of the ten selection criteria and the corresponding effectiveness values of the three PDMs that are predetermined from AHP would be calculated
- Aggregate scores will then be calculated to rank the three PDMs using a built-in macro function and the project delivery method with the highest aggregate score will then be the most appropriate alternative.

The suggested models will then be verified through a case study where responses will be gathered from practicing project managers who will be invited to use them to select delivery systems for a hypothetical sustainable construction project.

The fifth objective is to develop a prototype customizable software that assists clients in using the developed model. The prototype will be used to simulate the characteristics of the decision support model developed in objective 5. It will provide owners and project managers with a defensible rationale for project delivery method selection. It has been established that end users of this procedure will be busy construction executives who are not expected to spend time mastering decision analysis techniques. In light of this:

- A simple database with user interface will be developed. Where operations such as performing sensitivity analysis on results of the selection model and evaluating the effectiveness of the delivery methods in relation to a comprehensive criteria list were already pre-performed.
- The unfamiliar operations required in the adopted technique would be transparent to the end-users who can then focus on the parts of the process that are most beneficial to them without worrying about the other arduous tasks.

3.4. Time Horizons

The Time horizon for this research is considered cross-sectional. This is due to the fact that like any academic research, the dissertation has to be finished within a specific timeframe.

3.5. Data Collection Techniques

Data triangulation will be used to gather data where mixed methods that combine both qualitative and quantitative measures will be adopted using literature review, questionnaire surveys and a case study. Literature review will be used to determine the challenges of sustainable construction, the dimensions of success for sustainable construction projects as well as the project delivery methods and selection criteria available in practice. After that, questionnaire surveys will be used to rank challenges, retrieve the relative weight of the selection criteria and their impact on the success criteria of sustainable construction projects as well as determine the effectiveness levels of the most common project delivery methods with regards to the selection criteria. Finally, a case study will be used to validate the proposed decision support model that will be used to help clients choose the optimum delivery method for sustainable construction projects. Table 5 shows the research questions and objectives along with their data collection methods.

Table 5. Research Questions and Objectives with Data Collection Methods

Research Questions	Research Objectives	Literature Review	Surveys	Case Study
What are the challenges and selection criteria associated with sustainable construction projects delivery?	Identify the criteria required to overcome the challenges faced in the delivery of sustainable construction projects	✓	✓	
What is the relationship between	Determine the relationship between the	✓	✓	

the new sustainability selection criteria and the success of sustainable construction projects?	identified criteria for the selection of project delivery methods and the success of sustainable construction projects			
What are the different types of project delivery methods and their effectiveness in relation to sustainable construction project performance?	Evaluate the effectiveness of the most common project delivery methods in achieving the traditional and the sustainability-specific selection criteria	✓	✓	
What is the optimal project delivery method in relation to the identified comprehensive list of success criteria?	Develop a decision support model to assist clients in selecting the appropriate project delivery based on the traditional criteria and sustainability-specific criteria		✓	✓

3.6. Sampling Techniques

The theoretical population of this research is the construction industry in the United Arab Emirates, that is the population that the findings of this research will be generalized to. The end users of the decision support model are project managers who needs to determine the appropriate delivery method for their sustainable construction projects. The study population that this research will get access to, is construction professionals who have experience/knowledge about sustainable construction projects. While the sample population will include consultants, owners, contractors and construction project managers to be able to have a diverse set of perceptions from construction professionals with different job designations that will help develop generalized outcomes in the end. As far as the sampling strategy is concerned, this research will follow the snowball sampling approach where study subjects will refer

other potential subjects to participate through professional platforms. In fact, this is a very useful approach that allows the researcher to develop a network of connections and increase the number of participants.

3.7. Data Analysis Techniques

The data analysis for each objective will be as follows:

Objective #1: To identify the criteria required to overcome the challenges faced in the delivery of sustainable construction projects; the induced challenges will be ranked through a survey and then factor analysis will be used to interpret the underlying latent variables. The results will then be used to induce the criteria needed to overcome these challenges.

Objective #2: To determine the relationship between the identified criteria for the selection of project delivery methods and the success of sustainable construction projects; partial least structural equation modelling will be used to predict the significance of each criteria group with regards to successful sustainable construction delivery.

Objective #3: To evaluate the effectiveness of project delivery methods in achieving the traditional and the sustainability-specific criteria; surveys will be used with the help of AHP to compute the weights of the selection criteria and compare the effectiveness of the most common delivery methods against each other in achieving those criteria

Objective #4: To develop a decision support model to assist clients in selecting the appropriate project delivery based on the traditional criteria and sustainable criteria; 2 models will be developed. The first model is a multicriteria Excel-based decision support tool that comprises a comprehensive list of all the selection criteria and the three most common PDMs (DBB, DB, CMR) where the user will be asked to choose the most important criteria for their project. Excel will then normalize the weights of those selection criteria and compute the aggregate scores of the three alternative delivery methods for the user to choose the optimum one. While the second model will allow the user to input the weights of up to ten selection criteria and prioritize them according to their project's requirements and then use these weights along with the predefined effectiveness values of the three common PDMs in order to select the optimum delivery method.

Objective #5: To develop a prototype customizable software that assists clients in using the developed models; a case study will be used to validate the proposed decision support model in selecting the most appropriate delivery method for sustainable construction projects.

Figure 3 illustrates the methodology mapping for this research

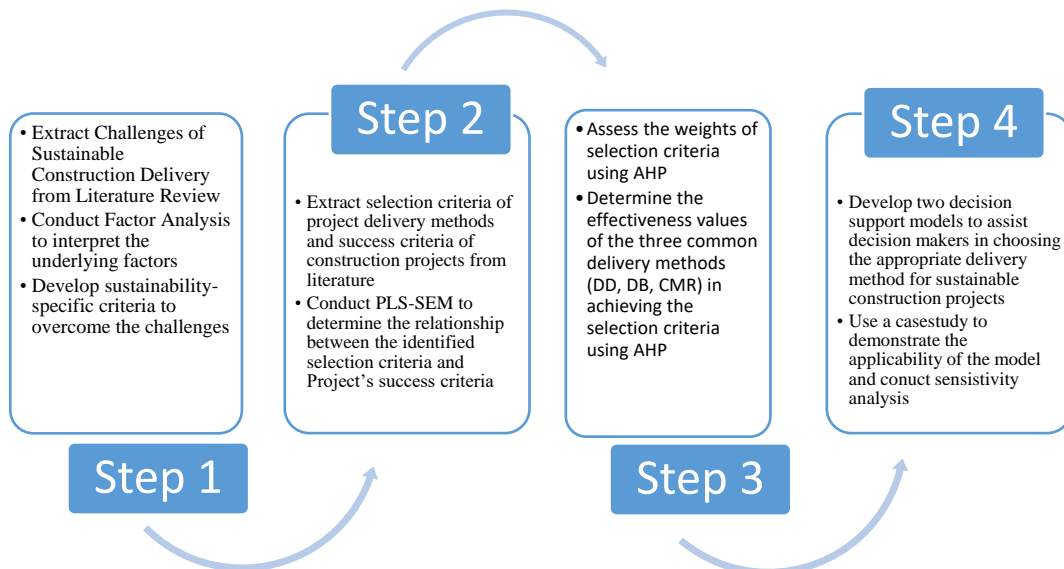


Figure 3. Research Methodology Mapping

3.8. Ethics

For the sake of ethical considerations, all applicants/construction professionals will be given full confidentiality and privacy. Where their identity shall not be revealed without their consent in writing. Additionally, they will have full freedom to choose whether they want to contribute to this research upon a voluntary nature and they will be provided the right to withdraw from the survey without any kind of stress as they will be secured from any harm.

3.9. Validity and Reliability

Data triangulation will be used to validate qualitative results by quantitative studies where data from literature review and questionnaire surveys and case study expert analysis will be used to help reverse the drawbacks of one method and reinforce the advantages of the other which will improve validity and reliability of the data. Furthermore, factor analysis will be done on the challenges of sustainable construction extracted from literature to achieve construct validity. To achieve internal validity, all

questionnaire surveys will be designed in a way to ensure that the questions will be understood by respondents. Moreover, extensive literature will be carried out to ensure that questionnaires adequately cover the research problems and objectives of this study. As far as reliability is concerned, the internal correlation coefficient Cronbach's alpha will be calculated to test for internal consistency. Finally, a case study will be used to validate the practicality of the proposed decision support model.

Chapter 4. Challenges and Selection Criteria of Sustainable Construction Projects Delivery

This chapter describes the most cited challenges in sustainable construction projects and their categorization into different clusters. Moreover, the chapter presents the selection criteria required to overcome these challenges and tests their significance with regards to the success of sustainable construction projects.

Sections 4.1 up to 4.3 below are extracted from an article published by Salma Ahmed and Sameh El Sayegh with the title of “The Challenges of Sustainable Construction Project Delivery in UAE- An Exploratory Factor Analysis Approach.” [161] in the Journal of Architectural Engineering and Design Management. Sections 4.4-4.9 are extracted from a manuscript under review in the International Journal of Construction Management with the title of “Relevant Criteria for Selecting Project Delivery”

4.1. Challenges of Sustainable Construction

Delivery of sustainable construction projects has witnessed several challenges over the years. One of the most cited challenges is lack of sufficient information, and proper knowledge of sustainable construction practices [17]. This leads to poor feasibility, planning, and risk management [162]. Besides, lack of experience of contractors and consultants is another critical challenge as it may lead to poor selection of sustainable construction techniques [163]. Furthermore, there is lack of reliable sustainable suppliers, especially because the sustainability market is still not mature enough [18].

Oke et al. [164] have claimed that there is a shortage of skilled workforce. This is because construction team players are accustomed to traditional construction practices and are unable to relinquish traditional construction methods, project management and delivery systems; making it challenging to successfully deliver sustainable projects [165]. Sustainable projects are more complicated than traditional ones, therefore, management practices need to be updated to overcome these complications [166]. Delivery of sustainable construction projects requires organizational leadership and management commitment [167]. Where leaders should possess the ability to earn the support of all stakeholders, and overcome barriers in collaboration with others to ensure successful sustainable construction delivery [168].

Moreover, sustainable projects demand advanced sustainable materials that are of limited availability [17]. Due to the absence of extensive research about these sustainable materials, there is inadequate information about their performance or their handling and storage [169]. Sustainable projects comprise a lot of technical systems that are interdependent; thereby demanding a high level of integration, communication and collaboration amongst stakeholders to attain successful delivery of sustainable projects [170]. Additionally, sustainable materials have a long lead time which may delay the approvals that will further delay onset of construction activities [9]. Moreover, sustainable materials and technologies experience rapid improvements which means that project participants must always be up to date to avoid including outdated materials and technologies in the design phase that might lead to repetition and further delays [171].

On another note, there are also design issues. These issues include frequent design changes by clients or architects due to their unfamiliarity with sustainable design which creates errors in design documents [163]. Plus, these changes prolong the decision-making process and delay the design phase [172]. It is also challenging to comply with sustainable codes set by governments due to extensive environmental analysis and incorporation of whole life cycle costs requirements for which traditional designers don't have enough experience in conducting them [173]. Furthermore, weak scope definitions of sustainable construction requirements and incomplete specifications can result in poor design documents [9].

Moreover, bidding evaluation should include sustainability criteria as traditional contractor selection method which is solely based on lowest price must be updated [174]. Indeed, there should be more contractual incentives as well as risk/profit sharing in contracts to motivate contractors to perform better in projects [175]. Additionally, Rasekh and McCarthy [176] claimed that delivery of sustainable projects requires extensive documentation. Getting governmental approvals for sustainable construction processes might impede the delivery of sustainable projects [177]. Besides, lack of government policies and the fact that available sustainability codes are constantly being updated makes it challenging to deliver a sustainable project that is coherent with ever-changing codes [16]. Current procurement guidelines for sustainable construction are

fragmented and there is insufficient information about the effectiveness of different delivery methods in achieving the sustainability criteria [178].

Tafazzoli [179] emphasized another challenge which is the unwillingness of owners to pay extra initial costs of sustainable buildings. There could also be funding issues due to poor cost and schedule planning. Due to the unfamiliarity with sustainable projects, contractors might find it challenging to budget projects [180]. Moreover, sustainable materials are costly, and if they are not available in the local market, they will need to be imported; making the delivery of sustainable projects more challenging [162]. Furthermore, price inflation is a challenge that might be of a huge concern with the aforementioned complexities in sustainable construction [181]. Finally, while it might be a positive strategy in traditional construction projects to develop tight schedule plans, it actually creates a challenge in sustainable projects as they require more time than traditional ones and if owners try to enforce an unreasonable schedule, it will lead to cost and time overruns [20]. Table 6 shows a summary of the challenges of sustainable construction delivery.

Table 6. Challenges of Sustainable Construction Projects Delivery

S/N	Challenges	Source
X1	Lack of knowledge and awareness	[182]; [17]; [183]; [176]
X2	Limited management commitment and organizational leadership	[167]; [184]; [168]
X3	Inability to relinquish traditional construction methods and project management practices	[165]; [185]; [186]
X4	Inadequacy of Suppliers	[17]; [18]
X5	Shortage of skilled workforce	[164]; [162]; [20]
X6	Poor feasibility, planning and risk management	[162]; [181]; [11]
X7	Limited experience in selection of sustainable construction procedures and techniques	[163, 187]
X8	Need for special materials	[17, 181] [188]
X9	Inadequate information about handling and storage of sustainable materials	[9]; [163]
X10	Insufficient information about performance quality of sustainable materials	[189]; [169]
X11	Rapid improvement and continuous updates of sustainable materials and technologies	[171]; [190]
X12	Long lead time of sustainable materials	[9]; [191]

X13	Complex technical systems with high levels of interdependence and interaction	[58]; [192]; [193]; [183]
X14	Extensive documentation and reporting	[11]; [106]; [176]
X15	Delays in governmental approvals for sustainable construction processes	[177]; [19]
X16	Lack of sustainability building codes and government policies	[16]; [183]
X17	Fragmented guidelines for sustainable procurement	[178]; [15]
X18	Incomplete sustainable specifications	[163]; [9]
X19	Sustainability criteria is not considered in bid evaluation	[194]; [174]
X20	Long and slow decision-making processes	[171]; [106]
X21	Weak scope definitions of sustainable construction requirements	[163]; [195]
X22	Frequent design changes/meetings by client and/or architect	[163]; [171]
X23	Difficulty of compliance to sustainable codes or certification	[171]; [173]
X24	Owner's unwillingness to pay extra initial costs of sustainable buildings	[179]; [19]
X25	Client's funding issues	[180]; [196]
X26	Contractor's inability to budget project	[197]; [163]; [198]
X27	Price Inflation of sustainable materials	[162]; [187]
X28	Additional cost as sustainable materials might need to be imported	[181]; [176]
X29	Cost overruns due to tight schedule plans	[20]; [199]
X30	Lack of communication and co-ordination amongst contracting parties	[11]; [200], [201]; [58]; [40]
X31	Lack of early involvement of construction professionals during design phase	[11]; [202]; [105]; [58]
X32	Lack of contractual incentives for contractors	[175]; [203]
X33	Lack of risk/profit sharing in contracts	[175]; [204]

4.2. Factor Analysis Results

Eighty-two responses were used in the analysis out of a total 200 surveys that were sent to construction professionals representing a 41% response rate. The team collected responses by email from owners, consultants, project managers and contractors based in the UAE with experience in sustainable construction projects. First part of the survey included general questions about the participants, such as their years of experience, project type/expertise and average project size as well as the type of the company

whether it is local or international. Second part of the survey was related to the significance of each one of the 33 challenges. A Likert scale was used with numbers ranging from one to five where one indicates very low and five indicates very high significance. Factor analysis with principal component analysis and varimax rotation was used to establish which of the variables could be measuring the same underlying constructs to be grouped together. Data's assessment was measured through three tests: Bartlett's test of sphericity, KMO and Cronbach's alpha. In Bartlett's test of sphericity, P value was less than 0.001, which according to Meyers et al. [205] indicates appropriateness of the factor model since this substantiates the availability of potential correlations among the variables. KMO was 0.78 which is greater than the threshold value of 0.5. A Cronbach's alpha of 0.92 was realized suggesting an acceptable level of reliability in the measures since it is greater than the desirable value of 0.7 as suggested by Hatcher & O'Rourke [206]. Table 7 shows the results.

Table 7. KMO, Bartlett's test of sphericity and Cronbach's alpha

KMO	0.78	
Bartlett's test of sphericity	Approx. Chi square	2010.18
	DF	528
	P-value	<0.001
Cronbach's alpha	0.92	

Moreover, average communality of the variables after extraction was 0.73 which supports the use of factor analysis on the variables since it is above the recommended value of 0.60 [207]. Table 8 shows the communalities. Also, the rotated component matrix resulted in 7 distinct factors as each variable belonged to a unique factor. Results indicated that all factor loadings of the variables exceed 0.5; therefore, they should be retained since they significantly contribute to the interpretation of the factor group. Plus, the 7 factors retained explain a total of 72.8% which is above the recommended value of 50% [206] and they all had eigen values greater than 1. First factor explained 30% of the variance and the second factor explained 13% of the variance while factors 3, 4 5, 6 and 7 explained 8%, 6.5%, 6%, 5.4% and 4% of the variance respectively. Also, the remaining percentage explained by the rest of the components is only 27.2%;

indicating that 7 components are adequate to explain the model. Figure 4 shows the final path diagram.

Table 8. Communalities of the thirty-three challenges

Variables	Communalities
X1	0.765
X2	0.664
X3	0.599
X4	0.822
X5	0.768
X6	0.534
X7	0.693
X8	0.931
X9	0.660
X10	0.629
X11	0.841
X12	0.768
X13	0.768
X14	0.550
X15	0.821
X16	0.867
X17	0.861
X18	0.645
X19	0.703
X20	0.727
X21	0.745
X22	0.796
X23	0.672
X24	0.406
X25	0.764
X26	0.780
X27	0.761
X28	0.744
X29	0.525
X30	0.823
X31	0.784
X32	0.831
X33	0.772

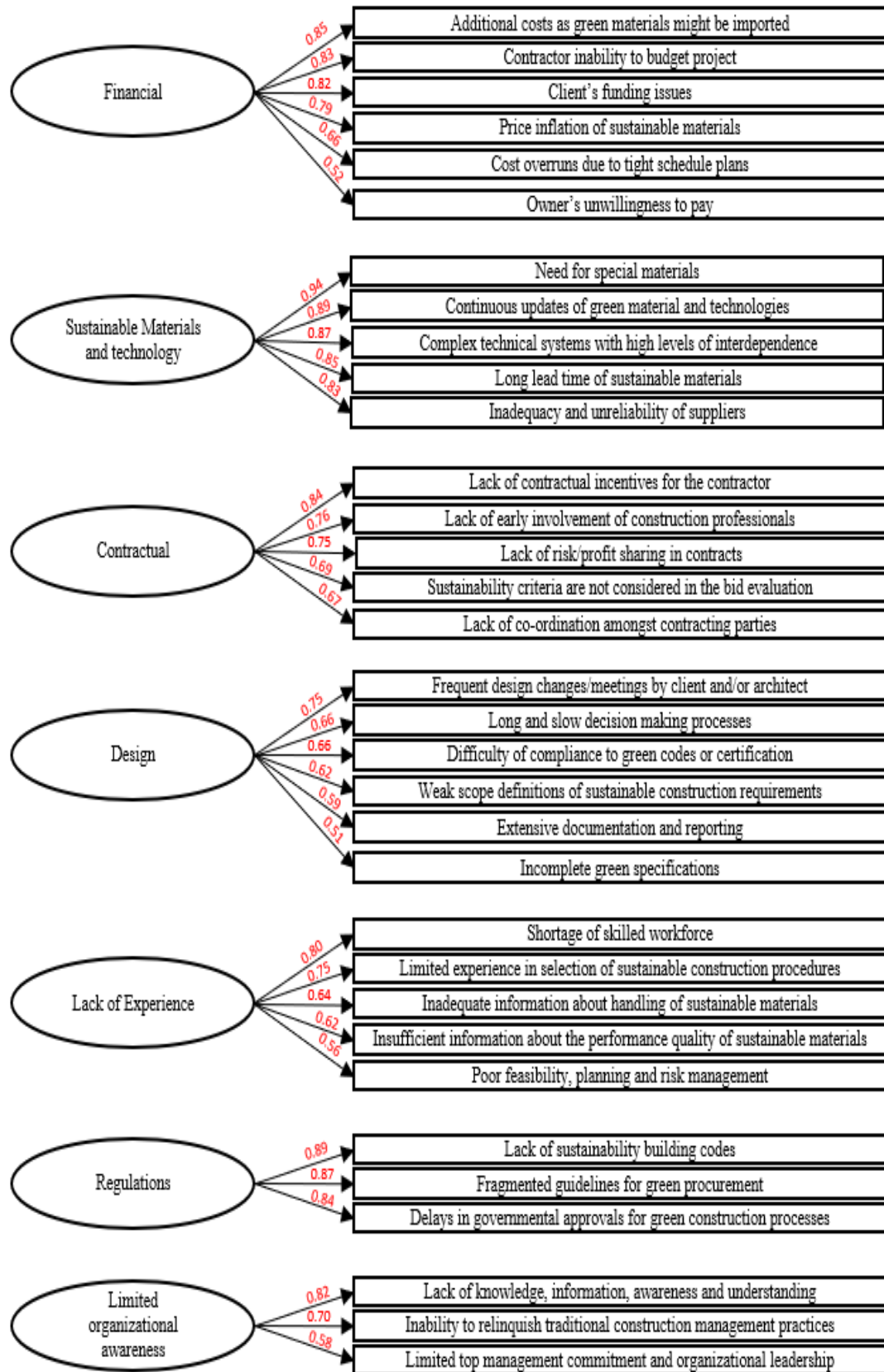


Figure 4. Final Path Diagram of the seven challenges clusters

4.3. Discussions of Factor Analysis Results

In this section, the seven factor categories will be discussed in detail.

4.3.1. Financial Challenges

The six challenges extracted for factor 1 were additional costs as sustainable materials might need to be imported (84.5%), Contractor's inability to budget project (83.1%), Client's funding issues (82.2%), price inflation of sustainable materials (78.7%), Cost overruns due to tight schedule plans (66.4%) and owner's unwillingness to pay (51.5%). Numbers in parenthesis represent factor loadings. This cluster explains financial challenges encountered in sustainable construction delivery. These results match the research done by Robichaud and Anantatmula [11] who stated that cost is the most significant barrier to sustainable development. The authors also stated that in order to overcome this cost constraint, traditional project management practices must be modified by considering risk analysis of the cost and inflation of sustainable facilities. Furthermore, there should be continuous training and communication throughout the construction phase so that project participants can work together in an integrative manner rather than following conventional fragmented practices to achieve a cost-effective delivery of sustainable projects [208]. Moreover, public private partnership could be a solution to overcome client's funding issues [185].

4.3.2. Sustainable Materials and Technology

The five challenges extracted for factor 2 were need for special materials (93.9%), continuous updates for sustainable materials and technology (88.9%), complex technical systems with high levels of interdependence (86.6%), long lead time of sustainable materials (85.3%) and inadequacy of suppliers (83.2%). This cluster explains sustainable materials and technology challenges. Results of this study are similar to studies done in Hongkong and China who stated that sustainable building materials and technologies supply chain is immature due to absence of suppliers [189]. This is closely associated with the unavailability of special materials and technologies in the market because if suppliers are unavailable then the materials and technologies themselves will consequently be missing from the market as well. Furthermore, development of key sustainable supplier selection criteria can aid suppliers understand and enhance their ranking in the most important criteria to be able to win more bids [209].

4.3.3. Contractual

The five challenges extracted for factor 3 were lack of contractual incentives for contractors (83.6%), lack of early involvement of construction professionals (75.8%), lack of risk/profit sharing (74.6%), sustainability criteria are not considered in the bid evaluation (69.2%), lack of co-ordination amongst contracting parties (66.8%). This cluster explains the contractual challenges around sustainable construction delivery. Robichaud and Anantamula [11] recommends the use of an integrated project team to overcome these challenges. As a contractor will be included in the early stages to translate the owner's vision and help in design and estimation processes and can commence construction upon documents completion. This will emphasize co-ordination and communication between project participants throughout all planning, design and construction phases of the project. Contracts should also include incentives for implementation of sustainable practices such as cost-plus fee arrangements with special clauses which encourages contractors to bid for sustainable projects and eliminates the need of adding a sustainability risk premium to contracts [210].

4.3.4. Design

The six challenges extracted for factor 4 were frequent design changes/meetings by client and/or architect (74.6%), long and slow decision-making processes (65.9%), difficulty of compliance to sustainable codes (65.9%), weak scope definitions of sustainable construction requirements (61.6), extensive documentation and reporting (59.2%), incomplete sustainable specifications (51%). This cluster explains design challenges of delivering sustainable construction projects. Previous research has recommended the concept of design with a whole team approach in order to overcome this challenge. Where all project team members would help in the design phase, initial price estimation and construction document development [11]. The input of these people will ensure that the documents are comprehensive with strong scope definitions and complete specifications that comply to sustainable codes. Additionally, continuous communication is critical to overcome design changes encountered during the delivery of sustainable projects [210].

4.3.5. Lack of Experience

The five challenges extracted for factor 5 were shortage of skilled workforce (79.3%), limited experience in selection of sustainable construction procedures (75.1%), inadequate information about handling and storage of sustainable materials (63.6%), insufficient information about the performance quality of sustainable materials (61.7%), poor feasibility and risk management (55.2%). This cluster explains the challenges associated with the lack of experience in sustainable construction projects delivery. These results are in line with the argument provided by Ozorhon and Cinar [211] who claimed that the absence of skilled workforce who have sufficient expertise on how to handle sustainable materials, make it difficult to deliver successful sustainable projects. Owing to these concerns, it is important to conduct training sessions with a sustainable education component for project participants to ensure they know how to handle new technologies and materials, there should also be frequent meetings orchestrated by project managers to keep track of project progress with the entire workforce [11]. Furthermore, a well-articulated sustainability agenda for every project that entails information and standards will make it easier for contractors to successfully deliver sustainable projects [212].

4.3.6. Regulations

The three challenges extracted for factor 6 were lack of sustainable building codes and practices (89%), fragmented guidelines for procuring sustainable construction (86.7%), delays in government approvals for sustainable construction processes (83.7%). This cluster explains governmental regulations around sustainable construction. This factor implies that governments should resume a more active role in developing procurement guidelines and building codes in order to clearly define expectations from sustainable construction so that stakeholders can comply to them and successfully deliver projects. The same finding has been reached by Gou et al. [213] who stated that promotion of sustainable construction largely depends on government policies currently available. This study indicates that more efforts need to be conducted by governments worldwide to incentivize the construction industry to deliver successful sustainable projects.

4.3.7. Limited Organizational Awareness

The three challenges extracted for factor 7 were lack of knowledge, information and awareness (81.5%), Inability to relinquish traditional construction projects (69.8%), limited top management commitment and organizational leadership (57.9%). This cluster explains organizational awareness and commitment challenges towards sustainable construction. This is in line with the results of Chan et al. [185] who stated that if management don't perceive sustainability as a priority, it would be impossible to execute sustainable construction projects. In fact, Lam et al. [18] argued that there is critical relationship between the degree of support and commitment from senior management and the willingness to adopt sustainable practices. This factor is deeply rooted with the managers' resistance to change traditional construction management practices which leads to cost complications when delivering sustainable construction projects as mentioned in factor 1.

4.4. Selection Criteria

This section explains both traditional and sustainability-specific selection criteria of project delivery methods

4.4.1. Traditional Selection Criteria

The traditional PDM selection criteria are divided into five groups. The first group, cost related factors, is always at the centre of decision making when choosing the appropriate project delivery method. This group includes controlling cost growth by finishing the project within budget but not necessarily the cheapest cost [214]. In other cases, however, ensuing the lowest possible cost to complete a project is a crucial driver to the selection of the delivery method [215]. Furthermore, this group also extends to include cashflow concerns such as the desire of the owner to have early cost estimates which are essential for budgeting and financial planning as well as key business decisions [111]. It's important to note that these early estimates demand the involvement of construction professionals during the early phases of the project. Besides, the effectiveness of the PDM in delaying or minimizing expenditure rate is another important selection criterion especially if the owner suffers from a constrained cashflow or the agency's financial capabilities are limited [52]. Not only this, but the management of risks and the creation of a proper risk allocation structure that matches the project's participant's advantages to the tasks and transfers risk to contractor when

needed, are all significant selection factors of PDMs as they are critical to improving the efficiency of the organization and hence critical to the project's success [216].

The second group includes time related factors. Oyetunji and Anderson [22] have emphasized the criticality of completing within schedule to the success of a project. Similarly, Touran et al. [84] have argued that the most influential factor in selecting the project delivery methods is the achievement of aggressive schedule compression that ensures the shortest time to finish the project and controls time growth throughout the different phases of project execution. Moreover, Martin et al. [82] highlighted time constraints among the top six factors that affect the choice of project delivery methods in developing oil and gas economies. Additionally, the promotion of early procurement of long lead equipment, as well as materials, is an important factor as it affects the design phase and the time taken to get the approvals required in order to be able to start the project [111].

The third group is related to scope factors. Indeed, there is a broad consensus about the association of the success of a project with a well-defined scope that explains project features and technical specifications in sufficient details at the award of the design or construction contract [22]. In some cases, the requirement to have flexibility that eases the incorporation of some changes in the scope definition of the project is an important factor to consider when selecting the delivery method [92]. However, changes in general have a great impact on the total cost growth of a project, therefore it is essential to select a delivery method that best manages and capitalizes on expected low levels of these change orders [85]. The fourth group is the owner and contractor related factors. Liu et al. [79] have concluded that responsibility, owner's willingness to be involved, owner's inhouse technical capability, risk allocation and owner's willingness to control over design are the top 5 owner's related factors that impact the project delivery selection. Furthermore, the contractor's capabilities which include their experience in handling similar projects, their ability to manage the project financially as well as their co-ordination skills and design capabilities are all key factors for the project's success under different delivery methods [217].

The fifth group is related to project's characteristics. Demetracopoulou et al. [52] emphasized the importance of well-known site conditions in the project as a decision driver in the choice of PDM. As, this will limit the amount of significant field changes

and will mitigate any site condition risks. In addition to this, the effectiveness of delivery systems in ensuring project confidentiality and protecting the secrecy of the organization's goals and technologies is another important selection criterion [22]. Moreover, the quality performance of a project is also another important selection factor as it impacts the client's satisfaction level with the outcomes of the project [74]. Table 9 summarizes the traditional selection criteria list of PDMs.

Table 9. Traditional Selection Criteria Groups and Tags

Group	Traditional Selection Criteria	Tags	Sources
Cost	Control cost growth	Cost1	[22, 61, 80, 88, 89, 111, 215, 218, 219]
	Ensure lowest cost	Cost2	[82, 85, 86, 111, 214, 215, 218]
	Facilitate early cost estimates	Cost3	[22, 111, 214]
	Reduce risks	Cost4	[22, 111, 114, 215, 220, 221]
	Delay or minimize expenditure rate	Cost5	[22, 52, 111, 214]
Time	Control time growth	Time1	[22, 89, 91, 98, 111]
	Ensure shortest time	Time2	[22, 82, 84, 111, 214]
	Promote early procurement of material and equipment	Time3	[22, 111]
Scope	Capitalize on well-defined scope	Scope1	[22, 111, 147, 222]
	Efficiently utilize poorly defined scope	Scope2	[22, 111]
	Ease change incorporation/flexibility	Scope3	[22, 92, 111, 147, 222]
	Capitalize on expected low levels of change orders	Scope4	[22, 85, 111, 223]
Owner and contractor	Owner's willingness to take risks	Owner1	[79, 147, 224]
	Owner's available human resources	Owner2	[56, 92, 149, 224]
	Owner's willingness to be involved	Owner3	[22, 79, 147]
	Contractor's capability and experience	Owner4	[109, 147, 149, 224]
Project's characteristics	Capitalize on project confidentiality	Project1	[22, 111, 215]
	Capitalize on familiar project conditions	Project2	[22, 111]
	Efficiently co-ordinate project complexity	Project3	[22, 92, 111, 147, 222, 225]
	Capitalize on Project's quality performance	Project4	[56, 61, 215, 226]

4.4.2. Sustainability-Specific Selection Criteria

The delivery processes of sustainable construction projects are more complex and involve more interdisciplinary interactions than their traditional counterparts, this necessitates the development of sustainability-specific criteria for sustainable project delivery selection [227]. Korkmaz et al. [105] presented that the integration level achieved in the delivery process affects the end goals of a project, specifically the sustainability goals. Where the integration level is an umbrella that covers characteristics such as early involvement of key participants, collaborative decision making and control, intensified planning, as well as joint development of project goals by project participants, shared risk and reward and liability waivers among key participants [42]. In fact, integration has been one of the main recommendations in order to overcome the 7 categories of sustainable construction projects delivery challenges identified by Ahmed and El-Sayegh [161] in the previous section as early involvement of contractors and continuous communication helps mitigate design and financial challenges as well as optimize sustainability goals.

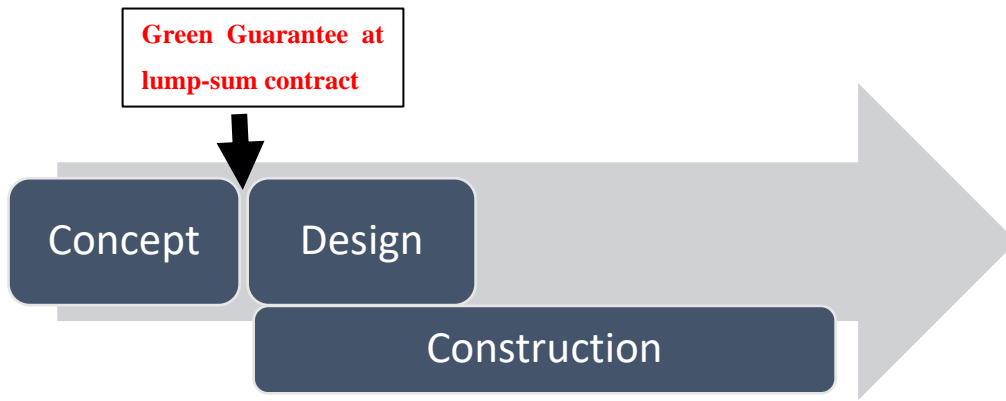
The technology level is also a big catalyst for sustainable project delivery selection, yet still remains largely unexplored. In fact, the integration of technology increases the efficiency of the project's lifecycle through sophisticated energy simulation and life-cycle analysis tools, it is key to providing effectiveness from the initial design to the postconstruction phase [228]. Moreover, the integration of technology helps manage the method of involvement and communication of the project participants and improves the team integration [58]. Technology is also important for project delivery selection because if the level of technology accessibility is low, the quality, cost, duration and risk sharing would be affected as well especially if the PDM is DB where the contractors will be allowed to undertake design and construction due to the close relationship between design and construction [100]. Indeed, Li et al. [86] concluded that technical and innovation related factors are positively correlated to the implementation of Green Mark certified projects. Besides, as per the recommendations to overcome the challenges of sustainable materials and technology, investment in scientific and technological research in this field may help promote cost reduction. Additionally, the ability to achieve sustainability goals is another criterion that needs to be emphasized when selecting the PDM. In fact, the need to converge the themes of sustainability and project management practices such as PDMs has been highlighted by

wang et al. [229]. Indeed, the traditional selection criteria already include the economic aspect, but the significance of the social aspects of sustainability with respect to the selection of project delivery method will be further studied in this research. The criteria that contribute to the achievement of green team in a construction project include management of the relationships between team members to minimize adversarial relationships as well as encouraging diversity and providing new opportunities [230].

Another criterion for the selection of sustainable project delivery selection is the green liability as explained by Molenaar [231] which includes the ultimate responsibility to deliver sustainable goals and the communication methods used by project participants to ensure the role of everyone in achieving this responsibility as well as the point at which the responsibility for obtaining a green certification is being assigned in the project delivery process. In fact, Enache-Pommer and Horman [232] identified the early timing and responsibility assignment of sustainability goals among the top three attributes that contribute to successful delivery of green construction projects. Additionally, green guarantee is the point at which there is a contractual responsibility to deliver the owner's desired green certification; choosing a delivery method that provides an early green guarantee is a critical selection criterion that will ultimately impact the success rate of sustainable construction projects [231]. Figure 5 represents a green guarantee model that further illustrates the green guarantee period difference between alternative delivery methods such as DBB and DB under a lump-sum contract.



5a. Green Guarantee for DBB with Lump-Sum Contract



5b. Green Guarantee for DB with Lump-Sum Contract

Figure 5. Green Guarantee Model

Green contract provisions also affect the PDM selection. For instance, the payment provisions should be carefully articulated to achieve sustainability goals [233]. Molenaar [231] concluded that in cases where the scope and cost of project is negotiated such as in Guaranteed Maximum Price (GMP) with shared risks and rewards clauses, the success rate of sustainability objectives is higher. This also satisfies the recommendations provided in the earlier section to overcome contractual challenges through incentives to implement sustainable practices such as cost-plus fee arrangements. Additionally, green contract provisions include the procurement approaches that best accomplish sustainability objectives. Different delivery methods are usually associated with different procurement approaches. For example, low bid is usually reserved for DBB while qualification-based selection usually goes with DB and CMR while integrated project delivery evaluates several factors to make the contract award [105]. The timing associated with the contract pricing provisions is also another key selection criterion. For instance, if the contract is awarded after the design phase is complete, it leaves little room to any changes or enhancements to attain the required sustainability goals as it would require a substantial increase to the project's cost. Therefore, it is essential to have flexible timing of the payment provisions to allow the contractor to verify the scope against budget constraints [234]. Table 10 summarizes the constructs for new selection criteria of PDMs.

Table 10. Sustainability-Specific Criteria

Group	New Selection Criteria	Tags	Sources
Level of Integration	Early Involvement of key participants	Intg1	[42, 58, 105, 146, 161, 235, 236]
	Collaborative Decision Making & Control	Intg2	[42, 58, 105, 161, 235, 236]
	Joint Development of Project Goals	Intg3	[42, 58, 105, 161, 235, 236]
	Intensified Planning	Intg4	[42, 58, 105, 161, 235, 236]
Green Team	Liability waivers among team players	GT1	[42, 58, 105, 235, 236]
	Minimize adversarial relationships between team members	GT2	[229],[230], [237]
	Capitalize on diversity and new opportunities	GT3	[229, 230]
	facilitates open communication between team members	GT4	[42, 58, 105, 161, 235-237]
Green Liability	Allow for the transfer of green liability	GL1	[231, 232]
	Promote early assignment of green certification responsibility	GL2	[231, 232]
	Promote early green guarantee	GL3	[231, 232]
Green Contract	Capitalize on awards and contractual incentive fees	GC1	[231, 233, 234]
	Green Procurement Approach – Allows for Qualification Based Selection	GC2	[231, 233, 234]
	Contract Payment Provisions - Facilitate flexible payment provisions – Ability to negotiate scope and cost	GC3	[231, 233, 234]
	Allow shared risks and rewards	GC4	[42, 58, 105, 235, 236]
Technology and innovation	Capitalize on innovation	Tech1	[86],[228],[100, 238]
	Ability to use technology to enhance communications	Tech2	[86],[228],[100]
	Improve the ability to use the full potential of BIM	Tech3	[86],[228],[100], [239, 240]
	Efficiently utilize advanced technological tools to achieve sustainable goals	Tech4	[86],[228],[100]

4.5. Project Success Criteria

Many studies have explored the criteria that define the success of a construction project. Generally, it is very hard to develop a universal set of project success criteria as each project is unique in terms of its type and complexity. It also depends on the perceptions of the project's stakeholders to develop and prioritize the dimensions of their project success [241]. Nevertheless, several frameworks and definitions have been developed throughout the years to measure project success. Earlier definitions conceptualized project success as a uni-dimensional construct that focused on achieving budget, quality and time constraints which was also referred to as the 'iron triangle' [242]. But as time progressed, project success was viewed more as a multi-dimensional concept with other dimensions [243-245]. Among these other dimensions is team effectiveness which is a cluster of other sub dimensions such as the working environment for team members and the inter-personal relationships, their satisfaction and productivity levels as well as their loyalty towards achieving project goals [246, 247]. Similarly, Bryde [248] also advocated for the importance of team effectiveness as a valuable component in the project success dimensions framework.

Furthermore, among the pioneering frameworks for project success is the work of Shenhar et al. [249] who listed 4 clusters of success dimensions; efficiency in terms of meeting schedule and budget goals, impact on customer in terms of meeting customer needs and customer benefits in end products' performance, business success in terms of market share and commercial value as well as fulfilment of the business strategic short term and long-term goals, and the last cluster included future opportunities in terms of advances in technological infrastructure as well as market opportunities. In fact, this 4 clusters framework along with the fifth cluster of team effectiveness has been cited in the work of Mir and Pinnington [250] who analysed the relationship between project management performance and project success. An alternative framework for measuring project success was developed by Jha and Iyer [251] who presented two categories; the first group was objective criteria which included satisfying budget, schedule and specification targets, while the second group was subjective criteria which included the overall satisfaction of customer and other team players as well as adding value to the client and improving their life quality. Moreover, another dimension that has been gaining a lot of attention recently is sustainability.

With more emphasis placed on the social and environmental pillars of sustainability [252, 253] as the economical pillar was considered in the model developed by Shenhar et al. [249] as a sub dimension of the business success and future opportunities clusters. Similarly, Khalifeh et al. [254] argued that sustainability should be incorporated as a component of the project success criteria framework. Table 11 summarizes the constructs for construction project success criteria.

Table 11. Project Success Criteria

Group	Project Success criteria	Tags	Sources
Efficiency	Meeting Cost Goals	Eff1	[244, 245, 249, 250]
	Meeting Time Goals	Eff2	
	Meeting Quality Goals	Eff3	
	Meeting Scope Goals	Eff4	
Impact on Client	Satisfying Client's Needs	Client1	[244, 245, 249, 250]
	Adding Value to Client	Client2	
	Improvement of the Client's Quality of Life	Client3	
Team Effectiveness	Motivation of Employees	Team1	[241],[247],[246],[248]
	Improvement of Learning and Team Development	Team2	
	Team Loyalty to Achieving Project's Goals	Team3	
Sustainability	Achieving Sustainable Goals	Sus1	[252],[253, 254]
	Contribute to Success of Future Sustainable Projects	Sus2	
	Better Sustainable Management Practices	Sus3	

4.6. Theoretical Framework

The aforementioned literature has provided the foundation to build the theoretical models in this research. The traditional criteria list for selecting PDMs is determined by 5 groups: cost, time, scope, owner and contractor, and project's characteristics. While project success is determined by 4 groups which are: efficiency, impact on client, team effectiveness and sustainability. Each identified dimension has several key attributes that were also extracted from literature. Figure 6 presents the theoretical framework of the traditional selection criteria and project success criteria where each arrow represents the direction of the hypothesized influences in the structural model as suggested by literature. Similarly, Figure 7 presents the theoretical framework of the new selection criteria and project success criteria. Where the new selection criteria is determined by 5 groups which are: level of integration, green liability, green team, green contract, technology and innovation. It is also worth noting that both models are reflective where the exogenous variables are realized from latent to exogenous variables. These two frameworks will help predict the general hypothesis that traditional and sustainability-specific selection criteria are significant for the success of sustainable construction projects. In order to achieve this, the following ten hypothesis statements need to be predicted:

- H₁-The inclusion of cost-related criteria in the selection of project delivery methods is significant to achieve project success criteria: efficiency, impact on client, team effectiveness, sustainability
- H₂-The inclusion of time-related criteria in the selection of project delivery methods is significant to achieve project success criteria: efficiency, impact on client, team effectiveness, sustainability
- H₃-The inclusion of scope-related criteria in the selection of project delivery methods is significant to achieve project success criteria: efficiency, impact on client, team effectiveness, sustainability
- H₄-The inclusion of the owners and contractor's characteristics criteria in the selection of project delivery methods is significant to achieve project success criteria: efficiency, impact on client, team effectiveness, sustainability.

- H₅-The inclusion of the project's characteristics criteria in the selection of project delivery methods is significant to achieve project success criteria: efficiency, impact on client, team effectiveness, sustainability
- H₆-The inclusion of the level of integration criteria in the selection of project delivery methods is significant to achieve project success criteria: efficiency, impact on client, team effectiveness, sustainability
- H₇-The inclusion of the green team criteria in the selection of project delivery methods is significant to achieve project success criteria: efficiency, impact on client, team effectiveness, sustainability.
- H₈-The inclusion of the green liability criteria in the selection of project delivery methods is significant to achieve project success criteria: efficiency, impact on client, team effectiveness, sustainability.
- H₉-The inclusion of the green contract criteria in the selection of project delivery methods is significant to achieve project success criteria: efficiency, impact on client, team effectiveness, sustainability.
- H₁₀-The inclusion of the technology& innovation criteria in the selection of project delivery methods is significant to achieve project success criteria: efficiency, impact on client, team effectiveness, sustainability.

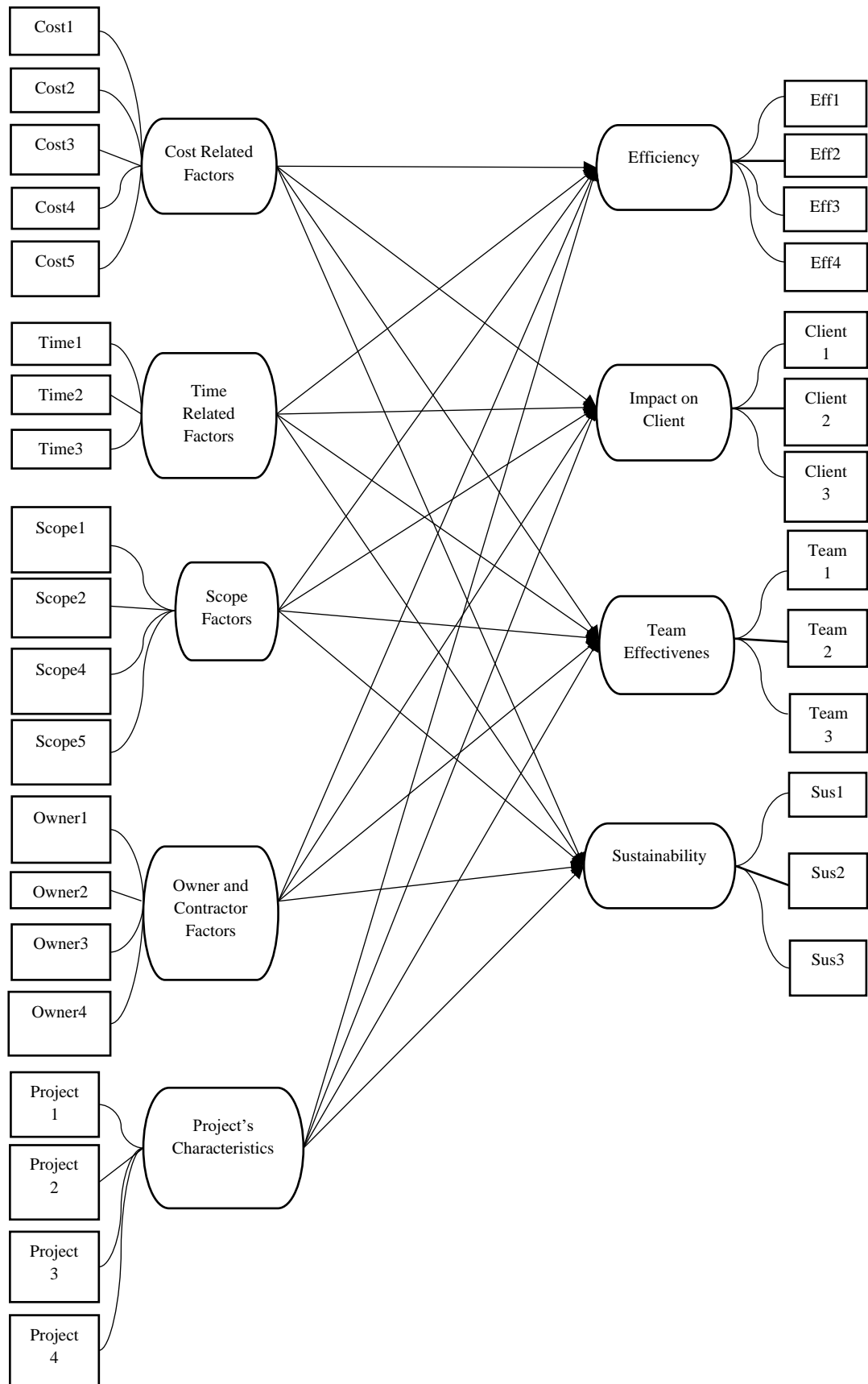


Figure 6. Traditional Selection Criteria Theoretical Framework

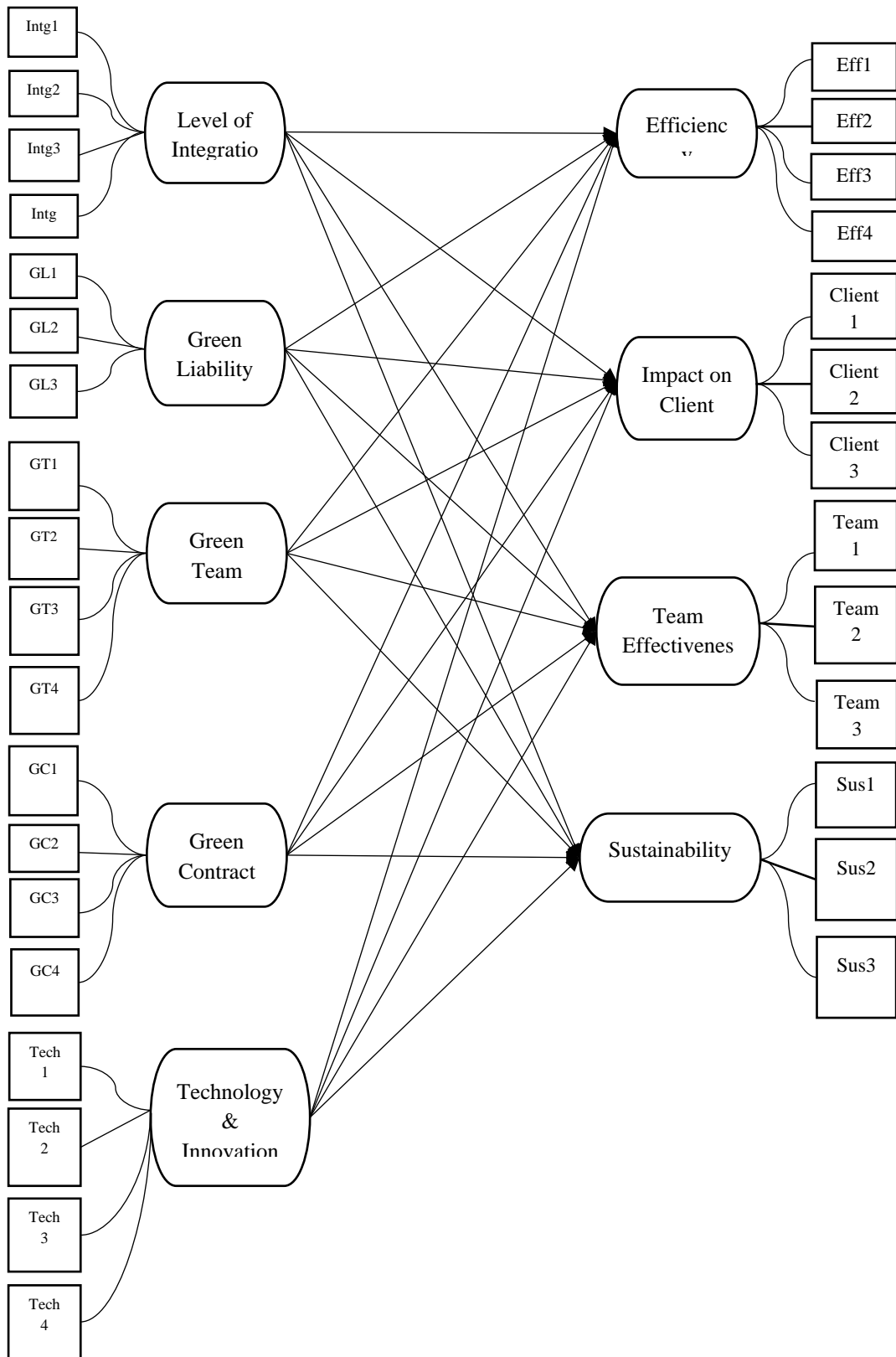


Figure 7. Sustainability-Specific Selection Criteria Theoretical Framework

4.7. PLS-SEM Final Results

110 responses were collected from the survey out of 250 surveys that were administered online, representing a 44% response rate. The results showed that 51.8% of the respondents worked in international companies while 48.2% worked in local companies. Moreover, 49.1% of the respondents had 5-10 years of experience while 11.8% had more than 20 years of experience in the field of construction.

4.7.1. Traditional Selection Criteria Structural Model

Prior to the derivation of the final structural model of the traditional selection criteria, the reliability and validity of the measurement model were assessed based on the recommendations explained in the methodology. Table 12 shows the CR, AVE and Cronbach's alpha of the latent variables and the results have revealed that all values exceed their respective thresholds that were suggested by Qu [255] where all CR values were more than 0.6, all AVE values were more than 0.5 and all Cronbach's alpha values were more than 0.5. Additionally, the factor loadings of the confirmatory factor analysis were computed and compared to the threshold of the 0.5 value (Table 13). The results have shown that 'cost 2' which is 'ensure lowest cost' is not significant as the factor loading is only 0.021 and needs to be eliminated from the model. Moreover, the factor loading of 'scope 4' which is 'capitalize on expected low levels of change orders' is 0.274 which further necessitates its elimination from the final structural model. Similarly, the factor loading of 'owner1' which is the 'owner's willingness to take risks' is 0.435 which is slightly less than the threshold of 0.5 will also be eliminated from the final model. Furthermore, 5000 bootstrap samples were evaluated as suggested by Hair et al. [157] to predict the significance of the path coefficients in the final structural model. The results of this bootstrap technique have revealed that all the hypothesized paths had t-values greater than 1.96 and were statistically significant at the 0.05 level (Table 14). Thus, all paths of the hypothesized model of the traditional selection criteria were supported.

Table 12. CR, AVE and Cronbach's alpha of Traditional Selection Criteria Latent Variables

Latent Variable	CR	AVE	Cronbach's Alpha
Cost	0.832	0.554	0.729
Time	0.882	0.714	0.8
Scope	0.833	0.585	0.712
Owner and Contractor	0.843	0.586	0.74
Project Characteristics	0.834	0.56	0.737
Efficiency	0.883	0.654	0.83
Impact on Client	0.811	0.588	0.65
Team Effectiveness	0.924	0.802	0.875
Sustainability	0.926	0.807	0.88

Table 13. Factor Loadings

	Factor loadings
Cost-> Cost1	0.801
Cost-> Cost2	0.021
Cost-> Cost3	0.751
Cost-> Cost4	0.638
Cost-> Cost5	0.779
Time-> Time1	0.84
Time-> Time2	0.883
Time-> Time3	0.809
Scope -> Scope1	0.917
Scope -> Scope2	0.857
Scope -> Scope3	0.83
Scope -> Scope4	0.274
Owner & Contractor -> Owner1	0.435
Owner & Contractor-> Owner 2	0.837
Owner & Contractor -> Owner3	0.839
Owner & Contractor -> Owner4	0.867
Project's characteristics -> Project1	0.822
Project's characteristics -> Project2	0.631
Project's characteristics -> Project3	0.77
Project's characteristics -> Project4	0.755
Efficiency -> Eff1	0.701
Efficiency -> Eff2	0.816
Efficiency -> Eff3	0.874
Efficiency -> Eff4	0.834
Impact on client -> Client1	0.775
Impact on client -> Client2	0.761
Impact on client -> Client3	0.765
Team effectiveness -> Team1	0.843

Team effectiveness-> Team2	0.924
Team effectiveness-> Team3	0.917
Sustainability -> Sus1	0.873
Sustainability -> Sus2	0.905
Sustainability -> Sus3	0.917

Table 14. Path Values

	Path Values	T Statistics (O/STDEV)	P Values
Cost -> Impact on client	0.363	3.725	0
Cost -> Efficiency	0.504	5.613	0
Cost -> Sustainability	0.552	8.116	0
Cost -> Team effectiveness	0.485	5.777	0
Time -> Impact on client	0.367	3.899	0
Time -> Efficiency	0.323	3.456	0.001
Time -> Sustainability	0.297	3.479	0.001
Time -> Team effectiveness	0.336	3.602	0
Scope -> Impact on client	0.337	3.924	0
Scope -> Efficiency	0.365	4.104	0
Scope -> Sustainability	0.242	2.42	0.016
Scope -> Team effectiveness	0.258	2.885	0.004
Owner & Contractor -> Impact on client	0.353	3.903	0
Owner & Contractor-> Efficiency	0.443	4.985	0
Owner & Contractor -> Sustainability	0.33	3.437	0.001
Owner -> Team effectiveness	0.492	5.373	0
Project's characteristics -> Impact on client	0.558	8.458	0
Project's characteristics -> Efficiency	0.614	9.945	0
Project's characteristics -> Sustainability	0.428	5.46	0
Project's characteristics -> Team effectiveness	0.593	9.048	0

4.7.2. Sustainability-Specific Selection Criteria Structural Model

Similar analysis was done to assess the validity and reliability of the measurement model of the sustainability-specific selection criteria. Table 15 shows the values of the AVE, CR and Cronbach's alpha of all the latent variables. The results showed that all AVE values exceeded the threshold of 0.5, all CR values exceeded the threshold of 0.6 and all Cronbach's alpha exceeded the threshold of 0.5. Besides, the factor loadings of all exogenous variables with respect to their latent variables exceeded the threshold of 0.5 as shown in Table 16 and therefore, no exogenous variable will be eliminated from the final structural model as they all proved to be significant. The results of the bootstrapping technique that was conducted to predict the significance of the hypothesized path coefficients in the final structural model indicated that all the hypothesized paths were significant at the 0.05 level as all t-values were greater than 1.96 and hence all the hypothesized paths of the final model were supported (Table 17).

Table 15. AVE, CR and Cronbach's alpha of Sustainability-Specific Selection Criteria Latent Variables

Latent variable	AVE	CR	Cronbach's alpha
Level of integration	0.654	0.883	0.822
Green team	0.59	0.852	0.771
Green liability	0.798	0.922	0.874
Green contract	0.59	0.852	0.77
Technology & Innovation	0.705	0.905	0.86
Efficiency	0.65	0.881	0.82
Impact on client	0.629	0.835	0.706
Team effectiveness	0.808	0.927	0.882
Sustainability	0.817	0.93	0.82

Table 16. Factor Loadings

	Factor loadings
Level of integration-> Intg1	0.83
Level of integration-> Intg2	0.89
Level of integration-> Intg3	0.751
Level of integration-> Intg4	0.755
Green Team-> GT1	0.778
Green Team-> GT2	0.72
Green Team-> GT3	0.779
Green Team-> GT4	0.794
Green Liability-> GL1	0.861
Green Liability-> GL2	0.913
Green Liability-> GL3	0.905
Green Contract-> GC1	0.778
Green Contract-> GC2	0.784
Green Contract-> GC3	0.739
Green Contract-> GC4	0.769
Technology & Innovation-> Tech1	0.816
Technology & Innovation-> Tech2	0.84
Technology & Innovation-> Tech3	0.814
Technology & Innovation-> Tech4	0.887
Efficiency -> Eff1	0.747
Efficiency -> Eff2	0.837
Efficiency -> Eff3	0.799
Efficiency -> Eff4	0.84
Impact on client -> Client1	0.848
Impact on client -> Client2	0.795
Impact on client -> Client3	0.732
Team effectiveness-> Team1	0.872
Team effectiveness -> Team2	0.931
Team effectiveness-> Team3	0.893
Sustainability -> Sus1	0.892
Sustainability -> Sus2	0.912
Sustainability -> Sus3	0.907

Table 17. Path Values

Path	Path Value	T (O/STDEV)	Statistics	P Values
Level of integration -> Impact on client	0.537		6.352	0
Level of integration -> Efficiency	0.6		8.223	0
Level of integration -> Sustainability	0.578		8.33	0
Level of integration -> Team effectiveness	0.628		9.917	0
Green team -> Impact on client	0.512		5.729	0
Green team -> Efficiency	0.474		6.042	0
Green team -> Sustainability	0.645		10.242	0
Green team -> Team effectiveness	0.659		9.438	0
Green liability -> Impact on client	0.34		3.442	0.001
Green liability -> Efficiency	0.479		7.229	0
Green liability -> Sustainability	0.658		10.398	0
Green liability -> Team effectiveness	0.619		10.794	0
Green contract -> Impact on client	0.329		3.14	0.002
Green contract -> Efficiency	0.474		6.73	0
Green contract -> Sustainability	0.457		5.496	0
Green contract -> Team effectiveness	0.428		5.052	0
Innovation & technology -> Impact on client	0.473		5.078	0
Innovation & technology -> efficiency	0.534		8.71	0
Innovation & technology -> Sustainability	0.623		9.087	0
Innovation & technology -> Team effectiveness	0.628		9.098	0

4.8. Discussions of the PLS-SEM Results

As far as the traditional selection criteria framework is concerned, the results have shown that ‘cost1’ which is ‘control cost growth’ has the highest loading factor in the cost group. This outcome is of no surprise as this criterion is frequently cited by various papers in the delivery selection process as one of the most important parameters that affect the decision process in the project [84]. While ‘time2’ which is ‘ensure shortest time’ has the highest loading factor in the time group. This is due to the fact that achieving the project’s goals in the shortest possible duration, schedule compression and overcoming time constraints is a significant criterion when selecting the appropriate project delivery method [256]. Furthermore, ‘scope1’ which is ‘capitalize on well-defined scope’ is the criterion with the highest loading in the scope group. This can be justified as having a well-defined scope will minimize the risk of changes that may otherwise cause cost and time overruns in the project [111]. Moreover, ‘owner 4’ which is ‘contractor’s capability’ has the highest loading in the owner and contractor group. This puts emphasis on the technical ability, project experience and management ability of the contractor required to successfully execute and deliver the project [74]. Additionally, ‘project1’ which is ‘ensure project confidentiality’ has the highest loading in the project’s characteristics group. This supports the results extracted from literature which highlighted the importance of selecting a delivery method that is effective in protecting the secrecy of the projects documents and objects as well as proprietary technology [22].

On the other hand, some criteria had low loadings and were eliminated from the model such as ‘ensure lowest cost’, ‘owner’s willingness to take risks’ and ‘capitalize on expected low levels of change orders’. This can be attributed to the fact that new dimensions have been added to project success such as sustainability, where it is more significant to have a flexible scope that allows for negotiation and a procurement approach that relies on qualification-based selection rather than lowest cost [231]. Besides, all hypothesized paths of the model proved to be significant which confirms the importance of the traditional selection criteria of project delivery methods in achieving the overall project success. The results have also shown that project’s characteristics criteria group for project delivery selection has the highest path coefficient in relation to achieving efficiency, team effectiveness and positive impact

on client (0.614, 0.558 and 0.593 respectively). But cost group for project delivery selection has the highest path coefficient (0.552) in relation to achieving sustainability in a project. This stems from the fact that the main challenges of sustainable construction projects are financial [161] and that's why when choosing the project delivery method, it is significant to take into account their effectiveness in controlling cost growth and reducing financial risks.

While for the sustainability-specific selection criteria framework, the results have shown that 'Intg2' which is 'collaborative decision-making and control' has the highest factor loading in the criteria group of level of integration. For the green team criteria group, the highest factor loading belonged to 'GT4' which is 'open communication between team members'. This is due to the fact that collaboration and open communication encourage transparency that helps develop trust and respect among team players so that they can share information and knowledge that would ultimately enhance the success rate of a project [119]. Likewise, 'GL2' which is 'promote early assignment of green certification responsibility' has the highest factor loading in the green liability criteria category. This is in line with the results concluded by Molenaar [231] and other researchers such as Pommer and Horman [232] who emphasized the significance of this criterion to achieve successful sustainable construction projects. Plus, 'GC2' which is 'allow for qualification-based selection' has the highest loading in the green contract criteria group. This highlights the fact that construction professionals are more aware now of the significance of encouraging procurement approaches that rely on qualifications rather than lowest cost in order to achieve optimum project success rates.

As for the technology and innovation criteria group, 'Tech4' which is 'efficiently utilize technological tools to achieve sustainable goals' has proved to have the highest loading. This emphasizes the need to invest in sophisticated technological tools and select appropriate delivery methods that proficiently use them to achieve sustainable goals and successfully deliver sustainable construction projects. Additionally, all hypothesized paths of the model proved to be significant which confirms the importance of the new selection criteria of project delivery methods in achieving the overall project success. The results have also shown that level of integration criteria group for project delivery selection has the highest path coefficient with relation to

impact on client and efficiency (0.537 and 0.6 respectively). This comes as no surprise since integration has been highlighted in many previous studies as a response plan to optimize the success of sustainable construction projects through collaborative decision making, intensified planning and early involvement of key participants. All of which are key criteria to meeting project's goals in terms of cost, time and scope as well as ultimately satisfying the client's needs [223]. While to optimize team effectiveness, green team criteria group for project delivery selection has the highest path coefficient (0.659). Indeed, the key to motivating employees and improve their team development can only happen through open communication, minimizing adversarial relationships as well as allowing them the opportunity to embark on new opportunities [230]. With regards to sustainability, green liability criteria group for project delivery selection has the highest path coefficient (0.658). This is due to the fact that promoting early green guarantee, early assignment of green certification responsibility as well as green liability transfer will ultimately help develop better sustainable management practices and contribute to the success of sustainable projects in the future [232].

4.9. Summary and Conclusions

The construction industry is expanding in terms of the size and complexity of its projects which contributes to a great deal of environmental pollution and emission of greenhouse gases. This in turn has created more awareness and has led several countries specifically UAE to encourage the shift towards sustainable construction. However, with the introduction of sustainable construction, challenges affiliated with construction projects have been increasing and adding to the complexity of projects. Therefore, there is a need to identify and categorize the challenges associated with the delivery of sustainable construction projects. Thirty-three challenges were identified through extensive literature review and used in a survey designed to measure the significance of each of the identified challenges. Out of the 33 challenges extracted from literature, factor analysis revealed 7 clusters named in other of significance as financial, sustainable materials and technology, contractual, design, lack of experience, regulations, limited organizational awareness. The financial cluster accounted for 30% of the variance in the data which matches previous studies that claim that financial challenges are the most significant barrier to sustainable development. To address financial challenges, traditional management practices must be relinquished to

emphasize the importance of communication, collaboration and the development of an integrated team. While for sustainable materials and technology challenges, key selection criteria for sustainable suppliers should be developed to ensure the adequacy of suppliers selected in sustainable construction projects. Furthermore, for the contractual challenges, there should be contractual incentives to encourage implementation of sustainable construction as well as the use of an integrated team approach. Moreover, for the design challenges, it is recommended to design with a whole team approach so that project participants can help in design, price estimation and construction document development. For the lack of experience challenges, regular training sessions with a particular focus on sustainable construction education should be conducted along with a well-articulated sustainability agenda attached to every project to aid contractors in successfully delivering projects. For the regulations challenges, there is a need to further develop procurement guidelines, building codes and practices to incentivize the construction industry to deliver successful sustainable construction projects. Finally, for the limited organizational awareness challenges, there is a need for proper support and commitment from senior management to come up with innovative approaches to integrate the whole project team together and implement management practices that will help to successfully deliver sustainable construction projects.

Post identification of the challenges, the results paved the way to determine sustainability-specific criteria to be added to the traditional selection criteria list for project delivery methods in sustainable construction. A correlation was modelled between the traditional and sustainability-specific selection criteria exogenous variables and their corresponding latent variables. Where the hypothesized paths between traditional and sustainability-specific selection criteria of project delivery methods and the criteria of sustainable construction project success were evaluated and finally a PLS-SEM was created to be used as a guidance tool to develop a governing selection criteria system for project delivery methods in sustainable construction projects. The results have concluded that the top sustainability-specific criteria developed were: level of integration, green contract, green liability, green team, technology and innovation. Moreover, 3 of the traditional selection criteria were deemed insignificant as they had loading factors that were less than 0.5 which were: ensure lowest cost, capitalize on expected low levels of change orders and owner's

willingness to take risks. Furthermore, the results have confirmed that all the sustainability-specific selection criteria were significant with loading factors greater than 0.5. Additionally, all hypothesized paths in both the traditional and sustainability-specific selection criteria frameworks were significant which confirms the importance of the traditional and sustainability-specific selection criteria of project delivery methods in optimizing project success. Moreover, in the sustainability-specific selection criteria framework, the level of integration criteria group had the highest path coefficient in relation to achieving efficiency and impact on client. While green team had the highest path coefficient in relation to achieving team effectiveness and lastly, green liability criteria group had the highest path coefficient in relation to achieving sustainability in a construction project.

Chapter 5. Assessment of Criteria Weights and Effectiveness of Project Delivery Methods

Existing literature has extensively studied the weights of traditional selection criteria using different statistical tools. However, with the complex challenges of sustainable construction projects delivery presented earlier and as the selection criteria for project delivery methods have now expanded with the addition of sustainability-specific criteria generated in the previous chapter, it becomes rather essential to assess the weights of these sustainability-specific criteria and also reassess the weights of the traditional selection criteria that may no longer be the same as in traditional construction projects. Therefore, this chapter aims to assess the relative importance and the weights of the traditional and sustainability-specific criteria in order to establish priority amongst the criteria for clients of sustainable construction projects. Furthermore, this chapter also illustrates the effectiveness of the three most common project delivery methods (DBB, DB and CMR) with regards to the comprehensive list of selection criteria.

Sections 5.1-5.3 are extracted from a manuscript under review titled “Assessment of Selection Criteria for Project Delivery Methods in Sustainable Construction” in the journal *Engineering, Construction and Architectural Management*. While, sections 5.4 and 5.5. are extracted from a manuscript under review in the *ASCE Journal of Construction Engineering and Management* with the title of “Multi-Criteria Decision Support Model for Selecting the Appropriate Project Delivery Method in Sustainable Construction Projects”.

5.1. Identified Selection Criteria

Figure 8 summarizes the final selection criteria for project delivery methods in sustainable construction as per the results mentioned in the previous chapter. Thirty-six criteria were identified in total which were divided into 2 criteria: traditional and sustainability-specific. These two criteria were further subdivided into 5 groups each. The traditional criteria included a total of 17 selection criteria, while the sustainability-specific criteria included a total of 19 selection criteria.

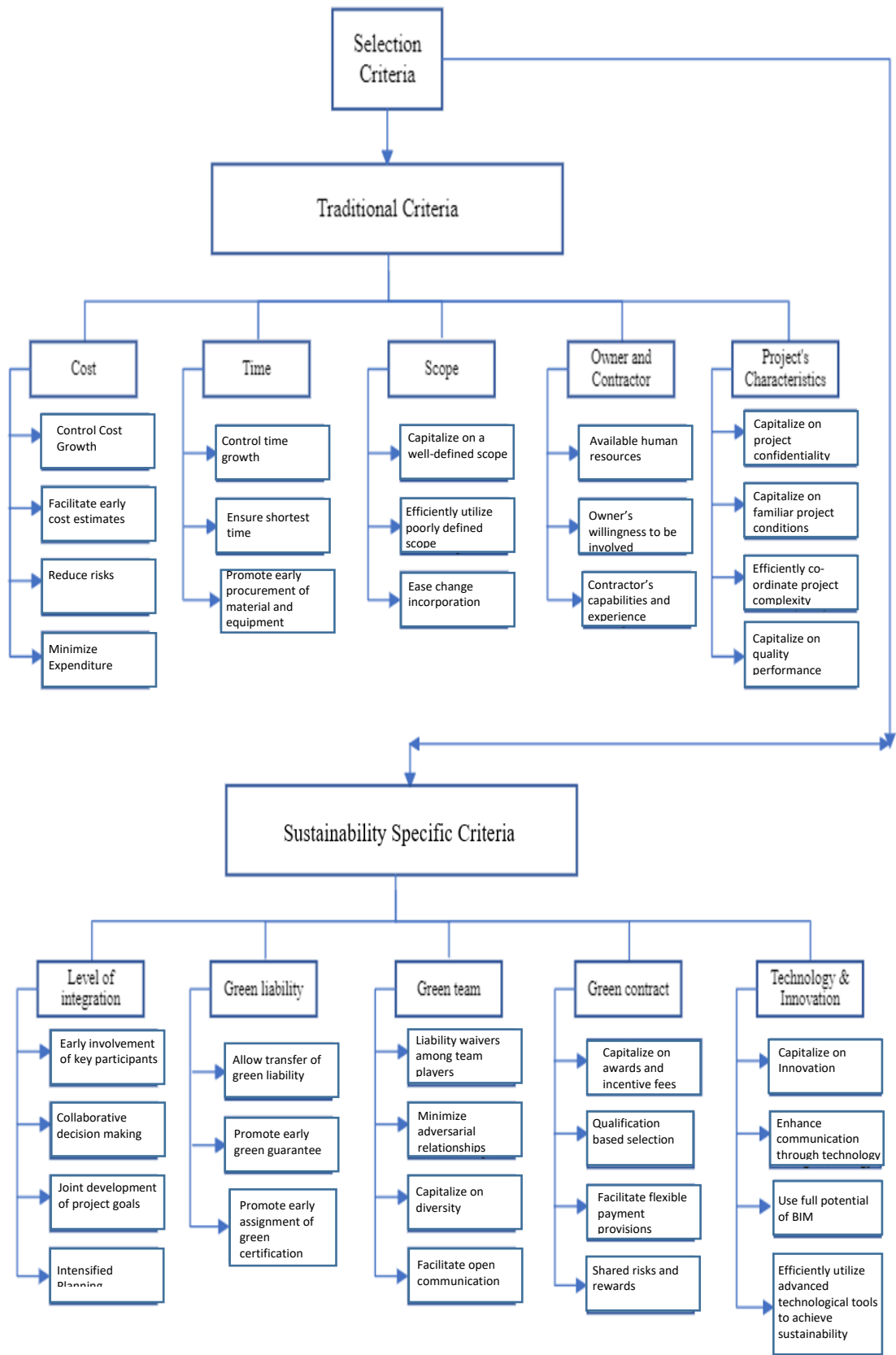


Figure 8. Traditional and Sustainability-Specific Selection Criteria

5.2. Assessment of Selection Criteria Weights

Seventy-five surveys were sent out to construction specialists, of which 30 complete responses were received. This demonstrates a response rate of 40%. 14 of the respondents (46.7%) work in international companies while 16 work in local companies (53.3%). Additionally, 33.3% of the respondents had 5-10 years of experience. Also 50% of the respondents work in the buildings industry. 50% of the respondents were contractors and 40% work on projects with average size more than 500 million.

The survey's comprehensive analysis is demonstrated in Table 18 and Table 19, which shows the main groups (traditional and sustainability-specific) and the criteria in each group with their weights based on local and global priorities. The traditional selection criteria consist of 5 groups: cost, time, scope, owner and contractor characteristics, project's characteristics with weights equal to 0.249, 0.208, 0.252, 0.165 and 0.126 respectively. While the sustainability-specific selection criteria also consist of 5 groups: level of integration. Green liability, green team, green team, technology & innovation with weights equal to 0.301, 0.147, 0.153, 0.176 and 0.223 respectively. Therefore, it can be seen from the results that the most important group in the traditional criteria list is scope and followed by cost in very close proximity. Whereas, the most important group in the sustainability-specific criteria is the level of integration. Moreover, the final weight of the overall traditional criteria list was 0.422, while the final weight of the sustainability-specific criteria was 0.578. Additionally, the top 10 criteria with the highest global weights in the whole comprehensive selection criteria list of both traditional and sustainability-specific criteria are: early involvement of key participants, joint development of project goals, collaborative decision making and control, intensified planning, capitalize on a well-defined cope, efficiently utilize poor-scope, ease change incorporation, ability to use full potential of BIM, efficiently utilize advanced technological tools to achieve sustainable goals, ability to use technology to enhance communication.

Table 18. Traditional Selection Criteria Local and Global Weights

GROUP	CRITERIA	GROUP PRIORITY	LOCAL WEIGHT	GLOBAL WEIGHT
TRADITIONAL		0.422		
	Cost	0.249		
	Control Cost Growth		0.265	0.0278
	Facilitate Early Cost Estimates		0.244	0.0256
	Reduce Risks		0.254	0.0267
	Minimize Expenditure		0.238	0.0250
	Time	0.208		
	Control Time Growth		0.342	0.0300
	Ensure Shortest Time		0.330	0.0290
	Promote Early Procurement of Material and Equipment		0.328	0.0284
	Scope	0.252		
	Capitalize on well-defined scope		0.358	0.0381
	Efficiently utilize poorly defined scope		0.327	0.0348
	Ease change incorporation		0.315	0.0335
	Owner and Contractor Characteristics	0.165		
	Owner's available human resources		0.314	0.0219
	Owner's willingness to be involved		0.305	0.0212
	Contractor's capabilities and experience		0.382	0.0266
	Project's Characteristics	0.126		
	Capitalize on Project Confidentiality		0.244	0.0130
	Capitalize on Familiar Project Conditions		0.235	0.0125
	Efficiently Co-ordinate Project Complexity		0.256	0.0136
	Capitalize on Project's Quality Performance		0.265	0.0141

Table 19. Sustainability-Specific Selection Criteria Local and Global Weights

	GROUP	CRITERIA	GROUP PRIORITY	LOCAL WEIGHT	GLOBAL WEIGHT
SUSTAINABILITY-SPECIFIC			0.578		
		Level of Integration	0.301		
		Early Involvement of Key Participants		0.266	0.0463
		Collaborative Decision Making and Control		0.245	0.0426
		Joint Development of Project Goals		0.247	0.0429
		Intensified Planning		0.243	0.0423
		Green Liability		0.147	
		Allow for transfer of green liability		0.341	0.0290
		promote early assignment of green certification responsibility		0.327	0.0277
		promote early green guarantee		0.332	0.0283
		Green Team		0.153	
		Liability Waivers among team players		0.243	0.0215
		Minimize Adversarial Relationships		0.248	0.0219
		Capitalize on Diversity and New Opportunities		0.227	0.0201
		Facilitate open communication between team members		0.282	0.0249
		Green Contract		0.176	
		Capitalize on awards and contractual incentive fees		0.242	0.0246
		Allow for qualification-based selection		0.260	0.0265
		Facilitate flexible payment provisions		0.242	0.0246
		Allow Shared Risks and Rewards		0.256	0.0261
		Technology & Innovation		0.223	
		Capitalize on Innovation		0.248	0.0320
		Ability to Use Technology to Enhance Communication		0.250	0.0323
		Improve the Ability to Use Full Potential of BIM		0.254	0.0327
		Efficiently Utilize Advanced Technological Tools to Achieve Sustainable Goals		0.251	0.0324

Tables 20 and 21 show a sample of the AHP calculations to determine the weights of the five groups in the traditional and sustainability-specific criteria list respectively. After the respondents have performed the pair-wise comparison between each two groups based on the ratio scales of AHP proposed by Saaty [257], the geometric mean of the responses was then calculated. These geometric mean values were then transformed to generate a normalized matrix. Finally, the average of each row in the normalized matrix was computed to yield the weight of each corresponding group. It is also worth mentioning that the consistency ratio in the AHP of the traditional criteria groups was 0.026 and in the AHP of the sustainability-specific criteria groups, it was 0.0073. Both values are less than the threshold value of 0.1. Therefore, it is safe to conclude that the results are consistent. Table 22 shows the top 10 selection criteria based on their global weights.

Table 20. Calculation of Normalized Traditional Criteria Groups Weights

Analytic Hierarchy Process (AHP)-Pairwise Comparison (Normalized Score)

	<i>Cost</i>	<i>Time</i>	<i>Scope</i>	<i>Owner and Contractor Characteristics</i>	<i>Project's Characteristics</i>	<i>Weight</i>
<i>Cost</i>	0.247	0.359	0.283	0.167	0.190	0.249
<i>Time</i>	0.136	0.197	0.234	0.257	0.218	0.208
<i>Scope</i>	0.213	0.206	0.244	0.279	0.317	0.252
<i>Owner and Contractor Characteristics</i>	0.242	0.125	0.143	0.163	0.150	0.165
<i>Project's Characteristics</i>	0.162	0.112	0.096	0.135	0.124	0.126

Table 21. Calculation of Normalized Sustainability-Specific Criteria Groups Weights

Analytic Hierarchy Process (AHP)-Pairwise Comparison (Normalized Score)

	<i>Level of Integration</i>	<i>Green Liability</i>	<i>Green Team</i>	<i>Green Contract</i>	<i>Technology & Innovation</i>	<i>Weight</i>
<i>Level of Integration</i>	0.297	0.299	0.298	0.315	0.297	0.301
<i>Green Liability</i>	0.149	0.152	0.185	0.131	0.149	0.153
<i>Green Team</i>	0.146	0.122	0.149	0.157	0.161	0.147
<i>Green Contract</i>	0.177	0.199	0.163	0.172	0.170	0.176
<i>Technology & Innovation</i>	0.232	0.227	0.206	0.226	0.223	0.223

Table 22. Top 10 Selection Criteria

#	Selection Criteria	Global Weight
1	Early Involvement of Key Participants	0.0463
2	Joint Development of Project Goals	0.0429
3	Collaborative Decision Making and Control	0.0426
4	Intensified Planning	0.0423
5	Capitalize on a Well-Define Scope	0.0381
6	Efficiently Utilize Poor Scope	0.0348
7	Ease Change Incorporation	0.0355
8	Ability to Use Full Potential of BIM	0.0327
9	Efficiently Utilize Advanced Technological Tools to Achieve Sustainable Goals	0.0324
10	Ability to Use Technology to Enhance Communication	0.0323

5.3. Discussions of Selection Criteria Weights

The results in the tables above conclude that the top 10 criteria belonged to 3 main groups: level of integration, scope-related criteria as well as technology and innovation. These results indicate that almost 70% of the top 10 criteria belonged to the sustainability-specific groups, while the top traditional selection criteria represented only 30%. This further emphasizes the importance of the proposed sustainability-specific criteria in this research.

As far as the sustainability-specific selection criteria groups are concerned, the results have revealed that the level of integration is the most important group with a local weight of 0.301 and a global weight of 0.174 which is almost double the weight that other criteria groups such as green liability, green team and green contract received. The level of integration also turned out to be around 35% more important than the technology and innovation group when selecting the project delivery method in sustainable construction. In fact, these results echo the conclusions of previous studies that emphasized the significant impact of the level of integration achieved in the delivery process in optimizing the success rate of sustainable construction projects [105]. Not to mention that the criterion “early involvement of key participants” that belonged to the level of integration group had the highest global weight in the overall list of the both the traditional and sustainability-specific selection criteria that was equal to 0.0463. Indeed, involving the contractor during early design phases and receiving their input in a collaborative environment can have altering effects on the sustainability project outcomes [258]. As a matter of fact, the other 3 criteria that belonged to the level of integration group (joint development of project goals, collaborative decision making and intensified planning) also made it to the top 5 as criteria that have the highest impact on the selection process of project delivery methods in sustainable construction.

Whereas, the second most important group in the overall traditional and sustainability-specific selection criteria turned out to be technology and innovation with a global weight of 0.129. These results are in line with a previous study done by Li et al. [86] where the authors concluded that technical innovations are crucial for the achievement of Green Mark Certified projects. Especially, if these technological advanced tools aim to enhance communication through exploring the full potential of BIM to help achieve

sustainability goals. The results also revealed that other technology and innovation related criteria that made it to top 10 selection criteria include the efficient use of advanced technological tools to achieve sustainability and the ability to use technological tools to enhance communication. It is also worth mentioning that the remaining 3 criteria groups: green liability, green team and green contract all had approximately the same weight in the range of 0.15-0.17. Furthermore, the final weight of the overall traditional criteria list turned out to be 0.422, while the final weight of the overall sustainability-specific criteria list turned out to be 0.578. This means that the new criteria list turned out to be approximately 1.4 times more important than the traditional criteria list according to the perceptions of the construction professionals in the UAE. Such a finding further highlights the significance of this research as it proves that the newly identified selection criteria should be prioritized as compared to the traditional well-known criteria when selecting the appropriate project delivery method to be used in sustainable construction projects.

Moreover, according to the results mentioned earlier, scope group had the highest local weight of 0.252 in the traditional criteria groups and the third highest weight in the comprehensive list of both traditional and sustainability-specific criteria groups with a global weight of 0.106. This is due to the fact that having a well-articulated scope where all project team members work together in an integrated whole team approach to develop the construction documents will help provide strong scope definitions and complete specifications that will ultimately optimize the success rate of sustainable construction delivery [11]. In fact, to further solidify these theories, the criterion “capitalize on well-defined scope” that belonged to the scope group had the highest global weight (0.0381) in the overall list of traditional selection criteria and was ranked fifth in the overall comprehensive list of both traditional and sustainability-specific criteria. Other scope related criteria that also made it to the top 10 include efficient use of poor scope and flexibility in terms of change incorporation. Furthermore, cost turned out to be the second most important group in the traditional selection criteria list with a weight equal to 0.249 which is very close to the weight of the scope group. This once again confirms the results of previous studies that stated that financial challenges are one of the main barriers to sustainable development [161]. This in turn has emphasized the impact of cost related factors on the selection of project delivery methods in order to optimize the success rate of sustainable construction projects.

On the other hand, some traditional selection criteria were dropped to the bottom of the list as they had the lowest impact on the selection of project delivery methods in sustainable construction. For instance, project's characteristics had the lowest weight compared to other traditional criteria groups. This is perhaps due to the fact that capitalizing on familiar project conditions is not an urgent concern when it comes to selecting project delivery methods in sustainable construction. Especially because sustainable construction is unique in its nature with a need for special materials and technologies as well as other challenges that are different from traditional construction projects, which ultimately removes familiarity from the equation [18]. As a matter of fact, the criterion "capitalize on familiar project conditions" had the lowest global weight in the overall list of traditional and sustainability-specific selection criteria which was equal to 0.0125. Besides, the criterion "capitalize on project confidentiality" also had a low global weight of 0.0130 which matches a previous study done by Chen et al. [215] who analysed the selection of project delivery system in Chinese construction industry with data envelopment analysis and concluded that the confidentiality selection criterion ranked very low. These results confirm the low impact of this criterion on the selection of project delivery methods in both traditional and sustainable construction projects. Another traditional selection criterion that made it to the bottom of the list is the "owner's willingness to be involved" with a global weight of 0.0212. This could be due to the fact that this criterion is only significant in traditional delivery methods such as DBB which is outmatched by the collaborative and integrated nature of sustainable construction projects [106]. It is also worth mentioning that these results are in contrast with previous studies that evaluated the weight of these traditional criteria in traditional construction projects. For instance, Feghaly et al. [72] identified the criterion "owner involvement, experience and control" in the top 13 factors that affect the project delivery method selection process in water treatment plants. Indeed, these contrasting results further solidify the theory behind this research that the relative importance weights of traditional criteria are no longer the same in sustainable construction projects as other new relevant criteria have outranked them.

5.4. Effectiveness of Project Delivery Methods

This research only focuses on the three most common delivery methods: Design-Bid-Build, Design-Build and Construction Management at Risk as these are the most

prevalent delivery methods that are widely used in various countries around the world and comparing their performance has been the subject of many construction research studies in the past years [259] .

Twenty-six responses have been collected out of the 100 surveys that were distributed which indicates a 26% response rate. Although the sample size was relatively small, all the pairwise comparisons between the delivery methods in all the selection criteria had consistency ratios less than the threshold of 0.1 as suggested by Saaty [257] which further verifies the collected data. The results have shown that 53.8% of the responses belong to local companies while 46.1% belong to international offices. Besides, 58% of the respondents were contractors with 61.5% in the buildings industry and 30.8% in the infrastructure industry.

Table 23 illustrates the effectiveness values of the three most common delivery methods (DBB, DB, CMR) in achieving the thirty-six selection criteria identified in this research.

Table 23. Effectiveness of Project Delivery Methods

Selection Criteria		1	2	3	Inconsistency Ratio
		DBB	DB	CMR	
Cost-Related Criteria					
1	Control Cost Growth	10	62	27	0.005
2	Facilitate Early Cost Estimates	8	46	46	0.0001
3	Reduce Risks	14	30	56	0.003
4	Minimize Expenditure	69	11	20	0.008
Time-Related Criteria					
5	Control Time Growth	7	53	40	0.008
6	Ensure Shortest Time	8	58	34	0.017
7	Promote Early Procurement of Material and Equipment	7	58	35	0.011
Scope-Related Criteria					
8	Capitalize on a Well-defined Scope	10	65	25	0.001
9	Efficiently Utilize Poor Scope	60	9	32	0.007
10	Ease Change Incorporation	67	9	24	0.018
Owner and Contractor's Characteristics					
11	Owner's Available Human Resources	63	9	28	0.001
12	Owner's Willingness to be Involved	59	7	34	0.001
13	Capitalize on Contractor's Capabilities and Experience	8	45	47	0.001

Project's Characteristics Criteria					
14	Capitalize on Project Confidentiality	56	17	27	0.005
15	Capitalize on Familiar Project Conditions	63	18	19	0.032
16	Efficiently Co-ordinate Project Complexity	10	61	29	0.005
17	Capitalize on Project's Quality Performance Levels	25	31	44	0.001
Level of Integration Criteria					
18	Early Involvement of Key Participants	7	55	38	0.002
19	Collaborative Decision Making and Control	8	60	32	0.020
20	Joint Development of Goals	8	59	33	0.002
21	Intensified Planning	9	53	38	0.023
Green Liability Criteria					
22	Allow Transfer of Green Liability	48	24	28	0.004
23	Promote Early Assignment of Green Certification Responsibility	25	34	41	0.015
24	Promote Early Green Guarantee	7	61	32	0.012
Green Team Criteria					
25	Liability Waivers among Team Players	8	56	36	0.010
26	Minimize Adversarial Relationships	8	49	43	0.001
27	Capitalize on Diversity and New Opportunities	9	48	43	0.006
28	Open Communication between Team Members	7	47	45	0.003
Green Contract Criteria					
29	Contractual Incentive Fees and Awards	7	34	59	0.005
30	Qualification-Based Procurement Approach	7	36	57	0.0001
31	Flexible Payment Provisions	7	30	63	0.003
32	Shared Risks and Rewards	8	34	58	0.008
Technology and Innovation					
33	Capitalize on Innovation	8	46	46	0.008
34	Ability of Technology to Enhance Communication	7	53	40	0.017
35	Ability to Use Full Potential of BIM	6	50	44	0.011
36	Ability to Efficiently Utilize Advanced Technological Tools to Achieve Sustainable Goals	7	51	42	0.011

5.4.1. PDM Effectiveness- Traditional Selection Criteria

The results indicate that DB is better in terms of controlling cost growth than when compared to DBB and CMR. This echoes previous studies such as Kim et al. [260] who compared cost performance of project delivery methods in heavy construction projects in California and found out that the cost growth in DBB projects were 10.5% more than in DB projects. On the other hand, DBB outperformed DB and CMR in minimizing the expenditure rate. This is in line with the results provided by Oyteunji and Anderson [22] who concluded that DBB is 100% effective in reducing the expenditure rate while DB and CMR only had 40% and 10% effectiveness values respectively.

Furthermore, CMR ranked higher in reducing risks than DBB and DB. In fact, it has been argued by researchers that involving the construction manager in the preconstruction phases leads to a substantial decrease in risks [261]. Additionally, CMR and DB had similar effectiveness values in facilitating early cost estimates where they outperformed DBB. This is due to the fact that both these methods allow fast tracking and the overlap of construction along with the design phase which provides a fertile ground to develop early cost estimates [80]. Figure 9 illustrates the effectiveness values of the three delivery methods in achieving cost-related criteria.

As far as the time-related criteria are concerned, DB is more effective in all three criteria, followed by CMR, while DBB was the least effective in this group. These results are similar to the conclusion provided by Chen et al. [215] who claimed that if the dominant selection factors were time related, then DB projects would rank higher in efficiency. CMR has also proven itself to be more effective than DBB in allowing early project completion. In a study done by Kenig [261] CMR reported a reduced schedule duration of 15% to 20% with opportunities for early building occupancy. Figure 10 illustrates the differences in the effectiveness of the three common project delivery methods in achieving time-related criteria.

Results illustrated in Figure 11 indicate that DBB is more effective than DB and CMR in utilizing a poor scope as well as easing change incorporation. This is mainly due to the fact that contractors in DBB can only start construction with a completed design that the architect prepares prior to bidding. However, these initial designs are almost always subject to changes, which the owner and contractor should be willing to negotiate for compensation [262]. On the other hand, DB has the highest rank in

capitalizing on a well-defined scope. Moreover, if the owner desires to have more control over the project and to be more involved with the ability to use their human resources, then the delivery method that would be able to support this objective is the traditional DBB [214]. Additionally, DB and CMR turned out to have relatively similar effectiveness values when it comes to capitalizing the contractor’s capabilities and experience (Figure 12). This has been supported by previous research that highlighted the importance of qualification-based procurement that is adopted in alternative delivery methods over the lowest-cost method that is adopted in the traditional DBB [263].

As far as the project’s characteristic criteria are concerned, DBB outperformed DB and CMR in project confidentiality and familiar project conditions. Mahdi and Alreshaid [61] also nominated DBB as the most appropriate option if the owner or the contractor have little willingness to change well-known, traditional and familiar project settings. While, efficiently coordinating the project’s complexity turned out to be a specialty of the DB delivery method. Indeed, having both the contractor and consultant on board during early construction phases fosters collaboration which is beneficial for complex projects [264]. Figure 13 compares between the three delivery methods in achieving project’s characteristics criteria. All in all, DBB had the highest effective values in achieving 41% of the traditional selection criteria, while DB had the highest relative weight in achieving 35% of the traditional selection criteria and the remaining 24% of the traditional selection criteria were best achieved by CMR. These results indicate that decision makers still prefer the conventional industry standard of DBB project delivery method when it comes to achieving traditional selection criteria.

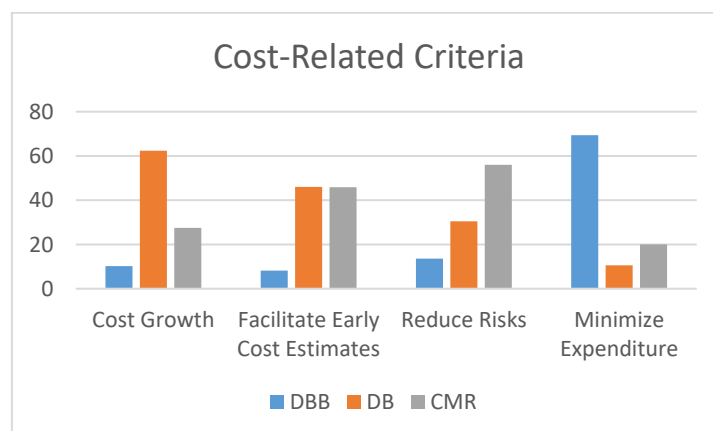


Figure 9. Cost-Related Criteria

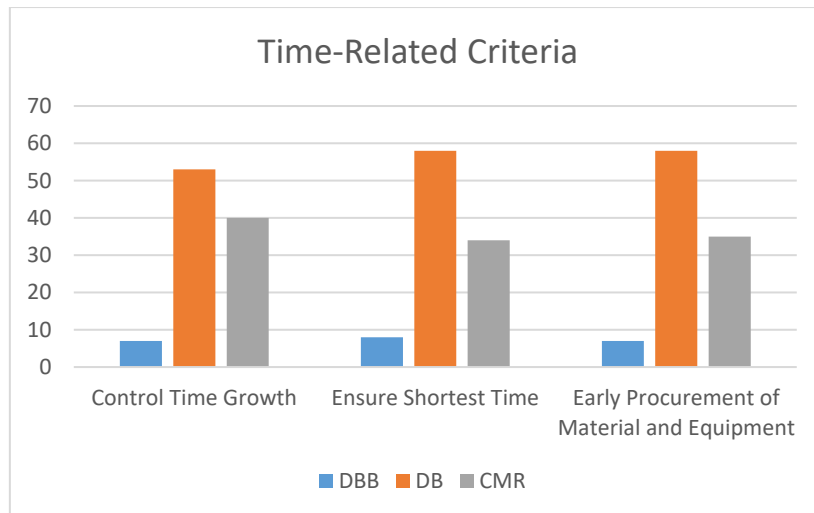


Figure 10. Time-Related Criteria

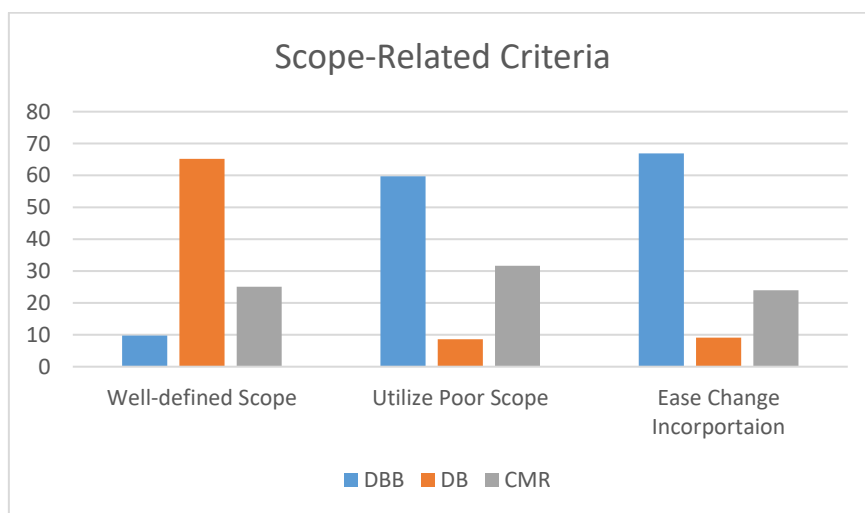


Figure 11. Scope-Related Criteria

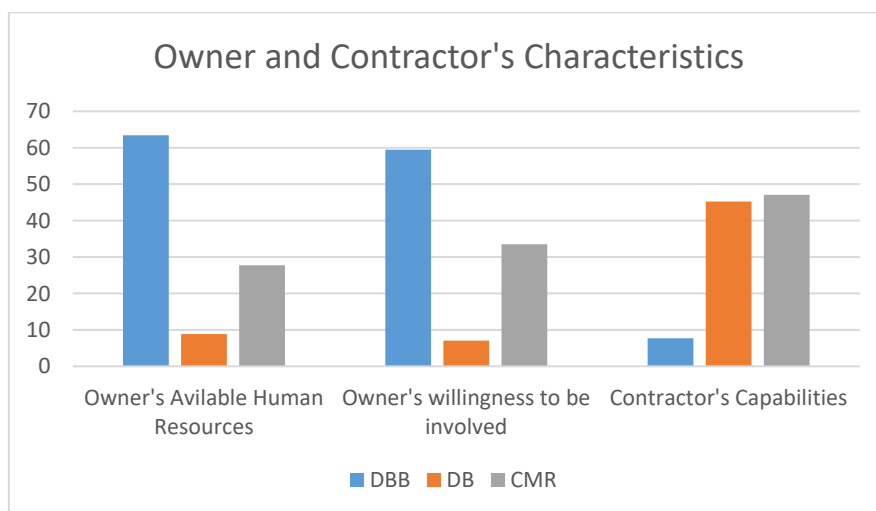


Figure 12. Owner and Contractor's Characteristics

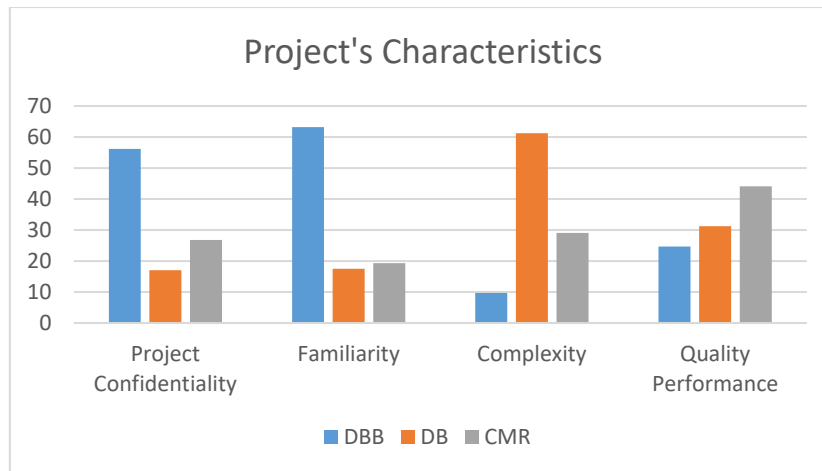


Figure 13. Project's Characteristics Criteria

5.4.2. PDM Effectiveness- Sustainability-Specific Selection Criteria

In contrast to the results mentioned earlier in the traditional selection criteria, analysis of the responses has revealed that DBB has the highest effective value in only one criterion (green liability) in the whole sustainability-specific criteria list which represents only 5% of the list. Perhaps, this high effectiveness value is justified due to the fact that respondents might have perceived green liability as a contractual obligation that can be added to the lump-sum contract associated with DBB. While the remaining 95% of the sustainability-specific criteria were best achieved by both CMR and DB. The results indicate that DB ranked the highest in achieving high levels of integration, followed by CMR, while DBB had minimal contribution to this criteria category (Figure 14). These results are analogous to a study done by Korkmaz et al. [105] who claimed that better levels of integration are facilitated by DB and CMR, while DBB might have the potential if the constructor is informally involved during the earlier stages of the project. Similarly, DB also had the highest effectiveness value in promoting early green guarantee (Figure 15). As the contractual responsibility to deliver the owner's desired green certificate is achieved early during DB due to the early involvement of the constructor [231]. While in the case of DBB, the green guarantee can only be provided after the whole design phase is complete and the contractor is assigned to the project which further delays the process significantly.

Not only this but, the effectiveness values of DB and CMR in achieving the green team criteria were very close to each other (Figure 16). This is mainly attributed to the integrated team approach adopted in these delivery methods that allows for open

communication and exchange of constructive ideas that ultimately minimizes adversarial relationships and provides room for diversity [89]. Additionally, CMR was superior to DBB and DB in accomplishing the green contract criteria which consist of facilitating flexible payment provisions, contractual incentive fees and awards, qualification-based procurement as well as shared risks and rewards (Figure 17). This is due to the fact that Guaranteed maximum Plus contract is usually adopted in CMR delivery methods that provides the opportunity for scope and cost negotiations [234].

As far as the technology and innovation criteria are concerned, both DB and CMR had relatively very similar effectiveness values with slight differences (Figure 18). DBB however has proven inefficient in this category mainly due to the resistance of this delivery system to integrate Building Information Modelling (BIM) which places a huge barrier to exploring new innovation opportunities [265]. These results match the conclusions made by other researchers who claimed that DB and CMR have a great potential in integrating advanced technological tools. For instance, Keskin et al. [266] studied how BIM implementation was enabled in CMR to deliver complex infrastructure airport projects. The results showed that the connectivity and collaboration between the various stakeholders and construction technology solutions were greatly enhanced. Last but not least, the results of this study prove that the traditional delivery method DBB is outmatched by the heightened need of sustainable construction projects for collaboration and integration, that can only be achieved through alternative delivery methods such as DB and CMR [106].

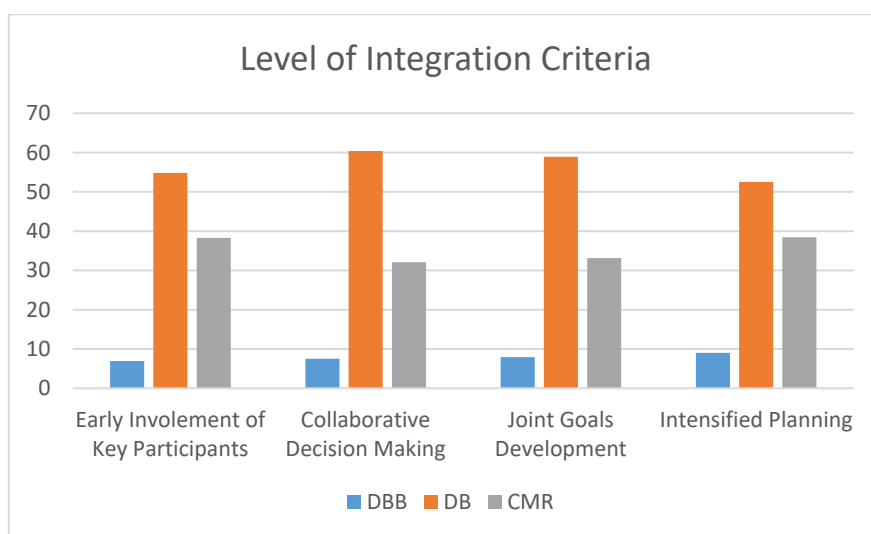


Figure 14. Level of Integration Criteria

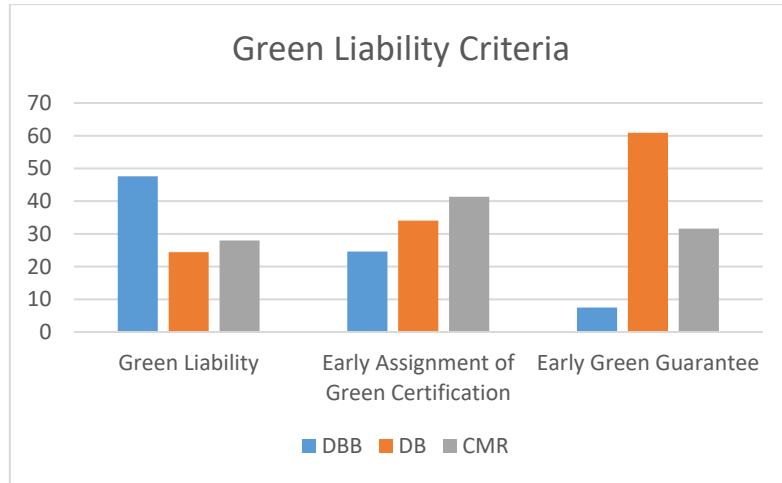


Figure 15. Green Liability Criteria

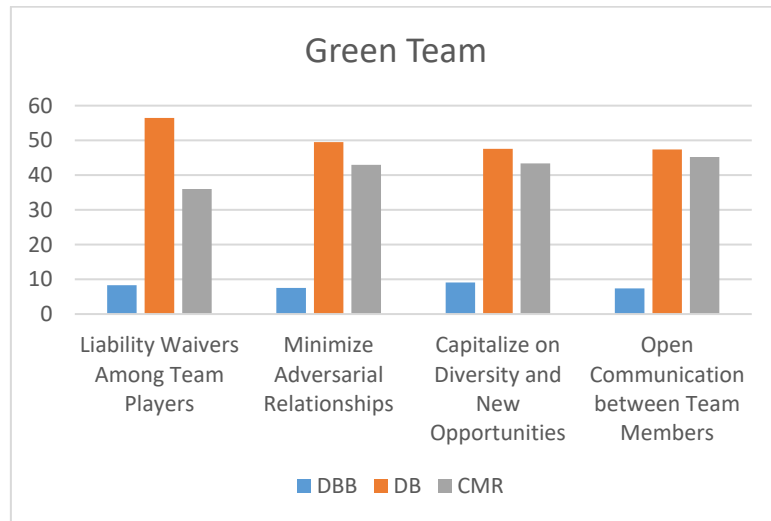


Figure 16. Green Team Criteria

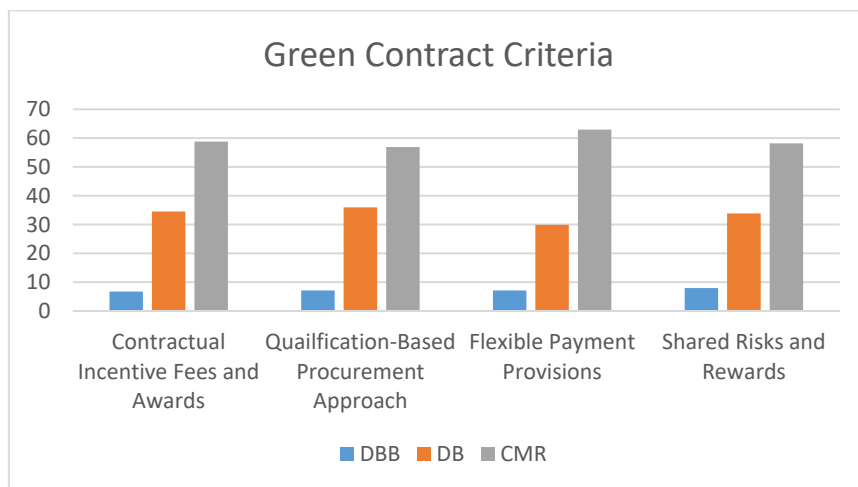


Figure 17. Green Contract Criteria

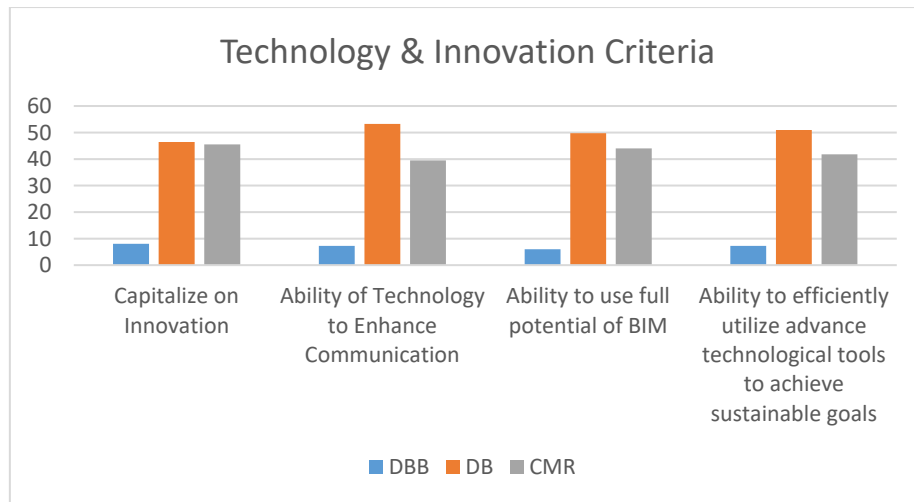


Figure 18. Technology & Innovation Criteria

5.5. Summary and Conclusions

The increasing shift towards sustainable construction projects urges the need to optimize their success rate. A decision that greatly impacts this success rate is the selection of an appropriate project delivery method. Traditional selection criteria of project delivery methods have been extensively investigated in literature. However, with the complexity and unique challenges that sustainable construction present to the market, it is safe to say that the relative importance weights of these traditional criteria may no longer be the same as in traditional construction projects. Not only this, but to properly select a delivery method that effectively addresses the challenges encountered in sustainable construction, other sustainability-specific criteria should also be added to the traditional selection criteria list.

The first part of this chapter assesses the weights of both the traditional and sustainability-specific criteria proposed in the previous chapter using analytical hierarchy pairwise comparisons. A survey was administered to construction professionals in the UAE to conduct analytical hierarchy pairwise comparisons between the selection criteria groups. Upon completion of the analysis, the results revealed that the newly proposed list of sustainability-specific selection criteria which include: level of integration, green liability, green team, green contract and technology & innovation were 1.4 times more important than the traditional selection criteria list. Moreover, the results also concluded that level of integration was the most important criteria group in the overall comprehensive list of both traditional and newly proposed list of

sustainability-specific selection criteria. This is due to the fact that early involvement of key participants is a big catalyst for achieving sustainability goals. While in the traditional selection criteria list, the most important criteria group for selecting project delivery methods in sustainable construction projects was scope with emphasis on having well-articulated details and technical specifications. These findings will provide decision makers with a justified rationale for prioritizing sustainability-specific criteria over the familiar traditional ones when choosing the most appropriate delivery method in sustainable construction projects.

The second part of this chapter evaluates the effectiveness of the three most common delivery methods (DBB, DB, CMR) in achieving the comprehensive list of thirty-six traditional and sustainability-specific selection criteria. Indeed, with different project delivery options presented to the owners to choose from, it becomes a convoluted decision to select the most appropriate project delivery method for their project. While it is true that no delivery method is perfect, some methods may be more suited than others depending on the specific project's requirements. Twenty-six surveys were collected from construction professionals in the UAE who were asked to conduct AHP pairwise comparisons between the three delivery methods. The small sample size considered in this study is due to the lengthy nature of the survey which consisted of more than 100 questions. That in turn limited the number of complete and consistent results that could be used in the final analysis. The results indicated that DBB is still the preferred delivery method among the traditional criteria. However, these results flipped when the effectiveness of the delivery methods were evaluated against the sustainability-specific criteria. The collaborative and multidisciplinary nature of sustainable construction projects have special requirements that have caused the capabilities of the traditional DBB method to be outmatched and hence, dropped to the bottom of the list in achieving the sustainability-specific criteria. Furthermore, results also revealed that both DB and CMR are relatively compatible with the sustainability-specific criteria such as green team criteria as well as technology and innovation criteria. DB however ranks higher in areas such as levels of integration such as collaborative decision control and joint development of project goals while CMR is more effective in achieving green contract criteria such as flexible payment provisions and contractual incentive fees

Chapter 6. Decision Support Models

Although there are many decision models for project delivery selection in traditional construction projects, there are no available models for project delivery methods selection in sustainable construction projects. This chapter proposes two multi-criteria decision support models to help decision makers select the most appropriate delivery method for sustainable construction projects.

Sections 6.1-6.3 are extracted from a manuscript under review in the ASCE Journal of Construction Engineering and Management with the title “Multi-Criteria Decision Support Model for Selecting the Appropriate Delivery Method in Sustainable Construction Projects.”

6.1. Model A

This model is unique as it includes a comprehensive selection criteria list that has both traditional and sustainability-specific selection criteria. Figure 19 shows the specific functions and tasks in the proposed model. The model consists of four functions: strategic alignment of project’s goals, screening of selection criteria, evaluation of PDMs and final selection of the appropriate delivery method.

The first function basically starts by identifying the project’s profile and the main characteristics as well as highlighting the project’s objectives and prioritizing them. This is an important exercise as it allows the decision maker to align the goals of the project with the relevant selection criteria of project delivery methods that will ensure the achievement of these goals. Hence, providing the decision makers with a justified rationale for choosing a specific project delivery method in the end. The second function is where the decision makers start screening the comprehensive selection criteria available in the model. They can either choose to keep all the selection criteria and evaluate the effectiveness of the PDMs in achieving the whole comprehensive list, or they can only choose the selection criteria they believe are required for the fulfilment of the preidentified project’s objectives. Upon determining the required selection criteria, their weights are then imported from Tables 18 and 19 where the global weights were precalculated using AHP as mentioned earlier. Upon shortlisting the required selection criteria and importing their weights, these weights are then normalized to ensure a common scale without any distorting differences in the ranges of weights.

The third function then deals with evaluating the three PDMs available in the model (DBB, DB, CMR) and comparing their effectiveness in achieving the required selection criteria. Similar to the selection criteria weights, the effectiveness values of the three PDMs in each selection criteria have also been precalculated using AHP as mentioned earlier. These effectiveness values are then imported from Table 23 into the decision support model to calculate the sum product of the required selection criteria weights with the corresponding effectiveness values of the three PDMs. Finally, the fourth function allows the decision maker to view the aggregate scores of each PDM, rank them and analyse the results. The delivery method with the highest score should typically be chosen as it means it is the most capable delivery method in achieving the sustainable construction project's objectives. Indeed, this decision support model saves time and resources for the decision makers as all the cumbersome mathematical AHP calculations are already embedded in the software.

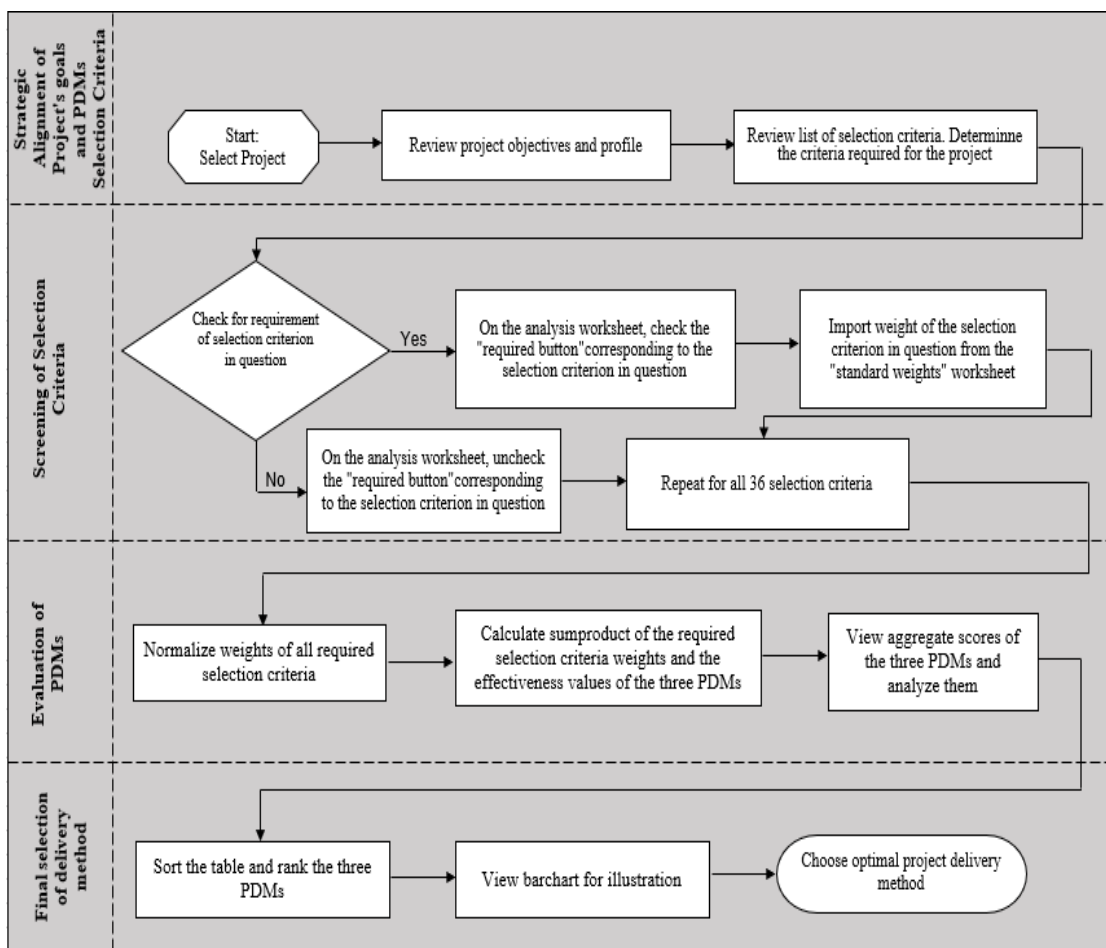


Figure 19. Model A

6.2. Model B

Model B is a derivative of model A that allows the users to enter their own weights of the selection criteria that are critical to the achievement of their sustainable construction project's goals. The model consists of three functions: strategic alignment of project's goals and PDMs selection criteria, screening of selection criteria and evaluation of PDMs. Figure 20 further illustrates the flowchart for model B.

The first function is similar to model A where the user first starts by identifying the project's profile and the main characteristics as well as highlighting the project's objectives and prioritizing them. After that, the user would review the whole list of selection criteria available and would be asked to choose up to 10 selection criteria that are most relevant and best aligned with the goals of their considered project. In the second function of the model which deals with the screening of the selection criteria, the user would then be asked to rank the chosen criteria from 1 to 10 on the analysis worksheet. The next step would be assigning preference score to the chosen criteria, where 100 would be assigned to the most important criterion ranked as 1 in the previous stage and then the other criteria would be ranked less than 100 based on their relative importance to the first-ranked criteria. Excel software is then automatically programmed to compute the relative weight of these 10 chosen criteria.

The third and the last function of this model is the evaluation of the three PDMs (DBB, DB, CMR). It is important to note that the effectiveness values of the three PDMs for the chosen criteria will remain the same as they have been precalculated using AHP as mentioned earlier and imported from Table 23 into the decision supported model. The sum product of the relative weights of the 10 chosen criteria with the corresponding effectiveness values of the three PDMs is calculated. This results in three different aggregate scores for DBB, DB and CMR. The user would then be asked to use the built-in macro function in order to sort and rank these results. The built-in macro function also allows the generation of a bar chart to better illustrate and rank the three PDMs. In the end, the delivery method with the highest score should typically be chosen as it means it is the most capable delivery method in achieving the sustainable construction project's objectives. Some users would prefer to use this model over model A as it gives them the flexibility to rank the selection criteria and tailor their relevance according to their project's specific characteristics.

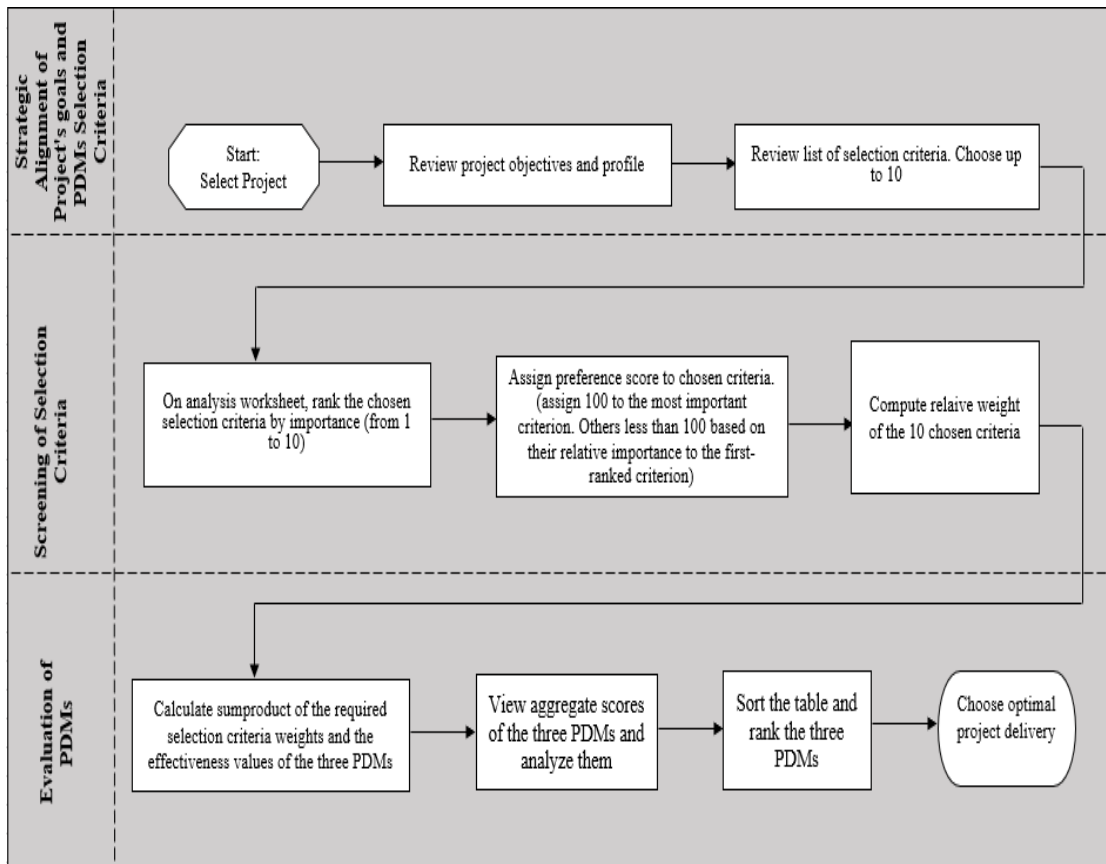


Figure 20. Model B

6.3. Case Study- Model A

This section presents a case study to illustrate the implementation of the decision model. The owner in this case study is a private university in the UAE wishing to build an innovative sustainable engineering building with a “Certified” LEED level to keep up with the increasing demand for sustainability in the country.

Strategic Alignment & Screening of Selection Criteria

The main objective of this project is the integration of advanced technological tools to their full potential to be able to achieve sustainable goals and maximize innovation. Other objectives include efficient communication and coordination between the design and construction teams to successfully deliver the project with high quality standards. Not only this but the contractor should also be properly qualified to overcome the unique challenges of sustainable construction projects. Furthermore, timely completion of the project and early assignment of green certification responsibility is also essential to ensure the operation of the building at the start of the new academic year. Another

important objective is to minimize and share the risks of the project as sustainable construction is very risky especially with lack of material availability in the local UAE market and sudden changes in prices among others which would require the ease of change incorporation.

Upon reviewing the project’s portfolio and the important objectives, the decision maker was able to choose ten selection criteria that they believed were relevant to the successful delivery of the new innovative sustainable engineering building. The eight selection criteria were: control time growth, capitalize on a well-defined scope, capitalize on project’s quality performance levels, early involvement of key participants, promote early assignment of green certification responsibility, open communication between team members, shared risks and rewards, capitalize on qualification-based procurement and ease change incorporation as well as ability to efficiently utilize advanced technological tools to achieve sustainable goals. Table 24 shows the ten chosen selection criteria with their imported global weights from AHP and their final normalized weights as well.

Table 24. The Ten Selected Criteria with Their Normalized Weights

Selected Selection Criteria	Normalized Weights
Control Time Growth	0.1
Capitalize on Qualification-based Procurement Approach	0.09
Capitalize on Project’s Quality Performance Levels	0.05
Early Involvement of Key Participants	0.15
Promote Early Assignment of Green Certification Responsibility	0.09
Open Communication Between Team Members	0.08
Shared Risks and Rewards	0.09
Ability to Efficiently Utilize Advanced Technological Tools to Achieve Sustainable Goals	0.11
Capitalize on Well-Defined Scope	0.13
Ease Change Incorporation	0.11

Evaluation of PDMs & Final Selection of the Delivery Method

In order to compare the three PDMs against each other, the sum product of the required selection criteria weights and the corresponding effectiveness values of the PDMS was

calculated. Once all sum products were calculated, the aggregate score of each PDM was then generated. DB turned out to be the preferred delivery method as it scored the highest overall score of 43.2, followed by CMR in very close proximity with a score of 40.0. However, the aggregate score of DBB was almost negligible compared to DB and CMR as it scored only 16.7. The application of this case study demonstrates the incompatibility of the traditional DBB delivery method in successfully delivering sustainable construction projects.

Figures 21 and 22 illustrate the graphical user form and the decision support model used for this case study where the graphical user form was used to collect information about the project's profile such as project's name, type, objectives and desired LEED level. In the project type, the user was asked to choose from four options: residential building, commercial building, industrial facilities and infrastructure. Similarly, the user was also asked to choose one of the four LEED Levels: Certified, Silver, Gold, Platinum. The decision model was then used to choose the most appropriate delivery method according to the functions explained earlier.

The image shows a graphical user interface form titled "Project Profile". It contains four input fields on the left and their corresponding values on the right:

- Project Name:** Sustainable Engineering Building
- Project Type:** Residential Building (selected from a dropdown menu)
- Project Objectives:** Contractor's Qualifications, Flexible Scope
- Desired LEED Level:** Certified (selected from a dropdown menu)

At the bottom center of the form is a large blue button labeled "Submit".

Figure 21. Graphical User Interface Form

Model A								Sort Results	
Select The Required Criteria for Your Project								Sort, then View Results Here	
Factor	Requirement	Standard Weight	Normalized Weight	PDMs	DBB	DB	CMR	PDM	Rating
Cost Related Criteria	1 Control Cost Growth	<input type="checkbox"/> Required	0.00	10	62	27		DB	43.2
	2 Facilitate Early Cost Estimates	<input type="checkbox"/> Required	0.00	8	46	46		CMR	40.0
	3 Reduce Risks	<input type="checkbox"/> Required	0.00	14	30	56		DBB	16.7
	4 Minimize Expenditure	<input type="checkbox"/> Required	0.00	69	11	20			
Time Related Criteria	5 Control Time Growth	<input checked="" type="checkbox"/> Required	0.0300	0.10	7	53	40		
	6 Ensure Shortest Time	<input type="checkbox"/> Required	0.00	8	58	34			
	7 Promote Early Procurement of Material and Equipment	<input type="checkbox"/> Required	0.00	7	58	35			
Scope Related Criteria	8 Capitalize on a Well-defined Scope	<input checked="" type="checkbox"/> Required	0.0381	0.13	10	65	25		
	9 Efficiently Utilize Poor Scope	<input type="checkbox"/> Required	0.00	60	9	52			
	10 Ease Change Incorporation	<input checked="" type="checkbox"/> Required	0.0335	0.11	67	9	24		
Owner's and Contractor's Characteristics	11 Owner's Available Human Resources	<input type="checkbox"/> Required	0.00	63	9	28			
	12 Owner's Willingness to be Involved	<input type="checkbox"/> Required	0.00	59	7	34			
	13 Capitalize on Contractor's Capabilities and Experience	<input type="checkbox"/> Required	0.00	8	45	47			
Project's Characteristics	14 Capitalize on Project Confidentiality	<input type="checkbox"/> Required	0.00	56	17	27			
	15 Capitalize on Familiar Project Conditions	<input type="checkbox"/> Required	0.00	63	18	19			
	16 Efficiently Co-ordinate Project Complexity	<input type="checkbox"/> Required	0.00	10	61	29			
	17 Capitalize on Project's Quality Performance Levels	<input checked="" type="checkbox"/> Required	0.0141	0.05	25	31	44		
Level of Integration	18 Early Involvement of Key Participants	<input checked="" type="checkbox"/> Required	0.0463	0.15	7	55	38		
	19 Collaborative Decision Making and Control	<input type="checkbox"/> Required	0.00	8	60	32			
	20 Joint Development of Goals	<input type="checkbox"/> Required	0.00	8	59	33			
	21 Intensified Planning	<input type="checkbox"/> Required	0.00	9	53	38			
Green Liability	22 Transfer of Green Liability	<input type="checkbox"/> Required	0.00	48	24	28			
	23 Promote Early Assignment of Green Certification	<input checked="" type="checkbox"/> Required	0.0277	0.09	25	34	41		
	24 Promote Early Green Guarantee	<input type="checkbox"/> Required	0.00	7	61	32			
Green Team	25 Liability Waivers among Team Players	<input type="checkbox"/> Required	0.00	8	56	36			
	26 Minimize Adversarial Relationships	<input type="checkbox"/> Required	0.00	8	49	43			
	27 Capitalize on Diversity and New Opportunities	<input type="checkbox"/> Required	0.00	9	48	43			
	28 Open Communication between Team Members	<input checked="" type="checkbox"/> Required	0.0249	0.08	7	47	45		
Green Contract	29 Contractual Incentive Fees and Awards	<input type="checkbox"/> Required	0.00	7	34	59			
	30 Qualification-Based Procurement Approach	<input checked="" type="checkbox"/> Required	0.0265	0.09	7	36	57		
	31 Flexible Payment Provisions	<input type="checkbox"/> Required	0.00	7	30	63			
	32 Shared Risks and Rewards	<input checked="" type="checkbox"/> Required	0.0261	0.09	8	34	58		
Technology and Innovation	33 Capitalize on Innovation	<input type="checkbox"/> Required	0.00	8	46	46			
	34 Ability of Technology to Enhance Communication	<input type="checkbox"/> Required	0.00	7	53	40			
	35 Ability to Use Full Potential of BIM	<input type="checkbox"/> Required	0.00	6	50	44			
	36 Ability to Efficiently Utilize Advanced Technological Tools to Achieve Sustainable Goals	<input checked="" type="checkbox"/> Required	0.0324	0.11	7	51	42		
SUM			0.2966	100					

Delivery Method	Rating
DB	43.2
CMR	40.0
DBB	16.7

Figure 22. Screenshot of Case Study Model A on Excel Software

6.4. Sensitivity and Scenario Analysis

Before reaching the final decision, one last important step is sensitivity and scenario analysis. The purpose of this step is to check how sensitive the decision is to the selection criteria. This is significant in the case study presented as the aggregate scores of DB and CMR are very close to each other. DBB is ignored in this stage since its aggregate score was very small compared to the aggregate scores of DB and CMR. This analysis would allow the determination of whether the final decision is sensitive to small variations in the model. In fact, Clemen and Reilly [267] stated that if the decision turned out to be sensitive, the decision maker would then be obligated to reconsider the parameters to which the decision is sensitive very carefully.

Sensitivity analysis was achieved by changing the weight of each one of the 10 selected criteria by $\pm 25\%$ and observing the changes in the aggregate scores of DB and CMR. Figures 23 and 24 show the tornado graphs that illustrate the sensitivity of the two delivery methods to each selection criterion. Furthermore, Figure 25 compares between the percentage change in the aggregate score of DB and CMR caused by the variation in each selection criterion. The results indicate that the four selection criteria that caused the highest percentage change in the aggregate score of CMR were: shared risks and rewards, qualification-based procurement, promote early assignment of green certification responsibility and ease change incorporation. While DB is most sensitive to the following criteria: capitalize on well-defined scope, early involvement of key participants and control time growth.

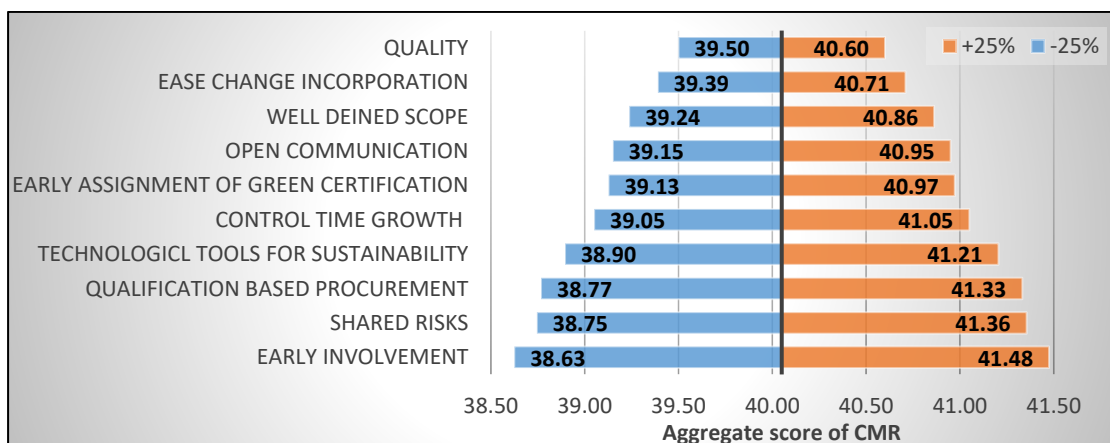


Figure 23. Tornado Graph for CMR Aggregate Scores

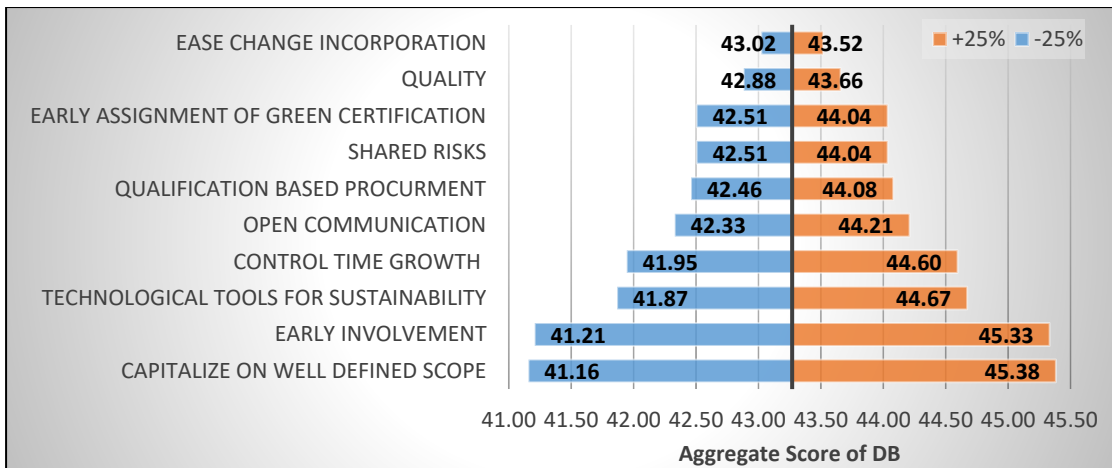


Figure 24. Tornado Graph for DB Aggregate Scores

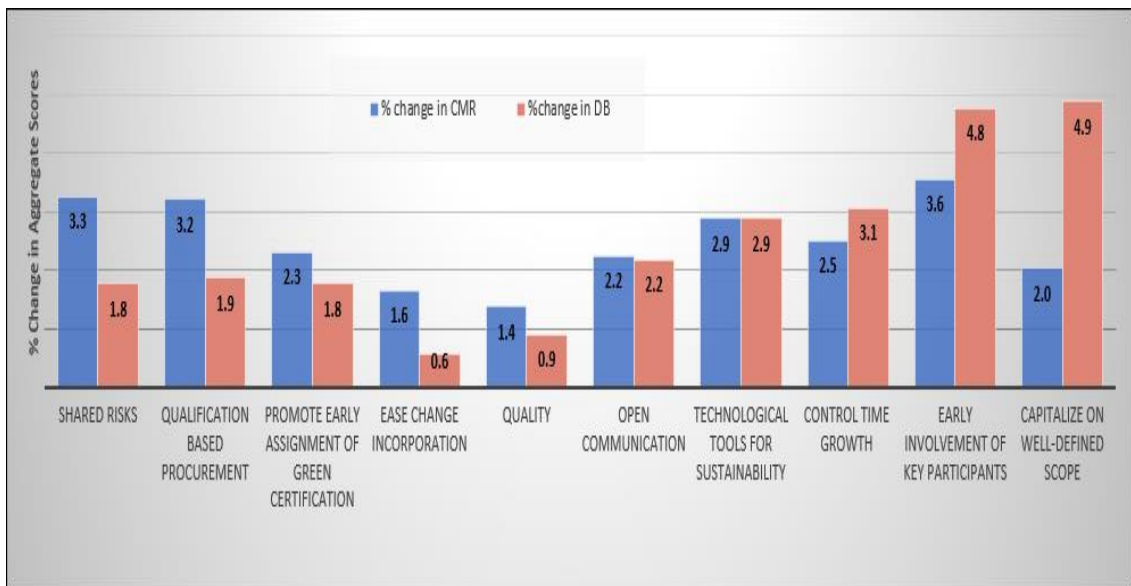


Figure 25. Percentage Change in DB and CMR Aggregate Scores

Scenario analysis was then conducted in order to reach a trade-off or a breakeven point where the aggregate score of DB would be equal to the aggregate score of CMR. The four criteria (shared risks and rewards, qualification-based procurement, promote early assignment of green certification responsibility and ease change incorporation) that had the most impact on the aggregate score of CMR were increased by 25% and the remaining criteria were adjusted dynamically in order to meet the constraint that the summation of all criteria should be equal to 1. The results showed that this scenario leads to a breakeven point where both DB and CMR had aggregate scores equal to 41. Further analysis was then conducted to see the impact of increasing these 4 criteria beyond the 25% to 30% while dynamically altering the weights of the remaining criteria

to maintain the sum at the value of 1. The results showed that this scenario leads to CMR outperforming DB as the aggregate score of CMR was 41 while the aggregate score of DB was 40. Table 25 further illustrates the three scenarios: current values where $DB > CMR$, Breakeven point where $DB = CMR$ and the third scenario where $CMR > DB$. This sensitivity and scenario analysis indicate that the decision is not sensitive to small changes in the weights of the selection criteria. Although the scores of DB and CMR were relatively close, the weights of shared risks and rewards, qualification-based procurement, early assignment of green certification and ease change incorporation would have to change considerably by at least 25% to reverse the decision. The decision makers should feel comfortable in choosing DB as the most appropriate delivery method for this specific sustainable construction project

Table 25. Scenario Analysis

	Current Values: DB > CMR	Breakeven point: DB = CMR	CMR > DB
Changing Criteria			
Control Time Growth	0.1	0.085	0.082
qualification based procurement approach	0.09	0.113	0.117
Capitalize on Project's Quality Performance Levels	0.05	0.042	0.041
Early Involvement of Key Participants	0.15	0.127	0.122
Promote Early Assignment of Green Certification Responsibility	0.09	0.113	0.117
Open Communication Between Team Members	0.08	0.068	0.065
Shared Risks and Rewards	0.09	0.113	0.117
Ability to Efficiently Utilize Advanced Technological Tools to Achieve Sustainable Goals	0.11	0.093	0.090
Capitalize on well-defined scope	0.13	0.110	0.106
Ease change incorporation	0.11	0.138	0.143
Result Cells			
Aggregate Score of DB	43	41	40
Aggregate Score of CMR	40	41	41

6.5. Conclusions

Two decision support models were presented in this chapter to assist decision makers in choosing the most appropriate delivery method for their sustainable construction projects. Model A consisted of four functions: strategic alignment of project's goals and PDMs selection criteria, screening of selection criteria and evaluation of PDMs. The end-user can either opt to use all of the comprehensive criteria or select only the required ones and their weights would be normalized accordingly. While Model B consists of three functions: strategic alignment of project's goals and PDMs selection criteria, screening of selection criteria and evaluation of PDMs. The end-user is given the flexibility to choose up to ten selection criteria and assign their preference score according to his prior knowledge and experience. Furthermore, a hypothetical case-study of a sustainable engineering building in a private university in the UAE has been conducted to demonstrate the applicability of Model A and run sensitivity analysis. The results revealed that the aggregate scores of DB and CMR were very close to each other and they were almost 2.5 times greater than the aggregate score of DBB. Lastly sensitivity analysis indicated that the model is not sensitive to small variations in the weights of the selection criteria. Although the scores of DB and CMR were relatively close, the weights of selection criteria such as shared risks and rewards, qualification-based procurement, early assignment of green certification and ease change incorporation would have to change considerably by at least 25% to reverse the decision.

Chapter 7. Summary and Conclusions

This final chapter of the dissertation presents the takeaways and the main conclusions of this research as well as recommendations for future research ideas.

7.1. Summary

As the demand for sustainable construction increases, the need to update project management practices in order to satisfy the objectives of sustainability becomes more significant. Project delivery method is a crucial decision in project management that impacts the success of construction projects. The extensive literature review conducted has identified the project delivery methods, selection criteria and selection decision models available in practice as well as the significance and the challenges encountered in sustainable construction. However, gaps were identified as there was a lack of a comprehensive criteria list to select project delivery methods in sustainable construction projects and a lack of selection model that comprises that comprehensive criteria list. In light of this, the main aim of this research was to develop a comprehensive decision support model that will assist clients in choosing the most appropriate delivery method for their sustainable construction projects. In order to achieve this aim, the underlying challenges of sustainable construction delivery were categorized using factor analysis. This helped derive relevant sustainability -specific criteria to overcome these challenges which consisted of 5 groups: level of integration, green liability, green team, green criteria, technology and innovation. PLS-SEM was then used to predict the significance of these sustainability-specific selection criteria to the achievement of project success criteria such as efficiency, impact on client, team effectiveness and sustainability. Moreover, AHP was used to calculate the relative weights of the traditional and sustainability-specific criteria. Similarly, AHP was also used to compute the effectiveness values of the three most common delivery methods (DBB, DB, CMR) in achieving the comprehensive criteria. Lastly, the outputs of all these statistical procedures were used to develop two decision support models that incorporate a comprehensive selection criterion of both traditional and sustainability-specific criteria and the three most common delivery methods: DBB, DB and CMR. A case study was administered to demonstrate the applicability of the model. The results showed that DBB is outmatched by the integration and advanced technological requirements of sustainable construction. While DB and CMR have great potential in

optimizing the success rate of sustainable construction projects. A customizable prototype software of the decision model was also developed where the unfamiliar operations required in the adopted technique would be transparent to the end-users who can then focus on the parts of the process that are most beneficial to them without worrying about the other arduous tasks. This decision support model will provide users with a justifiable rationale for selecting the delivery method for their sustainable construction projects.

7.2. Conclusions

The following conclusions have been made from this research:

1. Thirty-three challenges of sustainable construction projects delivery were extracted from literature and clustered through factor analysis into 7 groups: financial, sustainable material and technology, contractual, design, lack of experience, regulations and limited organizational awareness.
2. Financial challenges accounted for 30% of the variance in the data which further confirms that these challenges are the most significant barriers to sustainable development.
3. Five sustainability-specific criteria groups were derived to overcome these challenges which were: level of integration, green liability, green team, green contract, technology and innovation.
4. Three of the traditional selection criteria were deemed insignificant as they had loading factors that were less than the cut-off value of 0.5 which were: ensure lowest cost, capitalize on expected low levels of change orders and owner's willingness to take risks.
5. All of the sustainability-specific selection criteria were significant with loading factors greater than 0.5.
6. All predicted hypothesized paths in both the traditional and sustainability-specific selection criteria PLS-SEM frameworks were significant at the 0.05 level which confirms the importance of the traditional and sustainability-specific selection criteria of project delivery methods in optimizing construction project success.

7. The level of integration criteria group had the highest path coefficient in relation to achieving efficiency and impact on client which were equal to 0.6 and 0.537 respectively.
8. Green team had the highest path coefficient in relation to achieving team effectiveness which was equal to 0.659.
9. Green liability criteria group had the highest path coefficient in relation to achieving sustainability in a construction project which was equal to 0.658.
10. Sustainability-specific criteria were 1.4 times more important than traditional selection criteria.
11. Level of integration was the most important criteria group in the overall comprehensive list of both traditional and newly proposed sustainability-specific selection criteria with a global weight of 0.174.
12. Project's characteristics criteria dropped to the bottom of the list with a global weight of 0.0532.
13. The top 10 criteria with the highest global weights in the whole comprehensive selection criteria of both traditional and sustainability-specific criteria are: early involvement of key participants, joint development of project goals, collaborative decision making and control, intensified planning, capitalize on a well-defined cope, efficiently utilize poor-scope, ease change incorporation, ability to use full potential of BIM, efficiently utilize advanced technological tools to achieve sustainable goals, ability to use technology to enhance communication.
14. DBB is still the preferred delivery method among the traditional selection criteria.
15. Sustainable construction projects have special requirements that have caused the capabilities of the traditional DBB method to be outmatched.
16. DB and CMR are relatively compatible in achieving sustainability-specific criteria such as green team criteria as well as technology and innovation criteria.
17. DB ranks higher in areas such as levels of integration that include collaborative decision control and joint development of project goals.
18. CMR is more effective in achieving green contract criteria such as flexible payment provisions and contractual incentive fees.

19. Model A saves time and resources for the decision makers as all the cumbersome mathematical AHP calculations are already embedded in the software.
20. Model B gives users the flexibility to rank up to ten selection criteria and tailor their relevance according to their project's specific characteristics.
21. Scenario analysis conducted on the case study indicate that increasing the weights of shared risks and rewards, qualification-based procurement, early assignment of green certification and ease change incorporation by 25% while dynamically adjusting the weights of the remaining six criteria to maintain the sum of all ten selection criteria weights at the value of "1" would result in a breakeven point where aggregate score of DB= aggregate score of CMR= 41.
22. The sensitivity analysis conducted on the case study indicate that the decision is not sensitive to small variations in the weights of the selection criteria. Although the scores of DB and CMR were relatively close, the weights of shared risks and rewards, qualification-based procurement, early assignment of green certification and ease change incorporation would have to change considerably by at least 25% to reverse the decision.

7.3. Future Recommendations

The limitations experienced in this dissertation include:

1. The decision support model considered only three project delivery alternatives due to the complexity of AHP
2. The model only relied on data from the UAE as it was very hard to collect a more global database.

The following points are recommended for future research areas in the field of sustainable construction projects delivery:

1. Test the application of the decision support models on real-life sustainable construction projects.
2. Expand the set of project delivery alternatives available in the decision support model to include other derivatives of the most common forms of project delivery methods such as design-build-transfer and turnkey.

3. Utilize other statistical tools to compute the effectiveness values of the project delivery methods in achieving the selection criteria such as Fuzzy AHP and compare with the values produced in this research
4. Utilize covariance-based structural equation model with a large sample size to test the established theoretical frameworks that have been predicted in this research through partial least square structural equation modelling.
5. Expand the decision support model to include contract pricing methods as well.

References

- [1] H. Blutstein, "A forgotten pioneer of sustainability," *Journal of Cleaner Production*, vol. 11, no. 3, pp. 339-341, 2003.
- [2] Y. Tan, L. Shen, and H. Yao, "Sustainable construction practice and contractors' competitiveness: A preliminary study," *Habitat international*, vol. 35, no. 2, pp. 225-230, 2011.
- [3] L. Shen, Y. Wu, and X. Zhang, "Key Assessment Indicators for the Sustainability of Infrastructure Projects," *Journal of Construction Engineering and Management*, vol. 137, no. 6, pp. 441-451, 2019/10/21 2011, doi: 10.1061/(ASCE)CO.1943-7862.0000315.
- [4] C. Oltean-Dumbrava, R. Watts Greg, and S. Miah Abdul Hakim, "'Top-Down-Bottom-Up' Methodology as a Common Approach to Defining Bespoke Sets of Sustainability Assessment Criteria for the Built Environment," *Journal of Management in Engineering*, vol. 30, no. 1, pp. 19-31, 2019/10/21 2014, doi: 10.1061/(ASCE)ME.1943-5479.0000169.
- [5] L. Montalbán-Domingo, T. García-Segura, M. Amalia Sanz, and E. Pellicer, "Social Sustainability in Delivery and Procurement of Public Construction Contracts," *Journal of Management in Engineering*, vol. 35, no. 2, 2019, doi: 10.1061/(ASCE)ME.1943-5479.0000674.
- [6] J. Zuo, X. H. Jin, and L. Flynn, "Social sustainability in construction - An explorative study," *International Journal of Construction Management*, vol. 12, no. 2, pp. 51-63, 2012, doi: 10.1080/15623599.2012.10773190.
- [7] J. Hao, Z. Chen, Z. Zhang, and G. Loehlein, "Quantifying construction waste reduction through the application of prefabrication: a case study in Anhui, China," *Environmental Science and Pollution Research*, 2020, doi: 10.1007/s11356-020-09026-2.
- [8] G. Ozcan-Deniz and Y. Zhu, "Multi-objective optimization of greenhouse gas emissions in highway construction projects," *Sustainable cities and society*, vol. 28, pp. 162-171, 2017.
- [9] A. Al-Hajj and K. Hamani, "Material waste in the UAE construction industry: Main causes and minimization practices," *Architectural Engineering and Design Management*, vol. 7, no. 4, pp. 221-235, 2011, doi: 10.1080/17452007.2011.594576.
- [10] N. Ghodrati, M. Samari, and M. W. M. Shafiei, "Green Buildings Impacts on Occupants' Health and Productivity," *Journal of Applied Sciences Research*, vol. 8, no. 8, pp. 4235-4241, 2012.
- [11] B. Robichaud Lauren and S. Anantatmula Vittal, "Greening Project Management Practices for Sustainable Construction," *Journal of Management in Engineering*, vol. 27, no. 1, pp. 48-57, 2020/02/19 2011, doi: 10.1061/(ASCE)ME.1943-5479.0000030.
- [12] B. K. Nguyen and H. Altan, "Comparative review of five sustainable rating systems," in *Procedia Engineering*, 2011, vol. 21, pp. 376-386, doi: 10.1016/j.proeng.2011.11.2029. [Online]. Available: <https://www.scopus.com/inward/record.uri?eid=2-s2.0-84255192335&doi=10.1016%2fj.proeng.2011.11.2029&partnerID=40&md5=1e3e80a514fee1d307ed67d6f8401abf>

- [13] E. P. Small and M. A. Mazrooei, "Evaluation of Construction-specific Provisions of Sustainable Design Codes and Standards in the United Arab Emirates," in *Procedia Engineering*, 2016, vol. 145, pp. 1021-1028, doi: 10.1016/j.proeng.2016.04.132. [Online]. Available: <https://www.scopus.com/inward/record.uri?eid=2-s2.0-84999885269&doi=10.1016%2fj.proeng.2016.04.132&partnerID=40&md5=d66313493313e26a5fcc8968ed3e1c86>
- [14] T. Mezher, D. Goldsmith, and N. Choucri, "Renewable energy in Abu Dhabi: Opportunities and challenges," *Journal of Energy Engineering*, vol. 137, no. 4, pp. 169-176, 2011, doi: 10.1061/(ASCE)EY.1943-7897.0000042.
- [15] A. Tawfik Alqadami, N. A. W. Abdullah Zawawi, Y. Rahmawati, W. Alaloul, and A. F. Alshalif, "Challenges of Implementing Green Procurement in Public Construction Projects in Malaysia," in *IOP Conference Series: Earth and Environmental Science*, 2020, vol. 498, 1 ed., doi: 10.1088/1755-1315/498/1/012097. [Online]. Available: <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85086887526&doi=10.1088%2f1755-1315%2f498%2f1%2f012097&partnerID=40&md5=f3eb6c3c4a657f0ba73a3c195e63fc7c>
- [16] S. Alsanad, "Awareness, Drivers, Actions, and Barriers of Sustainable Construction in Kuwait," in *Procedia Engineering*, 2015, vol. 118, pp. 969-983, doi: 10.1016/j.proeng.2015.08.538. [Online]. Available: <https://www.scopus.com/inward/record.uri?eid=2-s2.0-84948395203&doi=10.1016%2fj.proeng.2015.08.538&partnerID=40&md5=5e8850c338e1510e004e3891ca272123>
- [17] D. O. Aghimien, C. O. Aigbavboa, and W. D. Thwala, "Microscoping the challenges of sustainable construction in developing countries," *Journal of Engineering, Design and Technology*, vol. 17, no. 6, pp. 1110-1128, 2019, doi: 10.1108/JEDT-01-2019-0002.
- [18] P. T. I. Lam, E. H. W. Chan, C. K. Chau, C. S. Poon, and K. P. Chun, "Integrating green specifications in construction and overcoming barriers in their use," *Journal of Professional Issues in Engineering Education and Practice*, vol. 135, no. 4, pp. 142-152, 2009, doi: 10.1061/(ASCE)1052-3928(2009)135:4(142).
- [19] S. D. Djokoto, J. Dadzie, and E. Ohemeng-Ababio, "Barriers to sustainable construction in the ghanaian construction industry: Consultants perspectives," *Journal of Sustainable Development*, vol. 7, no. 1, pp. 134-143, 2014, doi: 10.5539/jsd.v7n1p134.
- [20] B.-G. Hwang and W. J. Ng, "Project management knowledge and skills for green construction: Overcoming challenges," *International Journal of Project Management*, vol. 31, no. 2, pp. 272-284, 2013, doi: <https://doi.org/10.1016/j.ijproman.2012.05.004>.
- [21] S. El-Sayegh, "Evaluating the effectiveness of project delivery methods," *Journal of Construction Management and Economics*, vol. 23, pp. 457-465, 2008.
- [22] A. Oyetunji Adetokunbo and D. Anderson Stuart, "Relative Effectiveness of Project Delivery and Contract Strategies," *Journal of Construction Engineering and Management*, vol. 132, no. 1, pp. 3-13, 2006/02/10 2006, doi: 10.1061/(ASCE)0733-9364(2006)132:1(3).

- [23] R. Hale Darren, P. Shrestha Pramen, G. E. Gibson, and C. Migliaccio Giovanni, "Empirical Comparison of Design/Build and Design/Bid/Build Project Delivery Methods," *Journal of Construction Engineering and Management*, vol. 135, no. 7, pp. 579-587, 2009, doi: 10.1061/(ASCE)CO.1943-7862.0000017.
- [24] K. A. Tenah, "Project delivery systems for construction: An overview," *Cost Engineering*, vol. 43, no. 1, p. 30, 2001.
- [25] E. O. P. Akpan, B. Amade, S. E. Okangba, and C. O. Ekweozor, "Constructability practice and project delivery processes in the Nigerian construction industry," *Journal of Building Performance*, vol. 5, no. 1, 2014.
- [26] A. Engebø, O. Lædre, B. Young, P. F. Larssen, J. Lohne, and O. J. Klakegg, "Collaborative project delivery methods: A scoping review," *Journal of Civil Engineering and Management*, vol. 26, no. 3, pp. 278-303, 2020, doi: 10.3846/jcem.2020.12186.
- [27] S. Ahmed and S. El-Sayegh, "Critical Review of the Evolution of Project Delivery Methods in the Construction Industry," *Buildings*, vol. 11, no. 1, p. 11, 2021.
- [28] C. Friedlander Mark, "FEATURE: Design/Build Solutions," *Journal of Management in Engineering*, vol. 14, no. 6, pp. 59-64, 2020/03/10 1998, doi: 10.1061/(ASCE)0742-597X(1998)14:6(59).
- [29] N. Azhar, Y. Kang, and I. U. Ahmad, "Factors Influencing Integrated Project Delivery in Publicly Owned Construction Projects: An Information Modelling Perspective," *Procedia Engineering*, vol. 77, pp. 213-221, 2014, doi: <https://doi.org/10.1016/j.proeng.2014.07.019>.
- [30] F. Griffiths, "Project contract strategy for 1992 and beyond," *International Journal of Project Management*, vol. 7, no. 2, pp. 69-83, 1989, doi: [https://doi.org/10.1016/0263-7863\(89\)90019-7](https://doi.org/10.1016/0263-7863(89)90019-7).
- [31] P. M. Teicholz and D. B. Ashley, "Optimal bid prices for unit price contract," *Journal of the Construction Division*, vol. 104, no. 1, pp. 57-67, 1978.
- [32] G. Douglas, J. Koch, and K. Molenaar, "Preparing for Design-build Projects: A Primer for Owners, Engineers, and Contractors," ed: United State of America, American Society of Civil Engineers, 2006.
- [33] G. Okere, "Comparison of DB to DBB on highway projects in Washington State, USA," *Journal of Construction Supply Chain Management Vol*, vol. 8, no. 2, pp. 73-86.
- [34] B. Xia, P. C. Chan Albert, and F. Y. Yeung John, "Developing a Fuzzy Multicriteria Decision-Making Model for Selecting Design-Build Operational Variations," *Journal of Construction Engineering and Management*, vol. 137, no. 12, pp. 1176-1184, 2020/03/10 2011, doi: 10.1061/(ASCE)CO.1943-7862.0000381.
- [35] M. Algarni Ayed, D. Arditi, and G. Polat, "Build-Operate-Transfer in Infrastructure Projects in the United States," *Journal of Construction Engineering and Management*, vol. 133, no. 10, pp. 728-735, 2020/11/01 2007, doi: 10.1061/(ASCE)0733-9364(2007)133:10(728).
- [36] F. E. Gould, *Managing the construction process : estimating, scheduling, and project control*. Boston: Prentice Hall (in English), 2012.
- [37] M. Rojas Eddy and I. Kell, "Comparative Analysis of Project Delivery Systems Cost Performance in Pacific Northwest Public Schools," *Journal of*

- Construction Engineering and Management*, vol. 134, no. 6, pp. 387-397, 2020/08/03 2008, doi: 10.1061/(ASCE)0733-9364(2008)134:6(387).
- [38] N. Carpenter and D. C. Bausman, "Project Delivery Method Performance for Public School Construction: Design-Bid-Build versus CM at Risk," *Journal of Construction Engineering and Management*, vol. 142, no. 10, 2016, doi: 10.1061/(ASCE)CO.1943-7862.0001155.
- [39] R. Azari-Najafabadi, G. Ballard, S. Cho, and Y.-W. Kim, "A Dream of Ideal Project Delivery System," *AEI 2011*, pp. 427-436, 2020/03/11, doi: doi:10.1061/41168(399)50.
- [40] M. H. Al Mousli and S. M. El-Sayegh, "Assessment of the design–construction interface problems in the UAE," *Architectural Engineering and Design Management*, vol. 12, no. 5, pp. 353-366, 2016.
- [41] C. C. Aia and M. H. Construction, "Integrated project delivery: a working definition," *The American Institute of Architects, California Council, Sacramento*, 2007.
- [42] N. Azhar, Y. Kang, and I. Ahmad, "Critical look into the relationship between information and communication technology and integrated project delivery in public sector construction," *Journal of Management in Engineering*, vol. 31, no. 5, 2015, doi: 10.1061/(ASCE)ME.1943-5479.0000334.
- [43] B. Tatum Clyde, "Issues in Professional Construction Management," *Journal of Construction Engineering and Management*, vol. 109, no. 1, pp. 112-119, 2020/12/08 1983, doi: 10.1061/(ASCE)0733-9364(1983)109:1(112).
- [44] M. P. Gallaher, A. O’connor, J. L. Dettbarn, and L. T. Gilday, "Cost analysis of inadequate interoperability in the US capital facilities industry (NIST GCR 04-867)," *National Institute of Standards and Technology, Gaithersburg, MD, USA*, 2004.
- [45] J. Choi, S. Yun, F. Leite, and S. P. Mulva, "Team Integration and Owner Satisfaction: Comparing Integrated Project Delivery with Construction Management at Risk in Health Care Projects," *Journal of Management in Engineering*, vol. 35, no. 1, 2019, doi: 10.1061/(ASCE)ME.1943-5479.0000654.
- [46] C. Kent David and B. Becerik-Gerber, "Understanding Construction Industry Experience and Attitudes toward Integrated Project Delivery," *Journal of Construction Engineering and Management*, vol. 136, no. 8, pp. 815-825, 2020/07/11 2010, doi: 10.1061/(ASCE)CO.1943-7862.0000188.
- [47] S. A.Dargham, M. Bou Hatoum, M. Tohme, and F. Hamzeh, *Implementation of Integrated Project Delivery in Lebanon: Overcoming the Challenges*. 2019.
- [48] R. E. Levitt, "Towards project management 2.0," *Engineering project organization journal*, vol. 1, no. 3, pp. 197-210, 2011.
- [49] M. El Asmar, S. Hanna Awad, and W.-Y. Loh, "Quantifying Performance for the Integrated Project Delivery System as Compared to Established Delivery Systems," *Journal of Construction Engineering and Management*, vol. 139, no. 11, p. 04013012, 2020/07/11 2013, doi: 10.1061/(ASCE)CO.1943-7862.0000744.
- [50] S. Hanna Awad, "Benchmark Performance Metrics for Integrated Project Delivery," *Journal of Construction Engineering and Management*, vol. 142, no. 9, p. 04016040, 2020/08/03 2016, doi: 10.1061/(ASCE)CO.1943-7862.0001151.

- [51] S. M. E. Sepasgozar, R. Karimi, S. Shirowzhan, M. Mojtahedi, S. Ebrahimzadeh, and D. McCarthy, "Delay causes and emerging digital tools: A novel model of delay analysis, including integrated project delivery and PMBOK," *Buildings*, vol. 9, no. 9, p. 191, 2019.
- [52] V. Demetracopoulou, J. O'Brien William, and N. Khwaja, "Lessons Learned from Selection of Project Delivery Methods in Highway Projects: The Texas Experience," *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, vol. 12, no. 1, p. 04519040, 2020/08/03 2020, doi: 10.1061/(ASCE)LA.1943-4170.0000340.
- [53] S. Ghosh and K. F. Robson, "Analyzing the Empire State Building Project from the Perspective of Lean Delivery System—A Descriptive Case Study," *International Journal of Construction Education and Research*, vol. 11, no. 4, pp. 257-267, 2015, doi: 10.1080/15578771.2015.1059395.
- [54] P. Lahdenperä, "Making sense of the multi-party contractual arrangements of project partnering, project alliancing and integrated project delivery," *Construction Management and Economics*, vol. 30, no. 1, pp. 57-79, 2012, doi: 10.1080/01446193.2011.648947.
- [55] M. Konchar and V. Sanvido, "Comparison of U.S. Project Delivery Systems," *Journal of Construction Engineering and Management*, vol. 124, no. 6, pp. 435-444, 2019/11/06 1998, doi: 10.1061/(ASCE)0733-9364(1998)124:6(435).
- [56] T. Alhazmi and R. McCaffer, "Project procurement system selection model," *Journal of Construction Engineering and management*, vol. 126, no. 3, pp. 176-184, 2000.
- [57] A. Kunz and H. G. Ballard, "Global Project Delivery Systems Using BIM," *AEI 2011*, pp. 472-479, 2020/04/30, doi: doi:10.1061/41168(399)55.
- [58] S. Korkmaz, D. Riley, and M. Horman, "Piloting Evaluation Metrics for Sustainable High-Performance Building Project Delivery," *Journal of Construction Engineering and Management*, vol. 136, no. 8, pp. 877-885, 2019/09/09 2010, doi: 10.1061/(ASCE)CO.1943-7862.0000195.
- [59] L. Benson, B. Bodniewicz, J. P. Vittands, J. Carr, and K. Watson, "Innovative design-build procurement approach for large wastewater facility," *Proceedings of the Water Environment Federation*, vol. 2013, no. 6, pp. 7253-7269, 2013.
- [60] J. Giachino, M. Cecil, B. Husselbee, and C. Matthews, "Alternative project delivery: construction management at risk, design-build and public-private partnerships," *Proceedings of the Water Environment Federation*, vol. 2015, no. 4, pp. 1-11, 2015.
- [61] I. M. Mahdi and K. Alreshaid, "Decision support system for selecting the proper project delivery method using analytical hierarchy process (AHP)," *International journal of project management*, vol. 23, no. 7, pp. 564-572, 2005.
- [62] D. Tran and K. Molenaar, "Critical Risk Factors in Project Delivery Method Selection for Highway Projects," *Construction Research Congress 2012*, pp. 331-340, 2020/04/26, doi: doi:10.1061/9780784412329.034.
- [63] B. Farnsworth Clifton, O. Warr Rebecca, E. Weidman Justin, and D. Mark Hutchings, "Effects of CM/GC Project Delivery on Managing Process Risk in Transportation Construction," *Journal of Construction Engineering and Management*, vol. 142, no. 3, p. 04015091, 2020/07/11 2016, doi: 10.1061/(ASCE)CO.1943-7862.0001091.
- [64] O. S. Al-Sobiei, D. Arditi, and G. Polat, "Predicting the risk of contractor default in Saudi Arabia utilizing artificial neural network (ANN) and genetic algorithm

- (GA) techniques," *Construction Management and Economics*, vol. 23, no. 4, pp. 423-430, 2005.
- [65] D. D. Gransberg, W. D. Dillon, L. Reynolds, and J. Boyd, "Quantitative analysis of partnered project performance," *Journal of construction engineering and management*, vol. 125, no. 3, pp. 161-166, 1999.
- [66] R. Loudoun and K. Townsend, "Implementing health promotion programs in the Australian construction industry," *Engineering, Construction and Architectural Management*, vol. 24, no. 2, pp. 260-274, 2017, doi: 10.1108/ECAM-09-2015-0140.
- [67] E. S. Hanna and S. Markham, "Constructing better health and wellbeing? Understanding structural constraints on promoting health and wellbeing in the UK construction industry," *International Journal of Workplace Health Management*, vol. 12, no. 3, pp. 146-159, 2019, doi: 10.1108/IJWHM-03-2018-0031.
- [68] T. Osunsanmi, C. Aigbavboa, and A. Oke, "Construction 4.0: the future of the construction industry in South Africa," *World Academy of Science, Engineering and Technology, International Journal of Civil and Environmental Engineering*, vol. 12, no. 3, pp. 206-212, 2018.
- [69] A. Heidemann and F. Gehbauer, "The way towards cooperative project delivery," *Journal of Financial Management of Property and Construction*, vol. 16, no. 1, pp. 19-30, 2011, doi: 10.1108/13664381111116052.
- [70] B.-G. Hwang and E. S. J. Lim, "Critical Success Factors for Key Project Players and Objectives: Case Study of Singapore," *Journal of Construction Engineering and Management*, vol. 139, no. 2, pp. 204-215, 2013, doi: 10.1061/(ASCE)CO.1943-7862.0000597.
- [71] F. M. Al-Sinan and D. E. Hancher, "Facility project delivery selection model," *Journal of Management in Engineering*, vol. 4, no. 3, pp. 244-259, 1988, doi: 10.1061/(ASCE)9742-597X(1988)4:3(244).
- [72] J. Feghaly, M. El Asmar, S. Ariaratnam, and W. Bearup, "Selecting project delivery methods for water treatment plants," *Engineering, Construction and Architectural Management*, vol. 27, no. 4, pp. 936-951, 2019, doi: 10.1108/ECAM-06-2019-0308.
- [73] E. Bingham, G. E. Gibson, and M. E. Asmar, "Measuring User Perceptions of Popular Transportation Project Delivery Methods Using Least Significant Difference Intervals and Multiple Range Tests," *Journal of Construction Engineering and Management*, vol. 144, no. 6, 2018, doi: 10.1061/(ASCE)CO.1943-7862.0001469.
- [74] M. Qiang, Q. Wen, H. Jiang, and S. Yuan, "Factors governing construction project delivery selection: A content analysis," *International Journal of Project Management*, vol. 33, no. 8, pp. 1780-1794, 2015, doi: <https://doi.org/10.1016/j.ijproman.2015.07.001>.
- [75] H. Li, Z. Wang, and H. Liu, "Design framework for construction project delivery systems," *Technics Technologies Education Management*, vol. 5, no. 4, pp. 847-852, 2010.
- [76] Y. Q. Chen, H. Lu, W. Lu, and N. Zhang, "Analysis of project delivery systems in Chinese construction industry with data envelopment analysis (DEA)," *Engineering, Construction and Architectural Management*, vol. 17, no. 6, pp. 598-614, 2010, doi: 10.1108/09699981011090215.

- [77] B. Liu, T. Huo, Y. Liang, Y. Sun, and X. Hu, "Key Factors of Project Characteristics Affecting Project Delivery System Decision Making in the Chinese Construction Industry: Case Study Using Chinese Data Based on Rough Set Theory," *Journal of Professional Issues in Engineering Education and Practice*, vol. 142, no. 4, 2016, doi: 10.1061/(ASCE)EI.1943-5541.0000278.
- [78] D. E. Lee and D. Arditi, "Total quality performance of design/build firms using quality function deployment," *Journal of Construction Engineering and Management*, vol. 132, no. 1, pp. 49-57, 2006, doi: 10.1061/(ASCE)0733-9364(2006)132:1(49).
- [79] B. Liu, T. Huo, Q. Shen, Z. Yang, J. Meng, and B. Xue, "Which Owner Characteristics Are Key Factors Affecting Project Delivery System Decision Making? Empirical Analysis Based on the Rough Set Theory," *Journal of Management in Engineering*, vol. 31, no. 4, p. 05014018, 2022/01/17 2015, doi: 10.1061/(ASCE)ME.1943-5479.0000298.
- [80] M. I. Al Khalil, "Selecting the appropriate project delivery method using AHP," *International journal of project management*, vol. 20, no. 6, pp. 469-474, 2002.
- [81] J. Ding, N. Wang, and L. Hu, "Framework for Designing Project Delivery and Contract Strategy in Chinese Construction Industry Based on Value-Added Analysis," *Advances in Civil Engineering*, vol. 2018, 2018, doi: 10.1155/2018/5810357.
- [82] H. Martin, T. M. Lewis, and A. Petersen, "Factors affecting the choice of construction project delivery in developing oil and gas economies," *Architectural Engineering and Design Management*, vol. 12, no. 3, pp. 170-188, 2016, doi: 10.1080/17452007.2016.1151762.
- [83] A. Khalafallah and A. Fahim, "Project delivery systems for healthcare projects: To lean or not to lean," *Lean Construction Journal*, vol. 2018, pp. 47-62, 2018.
- [84] A. Touran, D. D. Gransberg, K. R. Molenaar, and K. Ghavamifar, "Selection of project delivery method in transit: Drivers and objectives," *Journal of Management in Engineering*, vol. 27, no. 1, pp. 21-27, 2011.
- [85] D. Alleman, L. C. Antoine Arthur, M. S. Stanford, and R. Molenaar Keith, "Project Delivery Methods' Change-Order Types and Magnitudes Experienced in Highway Construction," *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, vol. 12, no. 2, p. 04520006, 2020/12/07 2020, doi: 10.1061/(ASCE)LA.1943-4170.0000380.
- [86] H. Li, D. Arditi, and Z. Wang, "Factors that affect transaction costs in construction projects," *Journal of Construction Engineering and Management*, vol. 139, no. 1, pp. 60-68, 2013, doi: 10.1061/(ASCE)CO.1943-7862.0000573.
- [87] B. Sirbovan, D. DiProspero, and B. Larson, "Primer of design and construction delivery methods for today's modern pharmaceutical and biotech facilities," *Pharmaceutical Engineering*, vol. 26, no. 3, pp. 8-18, 2006.
- [88] G. D. Creedy, M. Skitmore, and J. K. W. Wong, "Evaluation of risk factors leading to cost overrun in delivery of highway construction projects," *Journal of Construction Engineering and Management*, vol. 136, no. 5, pp. 528-537, 2010, doi: 10.1061/(ASCE)CO.1943-7862.0000160.
- [89] B. Franz, R. Leicht, K. Molenaar, and J. Messner, "Impact of Team Integration and Group Cohesion on Project Delivery Performance," *Journal of Construction Engineering and Management*, vol. 143, no. 1, p. 04016088, 2022/01/17 2017, doi: 10.1061/(ASCE)CO.1943-7862.0001219.

- [90] T. Koppinen and P. Lahdenperä, "The current and future performance of road project delivery methods," in *VTT Publications*, ed, 2004.
- [91] S. T. Ng, D. T. Luu, S. E. Chen, and K. C. Lam, "Fuzzy membership functions of procurement selection criteria," *Construction Management & Economics*, vol. 20, no. 3, pp. 285-296, 2002.
- [92] F. Mafakheri, L. Dai, D. Slezak, and F. Nasiri, "Project Delivery System Selection under Uncertainty: Multicriteria Multilevel Decision Aid Model," *Journal of Management in Engineering*, vol. 23, no. 4, pp. 200-206, 2007/01/17 2007, doi: 10.1061/(ASCE)0742-597X(2007)23:4(200).
- [93] M. M. Kumaraswamy and S. M. Dissanayaka, "Developing a decision support system for building project procurement," *Building and Environment*, vol. 36, no. 3, pp. 337-349, 2001.
- [94] K. R. Molenaar and A. D. Songer, "Model for public sector design-build project selection," *Journal of construction engineering and management*, vol. 124, no. 6, pp. 467-479, 1998.
- [95] K. M. Aldossari, B. C. Lines, J. B. Smithwick, K. C. Hurtado, and K. T. Sullivan, "Best practices of organizational change for adopting alternative project delivery methods in the AEC industry," *Engineering, Construction and Architectural Management*, 2020, doi: 10.1108/ECAM-03-2020-0166.
- [96] S. Moradi, K. Kähkönen, and K. Aaltonen, "Project Managers' Competencies in Collaborative Construction Projects," *Buildings*, vol. 10, no. 3, p. 50, 2020.
- [97] M. Bilec and R. Ries, "Preliminary Study of Green Design and Project Delivery Methods in the Public Sector," *Journal of Green Building*, vol. 2, no. 2, pp. 151-160, 11/29/2020 2007, doi: 10.3992/jgb.2.2.151.
- [98] S.-O. Cheung, T.-I. Lam, Y.-W. Wan, and K.-C. Lam, "Improving Objectivity in Procurement Selection," *Journal of Management in Engineering*, vol. 17, no. 3, pp. 132-139, 2020/04/07 2001, doi: 10.1061/(ASCE)0742-597X(2001)17:3(132).
- [99] H. Moon, K. Cho, T. Hong, and C. Hyun, "Selection Model for Delivery Methods for Multifamily-Housing Construction Projects," *Journal of Management in Engineering*, vol. 27, no. 2, pp. 106-115, 2019/11/09 2011, doi: 10.1061/(ASCE)ME.1943-5479.0000038.
- [100] B. Liu, B. Xue, T. Huo, G. Shen, and M. Fu, "Project external environmental factors affecting project delivery systems selection," *Journal of Civil Engineering and Management*, vol. 25, no. 3, pp. 276-286, 2019, doi: 10.3846/jcem.2019.7460.
- [101] X. Ding, Z. Sheng, J. Du, and Q. Li, "Computational experiment study on selection mechanism of project delivery method based on complex factors," *Mathematical Problems in Engineering*, vol. 2014, 2014, doi: 10.1155/2014/701652.
- [102] C. W. Ibbs, H. Kwak Young, T. Ng, and A. M. Odabasi, "Project Delivery Systems and Project Change: Quantitative Analysis," *Journal of Construction Engineering and Management*, vol. 129, no. 4, pp. 382-387, 2020/07/11 2003, doi: 10.1061/(ASCE)0733-9364(2003)129:4(382).
- [103] Y. H. Ahn, A. R. Pearce, and P. W. Holley, "Project delivery system for foreign manufacturers in the United States," *International Journal of Construction Education and Research*, vol. 5, no. 3, pp. 149-166, 2009, doi: 10.1080/15578770903152757.

- [104] B. C. Lines and G. G. Ravi Kumar, "Developing More Competitive Proposals: Relationship between Contractor Qualifications-Based Proposal Content and Owner Evaluation Scores," *Journal of Construction Engineering and Management*, vol. 144, no. 5, 2018, doi: 10.1061/(ASCE)CO.1943-7862.0001479.
- [105] S. Mollaoglu-Korkmaz, L. Swarup, and D. Riley, "Delivering Sustainable, High-Performance Buildings: Influence of Project Delivery Methods on Integration and Project Outcomes," *Journal of Management in Engineering*, vol. 29, no. 1, pp. 71-78, 2019/09/09 2013, doi: 10.1061/(ASCE)ME.1943-5479.0000114.
- [106] M. Raouf Ayman and G. Al-Ghamdi Sami, "Effectiveness of Project Delivery Systems in Executing Green Buildings," *Journal of Construction Engineering and Management*, vol. 145, no. 10, p. 03119005, 2020/07/11 2019, doi: 10.1061/(ASCE)CO.1943-7862.0001688.
- [107] H. D. R. R. Rosayuru, K. G. A. S. Waidyasekara, and M. K. C. S. Wijewickrama, "Sustainable BIM based integrated project delivery system for construction industry in Sri Lanka," *International Journal of Construction Management*, 2019, doi: 10.1080/15623599.2019.1645263.
- [108] S. Yun and W. Jung, "Benchmarking sustainability practices use throughout industrial construction project delivery," *Sustainability (Switzerland)*, vol. 9, no. 6, 2017, doi: 10.3390/su9061007.
- [109] D. T. Luu, S. T. Ng, and S. E. Chen, "Formulating procurement selection criteria through case-based reasoning approach," *Journal of computing in civil engineering*, vol. 19, no. 3, pp. 269-276, 2005.
- [110] D. T. Luu, S. T. Ng, and S. E. Chen, "A case-based procurement advisory system for construction," *Advances in Engineering Software*, vol. 34, no. 7, pp. 429-438, 2003.
- [111] A. Mostafavi and M. Karamouz, "Selecting Appropriate Project Delivery System: Fuzzy Approach with Risk Analysis," *Journal of Construction Engineering and Management*, vol. 136, no. 8, pp. 923-930, 2022/01/17 2010, doi: 10.1061/(ASCE)CO.1943-7862.0000190.
- [112] Z. P. Lee, R. A. Rahman, and S. I. Doh, "Key drivers for adopting design build: A comparative study between project stakeholders," *Physics and Chemistry of the Earth*, 2020, doi: 10.1016/j.pce.2020.102945.
- [113] M. El-Said, A. El-Dokhmaesy, and M. E. Younis, "Integrated project delivery and associated risk reduction in construction projects in Egypt," *Journal of Engineering and Applied Science*, vol. 66, no. 6, pp. 837-859, 2019.
- [114] D. Q. Tran and K. R. Molenaar, "Exploring critical delivery selection risk factors for transportation design and construction projects," *Engineering, Construction and Architectural Management*, 2014.
- [115] D. Q. Tran and K. R. Molenaar, "Impact of risk on design-build selection for highway design and construction projects," *Journal of Management in Engineering*, vol. 30, no. 2, pp. 153-162, 2014, doi: 10.1061/(ASCE)ME.1943-5479.0000210.
- [116] S. P. K. Bypaneni and D. Q. Tran, "Empirical Identification and Evaluation of Risk in Highway Project Delivery Methods," *Journal of Management in Engineering*, vol. 34, no. 3, 2018, doi: 10.1061/(ASCE)ME.1943-5479.0000602.

- [117] E. Osipova and P. E. Eriksson, "How procurement options influence risk management in construction projects," *Construction Management and Economics*, vol. 29, no. 11, pp. 1149-1158, 2011, doi: 10.1080/01446193.2011.639379.
- [118] F. T. Uhlik and M. D. Eller, "Alternative delivery approaches for military medical construction projects," *Journal of Architectural Engineering*, vol. 5, no. 4, pp. 149-155, 1999, doi: 10.1061/(ASCE)1076-0431(1999)5:4(149).
- [119] H. A. Mesa, K. R. Molenaar, and L. F. Alarcón, "Exploring performance of the integrated project delivery process on complex building projects," *International Journal of Project Management*, vol. 34, no. 7, pp. 1089-1101, 2016, doi: 10.1016/j.ijproman.2016.05.007.
- [120] M. Jefferies, G. J. Brewer, and T. Gajendran, "Using a case study approach to identify critical success factors for alliance contracting," *Engineering, Construction and Architectural Management*, vol. 21, no. 5, pp. 465-480, 2014, doi: 10.1108/ECAM-01-2012-0007.
- [121] M.-R. Pooyan, "A model for selecting project delivery systems in post-conflict construction projects," 2012.
- [122] N. Fenton and M. Neil, *Risk assessment and decision analysis with Bayesian networks*. Crc Press, 2018.
- [123] T. Krueger, T. Page, K. Hubacek, L. Smith, and K. Hiscock, "The role of expert opinion in environmental modelling," *Environmental Modelling & Software*, vol. 36, pp. 4-18, 2012.
- [124] M. Skitmore and D. Marsden, "Which procurement system? Towards a universal procurement selection technique," *Construction Management and Economics*, vol. 6, no. 1, pp. 71-89, 1988.
- [125] T. L. Saaty, *Decision making with dependence and feedback: The analytic network process*. RWS Publ., 1996.
- [126] S. El-Abbasy Mohammed, T. Zayed, M. Ahmed, H. Alzraiee, and M. Abouhamad, "Contractor Selection Model for Highway Projects Using Integrated Simulation and Analytic Network Process," *Journal of Construction Engineering and Management*, vol. 139, no. 7, pp. 755-767, 2020/04/11 2013, doi: 10.1061/(ASCE)CO.1943-7862.0000647.
- [127] N. Khwaja, J. O'Brien William, M. Martinez, B. Sankaran, T. O'Connor James, and W. "Bill" Hale, "Innovations in Project Delivery Method Selection Approach in the Texas Department of Transportation," *Journal of Management in Engineering*, vol. 34, no. 6, p. 05018010, 2020/08/03 2018, doi: 10.1061/(ASCE)ME.1943-5479.0000645.
- [128] A. Hartmann, P. E. D. Love, W. Ibbs, and Y. Y. Chih, "Alternative methods for choosing an appropriate project delivery system (PDS)," *Facilities*, 2011.
- [129] M. Gordon Christopher, "Choosing Appropriate Construction Contracting Method," *Journal of Construction Engineering and Management*, vol. 120, no. 1, pp. 196-210, 2020/04/13 1994, doi: 10.1061/(ASCE)0733-9364(1994)120:1(196).
- [130] A. N. Meshref, E. A. Elkasaby, and O. Wageh, "Innovative reliable approach for optimal selection for construction infrastructures projects delivery systems," *Innovative Infrastructure Solutions*, vol. 5, no. 2, 2020, doi: 10.1007/s41062-020-00307-w.

- [131] R. Schultz, A. Sarfaraz, and K. Jenab, "Analysis of risk and reliability in project delivery methods," in *Transportation Systems and Engineering: Concepts, Methodologies, Tools, and Applications*, vol. 2-3, 2015, pp. 612-622.
- [132] Z. Popic and O. Moselhi, "Project Delivery Systems Selection for Capital Projects Using the Analytical Hierarchy Process and the Analytical Network Process," *Construction Research Congress 2014*, pp. 1339-1348, 2020/04/13, doi: doi:10.1061/9780784413517.137.
- [133] T. L. Saaty, "The analytic hierarchy and analytic network processes for the measurement of intangible criteria and for decision-making," in *International Series in Operations Research and Management Science* vol. 233, ed, 2016, pp. 363-419.
- [134] M. Marzouk and L. Elmestekawi, "Analyzing procurement route selection for electric power plants projects using SMART," *Journal of Civil Engineering and Management*, vol. 21, no. 7, pp. 912-922, 2015, doi: 10.3846/13923730.2014.971131.
- [135] H. Li, K. Qin, and P. Li, "Selection of project delivery approach with unascertained model," *Kybernetes*, vol. 44, no. 2, pp. 238-252, 2015, doi: 10.1108/K-01-2014-0012.
- [136] M. Khanzadi, F. Nasirzadeh, S. M. H. Hassani, and N. N. Mohtashemi, "An integrated fuzzy multi-criteria group decision making approach for project delivery system selection," *Scientia Iranica*, vol. 23, no. 3, pp. 802-814, 2016, doi: 10.24200/sci.2016.2160.
- [137] Y. Cao, H. Li, and L. Su, "Decision-making for project delivery system with related-indicators based on pythagorean fuzzy weighted muirhead mean operator," *Information (Switzerland)*, vol. 11, no. 9, 2020, doi: 10.3390/INFO11090451.
- [138] X. An, Z. Wang, H. Li, and J. Ding, "Project Delivery System Selection with Interval-Valued Intuitionistic Fuzzy Set Group Decision-Making Method," *Group Decision and Negotiation*, vol. 27, no. 4, pp. 689-707, 2018, doi: 10.1007/s10726-018-9581-y.
- [139] L. Su, H. Li, Y. Cao, and L. Lv, "Project delivery system decision making using pythagorean fuzzy TOPSIS," *Engineering Economics*, vol. 30, no. 4, pp. 461-471, 2019, doi: 10.5755/j01.ee.30.4.22041.
- [140] X. Liu, F. Qian, L. Lin, K. Zhang, and L. Zhu, "Intuitionistic fuzzy entropy for group decision making of water engineering project delivery system selection," *Entropy*, vol. 21, no. 11, 2019, doi: 10.3390/e21111101.
- [141] H. Martin, M. Lewis Timothy, A. Petersen, and E. Peters, "Cloudy with a Chance of Fuzzy: Building a Multicriteria Uncertainty Model for Construction Project Delivery Selection," *Journal of Computing in Civil Engineering*, vol. 31, no. 1, p. 04016046, 2020/08/03 2017, doi: 10.1061/(ASCE)CP.1943-5487.0000614.
- [142] P. H. D. Nguyen, D. Q. Tran, and B. C. Lines, "Empirical Inference System for Highway Project Delivery Selection Using Fuzzy Pattern Recognition," *Journal of Construction Engineering and Management*, vol. 146, no. 12, 2020, doi: 10.1061/(ASCE)CO.1943-7862.0001950.
- [143] T. C. Tsai and M. L. Yang, "Risk assessment of design-bid-build and design-build building projects," *Journal of the Operations Research Society of Japan*, vol. 53, no. 1, pp. 20-39, 2010, doi: 10.15807/jorsj.53.20.

- [144] J. W. Zhu, L. N. Zhou, L. Li, and W. Ali, "Decision simulation of construction project delivery system under the sustainable construction project management," *Sustainability (Switzerland)*, vol. 12, no. 6, 2020, doi: 10.3390/su12062202.
- [145] A. Francis, "Simulating Uncertainties in Construction Projects with Chronographical Scheduling Logic," *Journal of Construction Engineering and Management*, vol. 143, no. 1, 2017, doi: 10.1061/(ASCE)CO.1943-7862.0001212.
- [146] N. Gil, I. D. Tommelein, and G. Ballard, "Theoretical comparison of alternative delivery systems for projects in unpredictable environments," *Construction Management and Economics*, vol. 22, no. 5, pp. 495-508, 2004, doi: 10.1080/01446190310001649100.
- [147] Y. Q. Chen, J. Y. Liu, B. Li, and B. Lin, "Project delivery system selection of construction projects in China," *Expert Systems with Applications*, vol. 38, no. 5, pp. 5456-5462, 2011, doi: <https://doi.org/10.1016/j.eswa.2010.10.008>.
- [148] M. M. Kumaraswamy, "Industry development through creative project packaging and integrated management," *Engineering, Construction and Architectural Management*, 1998.
- [149] F. Y. Y. Ling and M. Liu, "Using neural network to predict performance of design-build projects in Singapore," *Building and Environment*, vol. 39, no. 10, pp. 1263-1274, 2004.
- [150] I. Flood, "Towards the next generation of artificial neural networks for civil engineering," *Advanced Engineering Informatics*, vol. 22, no. 1, pp. 4-14, 2008.
- [151] K. R. Molenaar and A. D. Songer, "Web-based decision support systems: Case study in project delivery," *Journal of Computing in Civil Engineering*, vol. 15, no. 4, pp. 259-267, 2001, doi: 10.1061/(ASCE)0887-3801(2001)15:4(259).
- [152] D. T. Luu, S. T. Ng, and S. E. Chen, "Parameters governing the selection of procurement system—an empirical survey," *Engineering, Construction and Architectural Management*, 2003.
- [153] X. Zhu, X. Meng, and Y. Chen, "A novel decision-making model for selecting a construction project delivery system," *Journal of Civil Engineering and Management*, vol. 26, no. 7, pp. 635-650, 2020, doi: 10.3846/jcem.2020.12915.
- [154] Y. Yoon, J. Jung, and C. Hyun, "Decision-making support systems using case-based reasoning for construction project delivery method selection: Focused on the road construction projects in Korea," *Open Civil Engineering Journal*, vol. 10, pp. 500-512, 2016, doi: 10.2174/1874149501610010500.
- [155] Q. Tran Dai and R. Molenaar Keith, "Risk-Based Project Delivery Selection Model for Highway Design and Construction," *Journal of Construction Engineering and Management*, vol. 141, no. 12, p. 04015041, 2019/09/18 2015, doi: 10.1061/(ASCE)CO.1943-7862.0001024.
- [156] K. R. Molenaar, "Programmatic cost risk analysis for highway megaprojects," *Journal of construction engineering and management*, vol. 131, no. 3, pp. 343-353, 2005.
- [157] J. F. Hair, W. C. Black, B. J. Babin, R. E. Anderson, and R. L. Tatham, "Multivariate Data Analysis, 7th Edn New York," *NY: Pearson.[Google Scholar]*, 2010.
- [158] M. K. Watfa, A. Abdelrehim, N. Shahin, and K. Jaafar, "A structural equation model to assess the impact of sustainability management on the success of

- construction projects," *International Journal of Construction Management*, pp. 1-12, 2021.
- [159] R. Baki, "An Integrated Multi-criteria Structural Equation Model for Green Supplier Selection," *International Journal of Precision Engineering and Manufacturing-Green Technology*, pp. 1-14, 2022.
- [160] V. Demetracopoulou, W. J. O'Brien, N. Khwaja, J. Feghaly, and M. El Asmar, "A critical review and analysis of decision-support processes and tools for project delivery method selection," *Engineering, Construction and Architectural Management*, no. ahead-of-print, 2022.
- [161] S. Ahmed and S. El-Sayegh, "The challenges of sustainable construction projects delivery – evidence from the UAE," *Architectural Engineering and Design Management*, pp. 1-14, 2022, doi: 10.1080/17452007.2022.2027224.
- [162] B. G. Hwang, L. Zhu, Y. Wang, and X. Cheong, "Green Building Construction Projects in Singapore: Cost Premiums and Cost Performance," *Project Management Journal*, vol. 48, no. 4, pp. 67-79, 2017, doi: 10.1177/875697281704800406.
- [163] S. M. El-Sayegh, S. Manjikian, A. Ibrahim, A. Abouelyousr, and R. Jabbour, "Risk identification and assessment in sustainable construction projects in the UAE," *International Journal of Construction Management*, 2018, doi: 10.1080/15623599.2018.1536963.
- [164] A. Oke, C. Aigbavboa, and T. Khangale, "Effect of skills shortage on sustainable construction," in *Advances in Intelligent Systems and Computing* vol. 600, ed, 2018, pp. 303-309.
- [165] D. O. Aghimien, C. O. Aigbavboa, A. E. Oke, and C. Musenga, "Barriers to sustainable construction practices in the Zambian construction industry," in *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 2018, vol. 2018, JUL ed., pp. 2383-2392. [Online]. Available: <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85066929524&partnerID=40&md5=d730411463b7219429a0e6d8b108aa4f>
- [166] L. N. Dwaikat and K. N. Ali, "Green buildings cost premium: A review of empirical evidence," *Energy and Buildings*, vol. 110, pp. 396-403, 2016, doi: 10.1016/j.enbuild.2015.11.021.
- [167] A. Opoku, H. Cruickshank, and V. Ahmed, "Organizational leadership role in the delivery of sustainable construction projects in UK," *Built Environment Project and Asset Management*, vol. 5, no. 2, pp. 154-169, 2015, doi: 10.1108/BEPAM-12-2013-0074.
- [168] C. Lueneburger and D. Goleman, "The change leadership sustainability demands," *MIT Sloan Management Review*, vol. 51, no. 4, pp. 49-55, 2010.
- [169] X. Zhang, M. Skitmore, and Y. Peng, "Exploring the challenges to industrialized residential building in China," *Habitat International*, vol. 41, pp. 176-184, 2014, doi: 10.1016/j.habitatint.2013.08.005.
- [170] Q. Wang, D. Zhao, B. Yang, and C. Li, "Risk assessment of the UPIoT construction in China using combined dynamic weighting method under IFGDM environment," *Sustainable Cities and Society*, vol. 60, 2020, doi: 10.1016/j.scs.2020.102199.
- [171] A. A. E. Othman and N. M. A. Abdelwahab, "Achieving sustainability through integrating risk management into the architectural design process," *Journal of Engineering, Design and Technology*, vol. 16, no. 1, pp. 25-43, 2018, doi: 10.1108/JEDT-09-2017-0087.

- [172] R. Ayman, Z. Alwan, and L. McIntyre, "BIM for sustainable project delivery: review paper and future development areas," *Architectural Science Review*, vol. 63, no. 1, pp. 15-33, 2020, doi: 10.1080/00038628.2019.1669525.
- [173] A. Whyte and D. Scott, "Life-cycle costing analysis to assist design decisions: Beyond 3D building information modelling," in *EG-ICE 2010 - 17th International Workshop on Intelligent Computing in Engineering*, 2019. [Online]. Available: <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85083944996&partnerID=40&md5=e812771b01f732c389fa0e3909b7643b>
- [174] S. M. El-Sayegh, T. AbdRaboh, D. Elian, N. ElJarad, and Y. Ahmad, "Developing a bi-parameter bidding model integrating price and sustainable construction practices," *International Journal of Construction Management*, 2020, doi: 10.1080/15623599.2020.1768625.
- [175] M. Suprpto, H. L. M. Bakker, H. G. Mooi, and M. J. C. M. Hertogh, "How do contract types and incentives matter to project performance?," *International Journal of Project Management*, vol. 34, no. 6, pp. 1071-1087, 2016, doi: <https://doi.org/10.1016/j.ijproman.2015.08.003>.
- [176] H. Rasekh and T. J. McCarthy, "Delivering sustainable building projects – Challenges, reality and success," *Journal of Green Building*, vol. 11, no. 3, pp. 143-161, 2016, doi: 10.3992/jgb.11.3.143.1.
- [177] T. Zayed, M. Amer, and J. Pan, "Assessing risk and uncertainty inherent in Chinese highway projects using AHP," *International Journal of Project Management*, vol. 26, no. 4, pp. 408-419, 2008, doi: 10.1016/j.ijproman.2007.05.012.
- [178] A. A. M. Bohari, M. Skitmore, B. Xia, and M. Teo, "Green oriented procurement for building projects: Preliminary findings from Malaysia," *Journal of Cleaner Production*, vol. 148, pp. 690-700, 2017, doi: 10.1016/j.jclepro.2017.01.141.
- [179] M. Tafazzoli, S. Kermanshachi, K. Shrestha, and K. Kisi, "Investigating the relative importance barriers to sustainable construction related to owners, contractors, and government," in *Construction Research Congress 2020: Infrastructure Systems and Sustainability - Selected Papers from the Construction Research Congress 2020*, 2020, pp. 341-350, doi: 10.1061/9780784482858.038. [Online]. Available: <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85096926322&doi=10.1061%2f9780784482858.038&partnerID=40&md5=2bf131815a224262fa141dfdb12200f8>
- [180] P. X. W. Zou, G. Zhang, and J. Wang, "Understanding the key risks in construction projects in China," *International Journal of Project Management*, vol. 25, no. 6, pp. 601-614, 2007, doi: 10.1016/j.ijproman.2007.03.001.
- [181] B. G. Hwang, M. Shan, and N. N. B. Supa'at, "Green commercial building projects in Singapore: Critical risk factors and mitigation measures," *Sustainable Cities and Society*, vol. 30, pp. 237-247, 2017, doi: 10.1016/j.scs.2017.01.020.
- [182] K. Williams and C. Dair, "A framework for assessing the sustainability of brownfield developments," *Journal of Environmental Planning and Management*, vol. 50, no. 1, pp. 23-40, 2007, doi: 10.1080/09640560601048275.

- [183] A. L. Olanrewaju, C. S. Min, S. Sanmargaraja, and V. Ponniah, "What is Stopping the Adoption of Sustainable Residential Buildings in Malaysia?," in *Green Energy and Technology*, ed, 2020, pp. 181-198.
- [184] S. Parkin, *The positive deviant: Sustainability leadership in a perverse world* (The Positive Deviant: Sustainability Leadership in a Perverse World). 2010, pp. 1-316.
- [185] A. P. C. Chan, A. Darko, A. O. Olanipekun, and E. E. Ameyaw, "Critical barriers to green building technologies adoption in developing countries: The case of Ghana," *Journal of Cleaner Production*, vol. 172, pp. 1067-1079, 2018, doi: 10.1016/j.jclepro.2017.10.235.
- [186] M. Tafazzoli, "Becoming Greener in Construction: Overcoming Challenges and Developing Strategies," *International Conference on Sustainable Infrastructure 2017*, pp. 1-13, 2019/10/22, doi: doi:10.1061/9780784481202.001.
- [187] C. Aigbavboa, I. Ohiomah, and T. Zwane, "Sustainable Construction Practices: "a Lazy View" of Construction Professionals in the South Africa Construction Industry," in *Energy Procedia*, 2017, vol. 105, pp. 3003-3010, doi: 10.1016/j.egypro.2017.03.743. [Online]. Available: <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85020733663&doi=10.1016%2fj.egypro.2017.03.743&partnerID=40&md5=94841aef29101723ee61f9e5df15acea>
- [188] T. O. Olawumi, D. W. M. Chan, A. P. C. Chan, and J. K. W. Wong, "Development of a building sustainability assessment method (BSAM) for developing countries in sub-Saharan Africa," *Journal of Cleaner Production*, vol. 263, 2020, doi: 10.1016/j.jclepro.2020.121514.
- [189] Q. Shi, J. Zuo, R. Huang, J. Huang, and S. Pullen, "Identifying the critical factors for green construction - An empirical study in China," *Habitat International*, vol. 40, pp. 1-8, 2013, doi: 10.1016/j.habitatint.2013.01.003.
- [190] G. Tunstall, *Managing the building design process: Second edition* (Managing the Building Design Process: Second Edition). 2006, pp. 1-368.
- [191] A. Qazi, A. Shamayleh, S. El-Sayegh, and S. Formanek, "Prioritizing risks in sustainable construction projects using a risk matrix-based Monte Carlo Simulation approach," *Sustainable Cities and Society*, vol. 65, 2021, doi: 10.1016/j.scs.2020.102576.
- [192] T. Ahmad, M. J. Thaheem, and A. Anwar, "Developing a green-building design approach by selective use of systems and techniques," *Architectural Engineering and Design Management*, vol. 12, no. 1, pp. 29-50, 2016, doi: 10.1080/17452007.2015.1095709.
- [193] A. M. Raouf and S. G. Al-Ghamdi, "Effectiveness of Project Delivery Systems in Executing Green Buildings," *Journal of Construction Engineering and Management*, vol. 145, no. 10, 2019, doi: 10.1061/(ASCE)CO.1943-7862.0001688.
- [194] R. Ruparathna and K. Hewage, "Sustainable procurement in the Canadian construction industry: Current practices, drivers and opportunities," *Journal of Cleaner Production*, vol. 109, pp. 305-314, 2015, doi: 10.1016/j.jclepro.2015.07.007.
- [195] Y. Kang, C. Kim, H. Son, S. Lee, and C. Limsawasd, "Comparison of Preproject Planning for Green and Conventional Buildings," *Journal of Construction Engineering and Management*, vol. 139, no. 11, p. 04013018, 2013/02/11 2013, doi: 10.1061/(ASCE)CO.1943-7862.0000760.

- [196] L. Jing and X. Qin, "Understanding the key risks in green building in China from the perspectives of life cycle and stakeholder," in *Proceedings of the 16th International Symposium on Advancement of Construction Management and Real Estate, CRIOCM 2011*, 2011, pp. 416-422. [Online]. Available: <https://www.scopus.com/inward/record.uri?eid=2-s2.0-84892655863&partnerID=40&md5=fdad234947b14b1cb6f92002adaa8f1f>
- [197] N. Zainul Abidin Nazirah, "Investigating the awareness and application of sustainable construction concept by Malaysian developers," *Habitat International*, vol. 34, no. 4, pp. 421-426, 2010, doi: 10.1016/j.habitatint.2009.11.011.
- [198] S. M. El-Sayegh, M. Basamji, A. Haj Ahmad, and N. Zarif, "Key contractor selection criteria for green construction projects in the UAE," *International Journal of Construction Management*, 2019, doi: 10.1080/15623599.2019.1610545.
- [199] S. M. El-Sayegh, "Risk assessment and allocation in the UAE construction industry," *International Journal of Project Management*, vol. 26, no. 4, pp. 431-438, 2008, doi: 10.1016/j.ijproman.2007.07.004.
- [200] Y. Li Yuan, P.-H. Chen, S. Chew David Ah, C. Teo Chee, and G. Ding Rong, "Critical Project Management Factors of AEC Firms for Delivering Green Building Projects in Singapore," *Journal of Construction Engineering and Management*, vol. 137, no. 12, pp. 1153-1163, 2021/02/28 2011, doi: 10.1061/(ASCE)CO.1943-7862.0000370.
- [201] G. Wu, J. Zuo, and X. Zhao, "Incentive Model Based on Cooperative Relationship in Sustainable Construction Projects," *Sustainability*, vol. 9, no. 7, 2017, doi: 10.3390/su9071191.
- [202] A. R. Lapinski, M. J. Horman, and D. R. Riley, "Lean processes for sustainable project delivery," *Journal of Construction Engineering and Management*, vol. 132, no. 10, pp. 1083-1091, 2006, doi: 10.1061/(ASCE)0733-9364(2006)132:10(1083).
- [203] X. Meng and B. Gallagher, "The impact of incentive mechanisms on project performance," *International Journal of Project Management*, vol. 30, no. 3, pp. 352-362, 2012, doi: <https://doi.org/10.1016/j.ijproman.2011.08.006>.
- [204] J. Kivilä, M. Martinsuo, and L. Vuorinen, "Sustainable project management through project control in infrastructure projects," *International Journal of Project Management*, vol. 35, no. 6, pp. 1167-1183, 2017, doi: <https://doi.org/10.1016/j.ijproman.2017.02.009>.
- [205] L. S. Meyers, G. Gamst, and A. J. Guarino, *Data analysis using SAS enterprise guide*. Cambridge University Press, 2009.
- [206] L. Hatcher and N. O'Rourke, *A step-by-step approach to using SAS for factor analysis and structural equation modeling*. Sas Institute, 2013.
- [207] M. Matsunaga, "How to Factor-Analyze Your Data Right: Do's, Don'ts, and How-To's," *International journal of psychological research*, vol. 3, no. 1, pp. 97-110, 2010.
- [208] C. McGraw-Hill, "Green building smart market report: Design and construction intelligence," ed, 2006.
- [209] A. Asaad and S. M. El-Sayegh, "Key criteria for selecting green suppliers for construction projects in the UAE," *Journal of Financial Management of Property and Construction*, vol. ahead-of-print, no. ahead-of-print, 2021/04/21 2021, doi: 10.1108/JFMPC-11-2019-0083.

- [210] M. H. Pulaski *et al.*, "Field guide for sustainable construction," *Pentagon Renovation and Construction Program Office Safety Sustainability and Environment IPT and Washington Headquarters Services Defense Facilities Directorate, USA*, 2004.
- [211] B. Ozorhon and E. Cinar, "Critical success factors of enterprise resource planning implementation in construction: Case of Turkey," *Journal of Management in Engineering*, vol. 31, no. 6, p. 04015014, 2015.
- [212] C. Berry and S. McCarthy, *Guide to sustainable procurement in construction*. Ciria London, 2011.
- [213] Z. Gou, S. S.-Y. Lau, and D. Prasad, "Market readiness and policy implications for green buildings: case study from Hong Kong," *Journal of Green Building*, vol. 8, no. 2, pp. 162-173, 2013.
- [214] S. M. El-Sayegh, "Evaluating the effectiveness of project delivery methods," *Journal of Construction Management and Economics*, vol. 23, no. 5, pp. 457-465, 2008.
- [215] Y. Q. Chen, H. Lu, W. Lu, and N. Zhang, "Analysis of project delivery systems in Chinese construction industry with data envelopment analysis (DEA)," *Engineering, Construction and Architectural Management*, 2010.
- [216] H.-Y. Chong and C. N. Preece, "Improving construction procurement systems using organizational strategies," *Acta Polytechnica Hungarica*, vol. 11, no. 1, pp. 5-20, 2014.
- [217] B. Liu, T. Huo, J. Meng, J. Gong, Q. Shen, and T. Sun, "Identification of Key Contractor Characteristic Factors That Affect Project Success under Different Project Delivery Systems: Empirical Analysis Based on a Group of Data from China," *Journal of Management in Engineering*, vol. 32, no. 1, p. 05015003, 2022/01/21 2016, doi: 10.1061/(ASCE)ME.1943-5479.0000388.
- [218] E. Bingham, G. E. Gibson Jr, and M. E. Asmar, "Measuring user perceptions of popular transportation project delivery methods using least significant difference intervals and multiple range tests," *Journal of Construction Engineering and Management*, vol. 144, no. 6, p. 04018033, 2018.
- [219] J. Zhang, F. Chen, and X. X. Yuan, "Comparison of cost and schedule performance of large public projects under P3 and traditional delivery models: a Canadian study," *Construction Management and Economics*, vol. 38, no. 8, pp. 739-755, 2020, doi: 10.1080/01446193.2019.1645344.
- [220] S. P. K. Bypaneni and D. Q. Tran, "Empirical identification and evaluation of risk in highway project delivery methods," *Journal of Management in Engineering*, vol. 34, no. 3, p. 04018007, 2018.
- [221] B. Li, A. Akintoye, P. J. Edwards, and C. Hardcastle, "Critical success factors for PPP/PFI projects in the UK construction industry," *Construction Management and Economics*, vol. 23, no. 5, pp. 459-471, 2005, doi: 10.1080/01446190500041537.
- [222] B. Liu, T. Huo, Y. Liang, Y. Sun, and X. Hu, "Key Factors of Project Characteristics Affecting Project Delivery System Decision Making in the Chinese Construction Industry: Case Study Using Chinese Data Based on Rough Set Theory," *Journal of Professional Issues in Engineering Education and Practice*, vol. 142, no. 4, p. 05016003, 2022/01/17 2016, doi: 10.1061/(ASCE)EI.1943-5541.0000278.
- [223] R. Riley David, E. Diller Brenton, and D. Kerr, "Effects of Delivery Systems on Change Order Size and Frequency in Mechanical Construction," *Journal of*

- Construction Engineering and Management*, vol. 131, no. 9, pp. 953-962, 2022/01/17 2005, doi: 10.1061/(ASCE)0733-9364(2005)131:9(953).
- [224] A. Hosseini, O. Lædre, B. Andersen, O. Torp, N. Olsson, and J. Lohne, "Selection criteria for delivery methods for infrastructure projects," *Procedia-Social and Behavioral Sciences*, vol. 226, pp. 260-268, 2016.
- [225] P. H. D. Nguyen, D. Q. Tran, and S. P. K. Bypaneni, "Exploring the impact of project size on design-bid-build and design-build project delivery performance in highways," *Construction Management and Economics*, vol. 39, no. 11, pp. 879-893, 2021, doi: 10.1080/01446193.2021.1993289.
- [226] J. Feghaly, M. El Asmar, S. Ariaratnam, and W. Bearup, "Selecting project delivery methods for water treatment plants," *Engineering, Construction and Architectural Management*, vol. 27, no. 4, pp. 936-951, 2022/01/17 2020, doi: 10.1108/ECAM-06-2019-0308.
- [227] L. Klotz and M. Horman, "Counterfactual Analysis of Sustainable Project Delivery Processes," *Journal of Construction Engineering and Management*, vol. 136, no. 5, pp. 595-605, 2019/10/15 2010, doi: 10.1061/(ASCE)CO.1943-7862.0000148.
- [228] S. Gunhan, "Analyzing Sustainable Building Construction Project Delivery Practices: Builders' Perspective," *Practice Periodical on Structural Design and Construction*, vol. 24, no. 1, p. 05018003, 2019/09/09 2019, doi: 10.1061/(ASCE)SC.1943-5576.0000397.
- [229] T. Wang, A. P. C. Chan, Q. He, and J. Xu, "Identifying the gaps in construction megaproject management research: a bibliographic analysis," *International Journal of Construction Management*, pp. 1-12, 2020.
- [230] A. J. G. Silvius and R. P. J. Schipper, "Sustainability in project management competencies: analyzing the competence gap of project managers," *Journal of Human Resource and Sustainability Studies*, vol. 2014, 2014.
- [231] K. Molenaar, N. Sobin, D. Gransberg, T. McCuen, S. Korkmaz, and M. Horman, "Sustainable, high performance projects and project delivery methods: A state-of-practice report," *White Paper for the Design-Build Institute of America and the Charles Pankow Foundation*, 2009.
- [232] E. Enache-Pommer and M. Horman, "Key Processes in the Building Delivery of Green Hospitals," *Building a Sustainable Future*, pp. 636-645, 2022/10/24, doi: doi:10.1061/41020(339)65.
- [233] T. Ahmad and A. A. Aibinu, "Project delivery attributes influencing green building project outcomes," *Built Environment Project and Asset Management*, vol. 7, no. 5, pp. 471-489, 2021/10/17 2017, doi: 10.1108/BEPAM-11-2016-0066.
- [234] B. Xia, M. Skitmore, P. Wu, and Q. Chen, "How Public Owners Communicate the Sustainability Requirements of Green Design-Build Projects," *Journal of Construction Engineering and Management*, vol. 140, no. 8, p. 04014036, 2021/10/17 2014, doi: 10.1061/(ASCE)CO.1943-7862.0000879.
- [235] J. Yudelson, *Green Building Through Integrated Design (GreenSource Books)*. McGraw-Hill Education, 2009.
- [236] D. Riley, V. Sanvido, M. Horman, M. McLaughlin, and D. Kerr, "Lean and Green: The Role of Design-Build Mechanical Competencies in the Design and Construction of Green Buildings," *Construction Research Congress 2005*, pp. 1-10, 2022/03/14, doi: doi:10.1061/40754(183)23.

- [237] B. Manata, A. J. Garcia, S. Mollaoglu, and V. D. Miller, "The effect of commitment differentiation on integrated project delivery team dynamics: The critical roles of goal alignment, communication behaviors, and decision quality," *International Journal of Project Management*, vol. 39, no. 3, pp. 259-269, 2021, doi: <https://doi.org/10.1016/j.ijproman.2020.12.003>.
- [238] J. Larsson, P. E. Eriksson, S. Lingegård, and A.-T. Järvenpää, "Innovation outcomes and processes in infrastructure projects – a comparative study of Design-Build and Design-Build-Maintenance contracts," *Construction Management and Economics*, vol. 40, no. 2, pp. 142-156, 2022, doi: 10.1080/01446193.2021.2024864.
- [239] D. Bryde, M. Broquetas, and J. M. Volm, "The project benefits of Building Information Modelling (BIM)," *International Journal of Project Management*, vol. 31, no. 7, pp. 971-980, 2013, doi: <https://doi.org/10.1016/j.ijproman.2012.12.001>.
- [240] B. F. Brahmi, S. Sassi Boudemagh, I. Kitouni, and A. Kamari, "IPD and BIM-focussed methodology in renovation of heritage buildings," *Construction Management and Economics*, vol. 40, no. 3, pp. 186-206, 2022, doi: 10.1080/01446193.2021.1933557.
- [241] R. Müller and R. Turner, "The influence of project managers on project success criteria and project success by type of project," *European management journal*, vol. 25, no. 4, pp. 298-309, 2007.
- [242] A. Brown and J. Adams, "Measuring the effect of project management on construction outputs: a new approach," *International Journal of project management*, vol. 18, no. 5, pp. 327-335, 2000.
- [243] K. Jugdev and R. Müller, "A retrospective look at our evolving understanding of project success," *Project management journal*, vol. 36, no. 4, pp. 19-31, 2005.
- [244] A. J. Shenhar and D. Dvir, *Reinventing project management: the diamond approach to successful growth and innovation*. Harvard Business Review Press, 2007.
- [245] A. Shenhar, "Meeting time, cost, and money-making goals with Strategic Project Leadership®," 2011: Project Management Institute Newtown Square, PA.
- [246] E. Westerveld, "The Project Excellence Model®: linking success criteria and critical success factors," *International Journal of Project Management*, vol. 21, no. 6, pp. 411-418, 2003, doi: [https://doi.org/10.1016/S0263-7863\(02\)00112-6](https://doi.org/10.1016/S0263-7863(02)00112-6).
- [247] R. Müller and K. Jugdev, "Critical success factors in projects: Pinto, Slevin, and Prescott—the elucidation of project success," *International journal of managing projects in business*, 2012.
- [248] D. Bryde, "Perceptions of the impact of project sponsorship practices on project success," *International Journal of Project Management*, vol. 26, no. 8, pp. 800-809, 2008, doi: <https://doi.org/10.1016/j.ijproman.2007.12.001>.
- [249] A. J. Shenhar, D. Dvir, O. Levy, and A. C. Maltz, "Project Success: A Multidimensional Strategic Concept," *Long Range Planning*, vol. 34, no. 6, pp. 699-725, 2001, doi: [https://doi.org/10.1016/S0024-6301\(01\)00097-8](https://doi.org/10.1016/S0024-6301(01)00097-8).
- [250] F. A. Mir and A. H. Pinnington, "Exploring the value of project management: linking project management performance and project success," *International journal of project management*, vol. 32, no. 2, pp. 202-217, 2014.

- [251] K. N. Jha and K. C. Iyer, "Commitment, coordination, competence and the iron triangle," *International Journal of Project Management*, vol. 25, no. 5, pp. 527-540, 2007.
- [252] M. M. d. Carvalho and R. Rabechini Junior, "Impact of risk management on project performance: the importance of soft skills," *International Journal of Production Research*, vol. 53, no. 2, pp. 321-340, 2015.
- [253] L. A. Ika, A. Diallo, and D. Thuillier, "Critical success factors for World Bank projects: An empirical investigation," *International journal of project management*, vol. 30, no. 1, pp. 105-116, 2012.
- [254] A. Khalifeh, P. Farrell, and M. Al-edenat, "The impact of project sustainability management (PSM) on project success: A systematic literature review," *Journal of Management Development*, 2019.
- [255] X. Qu, "Multivariate Data Analysis," *Technometrics*, vol. 49, no. 1, pp. 103-104, 2007, doi: 10.1198/tech.2007.s455.
- [256] A. Touran, K. R. Molenaar, D. D. Gransberg, and K. Ghavamifar, "Decision support system for selection of project delivery method in transit," *Transportation research record*, vol. 2111, no. 1, pp. 148-157, 2009.
- [257] T. L. Saaty, *Decision making for leaders: the analytic hierarchy process for decisions in a complex world*. RWS publications, 2001.
- [258] L. Swarup, S. Korkmaz, and D. Riley, "Project Delivery Metrics for Sustainable, High-Performance Buildings," *Journal of Construction Engineering and Management*, vol. 137, no. 12, pp. 1043-1051, 2019/09/09 2011, doi: 10.1061/(ASCE)CO.1943-7862.0000379.
- [259] J. Sullivan, E. Asmar Mounir, J. Chalhoub, and H. Obeid, "Two Decades of Performance Comparisons for Design-Build, Construction Manager at Risk, and Design-Bid-Build: Quantitative Analysis of the State of Knowledge on Project Cost, Schedule, and Quality," *Journal of Construction Engineering and Management*, vol. 143, no. 6, p. 04017009, 2019/10/16 2017, doi: 10.1061/(ASCE)CO.1943-7862.0001282.
- [260] J. J. Kim, A. L. Petrov, J. Lim, and S. Kim, "Comparing cost performance of project delivery methods using quantifiable RFIs: cases in California heavy civil construction projects," *International journal of civil engineering*, vol. 20, no. 3, pp. 323-335, 2022.
- [261] M. E. Kenig, *Project Delivery Systems*. AGC of America, 2011.
- [262] J. Park and Y. H. Kwak, "Design-bid-build (DBB) vs. design-build (DB) in the US public transportation projects: The choice and consequences," *International Journal of Project Management*, vol. 35, no. 3, pp. 280-295, 2017.
- [263] I. Aje, "The impact of contractors' prequalification on construction project delivery in Nigeria," *Engineering, Construction and Architectural Management*, 2012.
- [264] D. Bilbo, B. Bigelow, E. Escamilla, and C. Lockwood, "Comparison of Construction Manager at Risk and Integrated Project Delivery Performance on Healthcare Projects: A Comparative Case Study," *International Journal of Construction Education and Research*, vol. 11, no. 1, pp. 40-53, 2015, doi: 10.1080/15578771.2013.872734.
- [265] O. Matthews and G. A. Howell, "Integrated project delivery an example of relational contracting," *Lean construction journal*, vol. 2, no. 1, pp. 46-61, 2005.

- [266] B. Keskin, B. Salman, and B. Ozorhon, "Airport project delivery within BIM-centric construction technology ecosystems," *Engineering, construction and architectural management*, vol. 28, no. 2, pp. 530-548, 2020.
- [267] R. Clemen and T. Reilly, "Making hard decisions with DecisionTools®(pp. 180–183 and 462–495)," ed: Pacific Grove, CA: Duxbury Thomson Learning, 2001.

Appendix A

This Appendix represents all the four surveys conducted in this research

Survey 1

Dear Sir/Madame,

My name is Salma Ahmed. I am conducting a research project for the thesis in Engineering Systems Management at the American University of Sharjah AUS. The objective of this research is to identify the most significant challenges of sustainable construction delivery. Your valuable input to the survey will contribute to the success of this research, and your identity and input will be anonymous and will be used for the research purposes only.

Kindly note the following:

- Your participation in this research project is voluntary
- You may refuse to participate or discontinue your participation at any time during the research
- The results will be reported in aggregate form
- There is no risk associated with your participation in this study.
- There are no direct benefits to you for participating in this study; however, others may benefit in the future from the information that is learned.

Thank you for agreeing to take part in this survey. This survey should take around 10-12 minutes to complete. Be assured that all answers you provide will be kept in the strictest confidentiality. If you have any questions or concerns regarding the research topic, please contact Salma Ahmed by e-mail g00043157@alumni.aus.edu, phone 056-9471558.

This study was reviewed and approved by the University IRB. If you have questions or concerns about this study and would like to consult someone other than the researcher(s), you may contact the University at:

American University of Sharjah

Main Building, M-263

PO Box 26666, Sharjah

United Arab Emirates

Tel: +(971) 6 515 4471

Email: IRB@aus.edu

- By clicking this, I consent to my participation in the survey

Section 1 (General Information)

In this section, you will be asked about your general information.

Your company?

- Local (Main Office in UAE) International (Main Office outside UAE)

Years of experience in UAE

- <5 5-10 11-20 > 20

Project Type/expertise

- Buildings Infrastructure Others

Current role

- Owner Consultant Contractor

The size of your projects

- <50M 50 to 200M 201 to 500M >500M

Do you have experience/knowledge in sustainable construction?

- Yes No

Section 2: Significance of the Challenges in Sustainable Construction Project Delivery

In this section, you will be asked to rate the significance of the challenges of the delivery of sustainable construction projects in the UAE using a 5-point Likert scale You will be asked to rate a total of 33 challenges.

1. Lack of knowledge, information, awareness and understanding

- Very high High Average Low Very Low
2. Limited top management commitment and organizational leadership
- Very high High Average Low Very Low
3. Inability to relinquish traditional construction methods and project management practices
- Very high High Average Low Very Low
4. Inadequacy and unreliability of Suppliers
- Very high High Average Low Very Low
5. Shortage of skilled workforce in execution of sustainable construction projects
- very high high Average Low Very Low
6. Poor feasibility, planning and risk management due to insufficient information
- very high high Average Low Very Low
7. Limited experience in selection of sustainable construction procedures and techniques
- very high high Average Low Very Low
8. Need for special materials
- very high high Average Low Very Low
9. Inadequate information about handling and storage of sustainable materials
- very high high Average Low Very Low
10. Insufficient information about the performance quality of sustainable materials
- very high high Average Low Very Low
11. Rapid improvement and continuous updates of green materials and technologies
- very high high Average Low Very Low
12. Long lead time of sustainable materials affecting start of construction activities

- very high high Average Low Very Low
13. Complex technical systems with high levels of interdependence and interaction
- very high high Average Low Very Low
14. Extensive requirements for documentation and reporting
- very high high Average Low Very Low
15. Delays in governmental approvals for green construction processes
- very high high Average Low Very Low
16. Lack of sustainability building codes and government policies
- very high high Average Low Very Low
17. Fragmented guidelines for green procurement
- very high high Average Low Very Low
18. Incomplete green specifications
- very high high Average Low Very Low
19. Absence of sustainability criteria in the bid evaluation
- very high high Average Low Very Low
20. Long and slow decision-making processes that delay design
- very high high Average Low Very Low
21. Weak scope definitions of sustainable construction requirements
- very high high Average Low Very Low
22. Frequent design changes/meetings by client and/or architect
- very high high Average Low Very Low
23. Difficulty of compliance to green codes or certification
- very high high Average Low Very Low
24. Owner's unwillingness to pay the extra initial costs of green construction

- very high high Average Low Very Low
25. Client's funding issues due to poor cost and schedule planning
- very high high Average Low Very Low
26. Contractor's inability to budget project due to lack of experience
- very high high Average Low Very Low
27. Price inflation of sustainable materials
- very high high Average Low Very Low
28. Additional cost as green materials might need to be imported
- very high high Average Low Very Low
29. Cost overruns due to tight schedule plans
- very high high Average Low Very Low
30. Lack of communication and coordination amongst contracting parties
- very high high Average Low Very Low
31. Lack of early involvement of construction professionals during the design phase
- very high high Average Low Very Low
32. Lack of contractual incentives for the contractor
- very high high Average Low Very Low
33. Lack of risk/profit sharing in contracts
- very high high Average Low Very Low

Survey 2

Dear Sir/Madame,

My name is Salma Ahmed and I am conducting a research project for my dissertation in Engineering Systems Management at the American University of Sharjah (AUS). The objective of this research is to rate the significance of the criteria for the selection of the appropriate project delivery method for construction projects. Your valuable

input to the survey will contribute to the success of this research, and your identity and input will be anonymous and will be used for the research purposes only.

Kindly note the following:

- Your participation in this research project is voluntary
- You may refuse to participate or discontinue your participation at any time during the research
- The results will be reported in aggregate form
- There is no risk associated with your participation in this study.
- There are no direct benefits to you for participating in this study; however, others may benefit in the future from the information that is learned.

Thank you for agreeing to take part in this survey. This survey should take around 10-12 minutes to complete. Be assured that all answers you provide will be kept in the strictest confidentiality. If you have any questions or concerns regarding the research topic, please contact Salma by:

- e-mail: g00043157@aus.edu
- phone: +971569471558

This study was reviewed and approved by the University IRB. If you have questions or concerns about this study and would like to consult someone other than the researcher(s), you may contact the University at:

American University of Sharjah

Main Building, M-263

PO Box 26666, Sharjah

United Arab Emirates

Tel: +(971) 6 515 4471

Email: IRB@aus.edu

- By clicking this, I consent to my participation in the survey

Section 1 (General Information)

In this section, you will be asked about your general information.

Your company?

- Local (Main Office in UAE)
- International (Main Office outside UAE)

Years of experience

- <5
- 5-10
- 11-20
- > 20

Project Type/expertise

- Buildings
- Infrastructure
- Others, please specify

Current role

- Owner
- Contractor
- Consultant
- Project/Construction Management Firm

Average size of projects

- <50M AED
- 50 to 200M AED
- >200- 500M AED
- >500M AED

Section 2: Traditional Selection Criteria

In this section, you will be asked to rate the significance of the traditional criteria used to select the project delivery method. All questions have a Likert Scale response of 1-5 where 1 being very low and 5 being very high significance.

The first group of criteria is “Cost”. This group consists of 5 criteria: control cost growth, ensure lowest cost, facilitate early cost estimates, reduce risks and delay or minimize expenditure rate.

1. How significant is the criterion “Control Cost Growth” to the criteria group ‘Cost’ for selecting the project delivery method?
 Very High High Neutral Low Very Low
2. How significant is the criterion “Ensure Lowest Cost” to the criteria group ‘Cost’ for selecting the project delivery method?
 Very High High Neutral Low Very Low
3. How significant is the criterion “Facilitate Early Cost Estimates” to the criteria group ‘Cost’ for selecting the project delivery method?
 Very High High Neutral Low Very Low
4. How significant is the criterion “Reduce Risks” to the criteria group ‘Cost’ for selecting the project delivery method?
 Very High High Neutral Low Very Low
5. How significant is the criterion “Delay or Minimize Expenditure Rate” to the criteria group ‘Cost’ for selecting the project delivery method?
 Very High High Neutral Low Very Low

The second group of criteria is “Time”. This group consists of 3 criteria: control time growth, ensure shortest time, promote early procurement of material and equipment.

6. How significant is the criterion “Control Time Growth” to the criteria group ‘Time’ for selecting the project delivery method?
 Very High High Neutral Low Very Low

7. How significant is the criterion “Ensure Shortest Time” to the criteria group ‘Time’ for selecting the project delivery method?

Very High High Neutral Low Very Low

8. How significant is the criterion “Promote Early Procurement of Material and Equipment” to the criteria group ‘Time’ for selecting the project delivery method?

Very High High Neutral Low Very Low

The third group of criteria is “Scope”. This group consists of 4 criteria: capitalize on well-defined scope, efficiently utilize poorly defined scope, ease change incorporation, capitalize on expected low levels of change orders.

9. How significant is the criterion “Capitalize on Well-Defined Scope” to the criteria group ‘Scope’ for selecting the project delivery method?

Very High High Neutral Low Very Low

10. How significant is the criterion “Efficiently Utilize Poorly Defined Scope” to the criteria group ‘Scope’ for selecting the project delivery method?

Very High High Neutral Low Very Low

11. How significant is the criterion “Ease Change Incorporation” to the criteria group ‘Scope’ for selecting the project delivery method?

Very High High Neutral Low Very Low

12. How significant is the criterion “Capitalize on Expected Low Levels of Change Orders” to the criteria group ‘Scope’ for selecting the project delivery method?

Very High High Neutral Low Very Low

The fourth group of criteria is “Owner and Contractor”. This group consists of 4 criteria: owner’s willingness to take risks, owner’s available human resources, owner’s willingness to be involved, contractor’s capability and experience.

13. How significant is the criterion “Owner’s Willingness to Take Risks” to the criteria group ‘Owner and Contractor’ for selecting the project delivery method?

Very High High Neutral Low Very Low

14. How significant is the criterion “Owner’s Available Human Resources” to the criteria group ‘Owner and Contractor’ for selecting the project delivery method?

Very High High Neutral Low Very Low

15. How significant is the criterion “Owner’s Willingness to be Involved” to the criteria group ‘Owner and Contractor’ for selecting the project delivery method?

Very High High Neutral Low Very Low

16. How significant is the criterion “Contractor’s Capability and Experience” to the criteria group ‘Owner and Contractor’ for selecting the project delivery method?

Very High High Neutral Low Very Low

The fifth group of criteria is “Project’s Characteristics”. This group consists of 4 criteria: capitalize on project confidentiality, capitalize on familiar project conditions, efficiently co-ordinate project complexity, capitalize on project’s quality performance

17. How significant is the criterion “Capitalize on Project Confidentiality” to the criteria group ‘Projects Characteristics’ for selecting the project delivery method?

Very High High Neutral Low Very Low

18. How significant is the criterion “Capitalize on Familiar Project Conditions” to the criteria group ‘Projects Characteristics’ for selecting the project delivery method?

Very High High Neutral Low Very Low

19. How significant is the criterion “Efficiently Co-ordinate Project Complexity” to the criteria group ‘Projects Characteristics’ for selecting the project delivery method?

Very High High Neutral Low Very Low

20. How significant is the criterion “Capitalize on Project’s Quality Performance” to the criteria group ‘Projects Characteristics’ for selecting the project delivery method?

Very High High Neutral Low Very Low

Section 3: New Selection Criteria

In this section, you will be asked to rate the significance of the new criteria used to select the project delivery method. All questions have a Likert Scale response of 1-5 where 1 being very low and 5 being very high significance.

The first group of criteria is “Level of Integration”. This group consists of 4 criteria: early involvement of key participants, collaborative decision making and control, joint development of project goals, intensified planning

21. How significant is the criterion “Early Involvement of Key Participants” to the criteria group ‘Level of Integration’ for selecting the project delivery method?

Very High High Neutral Low Very Low

22. How significant is the criterion “Collaborative Decision Making and Control” to the criteria group ‘Level of Integration’ for selecting the project delivery method?

Very High High Neutral Low Very Low

23. How significant is the criterion “Joint Development of Project Goals” to the criteria group ‘Level of Integration’ for selecting the project delivery method?

Very High High Neutral Low Very Low

24. How significant is the criterion “Intensified Planning” to the criteria group ‘Level of Integration’ for selecting the project delivery method?

Very High High Neutral Low Very Low

The second group of criteria is “Green Team”. This group consists of 4 criteria: liability waivers among team players, minimize adversarial relationships between team members, capitalize on diversity and new opportunities, facilitate open communication between team members.

25. How significant is the criterion “Liability Waivers among Team Players” to the criteria group ‘Green Team’ for selecting the project delivery method?

Very High High Neutral Low Very Low

26. How significant is the criterion “Minimize Adversarial Relationships between Team Members” to the criteria group ‘Green Team’ for selecting the project delivery method?

Very High High Neutral Low Very Low

27. How significant is the criterion “Capitalize on Diversity and New Opportunities” to the criteria group ‘Green Team’ for selecting the project delivery method?

Very High High Neutral Low Very Low

28. How significant is the criterion “Facilitate Open Communication between Team Members” to the criteria group ‘Green Team’ for selecting the project delivery method?

Very High High Neutral Low Very Low

The third group of criteria is “Green Liability”. This group consists of 3 criteria: allow for transfer of green liability, promote early assignment of green certification responsibility, promote early green guarantee

29. How significant is the criterion “Allow for Transfer of Green Liability” to the criteria group ‘Green Liability’ for selecting the project delivery method?

Very High High Neutral Low Very Low

30. How significant is the criterion “Promote Early Assignment of Green Certification Responsibility” to the criteria group ‘Green Liability’ for selecting the project delivery method?

Very High High Neutral Low Very Low

31. How significant is the criterion “Promote Early Green Guarantee” to the criteria group ‘Green Liability’ for selecting the project delivery method?

Very High High Neutral Low Very Low

The fourth group of criteria is “Green Contract”. This group consists of 4 criteria: capitalize on awards and incentive fees, allows for qualification-based selection, facilitate flexible payment provisions, allow shared risks and rewards.

32. How significant is the criterion “Capitalize on Awards and Contractual Incentive Fees” to the criteria group ‘Green Contract’ for selecting the project delivery method?
- Very High High Neutral Low Very Low
33. How significant is the criterion “Allows for Qualification Based Selection” to the criteria group ‘Green Contract’ for selecting the project delivery method?
- Very High High Neutral Low Very Low
34. How significant is the criterion “Facilitate Flexible Payment Provisions” to the criteria group ‘Green Contract’ for selecting the project delivery method?
- Very High High Neutral Low Very Low
35. How significant is the criterion “Allow Shared Risks and Rewards” to the criteria group ‘Green Contract’ for selecting the project delivery method?
- Very High High Neutral Low Very Low

The fifth group of criteria is “Technology and Innovation”. This group consists of 4 criteria: capitalize on innovation, ability to use technology to enhance communications, improve the ability to use the full potential of BIM, efficiently utilize advanced technological tools to achieve sustainable goals

36. How significant is the criterion “Capitalize on Innovation” to the criteria group ‘Technology and Innovation’ for selecting the project delivery method?
- Very High High Neutral Low Very Low
37. How significant is the criterion “Ability to Use Technology to Enhance Communications” to the criteria group ‘Technology and Innovation’ for selecting the project delivery method?
- Very High High Neutral Low Very Low
38. How significant is the criterion “Improve the Ability to Use the Full Potential of BIM” to the criteria group ‘Technology and Innovation’ for selecting the project delivery method?
- Very High High Neutral Low Very Low

39. How significant is the criterion “Efficiently Utilize Advanced Technological Tools to Achieve Sustainable Goals” to the criteria group ‘Technology and Innovation’ for selecting the project delivery method?

Very High High Neutral Low Very Low

Section 4: Project Success criteria

In this section, you will be asked to rate the significance of the project success criteria. All questions have a Likert Scale response of 1-5 where 1 being very low and 5 being very high significance.

The first group of criteria is “Efficiency”. This group consists of 4 criteria: meeting cost goals, meeting time goals, meeting quality goals, meeting scope goals

40. How significant is the criterion ‘Meeting Cost Goals’ to achieve efficiency in a project?

Very High High Neutral Low Very Low

41. How significant is the criterion “Meeting Time Goals” to achieve efficiency in a project?

Very High High Neutral Low Very Low

42. How significant is the criterion “Meeting Quality Goals” to achieve efficiency in a project?

Very High High Neutral Low Very Low

43. How significant is the criterion “Meeting Scope Goals” to achieve efficiency in a project?

Very High High Neutral Low Very Low

The second group of criteria is “Impact on Client”. This group consists of 3 criteria: Satisfying client’s needs, adding value to the client, improvement of the client’s quality of life

44. How significant is the criterion “Satisfying Client’s Needs” to enhance the impact on client?

Very High High Neutral Low Very Low

45. How significant is the criterion “Adding Value to the Client” to enhance the impact on client?

Very High High Neutral Low Very Low

46. How significant is the criterion “Improvement of the Client’s Quality of Life” to enhance the impact on client?

Very High High Neutral Low Very Low

The third group of criteria is “Team Effectiveness”. This group consists of 3 criteria: motivation of the employees, improvement of learning and team development, team loyalty to achieving project’s goals

47. How significant is the criterion “Motivation of the Employees” to enhance team effectiveness in a project?

Very High High Neutral Low Very Low

48. How significant is the criterion “Improvement of Learning and Team Development” to enhance team effectiveness in a project?

Very High High Neutral Low Very Low

49. How significant is the criterion “Team Loyalty to Achieving Project’s Goals” to enhance team effectiveness in a project?

Very High High Neutral Low Very Low

The fourth group of criteria is “Sustainability”. This group consists of 3 criteria: accomplish sustainable goals, capitalize on future sustainable projects opportunities, enhance sustainable management practices.

50. How significant is the criterion “Accomplish Sustainable Goals” to improve the level of sustainability of construction projects?

Very High High Neutral Low Very Low

51. How significant is the criterion “Capitalize on Future Sustainable Projects Opportunities” to improve the level of sustainability of construction projects?

Very High High Neutral Low Very Low

52. How significant is the criterion “Enhance Sustainable Management Practices” to improve the level of sustainability of construction projects?

Very High High Neutral Low Very Low

Survey 3

Dear Sir/Madame,

My name is Salma Ahmed. I am conducting a research project for the thesis in Engineering Systems Management at the American University of Sharjah AUS. The objective of this research is to rate the significance of criteria for the selection of project delivery methods for sustainable construction projects and to conduct AHP pairwise comparisons between the selection criteria groups. Your valuable input to the survey will contribute to the success of this research, and your identity and input will be anonymous and will be used for the research purposes only.

Kindly note the following:

- Your participation in this research project is voluntary
- You may refuse to participate or discontinue your participation at any time during the research
- The results will be reported in aggregate form
- There is no risk associated with your participation in this study.
- There are no direct benefits to you for participating in this study; however, others may benefit in the future from the information that is learned.

Thank you for agreeing to take part in this survey. This survey should take around 10-12 minutes to complete. Be assured that all answers you provide will be kept in the strictest confidentiality. If you have any questions or concerns regarding the research topic, please contact Salma Ahmed by e-mail g00043157@alumni.aus.edu, phone 056-9471558.

This study was reviewed and approved by the University IRB. If you have questions or concerns about this study and would like to consult someone other than the researcher(s), you may contact the University at:

American University of Sharjah

Main Building, M-263

PO Box 26666, Sharjah

United Arab Emirates

Tel: +(971) 6 515 4471

Email: IRB@aus.edu

- By clicking this, I consent to my participation in the survey

Section 1 (General Information)

In this section, you will be asked about your general information.

Your company?

- Local (Main Office in UAE) International (Main Office outside UAE)

Years of experience in UAE

- <5 5-10 11-20 > 20

Project Type/expertise

- Buildings Infrastructure Others

Current role

- Owner Consultant Contractor

The size of your projects

- <50M 50 to 200M 201 to 500M >500M

Do you have experience/knowledge in sustainable construction?

- Yes No

Section 2: Selection Criteria

In this section, you will be asked to rate the significance of the selection criteria used to select the project delivery method. All questions have a Likert Scale response of 1-5 where 1 being very low and 5 being very high significance.

1. How significant are the following criteria for the selection of project delivery methods in sustainable construction?

1. Control Cost Growth	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
2. Facilitate Early Cost Estimates	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
3. Reduce Risks	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
4. Delay Expenditure Rate	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
5. Control Time Growth	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
6. Ensure Shortest Time	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
7. Promote Early Procurement of Material and Equipment	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
8. Capitalize on a Well-Defined Scope	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
9. Efficiently Utilize Poorly Defined Scope	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
10. Ease Change Incorporation	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
11. Owner's Available Human Resources	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
12. Owner's Willingness to be Involved	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
13. Contractor's Capability and Experience	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
14. Capitalize on Project Confidentiality	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
15. Capitalize on Familiar Project Conditions	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
16. Efficiently Co-ordinate Project Complexity	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low

17. Capitalize on Project's Quality Performance Levels	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
18. Early Involvement of Key Participants	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
19. Collaborative Decision Making and Control	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
20. Joint Development of Project Goals	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
21. Intensified Planning	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
22. Liability Waivers Among Team Players	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
23. Minimize Adversarial Relationships	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
24. Capitalize on Diversity and New Opportunities	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
25. Facilitate Open Communication between Team Members	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
26. Allow for Transfer of Green Liability	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
27. Promote Early Assignment of Green Certification	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
28. Promote Early Green Guarantee	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
29. Capitalize on Awards and Contractual Incentive Fees	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
30. Allow for Qualification Based Selection	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
31. Facilitate Flexible Payment Provisions	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
32. Allow Shared Risks and Rewards	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
33. Capitalize on Innovation	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
34. Ability to Use Technology to	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low

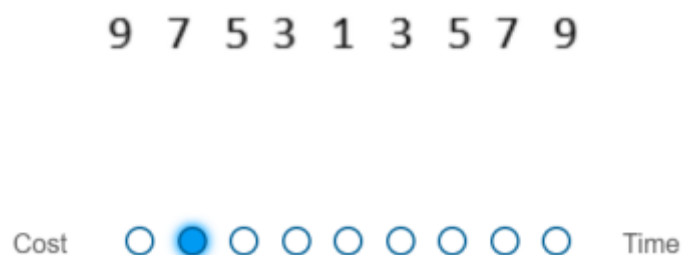
Enhance Communication					
35. Improve the Ability to Use the Full Potential of BIM	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low
36. Efficiently Utilize Advanced Technological Tools to Achieve Sustainable Goals	<input type="checkbox"/> Very High	<input type="checkbox"/> High	<input type="checkbox"/> Neutral	<input type="checkbox"/> Low	<input type="checkbox"/> Very Low

Section 3: AHP Pairwise Comparisons between Traditional Criteria Groups

If you compare each of the following pairs of criteria, which do you think is more important? Compare each of the following pairs of criteria and mark the number along the segment, the following table explains the scale:

AHP Scale of Importance for Comparison of Groups	Numeric Rating
Extremely More Important	9
Very Strongly More Important	7
Strongly More Important	5
Moderately More Important	3
Equally Important	1

In this section you will compare between the criteria groups. When comparing between criterion A and criterion B, if you feel A is more important than B then choose a number from the left side. If you feel that B is more important, then choose a number from the right side. For example, if cost is criterion A and time is criterion B, if you think cost is more important than time then choose a number from the left side as shown in the figure below



AHP comparisons between the traditional criteria groups

The criteria in each group are as follows:

Group
Cost: Control Cost Growth, Facilitate Early Cost Estimates, Reduce Risks, Minimize Expenditure Rate
Time: Control Time Growth, Ensure Shortest Time, Promote Early Procurement of Material and Equipment
Scope: Capitalize on a Well-Defined Scope, Efficiently Utilize Poorly Defined Scope, Ease Change Incorporation
Owner and Contractor Characteristics: Owner's Willingness to be Involved, Owner's Available Human Resources, Contractor's Capability and Experience
Project's Characteristics: Capitalize on Project Confidentiality, Capitalize on Familiar Project Conditions, Efficiently Coordinate Project Complexity, Capitalize on Project's Quality Performance

37. Compare between the following traditional criteria groups

	← Extremely		Equal Importance				Extremely →			
Cost	9	7	5	3	1	3	5	7	9	Time
Cost	9	7	5	3	1	3	5	7	9	Scope
Cost	9	7	5	3	1	3	5	7	9	Owner and Contractor
Cost	9	7	5	3	1	3	5	7	9	Project's Characteristics
Time	9	7	5	3	1	3	5	7	9	Scope
Time	9	7	5	3	1	3	5	7	9	Owner and Contractor
Time	9	7	5	3	1	3	5	7	9	Project's Characteristics
Scope	9	7	5	3	1	3	5	7	9	Owner and Contractor
Scope	9	7	5	3	1	3	5	7	9	Project's Characteristics
Owner and Contractor	9	7	5	3	1	3	5	7	9	Project's Characteristics

Section 4: AHP Pairwise Comparisons between New Criteria Groups

In this section, you will compare between the five groups of the new criteria: level of integration, green liability, green team, green contract, technology and innovation. The criteria in each group is shown in the following table:

Group
Early Involvement of Key Participants, Collaborative Decision Making and Control, Joint Development of Project Goals, Intensified Planning
Green Team:

Liability Waivers among Team Players, Minimize Adversarial Relationships, Capitalize on Diversity and New Opportunities, Facilitate Open Communication between Team Members
<u>Green Liability:</u> Allow for Transfer of Green Liability, Promote Early assignment of Green Certification Responsibility, Promote Early Green Guarantee
<u>Green Contract:</u> Capitalize on Awards and Incentive Fees, Allow for Qualification-Based Selection, Facilitate Flexible Payment Provisions, Allow Shared Risks and Rewards
<u>Technology and Innovation:</u> Capitalize on Innovation, Ability to Use Technology to Enhance Communication, Improve the Ability to Use the Full Potential of BIM, Efficiently Utilize Advanced Technological Tools to Achieve Sustainable Goals

38. Compare between the following new criteria groups

	Extremely		Equal Importance				Extremely			
	9	7	5	3	1	3	5	7	9	
Level of Integration	9	7	5	3	1	3	5	7	9	Green Liability
Level of Integration	9	7	5	3	1	3	5	7	9	Green Team
Level of Integration	9	7	5	3	1	3	5	7	9	Green Contract
Level of Integration	9	7	5	3	1	3	5	7	9	Technology and Innovation
Green Liability	9	7	5	3	1	3	5	7	9	Green Team
Green Liability	9	7	5	3	1	3	5	7	9	Green Contract
Green Liability	9	7	5	3	1	3	5	7	9	Technology and Innovation
Green Team	9	7	5	3	1	3	5	7	9	Green Contract
Green Team	9	7	5	3	1	3	5	7	9	Technology and Innovation
Green Contract	9	7	5	3	1	3	5	7	9	Technology and innovation

39. How significant are the traditional selection criteria groups compared to the new selection criteria groups?

The traditional criteria groups include: cost, time, scope, owner and contractor characteristics and project's characteristics. The new criteria groups include: level of integration, green team, green liability, green contract, technology and innovation

	Extremely		Equal Importance				Extremely			
	9	7	5	3	1	3	5	7	9	
Traditional Criteria	9	7	5	3	1	3	5	7	9	New Criteria

Survey 4

Dear Sir/Madame,

My name is Salma Ahmed and I am conducting a research project for my dissertation in Engineering Systems Management at the American University of Sharjah (AUS). The objective of this research is to measure the effectiveness of project delivery methods on achieving the selection criteria based on AHP pairwise comparisons. Your valuable input to the survey will contribute to the success of this research, and your identity and input will be anonymous and will be used for the research purposes only.

Kindly note the following:

- Your participation in this research project is voluntary
- You may refuse to participate or discontinue your participation at any time during the research
- The results will be reported in aggregate form
- There is no risk associated with your participation in this study.
- There are no direct benefits to you for participating in this study; however, others may benefit in the future from the information that is learned.

Thank you for agreeing to take part in this survey. This survey should take around 10-12 minutes to complete. Be assured that all answers you provide will be kept in the strictest confidentiality. If you have any questions or concerns regarding the research topic, please contact Salma by:

- e-mail: g00043157@aus.edu
- phone: +971569471558

This study was reviewed and approved by the University IRB. If you have questions or concerns about this study and would like to consult someone other than the researcher(s), you may contact the University at:

American University of Sharjah

Main Building, M-263

PO Box 26666, Sharjah

United Arab Emirates

Tel: +(971) 6 515 4471

Email: IRB@aus.edu

- By clicking this, I consent to my participation in the survey

Section 1 (General Information)

In this section, you will be asked about your general information.

Your company?

- Local (Main Office in UAE)
- International (Main Office outside UAE)

Years of experience

- <5
- 5-10
- 11-20
- > 20

Project Type/expertise

- Buildings
- Infrastructure
- Others, please specify

Current role

- Owner
- Contractor
- Consultant
- Project/Construction Management Firm

Average size of projects

- <50M AED
- 50 to 200M AED
- >200- 500M AED
- >500M AED

Section 2: AHP Pairwise Comparisons between Project Delivery Methods on Achieving the Selection Criteria

In this section you will compare between the effectiveness of the three common project delivery methods (DBB, DB and CMR) in achieving the selection criteria in question. The following table explains the scale.

AHP Scale of Importance for Comparison of Pairs	Numeric Rating
Extremely More Important	9
Very Strongly More Important	7
Strongly More Important	5
Moderately More Important	3
Equally Important	1

1. which project delivery method is more effective in achieving the criterion “control cost growth”?

	←		Extremely	Equal Importance					Extremely	→		
DBB	9	7	5	3	1	3	5	7	9		DB	
DBB	9	7	5	3	1	3	5	7	9		CMR	
DB	9	7	5	3	1	3	5	7	9		CMR	

2. which project delivery method is more effective in achieving the criterion “facilitate early cost estimates”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

3. which project delivery method is more effective in achieving the criterion “reduce risks”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

4. which project delivery method is more effective in achieving the criterion “minimize expenditure”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

5. Which project delivery method is more effective in achieving the criterion “ease change incorporation”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

6. which project delivery method is more effective in achieving the criterion “control time growth”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

7. which project delivery method is more effective in achieving the criterion “ensure shortest time”?

	Extremely		Equal Importance					Extremely		
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

8. which project delivery method is more effective in achieving the criterion “promote early procurement of material and equipment”?

	Extremely		Equal Importance					Extremely		
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

9. Which project delivery method is more effective in achieving the criterion “capitalize on well-defined scope”?

	Extremely		Equal Importance					Extremely		
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

10. Which project delivery method is more effective in achieving the criterion “ease change incorporation”?

	Extremely		Equal Importance					Extremely		
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

11. Which project delivery method is more effective in achieving the criterion “owner’s available human resources”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

12. Which project delivery method is more effective in achieving the criterion “owner’s willingness to be involved”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

13. Which project delivery method is more effective in achieving the criterion “contractor’s capabilities and experience”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

14. Which project delivery method is more effective in achieving the criterion “capitalize on project confidentiality”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

15. Which project delivery method is more effective in achieving the criterion “capitalize on familiar project conditions”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

16. Which project delivery method is more effective in achieving the criterion “efficiently co-ordinate project complexity”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

17. Which project delivery method is more effective in achieving the criterion “capitalize on project’s quality performance”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

18. Which project delivery method is more effective in achieving the criterion “early involvement of key participants”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

19. Which project delivery method is more effective in achieving the criterion “collaborative decision making and control”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

20. Which project delivery method is more effective in achieving the criterion “joint development of project goals”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

21. Which project delivery method is more effective in achieving the criterion “intensified planning”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

22. Which project delivery method is more effective in achieving the criterion “allow for transfer of green liability”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

23. Which project delivery method is more effective in achieving the criterion “promote early assignment of green certification responsibility”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

24. Which project delivery method is more effective in achieving the criterion “promote early green guarantee”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

25. Which project delivery method is more effective in achieving the criterion “liability waivers among team players”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

26. Which project delivery method is more effective in achieving the criterion “minimize adversarial relationships”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

27. Which project delivery method is more effective in achieving the criterion “capitalize on diversity and new opportunities”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

28. Which project delivery method is more effective in achieving the criterion “facilitate open communication between team members”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

29. Which project delivery method is more effective in achieving the criterion “capitalize on awards and contractual incentive fees”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

30. Which project delivery method is more effective in achieving the criterion “allow for qualification-based selection”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

31. Which project delivery method is more effective in achieving the criterion “facilitate flexible payment provisions”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

32. Which project delivery method is more effective in achieving the criterion “allow shared risks and rewards”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

33. Which project delivery method is more effective in achieving the criterion “capitalize on innovation”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

34. Which project delivery method is more effective in achieving the criterion “ability to use technology to enhance communication”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

35. Which project delivery method is more effective in achieving the criterion “improve the ability to use full potential of BIM”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

36. Which project delivery method is more effective in achieving the criterion “efficiently utilize advanced technological tools to achieve sustainable goals”?

	Extremely			Equal Importance			Extremely			
DBB	9	7	5	3	1	3	5	7	9	DB
DBB	9	7	5	3	1	3	5	7	9	CMR
DB	9	7	5	3	1	3	5	7	9	CMR

Vita

Salma Nasser Ahmed was born in Cairo, Egypt in February 1994. She moved to the United Arab Emirates at the age of four years. She studied in the Westminster School in Dubai. She joined American University of Sharjah and graduated with a Bachelor of Science degree in Civil Engineering in June 2015. She also graduated with a Master's degree in Civil Engineering in December 2017 from the American University of Sharjah.

Ms. Salma joined the PhD program in Engineering Systems Management in the American University of Sharjah in September 2019 and was awarded a graduate teaching and research assistantship.