A Model for Selecting Project Delivery Systems in Post-Conflict Construction Projects

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ABSTRACT

A Model for Selecting Project Delivery Systems in Post-Conflict Construction Projects

Mahmood-Reza Pooyan

Adopting the most suitable PDS (Project Delivery System) is a process that entails thorough analysis of multiple criteria and does not follow a "one size fits all" approach. In most cases, the development agencies in post-conflict states resort to informal procedures in selecting a project delivery approach. There is an oversimplification of the decision making process in such a way that conclusions are often drawn in absence of careful review, and consideration of alternatives, or all determinant factors.

The overarching objective of this research was to develop a scalable and site adaptable decision framework to facilitate objective selection of project delivery systems in post-conflict construction projects. This objective was primarily pursued through identifying the most pertinent selection factors in post-conflict projects. The research at hand consists of two PDS selection models. These models differ in their modality of judgment elicitation and score aggregation. At the output level, both models produce suitability index (SI) scores for the PDS options being considered. The SI Score is a sum product function of the relative importance weight (RIW) of the selection factors and the relative effectiveness values (REV) of the PDS options. In both models, the RIW's were obtained through Analytic Network Process while the REV's were directly assigned from a predefined measurement scale. The first model is predicated on individual assessment of the parameters leading to calculation of the suitability indices. This model applies Monte Carlo simulation to define a range for the suitability indices. The second model however, is hinged upon consensus-based assessment of the components of the suitability index. In the latter case, judgments are elucidated through successive decision conferencing workshops. The bottom line results of this research allude to Construction Manager at Risk (CM-R) as the more viable option. Ultimately, the research provides a comparative analysis of the results obtained from both models and tests the veracity of the models by confirming their utility and applicability outside the universe formed by the case study projects.

DEDICATION

I dedicate this thesis to my parents for all their love, sacrifice and support.

ACKNOWLEDGEMENTS

I gratefully acknowledge and commend the humanitarian aid workers across the globe for their selflessness, commitment and dedication to the cause. My heart goes out to the people in post-conflict states who are bravely facing the adversities of rebuilding their nations. It was the first hand observation of their plight and resilience in overcoming the hardships that led me to embark on this project.

I am indebted to my thesis advisors for their patience, understanding and support. I am particularly thankful to Dr. Tarek Zayed, my supervisor who so generously shared his time, expertise and experience with me to steer this research in the right direction. His persistence, commitment and exemplary professional attitude kept me motivated throughout this entire process. I am grateful to Dr. Govind Gopakumar for extending me all the possible help I required. I salute him for all his contributions of time, ideas and funding. I could not have accomplished this without his encouragements and support. I would also like to express my heartfelt gratitude to Dr. Osama Moselhi for his inspirational words and mentorship. I owe a debt of gratitude to Dr. Deborah Dysart-Gale for going out of her way to support my research.

I am grateful to all my friends and colleagues in the Construction and Automation Lab for their friendship and constructive comments. Finally, I owe my loving thanks to my parents for their prayers, encouragements and understanding. I am grateful to them for having instilled in me the discipline and determination to seek and strive for excellence. I would specially like to thank my brother for setting such a stellar example and being an instrumental part of my life.

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LIST OF ABBREVIATIONS

ACC	Airport Consultants Council
ACI-NA	Airports Council International of North America
AEC	Availability of Experienced Contractors
AGC	Associated General Contractors of America
AHP	Analytic Hierarchy Process
AIHC	Agency In-House Capacity
ANP	Analytic Network Process
ARM	Availability of Resources and Material
ASCE	American Society of Civil Engineers
BBO	Buy Build Operate
BOO	Build Own Operate
BOOT	Build Own Operate Transfer
BOT	Build Operate Transfer
BTO	Build Transfer Operate
CAD	Computer Aided Design
CBR	Case Based Reasoning
CLUES	Concordia University Libraries Electronic Search
CM	Construction Manager

CMR	Construction Manager at Risk
CON	Constructability
CONF	Confidentiality
CR	Consistency Ratio
CSU	Construction Speed and Urgency
DB	Design Build
DBB	Design Bid Build
DBOM	Design Build Operate Maintain
DSS	Decision Support System
EMS	Effectiveness Measure Scale
EPC	Engineering Procurement and Construction
FLX	Flexibility
GC	General Contractor
GMP	Guaranteed Maximum Price
H/E	Health and Educational
HR	Human Resources
HVAC	Heating Ventilation and Air Conditioning
LDO	Lease Develop Operate
MAUT	Multi-Attribute Utility Theory

MCDA	Multi-Criteria Decision Analysis
MCDM	Multi-Criteria Decision Making
MIT	Massachusetts Institute of Technology
NATO	North Atlantic Treaty Organization
NEDO	National Economic Development Office
O/G	Office and Government
OCW	Open Course Ware
PC	Project Cost
PDS	Project Delivery System
PDSSF	Project Delivery System Selection Factor
PPP	Public Private Partnership
PPSSM	Project Procurement System Selection Model
RA	Risk Allocation
REV	Relative Effectiveness Value
RI	Responsibility and Involvement
RIW	Relative Importance Weight
SCPI	Security Constraint and Political Impact
SD	Scope Definition
SI	Suitability Index

SMART Simple Multi-Attribute Rating Technique

SMARTS Simple Multi-Attribute Rating Technique with Swing Weights

TQ Turn-Over Quality

UHREC University Human Research Ethics Committee

UK United Kingdom

UNHCR United Nations High Commissioner for Refugees

US United States

VE Value Engineering

CHAPTER I

INTRODUCTION

1.1 Background

Over the years, international development and funding agencies have been facing the increasing challenge of coping with the technical problems of construction in post conflict countries. Despite existence of general frameworks and techniques for addressing construction obstacles, many of these shortcomings continue to undermine effectiveness of project mobilization, resource allocation and project delivery at large. As the dynamics of post-conflict reconstruction evolve and the demand for revamped infrastructure grows in unforeseen fashions, persistent technical gaps and emerging challenges will render development and funding agencies increasingly exposed.

Traditionally, crisis management was predicated upon limited notions of "response" that required the swift exit of relief workers once the "emergency" phase of a crisis is over. In spite of concentrated efforts to amend this approach, a reactive ethos still underlies much of the humanitarian sector. This mindset, combined with the disparate mix of humanitarian actors, has contributed to the sector's inability to address long-standing technical problems, as well as a perceived resistance to innovative engineering solutions. In order to tackle these vulnerabilities more consistently, the sector must embrace innovation and reach out to nontraditional responders who can offer wider skill sets.

Western donors and international development agencies may not possess the most applicable construction methods for rehabilitating infrastructure in other countries.

Afghanistan, for example, does not benefit from a well-documented engineering design and construction standards. The expat community arrived in Afghanistan with a perceived notion that the internationally funded construction projects would meet the international level of standard practiced in well-developed countries. While the international construction standards may have a logical appeal to be adopted for this purpose, it is often demanding and at times impossible to meet internationally accepted engineering design and construction standards in post-conflict states. This is due to the environmental constraints such as: shortage of high-quality construction materials and equipment, a scarcity of competent constructors and contractors, a lack of knowledge about the geographic terrain and environment, a lack of awareness of available local skills, a lack of skilled workforce, and poor security conditions.

1.2 Complexity in Construction Projects

Construction projects are intrinsically complex operations. A very diverse mix of individuals interacts while a project is under construction. Kasturi and Gransberg (2002), state that the analysis of project complexity requires and understanding of innumerable individuals involved in the process starting with the builder, the design professional, construction representative, subcontractor, supplier, and the entire professional and non-professional team members working under these responsibilities. It is surmised that every professional constructor will manage a host of factors related to environment, politics, risks, technology and econometrics. In reference to complex environments, Davies (2004) argues that "there is a very strong need for more and better implementation studies that can identify the particular conditions under which successful implementation and delivery materialize or fail to take place". Figure 1 exhibits the intricate conceptual risk framework and the interrelationships of these factors in a hypothetical construction project. Figure 1, classifies the elements of project risk into 5 categories and defines the sub-elements within each cluster.

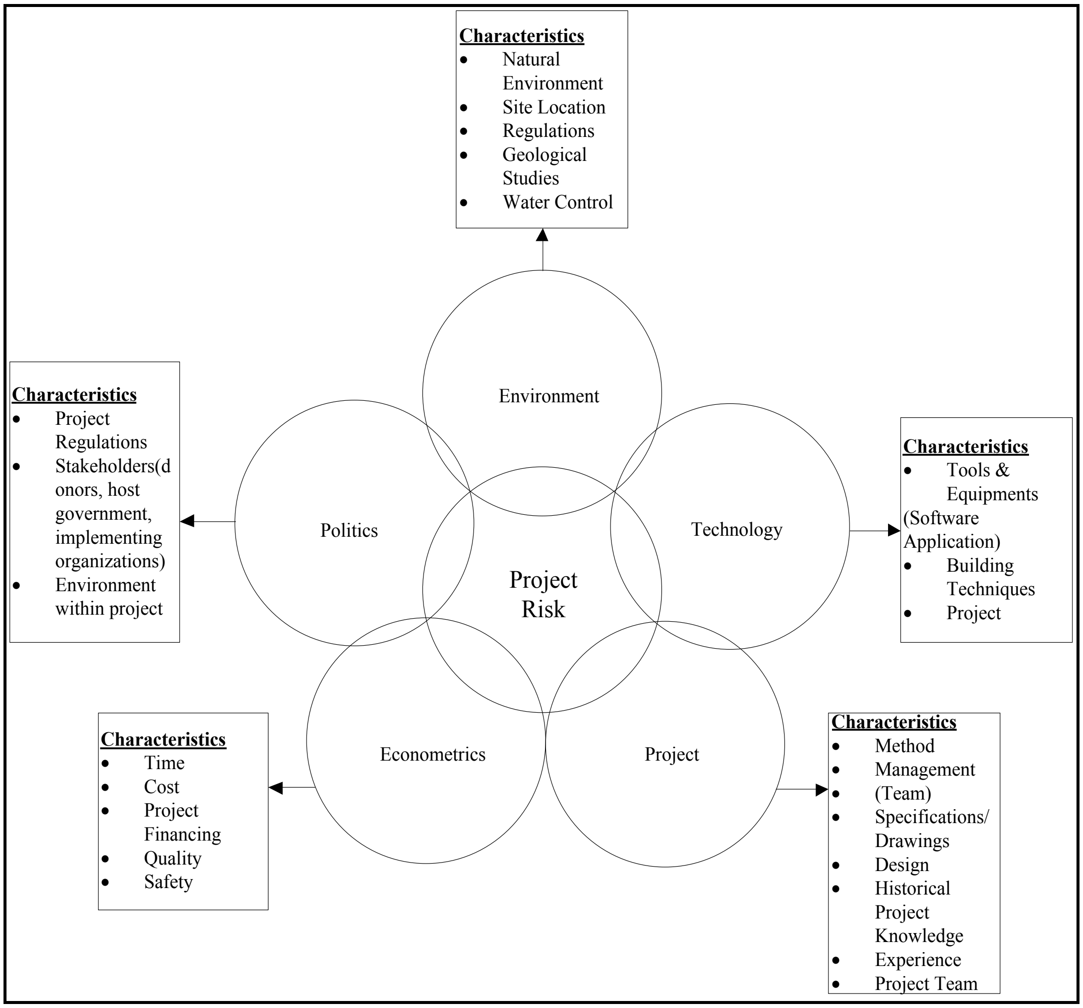


Figure 1.1 Conceptual Model for Project Complexity

1.3 Statement of Problem

The increasing complexity of construction projects and the evolution of construction management as a field of practice, has given rise to emergence of several methods for construction project delivery. Traditional, design-build, design-bid-build, and construction manager at risk are amongst the most popular delivery systems practiced worldwide. Selecting the most appropriate project delivery system, on the other hand, has for long been a subject of debate amongst project owners. Adopting the most appropriate PDS is a process that entails detailed analysis of multiple criteria and situations and does not follow a "one size fits all" approach. The present body of knowledge concerning project delivery systems imply that the type of delivery system applied in a project has a direct impact on the outcome of the project. Hitherto, there has been no categorical study about the impact of project delivery method on donor-driven post-conflict construction projects. Surveys indicate that in post-conflict construction projects, decisions are conventionally based upon preconceived advantages and disadvantages of each PDS. In majority of cases, project owners and development agencies resort to informal procedures in selecting a project delivery approach. There is an oversimplification of the decision making process in such a way that conclusions are often drawn in absence of careful review, and consideration of alternatives, or all determinant factors. On the other hand, in an environment marked by complexity and stress, clarifying project objectives and means for identifying project success at the outset of project, will facilitate evaluation of project success upon completion, beyond measures of schedule and performance. Gaining a better perspective on how each of these project delivery methods are organized and managed can help international development agencies and contractors to provide owners (donors, host governments and the community) with better value for the projects. Yet, the challenge lies in investigating how each project delivery system reacts to project owner's intended objectives and priorities. The distinct gap in the literature related to donor-driven post-conflict construction projects, highlights the exigency for developing specific research methodologies for a comprehensive analysis of this issue.

The backbone of this research comes from in-depth practitioner interviews and cluster group meetings. Following the preliminary targeted interviews, the main determinant factors in choosing a PDS were revealed as: Time, Cost, Safety and quality. This discovery, lead to formulating some fundamental questions, for which this research has attempted to find answers:

1. Which project delivery system (Design-Bid-Build, Design-Build and Construction manager at Risk) is more compatible with tight-timelines and fast changing priorities in post-conflict construction projects?
2. Which project delivery system is more likely to provide a better quality constructed facility in post-conflict construction projects?
3. Which Project delivery system is more sensitive to security and safety issues in post-conflict construction projects?

1.4 Research Objective and Scope

The objective of this research was pursued through aggregating the preferences of a broad sample of experienced practitioners into selection criteria for project delivery systems. In order to answer the questions in the preceding section, the prerequisite functions that were necessary for fulfillment of the research objective were identified and classified as sub-objectives. The overall objective of developing a site adaptable and scalable PDS selection model in post-conflict construction projects was divided into three sub-objectives presented below:

1. Identify and study the set of alternative project delivery systems and the factors relevant to the decision problem in post-conflict construction programs,
2. Define measurement attributes for selection factors in relation to characteristics of alternative project delivery systems evaluated in this research,
3. Develop a site adaptable decision making model suited for individual and group based selection of the project delivery system in post-conflict construction projects.

1.5 Research Methodology

The selection models proposed in this research are based upon a mixed-method approach. The technique proposed for aggregating the PDS suitability is built upon ANP and MAUT. The following points highlight the various steps of developing the selection models:

Step 1. Identifying the potential PDS options

Step 2. Defining the most pertinent PDS Selection Factors in post-conflict

Step 3. Assigning Relative Importance Weights to the Selection Factors

Step 4. Assigning Relative Effectiveness Values to the competing PDS options

Step 5. Aggregating the weighted scores of selection factors in relation to the PDS options to determine their suitability indices and

Step 6. Choosing the PDS with the highest suitability index as the most appropriate delivery option.

1.6 Thesis Organization

The thesis in hand consists of six chapters. In chapter one an overview of the research subject and its relation with the urgent gaps in post-conflict construction projects is presented. The introduction is followed by a discussion about the problem and the objective that this research is set out to achieve.

In Chapter II, a comprehensive review of literature related to project delivery system is presented. The literature review focused on definitions as well as the advantages and disadvantages of each PDS and is followed by a presentation of highlights of the research activities already performed pertaining to PDS selection techniques.

An exposition of the project delivery system decision framework is presented in Chapter III. This chapter elucidates the methodology employed for assisting project owners in choosing an appropriate project delivery system. Considering the preconceived resistance to innovation in post-conflict operations, the researcher has made an effort to adopt a simplistic approach in defining the methodology to encourage application of this framework in real life practice of construction projects in post-conflict. To this end, the results of previous research were used as a starting point for defining a generic set of selection factors. Post-conflict construction practitioners were then asked to aggregate these generic selection criteria into a set of pertinent selection factors as perceived by project owners and practitioners in the field. This practice resulted in classification of selection factors into three factor areas of: Project Related Parameters, Agency Preferences and Regional Parameters. Chapter III also provides a look into the structure of the decision framework model and application of a mix method approach hinged on analytic network process (ANP) and multi attribute utility theory (MAUT) methods. Chapter IV contains the information about the case study projects, the sample population, data collection mechanism and survey questionnaires as well as data assessment and analysis technique. Chapter IV also elaborates on the survey pilot test and pays particular attention to testing the consistency of practitioners' response.

Chapter V contains the result of the research and provides a comparative view of the results obtained from the two models proposed in this research. Conclusions and recommendation for future work are presented in Chapter VI. Also, this chapter provides a narrative of the possible limitations of this research and considerations that project officials should make whilst employing the framework proposed in this research.

CHAPTER II

LITERATURE REVIEW

2.1 The Organization of International Development Projects

In developed countries, capital projects are owned by either the government or a private entity. The owner in addition to funding the project will foster the idea and initiates the construction operation. However, this seemingly straightforward process takes a different turn in post conflict reconstruction. In post conflict countries the owner's role is assumed and carried out by different entities. This phenomenon alters the entire framework of project design and execution and influences the roles and responsibilities of project participants. The project delivery methods in post-conflict development projects have many similarities with the three most popular project deliveries practiced in developed countries. As earlier mentioned, in post-conflict construction projects, typical managerial and project related tasks are assumed by non-typical entities. In the interest of creating a common understanding, the following section elaborates on the organizational structure of international development projects and its components.

2.1.1 The Key Entities involved in International Development Projects

Improving the living conditions through restoration of the infrastructure has been the focus of international development efforts in many post-conflict situations. Successfulness of development programs depends on how well they manage to integrate and involve communities in the reconstruction process. Therefore the perception that considers communities as mere beneficiaries is one that requires further adjustment. Scholarly consensus is in favor of adopting a more adequate terminology to address communities. Terms such as "project partners or community owners" deserve consideration in community based development and community management (McCommon et al., 1990). In the context of international development projects, success is warranted only if development projects are collectively cared for, viewed as a public asset, and thus managed for the common good (Ratner and Rivera Gutiérrez, 2004).

Given the very nature of international development project, the concept of “project owner” has an elusive quality. Therefore, the role of the owner is intentionally skipped from the following list of project participants. In most post-conflict construction projects, the role of the owner is interchangeably assumed by the funding agency, the development agency and the community.

Development Agency: The development agency also referred to as the implementing organization is an international or an inter-governmental entity that initiates the project. This agency will establish contact with communities, conduct needs assessments to identify immediate infrastructure shortcomings of the community, and depending on its in-house capacity will provide the design package or contract a designer, award the contract for construction, and oversee construction. The development agency acts as a channel through which project funds are disbursed. Often the development agencies pool in funds from their resources to fund construction projects. In certain cases, a group of two or more development agencies with shared mandates jointly embarks on development initiatives.

Funding Agency: The funding agency is the driving force behind international development projects through which project funding is secured. The funding agency enters into An implementing contract with the development agency, delegating the management of the design and construction.

Designer: often where there is a lack of competent design companies, the development agency hires, trains and maintains designers to comply with the funding agencies' standards of design. Designers may also be contracted by the development agency to undertake the design and prepare construction cost estimates.

Construction Contractor: The timing of contractor's involvement in the project is determined by the development agency's choice of project delivery system. Typically, the development agency awards a construction contract to a contractor after the design and bid packages are prepared by the designer. The contractor is usually a local constructor who's up to speed with the locally accepted construction norms and techniques.

Project Partners or Community Owners: Communities are associations of people bound by kinship who live in proximity to one another. In this context, communities are categorized by their lack of proper infrastructure and common desire for improved living conditions. There is a shift in international development frameworks to engage the communities in rehabilitation efforts and inspire a sense of ownership as a mean to ensure sustainability and maintainability of the project.

2.1.2 Specific Technical Constraints in Post-Conflict

Afghanistan is an example of a country emerging from post-conflict. This country has witnessed a recurring state of conflict over the past three decades. This plight started with the 1979 Soviet invasion and occupation, followed by the outbreak of the Civil War from 1989 to 2001, and later by the U.S. invasion post 11 September 2001 terrorist attacks. The current war led by the NATO coalition aims at building capacity in areas of governance, security, education, and reconstruction. The reconstruction projects are diverse but mainly focused on security and army facilities, schools, clinics, hospitals, water, irrigation and roads.

Reconstruction efforts in Afghanistan are met by many challenges including shortage of qualified human resources. In the past 30 years, Afghanistan has only graduated a limited number of engineers, and some of these engineers often lack basic knowledge and expertise in comparison to their Western educated peers (Sargand 2009). The specific issues enumerated below exemplify some of the obstacles encountered on construction projects in Afghanistan. It is understood that these issues, for the most part, are common to all post-conflict states:

- Physical environment,
- Hostile geographic terrain,
- Construction standards,
- Brain drain,

- The impact of tribal social structure on construction projects,
- Challenges in quality control and monitoring of projects,
- Corruption,
- Security related concerns,
- Design-build challenges and,
- Quality of the construction material.

Consideration of these limitations is central to identification of the PDS selection factors in post-conflict. They are also instrumental in understanding the measurement attributes of the PDS options in relation to the selection factors. For reasons of brevity, the specific technical issues in post-conflict are reviewed more expressly in appendix V. The author strongly recommends that readers acquaint themselves with these limitations before they engage with this thesis.

2.2 Decision Making and Decision Aid Models

Decision making is an essential function of management. This statement is warranted by the increasing number of studies and continued development of decision aids in various fields of management. Ramamurthy, Wilson and Nystrom (1999), as well as Mitropoulus and Tatum (2000) studied decision making in the field of technology adoption decisions. Mitrpoulos and Tatum (2000) established a model of the rate of diffusion of three dimensional CAD technology in construction industries based on case studies. In their work, the relationship between industry factors and technological factors in technology adoption decisions versus organizational characteristics were elicited to better present the innovation mechanism in the industry. Moreover, Ramamurthy, Wilson and Nystrom (1999), took on technology adoption decisions from the context of imaging technology in medical facilities industry. Their research suggests that there is a link between climate and innovation. It also included attributes for measuring parameters of radicalness and relative advantage, on 68 different technologies in the field of hospital imaging. Accordingly, an organization's proclivity towards radicalness is indicative of the technological options that the organization would opt for and the relative advantage that could be gained from this decision.

In the field of capital facility project management, decision problems have been the subject of much deliberation and are at the center of numerous decision support tools. In some cases, the review of decision problems focused on shaping the alternatives that should be only acknowledged in specific subject areas or in defining the appropriate selection criteria for particular selection problems.

Numerous studies have focused on the selection problems in the case of capital facility project management. The challenge of choosing a construction method for underground pipeline construction was addressed in the study carried out by Ueki, Hass and Seo (1999). Moreover, Spainhour, Mtenga and Sobanjo (1999) proposed a decision support system for selection and installation of crash attenuators in highway construction. In 1999, Ziara and Ayyub developed a method to make effective use of the available resources in housing development projects in impoverished countries and McIntyre and

Parfitt (1998) suggested a decision support system for residential land development selection. The literature review in this area reveals that decision making and decision support systems have received significant attention and the work of researchers in this field is one of continued evolution.

2.3 Project Delivery Systems (PDS)

Researchers have asserted various definitions for project delivery system. Touran et al. (2008), define PDS as the process through which a construction project is comprehensively designed and constructed for an owner. These processes entail project scope definition, organization of designers, consultants and constructors, sequencing design and construction operations, execution of design and construction as well as close-out and start-up. Touran et al. (2008) also state that in certain cases, project delivery system may also encompass operation and maintenance. In project management, decision analysis plays a key role in determining the most appropriate project delivery system with respect to the characteristics of a specific project. Silva (2002), in “Model for optimizing the selection of project delivery systems using AHP”, states that Project delivery system is “a contractual structure and compensation arrangement that the project owner uses to acquire a completed facility that meets his/her requirements through the design as well as the construction services of the project” This definition, is one that more closely defines a PDS from the researcher’s point of view. The generic term “project delivery system” denotes the arrangement and interactions of different participants in order to transform the project owner’s goals and objectives into a finished facility.

A project delivery system is a way of organizing the building and management of construction projects (Rubin and Wordes, 1998). Different approaches to project delivery provide different ways of packaging the building process; each system brings a new character to the traditional structure of project delivery including the client, the designer and the builder and a subsequent change in the character's role depending on the applied system (Ribeiro, 2001).

Furthermore, having a clear understanding of the term "delivery system" in its specific context is essential to the project owners to visualize of the process and the alternative delivery methods. The term does not encompass the means and methods used in constructing a capital facility or the course of procuring equipment or material to mobilize the construction, but rather it signals to the project team to initiate hiring of construction professionals and the design of documents suitable to the building process.
It is the owner's needs that determine the modality and the timing of hiring design professionals and the type of contracts to be signed. Similarly, deciding upon the timing of hiring construction professionals and their contracts is left to the owners' discretion. Clear lines must be drawn between different parties outlining their extent of responsibility and the project owner must specify what degree of input is more befitting according to their knowledge base.

Delivering a building project in time and within budget is still an increasingly complex and risky business. A number of new project delivery methods and management techniques have been introduced to attain this objective. Ultimately, choosing and customizing the most suitable project delivery method to the needs of the project owner is a crucial task in the early stage of any construction project (Groton and Smith, 1998).

The client's choice of project delivery system is a decision that has the most effect on the relationships and the risk allocation in a construction project. Given that different project delivery systems orchestrate the building process in a different fashion, they may not be applied arbitrarily on all types of construction projects (Ribeiro, 2001). However, the belief that there is a perfect project delivery method for every building project stands, largely discredited. At the same time, there are no absolutes in project delivery methods, merely variations along a spectrum (Kluenker, 1996). Accordingly, the best method should be selected upon careful needs assessment of the customer, project characteristics as well as team members' expertise and experience (Ribeiro, 2001).

It is surmised that a project is considered as successful if the constructed facility is delivered at the right time, at the appropriate price with ample quality and to the satisfaction of the project owner (Naoum and Langford, 1988). Banwell and Emerson in their reports of the 1960s, stipulate that the type of project delivery implemented has a significant impact on the project's success. The increasing number of studies on project delivery systems in the recent years signifies that there is one delivery system that is in some sense more appropriate than all others for an individual project yet there is no single delivery system that is seemingly better than other alternatives for any project. (Skitmore, 1995).

Project delivery systems provide the framework for the undertaking of capital facility project as a business venture (Oyetunji, 2001). From a business point of view, this framework is comparable to the organizational structure of a commercial enterprise. Choosing the framework that best meets the project objectives, is the challenge that most project owners/managers have to face. Conventionally, this process includes selecting a method from the pool of available alternatives.

In recent years several alternative delivery methods have been developed to address the insufficiency of the traditional design-bid-build scenario. The following section includes an introduction to the most popular project delivery system alternatives.

2.4 Project Delivery System Alternatives

Project delivery systems refer to the overall processes with which a project is designed, constructed, and/or maintained. Within the public sector, the process has traditionally entailed the almost exclusive application of the design-bid-build system, characterized by the separation of design and construction services and sequential execution of design and construction. With the increasing demand for within budget and on time construction, the public sector has begun experimenting with alternative methods to improve the speed and address the efficiency of the project delivery process. The alternative methods slant towards to the integrated services approach to project delivery favored in the private sector.

Conventionally, Project delivery Methods can be grouped into two categories. This classification is based on the project's source of finance. Capital projects are either publicly funded or fully or partially funded through private investment. In the early project cycle, project owner should opt for an appropriate project delivery system for design, construction and commissioning, maintenance and operation of the project. In addition to the traditional design-bid-build process, a client can select from a range of alternative methods including design-build, fast-track, multiple primes or a variety of hybrids. Each of these methods has certain advantages and drawbacks and the best choice is governed by the specific requirements, complexity and urgency of the project and the owner's technical knowledge and available managerial resources.

There are as many variations of project delivery system as the vibrant minds of owners and financiers can conceive. By the same token, while there are many strategies which have been successfully tested for procurement of design and construction services, the thesis at hand focuses on the three project delivery methods suited for publicly funded reconstruction projects in post-conflict settings: traditional (Design-Bid-Build), design-build (DB) and construction manager at risk (CM-R). These methods are further discussed to provide an overview on how they are organized and managed. After explaining the principal components of the delivery methods, it is vital to elaborate on the advantages and disadvantages of the three project delivery methods adopted in public funded construction projects. Appendix III provides a closer look at some of the most notable project delivery methods not discussed in the body of this thesis. This information is adapted from the MIT Open Course Ware (OCW) material.

2.4.1 Design-Bid-Build (Traditional)

The design-bid-build approach also referred to as traditional or general contracting method is branded by a design-bid-build sequence where the key construction entity is the general contractor (GC). The traditional delivery system was predominantly used in the industry until the 1970's primarily because this system was in compliance with the legal bidding and contracting parameters of public owners. Figure 2.1, illustrates the relationship between parties in the traditional delivery method. In this diagram, solid lines indicate a contractual agreement and dashed lines signify non-contractual or administrative relationships.

As in figure 2.1, the contracting structure includes two prime contracts. A prime contact is defined as a contract undertaken by an owner in which the contracting entity is obligated to perform the scope of contract as per the terms and conditions agreed upon. In this setting, the first prime contract is the one between the owner and designer (Architect/Engineer). The designer (A/E) is the entity responsible for design and construction administration including project and contract management. The second contract is an independent one executed between the owner and the general contractor. The contract obligates the general contractor to undertake the construction, including the actual performance of the construction as well as subcontracting with trade contractors (subs) to execute specific packages of the work. Accordingly, coordination of the sub-contractors rests with the general contractor. In a design-bid-build approach as the name connotes, the sequence begins with design. The bidding phase comes after completion of the design and construction does not commence until after the prime construction contract is awarded. The general contractor comes into the picture only when the construction begins and has the responsibility to carry out the work in conformity with the contract and meet the project-

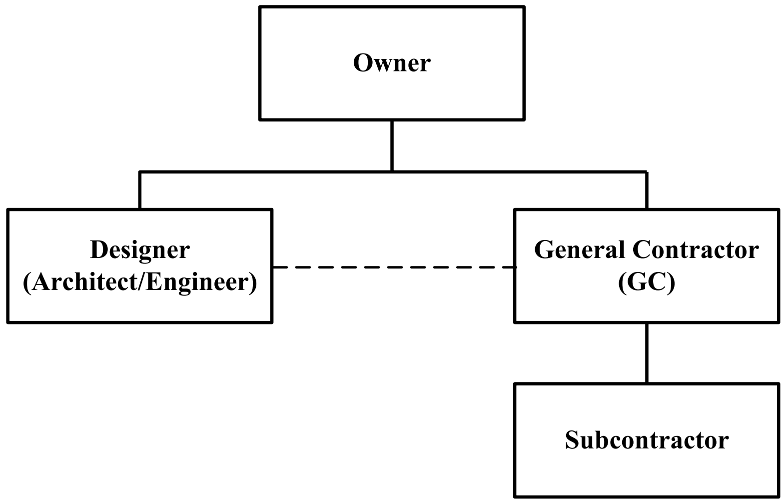


Figure 2.1 Design-Bid-Build (Traditional) Project Delivery Method Diagram

requirements until the end of the warranty period. The designer on the other hand is involved from the conceptual design step through the commissioning of the facility which is the time that owner has occupied the facility.

2.4.2 Variations of Design-Bid-Build Delivery Method

The traditional project delivery method has two widely accepted variations. These variations include: design-bid-build using separate-prime bidding and design-bid-build using single-prime bidding. There are four sequential phases as observed in both variations: selection, design, bid and construction. In the selection phase, designers are hired on basis of their technical qualification and expertise. The design phase begins right after designers are hired. The design phase entails three steps, commencing with the schematic design, during which basic features and the overall plan are developed. Second step in the design phase is design development whereby the functional and aesthetic features of the project are defined; and the third step or construction document, during which construction technology and details of assembly are decided upon. During the design phase, the owner streamlines the project requirements, also referred to as the project program. What separates single-prime from separate-prime bidding is the type of bid specification packages that branch out from the design documents.

I. Design-Bid-Build Using Separate (or Multi) Prime Bidding

In this variation of the traditional project delivery method, the designers create multiple bid packages for different segments of the construction operation such as HVAC, plumbing, electrical and general construction. Bids are then collected from respective prime contractors and

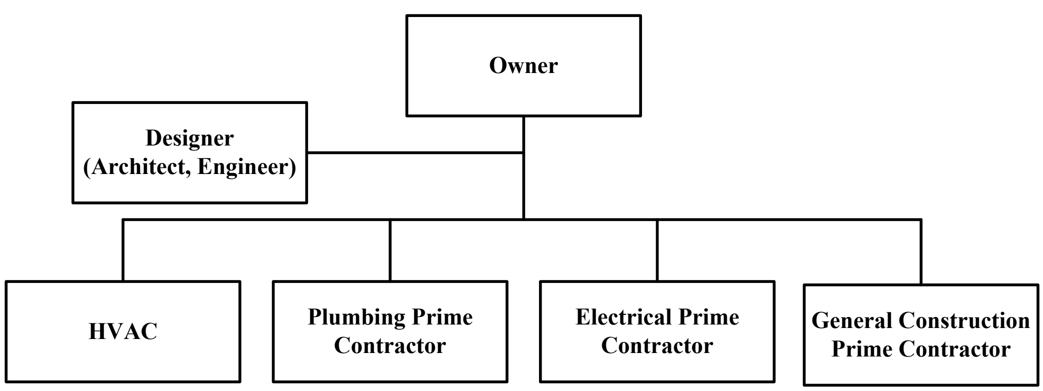


Figure 2.2 Design-Bid-Build Project Delivery Method Using Multi-Prime Bidding

the contract is awarded to the lowest, most qualified bidders. By the end of the bid phase, construction operation kicks off. According to this variation, the construction begins after the design documents are complete, and the owner signs a separate contract with the designers and prime contractor as shown in figure 2.2.

II. Design-Bid-Build Using Single-Prime Bidding

In a single-prime design-bid-build approach, contrary to the multi-prime approach where several design packages are produced, the designers create a single package from design document. Construction bidding will commence only after the single design package is developed. Bids are gathered from general contractors (GC) and the one with lowest most credible bid is awarded with the contract.

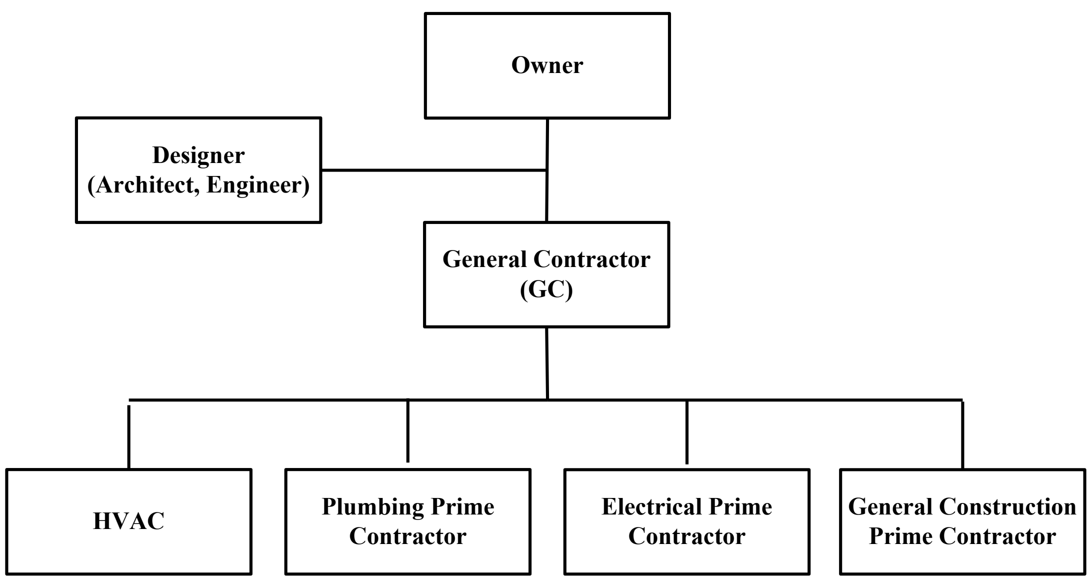


Figure 2.3 Design-Bid-Build Project Delivery Method Using Single-Prime Bidding

Upon completion of the bidding, a single contract is undertaken. Construction work begins after the design documents are complete and the construction operation is perceived as the project's final stage. The project owner undertakes separate contracts with the designer and the general contractor. The general contractor can execute contracts with subcontractors as illustrated in figure 2.3.

2.4.3 Design Build (DB)

The design-build approach is characterized by three sequential phases: bid-selection, design and construction. The key entity in this method is the design-build contractor. In a design-build approach, the designer and the construction professional are either a single c ompany or have come together through a joint venture and there is only one prime contract between them and the owner.

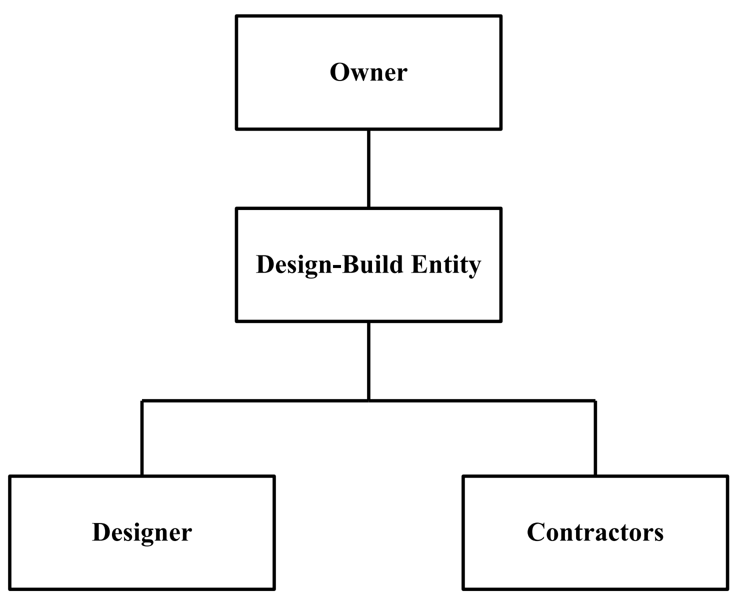


Figure 2.4 Design-Build Project Delivery Method

The selection, coordination and administration of trade contractor lie with the design-build contractor and the performance of all parties is the responsibility of the design-build company. In this method, the owner first prepares a detailed project program and subsequently calls for proposals to absorb a design-build contractor. Following the request for proposals, several companies are short-listed on the basis of their experience and qualifications. At the next step, the design-builders prepare detailed proposals that include design documents and a cost analysis. After developing the proposal, the owner reviews each proposal. In most cases, the owner may require justifications from design-builders in which case they should revert with adjustments and modifications as per owners' recommendations. After evaluating the revised proposals, the owner awards the contract to the most credible bidder. In the design-build approach, the design-build contractor may begin construction right after being awarded the contract. Under this method, the construction kicks off prior to completion of the design documents. Figure 2.4 could be referenced for relationships between different entities in the design-build delivery method.

2.4.4 Construction Manager at Risk (CM-R)

According to the American Society of Civil Engineers, a Construction Manager (CM) is a firm or an organization specialized in the practice of professional construction management. Conventionally, the CM does not engage its own workforce to perform major design or construction activity. The CM is perceived as a construction consultant with the professional status equal to that of a designer rather than a competitive, price motivated contractor.

Construction management is also viewed as a mechanism of communication whereby construction expertise is spread to the entire project team throughout all phases of project delivery. From a CM's standpoint, the planning, design and construction are integrated tasks. In the CM approach the project sequence starts with design and leads to bidding and culminates in construction of the facility with the input from the CM beginning with the commencement of design work and concluding with the expiration of the warranty period.

Similar to the design-bid-build method, CM-R entails sequential phases: selection of designer, design, bid selection of a construction manager, and construction. The process starts when the project owner develops the project program and then invites proposals from prospective design professionals. A similar call goes out for attracting construction management professionals and at times the owner merges these two by hiring a company that has both design and construction management capacities. In the latter case, a guaranteed maximum price is negotiated with the design entity later in the design phase to perform the construction oversight. In CM-R approach as well, the owner selects the CM on basis of qualification and cost. Selection of the construction manager (CM) comes after awarding the design contract to the deign entity and happens while the design documents are being developed.

In the pre-construction phase, the construction manager collaborates with the owner and the designer by providing inputs until the design documents are about 80 percent complete. It is the owner who determines the interval where the guaranteed maximum price (GMP) is negotiated. The literature suggests that the GMP is negotiated close to the end of the construction documents stage or at the point where the constructor is ready to accept the construction risk at which point the GMP will be added to the contract.

The term “at risk” in the construction manager at risk project delivery method signifies the degree of risk that the construction manager will assume through the guaranteed maximum price (GMP) clause. The GMP is a mechanism for passing responsibility to the construction manager in that the CM ensures the performance and financial viability of subcontractors and suppliers, market inflations and ensuing price fluctuations, schedule adherence and other risks resulting from circumstances beyond control such as weather and natural disasters. Once the guaranteed maximum price has been defined, the construction manager may go ahead with the construction, even in the absence of complete design documents. Should the construction start early, multiple bid packages must be prepared by the construction manager from the incomplete design documents and then start the bidding process.

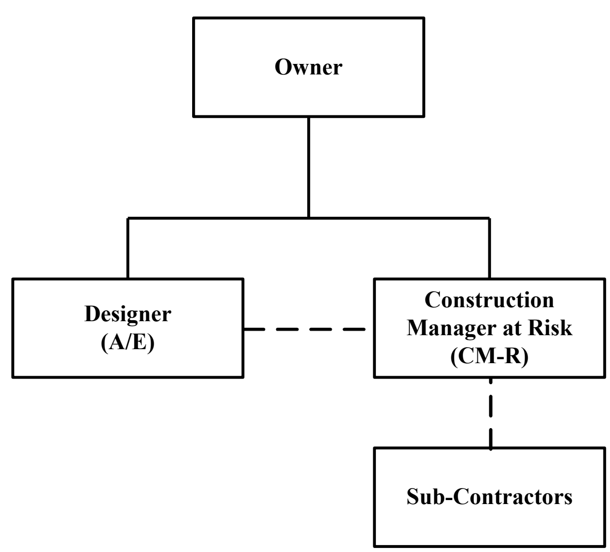


Figure 2.5 Construction Manager at Risk Project Delivery Method

In CM-R fast tracking of work is an option since the project can be divided into various phased bid packages and the sub-contractors could be employed (similar to the design-bid-build separate prime bidding method) as needed to meet the time constraints of the project. It has also been noted that the application of CM-R can provide the project owner with an early knowledge about the project cost. Figure 2.5 illustrates the relationships between different project entities in the construction manager at risk project delivery method where the owner contracts with the designer and the construction manager, and the construction manager contracts with the sub-contractors as needed.

2.5 Comparison of Project Delivery Systems

This section highlights some of the key advantages and disadvantages of the three project delivery systems so far discussed. The pros and cons presented in this section are discussed from the project owners' point of view and are compiled from several sources namely as Touran et al (2008) and Konchar et al (1997).

2.5.1 Advantages of Design-Bid-Build

A. Simplicity in contracts administration. In most cases, there is only one contract to administer.

B. Ease of coordination amongst subcontractors and suppliers and other project members due to relative familiarity with the traditional delivery method.

C. Design change is easily accommodated.

D. Price competition which benefits the owner in terms of fixing the construction price before the starting the construction.

E. A greater degree of certainty as the general contractor shoulders the majority of construction risk.
F. Well defined roles and responsibilities for all parties.
G. The owner is not required to take an active role in the construction.

2.5.2 Disadvantages of Design-Bid-Build

A. Lengthy process of design and construction.
B. Potential for disagreement between general contractor and designer due to their different interpretation of the project documents.
C. Potential for adversarial relationship between the owner and the general contractor resulting from the fixed price contract--changes in the work could lead to disputes.
D. Impending cost overruns due to general contractor's markup on subcontractors.
E. Owner has limited supervision or control over the subcontractors and suppliers.
F. The pressure resulting from selecting the lowest bid could result in hiring contractors lacking the qualification to deliver a satisfactory job.
G. Owner bears higher risk
H. Requires increased oversight and quality review by the owner due to the least-cost approach of the contractor.

2.5.3 Advantages of Design-Build

A. Merging of design and construction aspects into one contract.
B. Solid commitment to cost and time before starting the design.
C. Owner can reduce the construction time through phased work packages.

D. Improved communication between designer and constructer during the design and construction phase.

E. Risk is transferred to the design-builder to some extent.

F. Owner doesn’t need to be actively involved and will require less staff.

G. Owners can benefit from Design-build firms expertise and experience from previous projects.

H. Constructability and construction expertise is incorporated throughout the design phase.

I. Changes can be made with less restriction and repercussion.

2.5.4 Disadvantages of Design-Build

A. There is limited competition due to non-existent design documents.

B. Risk of cutting corners by the design-build firm to increase their profit, if the price is set prior to design.

C. The total project cost could remain in the shadow if a firm price is not set and the project is fast-tracked.

D. Owner has limited control over the project, e.g. selection of sub-contractors.

E. There is no mechanism for owner to monitor the project quality. The quality therefore is contingent upon the integrity of the design-build party.

F. Owner should be well acquainted with the construction process to negate the effect of the disadvantages listed above.

2.5.5 Advantages of Construction Manager at Risk (CM-R)

A. Owner could transfer the responsibility for construction and to some degree, the construction risk to the CM

B. Owner retains control over the design phase and at the same time receives pre-construction input from the constructor.

C. Project schedule is shortened due to elimination of the procurement phase between design and construction.

D. The construction cost is known and fixed during the design phase and could be guaranteed.

E. Probability of change orders is reduced.

F. Construction Manager is in control of trade/sub-contractors.

G. The probability of an adversarial relationship between the owner and the contractor is significantly diminished.

2.5.6 Disadvantages of Construction Manager at Risk (CM-R)

A. Construction manager (CM) acts as the general contractor (GC), not as the owner's agent.

B. Construction manager (CM) approach could potentially add to construction costs since project fees are defined on basis of negotiation not the lowest bid.

C. The fact that construction could start before the design is 100% complete could give rise to conflict.

2.6 Previous Studies

This section reflects on previously published literature on the project delivery systems selection models, with an emphasis on the decision support systems frameworks developed in recent years. An effort is made to review the research methodologies applicable to PDS selection problems as well as the methodologies applied in earlier studies and those related to the present research. Also, previous studies are reviewed to examine the evolution of selection variables and factors as a precursor of determining the most suitable project development method. This review is conducted to explore the evolution of PDS selection methods over the last couple of decades and to provide the groundwork for introducing new methods in the field of construction management and engineering. The project delivery method selection techniques so far published are assessed to determine their extent of contribution to this field of study and to demonstrate how this research brings something of value to the post-conflict reconstruction practitioners.

A number of studies have focused on how to identify the “best” individual project delivery system (e.g., NEDO, 1983) by alluding to an array of project characteristics, attributes and criteria. Some of the more positively reviewed studies namely as the works of Singh (1980) and Skitmore and Marsden (1988) propound a procedure involving weighting factors and priority rating for project attributes such as risk, time, flexibility, quality, complexity, price, etc. To ensure practicality of such procedure, it is required to elicit the weighting factors which relate project attributes to individual project delivery systems independent of individual projects. There is however a particular problem in using this method and it rises from obtaining the weighting factors. These weights cannot be easily attained by objective means and should be obtained from experts and practitioners in the field; reports indicate that practitioners have expressed some degree of difficulty in reaching an agreement on such matters (Hamilton, 1987).

There is an array of factors that may be used to choose project delivery options. Each option could be uniquely defined through application of different combination of these factors. Our options of project delivery alternative will proliferate as we take more factors into considerations and come up with more unique combinations (Mahdi, Alreshid, 2005).

In addition to the aforementioned studies, Bowers (2001) presents an exhaustive and validated list of generic project delivery system selection factors, determined from the owner's point of view, which are used today by practitioners in the construction industry. From the parameters defined by Bowers (2001), there are a total of thirty selection factors that could be presented to decision makers to make an informed and comprehensive decision. The thirty factors proposed by Bowers (2001) are holistic in a sense that they represent a wider range of project objectives that are ideally sought after in a construction project. Table 2.2 indicates the list of PDS selection factors as defined by Bowers (2001).

Table 2.1 List of Project Delivery System Selection Factors (according to Luu et al. 2003)

PDS Selection Factors					
Owner's Characteristics & Objectives	Ranking	Project Characteristics	Ranking	External Environment	Ranking
Owner's desire for completion within budget	1	Project type	4	Market's competitiveness	6
Owner's desire for completion on-time	2	Project size	5	Availability of seasoned contractors	8
Owner's requirement for value for money	3	Knowledge of potential Problem causing factors at construction site	10	Technology feasibility	11
Owner's risk ability and risk tolerance	7	Building construction type	15	Regulatory feasibility	21
Owner's confidence and trust in parties involved	9	Obscured risk factors at construction site	23	Materials availability	22
Owner's experience	12	Application of pioneering technology	27	Political impediments	25
Owner's proclivity to get involved	13	Project site location	29	Industrial actions	26
Owner type	14			Labor productivity	28
Owner's in house technical capacity	16			Complaint from neighbor	30
Owner's demand for reduced operational costs	17			Complaint from local lobby groups	31
Owner's requirement for minimized maintenance costs	18			Severe weather conditions	32
Owner's financial wherewithal	18			Cultural differences	33
Owner's demand for a technically superior facility	20			Natural disasters	34
Owner's aesthetic preference	24				

Source: Luu et al. (2003a)

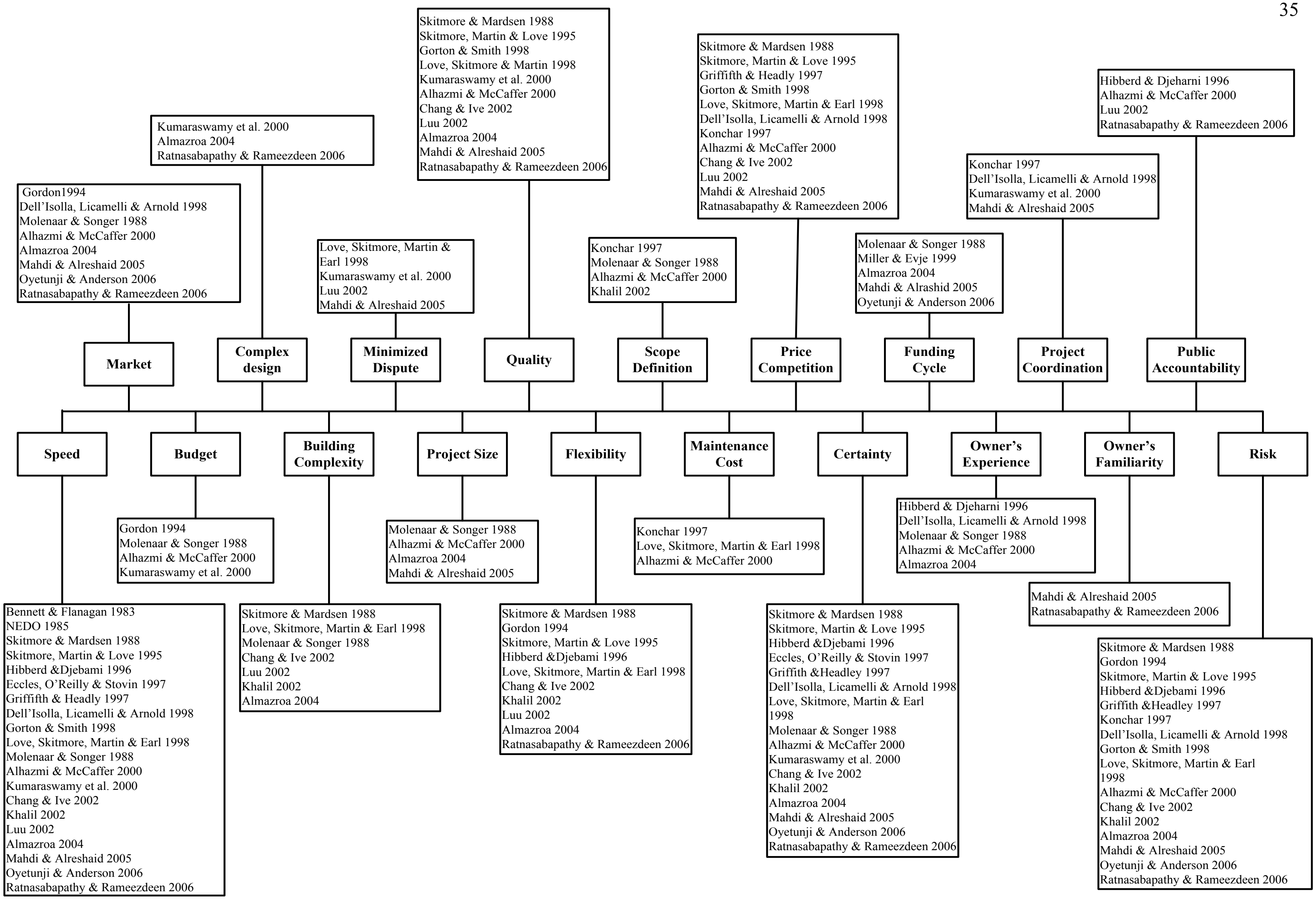


Figure 2.6 Citation Tree Diagram for Project Delivery System Selection Factors

2.6.1 Procedure for Selecting a Project Delivery Method

Traditionally, practitioners and decision makers are inclined to make their PDS decision based on their past experience and "gut feeling" rather than following a structured mechanism (Cheung et al. 2001; Luu et al. 2003). A general lack of understanding about the decision situation is present particularly at the start of the PDS selection procedure, states Masterman (2002). This lack of understanding is coupled with diminutive knowledge of alternative project delivery systems and means of evaluation and assessment of these alternatives. Such inadequacies could lead to selection of an inappropriate project delivery system which in turn could increase the risk of project failure and prevent attainment of certain benefits attributed to the chosen project delivery methods (Rwelamila and Meyer 1999).

The significance of adopting a structured PDS decision making process is highlighted in the work of many researchers and institutions. They have collectively encouraged the application of a formalized PDS selection procedure to multiply the chances of project success. A case in point is the British Treasury's Central Unit on Purchasing (1992) proposal of a six step process for choosing a PDS. Similarly, the joint committee of Airports Council Int'l of North America (ACI-NA), Airport Consultants Council (ACC) and the Associated General Contractors of America (AGC) produced a guideline that advocates the use of a four-step PDS decision-making process as follows:

I. Examine the ability to use alternative project delivery systems.

II. Establish a list of project delivery systems.

III. Select the appropriate project delivery system.

IV. Apply the selected project delivery system.

In a similar study, Sanvido and Konchar (1998) developed a framework that entails four integral steps. Their approach towards selecting an appropriate project delivery system is predicated upon series of questions that a decision-maker needs to consider. The four integral steps include:

I. Identify project owner's objective.
II. Search for alternative project delivery system.
III. Evaluate the alternative project delivery systems.
IV. Implement the selected project delivery system.

The decision making process as described in this approach depends on certain feedback and input namely as project characteristics, client's experience with certain project delivery methods, and past project performance. Accordingly, the overall output is expected to be a high quality construction project. The framework developed by Sanvido and Konchar (1998) in addition to the aforementioned input level, incorporates a level of constrains within the framework such as market conditions, regulatory constraints and agency policies. The framework is better articulated in figure 2.7.

2.6.2 Evolution of PDS Selection Model Development

As stipulated in chapter one under the problem statement, the increasing complexity of construction projects and the evolution of construction management as a field of practice, has given rise to emergence of several methods for the delivery of construction projects. This particularly holds true for the first half of the twentieth century and the post industrial revolution era. The literature review confirms that the earliest work on project delivery method selection is traced back to the United Kingdom during the first half of the twentieth century.

Table 2.2 Validated Project Delivery Method Selection Factors (Bowers 2001)

Validated Project Delivery Method Selection Factors	
1	Completion within original budget is critical to project's success.
2	Owner's cash flow for the project is constrained.
3	An above normal level of change is anticipated in the implementation of the project.
4	A below normal level of changes is anticipated in the implementation of the project.
5	Confidentiality of business/ engineering details of the project is critical to project's success.
6	Owner critically requires early and solid cost figures to allow for financial planning and business decisions.
7	Local conditions at project site are favorable to project execution.
8	Local conditions at project site are not favorable to project execution.
9	Owner requires a high degree of control/influence over project implementation.
10	Owner requires a minimal level of control/influence over project implementation.
11	Owner desires a maximal use of its own resources in the execution of the project.
12	Owner desires a minimal use of its own resources in the execution of the project.
13	Project features are well defined by the time of awarding the design and/or construction contract.
14	Project features are not well defined by the time of awarding the design and/or construction contract.
15	Owner requires a single party to be held accountable for project performance.
16	Project location is within reasonable distance to owner's resources.
17	Project location is situated far from owner's resources.
18	The project scope and monetary amount are large.
19	The project scope and monetary amount are small.
20	Owner assumes little financial risk on the project.
21	Completion within schedule is essential to project's success
22	Site condition could lead to design or construction changes.
23	Pioneering design and/or construction methods are required to meet the project objectives.
24	Project design/engineering is complex.
25	Project construction is complex.
26	Early procurement of long lead equipment/material is critical to project's success.
27	High safety performance is critical to project's success.
28	Minimal cost is critical to project's success.
29	Early completion is critical to project's success.
30	Familiarity with delivery approach/contractor is critical to project's success.

Simon (1944), Emerson (1962) and Banwell (1964) advocate an innovative approach to project delivery methods, pushing for an alternative to the traditional design-bid-build method. These discussions linger into the second half of the twentieth century and are further expanded in the 1970s and the 1980s.

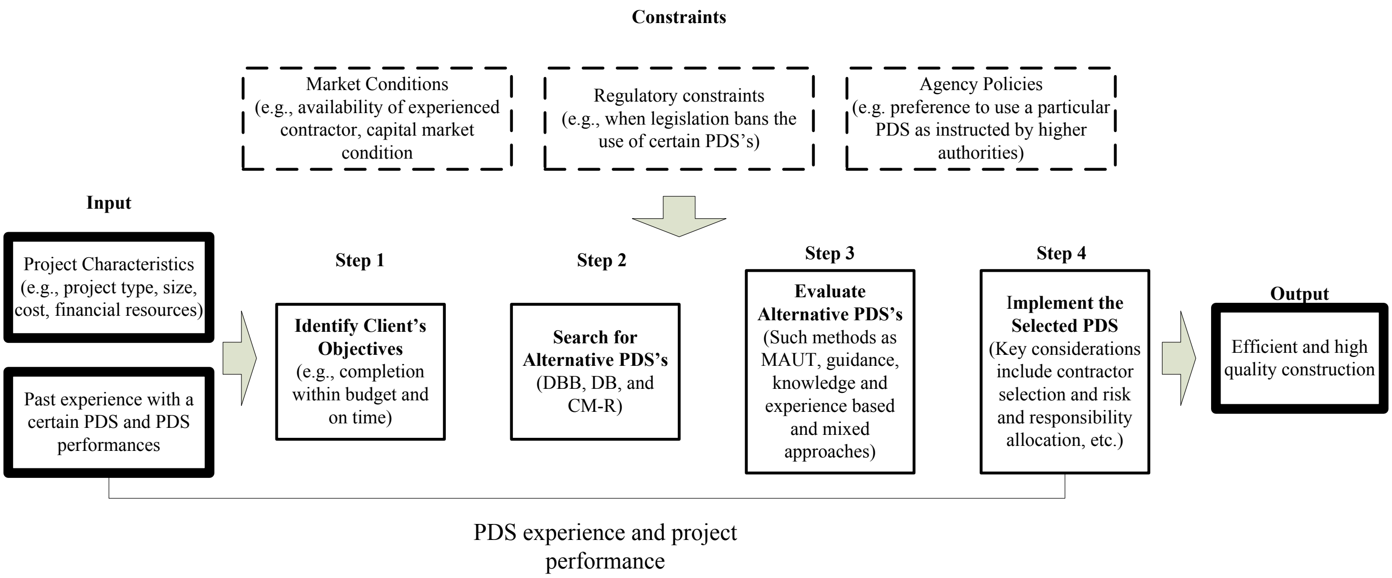


Figure 2.7 Project Delivery Method Decision Making Procedure (Sanvido and Konchar, 1998)

2.7 Overview of available PDS selection methods

The diversity of PDS selection methods is an irrefutable fact. For ease of review, these methods are categorized into four prominent groups. This categorization is based on the underpinning concepts applied in developing these methods. The following approaches stand out in terms of their application in PDS decision making process:

I. Guidance (decision charts and guidelines)

II. Multi Attribute Analysis

III. Knowledge and experience based

IV. Mix method

There are several methods associated with each of the aforementioned approaches. These methods will be introduced alongside their reference source in the following section. Also to establish a departure point for the methodology used in the research, a discussion on advantages and limitations as well as the underlying concepts of these methods will be presented.

2.7.1 Guidance Methods

The guidance methods could be classified as follows:

Methods	References
Individual project delivery methods	Songer and Molenaar (1996), Molenaar and Songer (1998), Beard et al. (2001), Chan et al. (2002), Gransberg et al.(2006)
Comparison of alternative PDS	Construction Industry Insititute (1997), Konchar and Sanvido (1998), National Institute of Standards of Technology (2002), Ibbs et al. (2003).
Formalized framework and guidelines	UK Treasury's Central Unit on Purchasing (1992), Sanvido and Konchar (1998), Joint committee of ACI-NA, ACC and AGC (1996).
Decision charts	Construction round table (1995).

In the literature there is allusion to methods that facilitate the PDS selection process by provision of general information about alternative project delivery methods and the guidelines for selecting the appropriate PDS. These methods encompass studies of single and multiple project delivery methods, formalized PDS decision making frameworks, decision matrices and guidelines. Amongst various PDS options, researchers have shown particular interest in the study of design build (DB) delivery method. For instance, Beard et al. (2001) and Gransberg et al. (2006) looked into different facets of design-build delivery system and argue its suitability for a certain spectrum of construction projects. Similar studies on this subject have been carried out by Molenaar and Sogner (1998), Chen et al. (2002), etc. Studies of this type, although provide an in-depth look into a single PDS, do not meet the particular needs of decision makers when it comes to comparing alternative PDS options. Decision makers require further information than just the particulars of an individual PDS to choose reasonably. Therefore, researchers like Konchar and Sanvido (1998) took the initiative to compare the performance of different PDS options. A case in point is the comparison that was made between the performance of design-build (DB), design-bid-build (DBB) and construction manager at risk (CM-R) with respect to criteria such as construction speed. Similarly, Ibbs et al. (2003) made a comparison between DB and DBB on such variables as cost, schedule and productivity as measures of performance.

Similar studies have been undertaken by the industry to improve the decision maker's perception of the performance nuances between different project delivery systems. Although these guidelines, charts and matrices provide a better perspective on different PDS alternatives, they are not sophisticated enough tools for decision makers to make solid decisions (Masterman 2002).

2.7.2 Multi attribute analysis

The PDS selection process involves a decision making based on multiple selection criteria. As such, many researchers have opted for a method that involves a multi attribute analysis technique. The multi attribute analysis allows for evaluation of alternatives with respect to multiple evaluation criteria. As listed in the table below, the methods using multi attribute analysis could be divided into four categories based on how a project owner/ decision maker decides which project delivery method is more appropriate. What follows is a succinct description of the methods using multi attribute analysis approach.

Methods	References
Weighted sum approach	Franks (1990), UK Treasury's Central Unit on Purchasing (1992).
MAUT	Skitmore and Marsden (1988), Love et al. (1998), Cheung et al. (2001), Construction industry institute (2003), Oyetunji and Anderson (2006)
AHP	Mahdi (2005), Al Khalil (2002)
Fuzzy logic	Ng et al. (2002), Chan (2007)

Weighted sum approach:

This approach conventionally consists of two steps. In the first step, each PDS is assigned a score using a numerical scale (e.g. 1-5) on such measures as its ability to satisfy a certain evaluation criteria. A higher score signifies better performance while a lower score reflects a poorer performance. In step 2, evaluation criteria are weighted. These weights indicate the relative importance of each criterion. The scores from each criterion are then summed to specify the overall score for the PDS. Ultimately, a PDS with the highest score is regarded as the most appropriate alternative for a specific project. The weighted sum approach could be a very useful tool, given its ease of application and simple calculation process, particularly to narrow down the potential PDS alternatives to a manageable number. However, there's a great degree of subjectivity in the inputs (weights and scores). Therefore the result may vary widely from one decision maker to another.

Multi attribute utility theory (MAUT):

This has been a method of choice for some researchers to address the PDS selection problem. In this method, the decision maker has to primarily define utility function for each evaluation criterion. These functions are later used to obtain the PDS's utility scores in reference to different criteria. Subsequently, weights are individually assigned to each criterion to reflect their relative importance. Finally, the utility scores for different criteria are weighted and added up to obtain a global utility score for a given project delivery method. Ultimately, a PDS with the highest utility score is recognized as the PDS of choice for better meeting the decision maker's objectives.

While the MAUT employs more objective means for deriving scores as oppose to the weighted sum approach, it has several limitations. In order to aggregate the decision maker's preferences, the MAUT uses utility functions. According to Ibbs and Crandall (1982), when there is a group of decision makers involved the process of producing a utility function can be arduous, time consuming and inaccurate. This problem along with the diversity of utility functions (e.g., linear or non-linear) and methods to aggregate the individual utility functions (e.g., additive or multiplicative aggregation) further intensify the challenge in identifying the appropriate utility functions and reaching an overall utility score.

Analytical hierarchy process (AHP):

In AHP, similar to the multi attribute utility theory (MAUT), the process begins with identification of alternative PDSs and building a hierarchy of evaluation criteria. What distinguishes the AHP from MAUT is in its modality of deriving and measuring the decision maker's preferences (Guitouni and Martel 1998). An integral function in AHP is the pair-wise comparison of alternatives whereby decision makers are required to compare all alternatives in connection to the evaluation criteria one at a time. The procedure for rating is such that decision maker's comparative preferences are translated into ratio scales (e.g., 5 or 1/5). These scores are then integrated into an overall weight. There are several advantages in application of AHP. According to Belton and Stewart (2002), the two most prominent advantages of AHP could be cited as: 1) dissecting the problem into a hierarchical format, that will enable decision makers to get a better grasp of the problem they want to address and, 2) AHP allows decision makers to come to a conclusion in a systematic fashion through the pair-wise comparison of alternatives. On the down side, AHP has been critiqued for its inadequacy in addressing uncertainty and lack of statistical theory (Belton and Stewart 2002). It also falls short of providing a practical solution when the number of evaluation criteria and PDS alternatives grows past a certain limit and relatively increases the number of judgments that decision makers have to make.

Fuzzy logic approach:

There are certain evaluation criteria that cannot be gauged by way of assigning numerical values. This is due to their fuzzy nature as argued by Ng et al. (2002). Quality, responsibility and flexibility are prime examples for fuzzy evaluation criteria. Assuming that former PDS selection methods are inept in dealing with fuzzy criteria, Ng et al. (2002) applied an empirical study to develop the membership functions for the fuzzy criteria. These membership functions are used to link a criterion to a degree of membership ranging between 0 and 1 in a fuzzy set. If the number 1 is assigned to criterion it implies that the criterion is a member while number 0 indicates otherwise. Application of the functions allows for the decision maker's preference to be translated into numeric values from linguistic terms like, low, medium and high. Chan (2007) capitalized on the work of Ng et al to expand the fuzzy PDS selection model.

One of the key advantages of fuzzy approach is that the decision makers can be very expressive about their preferences as they will be using linguistic terms that could more tangibly reflect their needs and inclinations. The fuzzy logic method has certain disadvantages as well. Application of this method has proven to be time consuming and cumbersome particularly when it comes to group decision making, as different interpretations from the same linguistic term could create confusion. Also, employing this method (to map the fuzzy membership functions and fuzzy relation rules) requires a certain degree of knowledge and expertise that limits its application.

2.7.3 Knowledge and experience based methods

The Knowledge and experience based methods as classified in the following table are developed on the premise of knowledge and experience sharing.

Methods	References
Case based reasoning approach	Luu et al. (2003; 2005; 2006).
Decision support system	Kumaraswamy and Dissanayaka (2000).

According to Masterman (2002), decision maker's past experience is an incremental factor in selecting a PDS. Luu et al. (2003, 2005, and 2006) applied a case based reasoning (CBR) approach to define evaluation and selection criteria and to establish a case based contracting advisory system. The mechanism employed in this method is based on early assessment of the project outcome with respect to the recorded feedbacks. In other words, the decision maker is referred to the experiences from the previous projects to get a sense of likely outcomes of a future project. In 2000, Kumaraswamy and Dissanayaka developed a DSS employing the same mechanism for selecting appropriate construction project procurement methods.

This method can facilitate the task of decision making to some extent. However, effective application of this method depends on availability of case data base consisting of thorough and detailed real world projects-- a requirement that is often in short supply. Moreover, in selecting an appropriate PDS there is no rule of thumb. Every project is unique in terms of it characteristics and even if an exhaustive data base of projects did exist, there would be no certainty in applicability and conformity of previous experiences to the projects in hand.

2.7.4 Mix-method approach

Methods	References
Mean utility values +AHP	Cheung et al. (2001)
AHP +VE+ Multi-criteria multi-screening	Alhazmi and McCaffer (2000)
Qualitative assessment + weighted score approach	Touran et al. (2009)
MAUT+ Project database	Ng and Cheung (2007)

As the title connotes, this approach provides a framework for PDS selection problems using a mixture of multiple methods. For example, the project procurement system selection model (PPSSM) developed by Alhazmi and McCaffer (2000), combines Value Engineering and AHP into a multi criteria system. In another study, Cheung et al. (2001) derived mean utility values for PDS selection criteria of various project delivery methods and applied AHP to elicit the relative importance of different criteria. In 2009, Touran et al. combined a weighted score approach and a qualitative assessment method to build a decision support system for transit projects.

The mixed method is looked upon favorably by some decision makers arguing that it can integrate the advantages of two or more methods into one packet. It should also be borne in mind that this combination may also harbor the intrinsic shortcomings of the integrated methods as well.

2.8 Multi criteria Decision Making/Analysis (MCDM/MCDA)

MCDM or MCDA is a decision making framework that explicitly considers multiple criteria in decision making environments (Belton and Stewart 2002). The method explicitly refers to the making of decisions in the face of uncoupled, multiple decision criteria (Moselhi and Martinnelli, 1990). Most applications of the methods of MCDA are developed for individuals who make decisions in lieu of others, either as managers of publicly held corporations or as government officials making decisions to secure public's best interest. In such cases, the decision makers should apply strategies backed by reasonable set of axioms as oppose to making intuitive or ad hoc decision analyses (Dyers, 2005). The decision making problem could involve a set of conflicting criteria, therefore, MCDM is deemed to moderate and create a balance between the envisaged criteria. Application of MCDM is not limited only to professional settings or corporations where decision makers face challenging decisions such as outsourcing production or transferring the production plant into a different country. In our everyday life, there are multiple conflicting criteria that affect our decision making whether it be renting a new apartment or purchasing a new car. In either case, the decision maker will require a clear understanding about the evolving and complex information that represent a broad spectrum of viewpoints, particularly when decision making is a group endeavor. Miller (1956) states that orchestrating a decision making problem in such a way that all criteria are adequately considered and complex information are properly combined calls for structured and well defined approaches. When there is a higher degree of risk, it is vital to adequately structure the problem and take multiple criteria into consideration. Multiple-

Criteria Decision Making (MCDM/MCDA) is an amalgam of approaches that can properly serve this purpose. For instance, the attempt to justify building a new nuclear plant and its location, involves a host of complex considerations including multiple criteria, as well as multiple parties who are potentially affected from its consequences. Proper structuring of complex problems and taking explicit account of multiple criteria leads to sound and informed decisions.

Typically, in MCDM problems, a unique and optimal solution is non-existent. It is therefore imperative to input decision maker's preferences to evaluate different solutions. Belton and Stewart (2002) stipulated that application of MCDM does not necessarily warrant a right answer.

Solving a multi criteria decision problem can be conceived in several ways. It could correspond to choosing the most preferred alternative from the decision maker's point of view. While from a different perspective, solving the problem could be seen as choosing a small set of viable alternatives, or grouping alternatives into different preference sets. A more radical definition of solving could be to find all efficient or "non-dominated" alternatives. The difficulty of the problem originates from the presence of more than one criterion. A non-dominated alternative is a solution so credible that it is not possible to move away from it to any other solution without sacrificing at least one criterion. The presence of such attributes in the non-dominated set makes them a reasonable alternative for the decision maker to choose from. In general, different MCDM approaches could lead to different solutions depending on how the decision maker's preferences are extracted, what information is noted and how the problem is structured.

As it is the case with most decision aid models, the results of MCDM approach are not meant to override the decision maker's better judgment or professional expertise but simply to complement these discernments. The use of MCDM approaches should instigate constructive discussions and debates amongst concerning decision makers and to conclude in a thoroughly considered and pragmatic decision.

The PDS selection model proposed in this thesis is developed following a mix-method approach. The methodology is hinged upon application of Saaty's analytic network process (ANP) and multi attribute utility theory (MAUT). This model capitalizes on the perceived advantages of the foregoing methods to create a model most suitable for assessing PDS alternatives in post-conflict building projects. The following sections will elaborate on ANP and MAUT techniques in more detail.

2.8.1 Analytic Network Process (ANP)

As earlier discussed, in MCDM, the optimal option is usually selected with respect to multiple, conflicting and interactive criteria. Hitherto, an overview of several methodologies for selecting optimal project delivery systems was provided. The chief disadvantage of the previously discussed techniques is the assumption of preferential independence, in such a way that dependence and feedback were systematically overlooked. However, in real life, consideration of dependence and feedback are inextricable parts of decision making (Yu and Tzeng 2006).

The Analytic Network Process (ANP) is one of the more recent methodologies in Multiple Criteria Decision Making (MCDM); it is based on a relatively new theory introduced by Thomas Saaty in 1996 that extends the framework of the Analytic

Hierarchy Process (AHP) by taking interconnections among decision factors into consideration. Unlike AHP, the Analytic Network Process (ANP) does not assume a one-way hierarchical relationship between decision levels. In other words; ANP generalizes AHP by replacing hierarchies with networks. ANP is also more versatile than AHP in terms of its applicability for both qualitative and quantitative data sets (Yu and Tzeng 2006). In ANP, judgments are derived from the fundamental scale of AHP (table 2.3) by answering twofold questions that clarify the extent of influence of any given pair of elements with respect to a third criterion (Saaty 2004).

Since the introduction of ANP by Saaty in 1996, it has been adopted by many researchers and academics to address multi criteria decision analysis problems in various fields of study. ANP has been most notably applied in such fields as strategic decision making (Cheng and Li 2004; Dagdeviren et al. 2005), product planning (Karsak et al. 2003), project selection (Lee and Kim 2000; Meade and Presley2002; Cheng and Li 2005; Dikmen et al. 2007a), optimal scheduling (Momoh and Zhu 2003) and performance prediction (Ozorhon et al. 2007).

The ANP solution application involves four steps: problem structuring and building a model, preparing pair-wise comparison matrices of independent component levels, formation of the super-matrix, and selection of the most appropriate alternative (Dikmen et al. 2007b). More precisely, in assessing suitability of the ANP approach when using qualitative components, it is recommended to observe the following steps (Cheng and Li 2005):

I. Identification of the decision problem (e.g., decision maker would like to choose the most appropriate form of project delivery system, the decision problem would be to " select the most appropriate PDS").

II. Ensure applicability of the ANP approach. ANP is usually appropriate for solving decision problems with a network structure, whereas problems with a hierarchical form could be addressed using AHP.

III. Break down the unstructured problem to groups of manageable and measurable sub-problems. The peak level problem represents the decision problem and lowest level usually represents the alternatives (Saaty 1980).

IV. Specify the group or the person whose responsibility is to rate the alternatives. Typically, a small group of top-level managers are best suited to provide the needful data. Top-level management could assign weights to upper levels and the middle to operational management teams could score the lower levels.

Alternatively, when quantitative component is used, decision makers ought to follow a different set of guidelines outlined below (Cheng and Li 2005):

1. For data collection, a quantitative questionnaire should be prepared and answered by decision makers. Saaty (1980) suggested the application of a nine-point priority scale.
2. In every matrix, a comparison between each two element (pair-wise comparison) is made and then the eigenvector of each of the developed matrices is calculated to determine the relative importance between the any given pair of elements.
3. Calculate the consistency ratio (CR) to measure the inconsistency of data in each of the matrices.

4. Form the super-matrix by placing the eigenvector of the individual matrices (sub-matrix).
5. Verify that the super-matrix is column stochastic. Subsequently, raise the super-matrix to exponential powers until the weights have converged and stay stable (Sarkis 1999).

2.8.2 Fundamentals of ANP

The Analytic Network Process (ANP) follows a multi criteria theory of measurement that draws upon individual judgments based on the fundamental scale of absolute numbers (table 2.3) to determine relative priority scales of absolute numbers (Saaty, 2005). The relative influence of one element over another is determined through the judgments, in a pair-wise comparison process over a third element also known as the control criterion (Saaty, 2005). The pair-wise comparison of elements in ANP is a process that occurs in each level with respect to the relative importance of elements vis-à-vis their control criterion. When the pair-wise comparison for the whole network is complete, vectors that correspond to the maximum eigenvalues of the constructed matrices are calculated and a priority vector is attained.

The priority value of a given element is obtained by normalizing the vector that corresponds to the maximum eigenvalues (Bu Qammaz et al. 2007). Subsequently, where building the super-matrix involves the arrangement of matrices of column priorities, the outcome of the comparison exercise is used to form the super-matrix. As earlier outlined in the five-step guideline, the super-matrix, which is column stochastic, has to be raised to exponential powers to the extent where weights converge and remain stable so that the limit super-matrix is achieved. In this final stage all columns of the limit super-matrix will be the same. By normalizing clusters of the limit super-matrix, final priorities of all elements in matrix can be attained.

Table 2.3 The Fundamental Scale of Absolute Numbers (Saaty 2005)

Intensity of Importance	Definition	Remarks
1	Equal importance	Two activities contribute equally to the objective
2	Weak or slight	Experience and judgment slightly favor one activity over another
3	Moderate importance	
4	Moderate plus	
5	Strong importance	Experience or judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order if affirmation

Throughout the comparison process, the consistency of judgments is of paramount importance. The same control criterion- that is the criterion with which respect the comparison is conducted- has to be used for each set of comparison matrix. According to Saaty (2005), it is essential to abide by the control criterion while making judgments as it ensures accuracy of thinking when answering questions of dominance.

To better understand the nuances of ANP, the difference between a hierarchy and a network are illustrated in figure 2.8. A hierarchy is defined to have a source cluster or a goal and if available alternatives are added in the model, the hierarchy will include a cluster or a sink node that pronounces the alternatives of the decision making problem. Furthermore, as the name suggests, a hierarchy has a linear top down format with zero interaction between higher and lower levels. However, once alternative are inputted to the model, there is a loop at the lowest level confirming that every alternative in the level depends on itself; therefore the elements are considered to be independent from one another. In a network however, an outer-dependence exists where influences could flow forward from one cluster to another and travel back either directly from the second cluster or through an intermediate cluster via a path. What defines the configuration of this path is the nature of the problem and the degree of dependence within the network model.

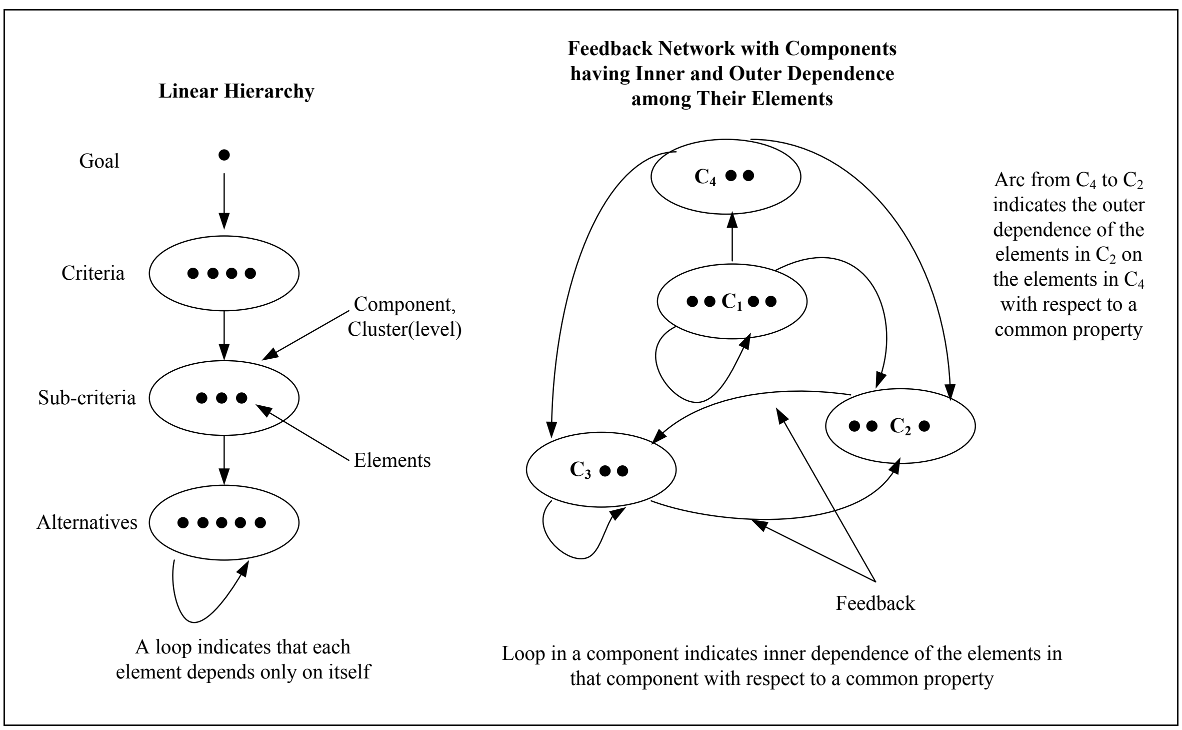


Figure 2.8 The comparison between Hierarchy and Network (Saaty, 2005)

Saaty (1996) proposed that ANP is best used in cases where the most thorough and systematic analysis of influences needs to be made. In the construction engineering and management field, several studies have used ANP to develop models for decision making problems in the evaluation of the environmental impact of various projects alternatives (Chen et al, 2005), project location selection (Cheng and Li, 2005) contractor selection (Cheng and Li, 2005), and project selection (Cheng and Li, 2005). The feedback from application of the ANP models in the construction management field attests to the usefulness of the ANP approach in choosing the best alternative using hypothetical cases. However, as these cases are mainly based on theoretical models, they have merely alluded to the potential areas of applicability of ANP thus leaving a gap in terms of its real life application. The aim of this research was to apply ANP for developing a model for project delivery system selection in post-conflict construction projects using real project data.

2.8.3 Multi-Attribute Utility Theory (MAUT)

Multi-attribute utility theory is a methodology that can be used to gauge objectivity in an otherwise subjective area of management (Fellows et al., 1980). Utility is a yardstick for measuring desirability or satisfaction. It provides a uniform scale to compare and/or combine palpable and impalpable criteria (Ang et al., 1984).

A utility function is a vehicle for quantifying the preferences of a decision-maker by conferring a numerical index to varying levels of satisfaction of a criterion (Mustafa et al., 1990).

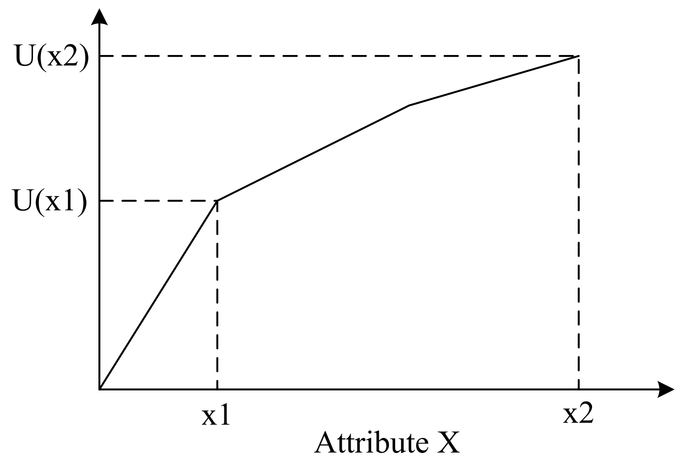


Figure 2.9 Increasing utility function

For criterion X, the utility of satisfaction of a consequence x′ is marked by u(x′). Utility functions are devised such that u(x′) < u(x″), if and only if x′ is less preferred to x″, i.e. x′ < x″. This relationship is further articulated in figure 2.9, where it can be said that a utility function is a transformation of some degree of importance or satisfaction (x′), measured on in its natural units into an equivalent level of decision-maker satisfaction (Hatush and Skitmore, 1998). The MAUT approach is usually invoked when a decision maker is to choose among a discrete number of alternatives being evaluated against two or more criteria. The alternatives may involve uncertainties.

2.8.4 Fundamentals of MAUT

In multi criteria decision analysis, decision making involves choosing one of the several available alternatives. Typically, each alternative is examined for desirability over a number of criteria. Utility functions bridge between the criteria score and desirability (Hatush and Skitmore, 1998).

In order to adequately represent an individual's preference through utility functions, certain conditions must be applied (Markowitz, 1959). These conditions have been further classified by Goicoechea et al. (1982), into four axioms that should be conformed so that an individual's preferences can be elicited through utility functions for both certain and uncertain outcomes:

I. For two alternatives, X_1 and X_2, one of the following conditions must apply:

   The decision-maker prefers X_1 to X_2, prefers *X2* to *X1*, or is indifferent between them.

   The decision-makers' assessment of alternatives is transitive: if they prefer X_1 to X_2 and X_2 to X_3, then they prefer X_1 to X_3.

II. Suppose that X_1 is preferred to X_2 and X_2 to X_3, then there exists a probability "*p*", where $0< p <1$, at which the decision-maker is indifferent between attaining outcome X_2 with certainty or getting X_1 with the probability *p* and X_3 with the probability (*1-p*). In other words, there exists a certainty equivalent to any lottery or gamble.

III. Assuming that decision-maker is indifferent between the alternatives, X_1 and X_2, and if X_3 is a third alternative, then the decision-maker will be indifferent between the following two lotteries:

lottery 1 presents an opportunity to attain X_1 *with* a probability p and a probability $(1-p)$ for attaining X_2, and lottery 2 warrants alternative X_2 with p and a alternative X_3 with a probability of $(1-p)$.

The MAUT stipulates that, the overall utility $U(x)$ of an alternative or an object x is defined as a weighted addition of its utility with respect to its relevant value dimensions also known as performance measures (Winterfeld and Edwards, 1986). The overall utility is defined by the following overall utility function:

$$U(x) = \sum_{i=1}^{n} W_i U_i(x) \tag{2.1}$$

Or

$$1 + ku(x_1, x_2, \ldots, x_n) = \prod_{i=1}^{n}[1 + kk_i u_i(x_i)] \tag{2.2}$$

Where:

$U_i(x)$ is the utility of the alternative on the i th performance measure or criteria; n represents the number of different performance measures or criteria; W_i is the weight that determines the impact of the i th criteria on the overall utility, i.e. the relative importance of i th criteria or performance measure where:

$$\sum_{i=1}^{n} W_i = 1 \tag{2.3}$$

K_i is the scaling factor to keep individual attribute assessments consistent with overall assessment $U(x)$ and $0 < k_i < 1$. The function (2.1) is usually referred to as the additive form, which is the most common form of multi-attribute utility functions (Keeney and

Raiffa, 1993). The advantage of the additive form lies in its simplistic approach. For any alternative, the overall utility function is determined by identifying *n* one-dimensional utility functions for that alternative. Equation (2.2) is usually referred to as the multiplicative utility function, which assumes that an individual's preferences are correlated.

The most notable textbook on multi attribute utility theory by Keeny and Raiffa (1993) promotes the application of multi-attribute preference models based on the theories of Von Neumann and Morgenstern (1986). Their theory is based on axioms involving risk. However, this approach is not appropriate for decisions comprising multiple objectives when risk is not a consideration. Alternatively, the more appropriate approach for decision making under certainty are either based on ordinal comparisons between the alternatives or on estimates of the intensity of preference between pairs of alternatives (Dyers, 2005).

2.8.5 Utility Functions vs. Value Functions

Adding uncertainty to the decision problem will increasingly complicate the solution process. The resulting complication often damages the coherence of the information that is obtained from the decision-makers and ultimately jeopardizes the accuracy of the outcome of the analysis. Review of the literature reveals that inclusion of uncertainty in defining utility functions adds inconsistency to the inputs received from the decision-makers (Borcherding et al., 1991).

Goodwin and Wright (1991) suggest that in problems which do involve a high level of uncertainty and risk, utility plays a central role, as long as the decision-maker is familiar with concept of probability and has the time and patience to exert the needful effort and thought to the questions required by the elucidation procedure. If the decision-maker does not embody these qualities, then eliciting utilities may not be worthwhile. Goodwin and Wright (1991) further challenge the application of utility to decision problems where risks and uncertainties are not crucial to decision-maker's concerns. Therefore, incorporating questions about lotteries and probabilities to such problems were considered to be redundant. Considering the potential errors that could occur in assessment of the utilities, the derivation of values instead of functions and the identification of the path that maximizes the expected value may offer a valid alternative approach. When consequences of each available path are almost certain, the elicitation procedure can be made less onerous by regarding each consequence as certain. Using such an approximation, Value functions derived from the certainty assumption will replace the utility functions in the multi-attribute utility theory (Dyer et al. 1998). The general from of value function can be formulated per below equation:

$$V\,(x) = \sum_{i=1}^{n} Wi\; Vi\; [l\,(x)] \qquad (2.6)$$

2.8.6 Simple Multi-Attribute Rating Technique with Swing Weights (SMARTS)

SMART is a variation of multi-attribute utility theory and a method for measurement of multi-attribute utility (Edwards and Barons, 1994). The utility approach is based on the alternatives having measures of value against every single performance measure or criteria. Aggregate utility scores are computed for each alternative on the measurement attributes of performance measures and the alternatives are then ranked on the basis of their aggregate utility scores. SMARTS uses linear approximations to single-dimension utility functions, an additive aggregation model as well as swing weights (Edwards and Barons, 1994). The mathematical expressions for this computation based on the additive aggregation model are demonstrated below:

For Alternative j: $U_j\,(X_1, X_2, \ldots, X_n) = \sum_{i=1}^{n} Wi\ Ui\ [X_{ij}]$ (2.7)

Where: U_j stands for the aggregate utility of Alternative j

X_{ij} represents the degree to which alternative j satisfies the performance measure or criterion i

U_i stands for the single attribute function on measure i

W_i stands for the "relative importance" or "priority weight" for criterion i,

and, $\sum \mathrm{W}i$ *for all I* = ***1.0*** (2.9)

2.9 Overall limitations of the Previous PDS selection methods

As stated under each method in the previous section, every PDS selection method has certain advantages and shortcomings. Reviewing the evolution of PDS selection methods in a chronologic order reveals that new methods are often developed as an effort to perfect the existing models and to overcome their methodological limitations. By the same token, the multi attribute utility theory was used to address the perceived shortcomings of weighted sum method by alleviating the subjectivity involved in the latter method through application of utility functions. Much in the same fashion, the weighted sum approach was used to address the inadequacies of the guidance methods. In the case of MAUT, a simple attribute rating technique (SMART) and mean utility scores of criteria were introduced to make it more pragmatic. Saaty's analytical hierarchy process (AHP) provided decision makers with the opportunity to assess and compare their evaluation criteria in a formulated manner. While all other methods were inept at addressing the fuzzy nature of some evaluation criteria, the fuzzy logic approach was introduced into the context of PDS selection process. Similarly, the mixed method - approach was introduced to capitalize on the advantages of multiple methods and pool in the expertise and experiences from previous projects into one integrated approach.

These methods not only vary in terms of their underlying concepts, but also in terms of difficulty and the level of input required to implement them. Accordingly, these methods could be compared and classified on basis of the level of expertise and the level of information which is required to successfully implement them. It is obvious that some of these methods like the weighted sum approach could be applied with relative ease as compared to MAUT or fuzzy logic approach that require a stronger theoretical background and skill set. Similarly, on the level of required information, methods like MAUT and fuzzy logic would require a more sophisticated level of input to function as opposed to guidance methods that only require certain information about project characteristics and owner objectives.

The methods so far discussed, also differ in their modality of extracting decision maker's preferences. Generally, preferences are derived through a direct rating process. However, in methods such as analytical hierarchy process (AHP), these preferences are drawn from a pair-wise comparison of criteria and alternatives. Also, distinction could be made between these methods in terms of how these preferences are expressed and gauged. In the fuzzy logic approach, as discussed earlier, linguistic terms are used to explicate one's preference, whereas in other methods, decision maker's preferences are recorded in form of numeric values.

Further to the above, selecting a PDS which is adaptive to post-conflict environments, bring an additional dimension to the process. The convoluted dependencies between different layers of the project, the project environment and selection criteria could significantly affect the project performance.

From the literature review conducted for this research, it is concluded that the existing methods do not account for the interdependencies between selection criteria and fail to apply a multivariate approach to analyze the underlying metrics of cost and schedule that are shared between large number of selection criteria, therefore blindsiding the decision makers in considering the time-cost trade-offs in their comparison of alternative project delivery systems.

CHAPTER III

METHODOLOGY

3.1 Overview

The novelty of this research lies in its innovative approach to bring some degree of objectivity to an otherwise subjective area of construction management. As earlier noted, selecting the appropriate project delivery system, more often than not, is carried out with little consideration about the particular circumstances of projects. Such an unstructured decision-making process may lead to selecting an unsuitable PDS. As established in the outset, execution of building projects in post-conflict is weighted down by an array of security, logistic and technical challenges. In post-conflict operations, where scarcity of resources is an ever-present concern, choosing a project delivery method that can secure project completion in a timely, cost-effective and safe manner will significantly enhance the anticipated output of development efforts. To offset the adversity of working conditions in post-conflict, decision makers and project managers tend to facilitate the work flow by adopting simplistic means to steer their projects. By the same token, the proposed PDS selection method has been developed with simplicity and applicability in mind. It is deemed that the emphasis on the pragmatic nature of this model will encourage its application thereby promoting the practice of objective decision-making amongst post-conflict construction practitioners. In this chapter, two approaches are described for development of the PDS selection model. While the two follow the same logic, they differ in their mode of judgment elicitation and data aggregation.

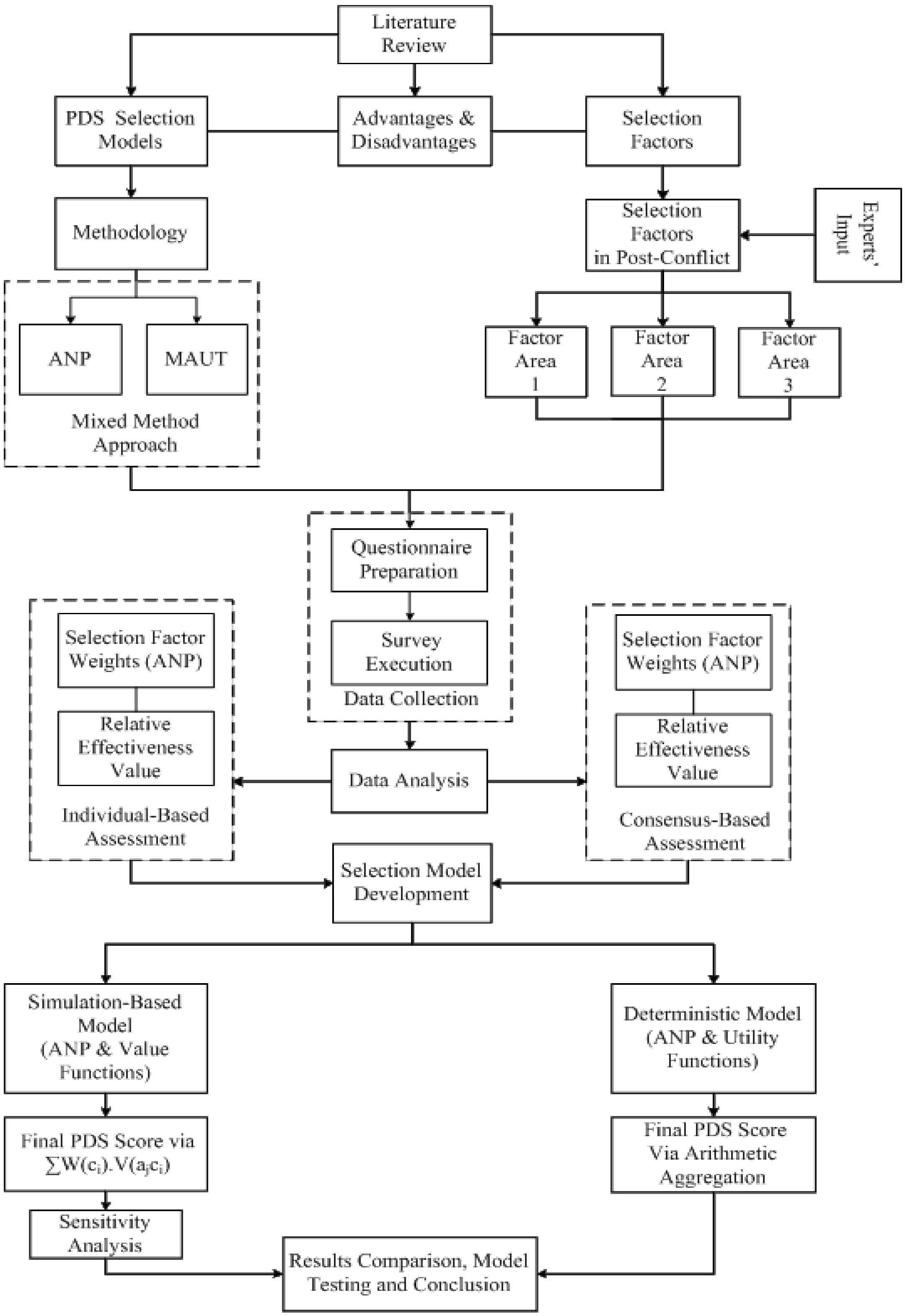


Figure 3.1 PDS Selection Model Methodology Diagram

The first is a multi-criteria decision making model hinged upon individual assessment of the relative criteria weights and relative effectiveness value of the PDS options. In this approach, a statistical aggregation method is applied as opposed to the behavioral aggregation method used in the second approach. The assessment results, otherwise referred to as "judgments" are separately recorded. The relative importance weight of selection factors were obtained through ANP. Assuming dependence between the selection criteria, a network diagram was constructed using Super Decision software and the relative weights were subsequently obtained. After all the judgments were compiled, an overall score for each PDS alternative was aggregated via Monte-Carlo simulation. This process was facilitated through application of the Palisade's @Risk analysis software. The second approach entails the same steps as stated in the former method. However, the relative effectiveness weights and relative effectiveness values were elucidated through consensus between the decision making group. Once the relative effectiveness values were attained following successive decision conferencing workshops, the utility values were defined for each set of judgment using a standard-gambling technique. The overall score of each PDS alternative was then aggregated from the confluence of these utility values and the relative importance weights through a simple arithmetic equation. Figure 3.1 illustrates in more detail, the numerous steps involved in the making of this model. In brief, the selection model developed in this research entails five major steps as outlined below:

Step 1. Identify the potential PDS options,

Step 2. Define the Project Delivery System Selection Factors in post-conflict,

Step 3. Assign Relative Importance Weights to the Selection Factors,

Step 4. Score the PDS options by assigning them Relative Effectiveness Value,

Step 5. Aggregate the weighted scores of selection factors in relation to the PDS options to determine their suitability indices,

Step 6. Select the most appropriate PDS by choosing the one that offers the highest suitability index.

3.2 Literature Review

The process of selecting an appropriate project delivery system is a multi-faceted exercise which cuts across from several scholarly domains. The literature review in the present research consists of three major blocks. The review begins with an in-depth investigation of the selection factors that influence the selection path. Previous studies in this field are used as a departure point to identify the most pertinent selection factors specific to post-conflict environments. The review then focuses on narrowing the list of available PDS alternatives based on their applicability and popularity down to DBB, DB, and CM-R. Later in the process, conceived advantages and disadvantages of the three PDS options are described and finally, an overview of the existing PDS selection methods and techniques concludes the literature review.

3.3 Data Collection

The credibility of the proposed model depends on the consistency, accuracy and the quality of the collected data. The model configuration dictates the kind of data required for functioning of the model. Upon completion of the conceptual PDS selection model, the type and nature of the required data came to light. Given the specific scope of this research, the sample population had to be selected from the target population of post-conflict practitioners, with considerable exposure and experience in post-conflict construction projects. Considering the extent and magnitude of rehabilitation, refurbishment and construction projects in the post-conflict Afghanistan, this country was selected as the pool from which the survey respondents were drawn. Also, the researcher's association with reconstruction endeavors in Afghanistan facilitated the interaction with respondents and the overall data collection process. This section, including the explanation on the size and background of the sample population is further described in chapter IV.

The data procured in this research is spread over three tiers. Tier one draws on the expertise of the sample population to prepare a list of the most pertinent selection factors considered in post-conflict construction projects. This goal is realized through application of Delphi (Linstone and Turoff, 1976) method. The Tiers two and three are designed to obtain the R.I.W of selection factors and the R.E.V of the PDS options by surveying the sample population. In order to conduct this survey, a questionnaire comprising of two parts was designed, tested and circulated to the target group in Afghanistan. Given the scarcity of the post-conflict practitioner population whose area of expertise corresponds with that sought in this research, the researcher assumed the upper limit of 30 respondents as the reliable sample size. As a rough rule of thumb, many statisticians believe that 30 is a large enough number for a reliable sample size. Although the construction efforts encompass a broad spectrum of capital and infrastructure projects, the scope of this research is focused only on two types of buildings with higher construction demand. These building types are grouped into health/educational and office/government buildings. The data collection chapter provides more detailed information on the questionnaire design, execution of the pilot survey, and its modifications. The template of the questionnaire used in this research is furnished in appendix I.

3.4 Identifying the PDS Alternatives

Project delivery system is a term that refers to the overall framework within which a project is designed and constructed, including outlining the contractual relations, roles and responsibilities of the parties involved as well as the sequence of the activities necessary for project completion. As stated in chapter II, project delivery methods are typically categorized based on the project's source of finance. Capital and infrastructure projects are either funded by the states or fully or partially funded through private investment. The three most popular forms of project delivery system for public projects are Design-Bid-Build, Design-Build and Construction manager at Risk. For so many years, the Design-Bid-Build approach was the dominant delivery system used by many project owners in public and private funded projects. The requirements for quality-based selection of designers and awarding the contract to the lowest responsible bidder gave rise to the popularity of the DBB method. However, the growing diversity of projects and shift in priorities lead to development of alternative delivery methods such as Design-Build and Construction manager at Risk. Public-Private-Partnership was also added to the list of alternative delivery methods as a mean to compensate for the shortages in public infrastructure findings. The latter method, however, is not considered as a viable option in post-conflict construction projects as the private sector is still unsure about the return on their investment. In this research the PDS alternatives considered for evaluation are the ones stated above. It may be noted that the best choice is conventionally governed by the specific requirements, complexity and urgency of the project and the owner's technical knowledge and available managerial resources.

3.5 Selection Factors

The PDS selection process starts with identification of the selection criteria. The selection criteria serve as the very backbone of this research. The proposed selection model is predicated on the alignment of the strengths and attributes of the PDS alternatives with the performance measures of the PDS selection criteria. As earlier mentioned, the best choice of PDS is bound by variety of factors. It is through assessment of these factors, and understanding of their special relationship with a given PDS option that a decision on suitability of a PDS could be rendered. These selection factors should be identified by the project owners and decision makers in harmony with the particular circumstances of the project.

As documented in chapter II, previous studies bring to light an extensive collection of selection factors and criteria for project delivery system selection. As shown in Figure 2.6, many of these selection factors have been repeatedly cited by different researchers. A list of selection factors with the highest citation frequency was assembled on the basis of the information revealed in the literature review. This list served as the starting block for the round one of the Delphi survey.

The following is a description of the selection criteria identification exercise that lead to the configuration of three factor areas consisting of 14 distinctive selection factors. The selection factor identification technique employed in this research is based on Delphi method. This method relies on the panel of experts and has proven most efficient when the panel is carefully assembled and that the process is properly facilitated. In this case, the researcher assumed the facilitator's role to ensure effective communication between the panel experts and to document the results of Delphi surveys. As stated under the data collection section in present chapter, the target population encompasses the post-conflict practitioners in Afghanistan. The expert panel was selected from the said target population.

3.6 PDS Selection Factors in Post-Conflict

The Delphi survey as earlier described, yielded 14 selection factors, also referred to as "sub-criteria" under three factor areas, also known as the "main criteria". These factors were selected by a panel of experts in post conflict construction projects. At the end of the Delphi exercise, the panel asserted in unison that these factors were the chief determinants of the PDS selection outcome in post-conflict construction projects. Therefore, the list of 14 selection factors was labeled as the "Project Delivery System Selection Factors in Post-Conflict". Since the proposed model was laid out on the basis of how the selection factors align with the characteristics of the PDS options, it was imperative to create a common understanding about the description and measurement attributes of the selection factors vis-à-vis the PDS options.

The literature review offers the requisite information to form this common ground. This information is contained in appendix IV. This appendix is included in an attempt to unveil the connections between the PDSSF in post-conflict and the PDS options set forth for evaluation in this research.

3.7 Development of the PDS Selection Model

As earlier outlined, the model follows a simple equation based on the additive aggregation model [$\sum W(c_i).V(a_jc_i)$]. The overall score or the suitability index results from the summation of the weighted score of all 14 PDS selection factors. As there are three PDS options being evaluated in this research, three weighted score values are recorded for each selection factor. These weighted scores are determined by multiplying of the Relative Importance Weight of the selection factor by the Relative Effectiveness Value of each PDS option for this selection factor. Depending on the approach used to arrive at the weighted score (individual-based or consensus-based assessment), these scores were aggregated and then summed for all 14 selection factors to determine an overall score for the PDS options. In the end, the PDS with a highest score is selected as the most appropriate delivery method.

3.8 Individual-Based Assessment Model

In this approach, the data necessary to run the model is obtained from individual respondents. To collect this data a questionnaire was prepared and submitted to experts. A total of 36 valid response sets were collected. An excel spread-sheet was created to store the response sets. A trial version of @Risk 5.7 was used to define a best fit distribution for the weighted scores of each selection factor. Then the mean value of the best fit distribution for each selection factor was considered as an input to the produce the model's output. The model determines the output by adding up all 14 inputs for each PDS option. The output was simulated using @Risk to determine the mean value that represents the suitability index. Also, using simulation, the selection factors are ranked based on their impact on the suitability index of PDS options.

3.8.1 Measuring Relative Importance Weights of the Selection Factors via ANP

The relative importance weight is a component of the selection model that governs the final outcome. It's obvious, that the selection factors have varying levels of importance from one respondent to another. The importance weight of each selection factor is a function of many things including the respondents' preferences, experience and technical capacity. Also, given the project's particulars and location, the perceived importance weight of a factor is subject to change. Similarly, it's unlikely that all respondents would assume a similar importance weight for a given selection factor.

The selection factors were identified following the Delphi survey. These selection factors were grouped into three categories also known as main criteria. This categorization was applied to facilitate the model conceptualization. This categorization intended to facilitate the comparison and allocation of relative weights to the selection factors. Also, having the selection criteria listed in three distinct clusters allows for examination and incorporation of the interdependencies amongst them. At the end of the Delphi exercise, the researcher alluded to the inherent interdependencies amongst the drafted selection criteria. In round two of the Delphi exercise, participants were advised to combine the duplicate or interrelated selection factors. However, as earlier explained, due to the shared underlying factors, varying levels of interdependence was detected amongst the 14 selection factors that made the cut.

With the assumption that the clusters were interdependent, the relative importance weight of each selection factor was obtained through application of Saaty's Analytic Network Process. The ANP allows for inclusion of dependence and feedback into decision making process. The manual calculation of these weights is a lengthy and arduous process. In the present research, this process has been facilitated by application of the Super Decision software. This software is designed for decision making with dependence and feedback. Super Decision follows the same fundamental prioritization as AHP. These priorities are derived through judgments based on pair-wise comparison of elements. In ANP, elements are arranged in flat networks of clusters. ANP stands out amongst other decision making methods in a sense that it allows for all possible and potential dependencies. The accuracy of the weights derived from ANP is contingent on the consistency of the judgements. In practice, to attain the desired consistency, within each set of comparison matrix, all comparison should be made with respect to one element, known as the control criterion. The control criterion will ensure that respondents remain focused while making judgements as to priority or dominance of the elements. The process for developing the ANP model and obtaining the relative importance weights is expressed in full detail under section 5.2 in chapter V.

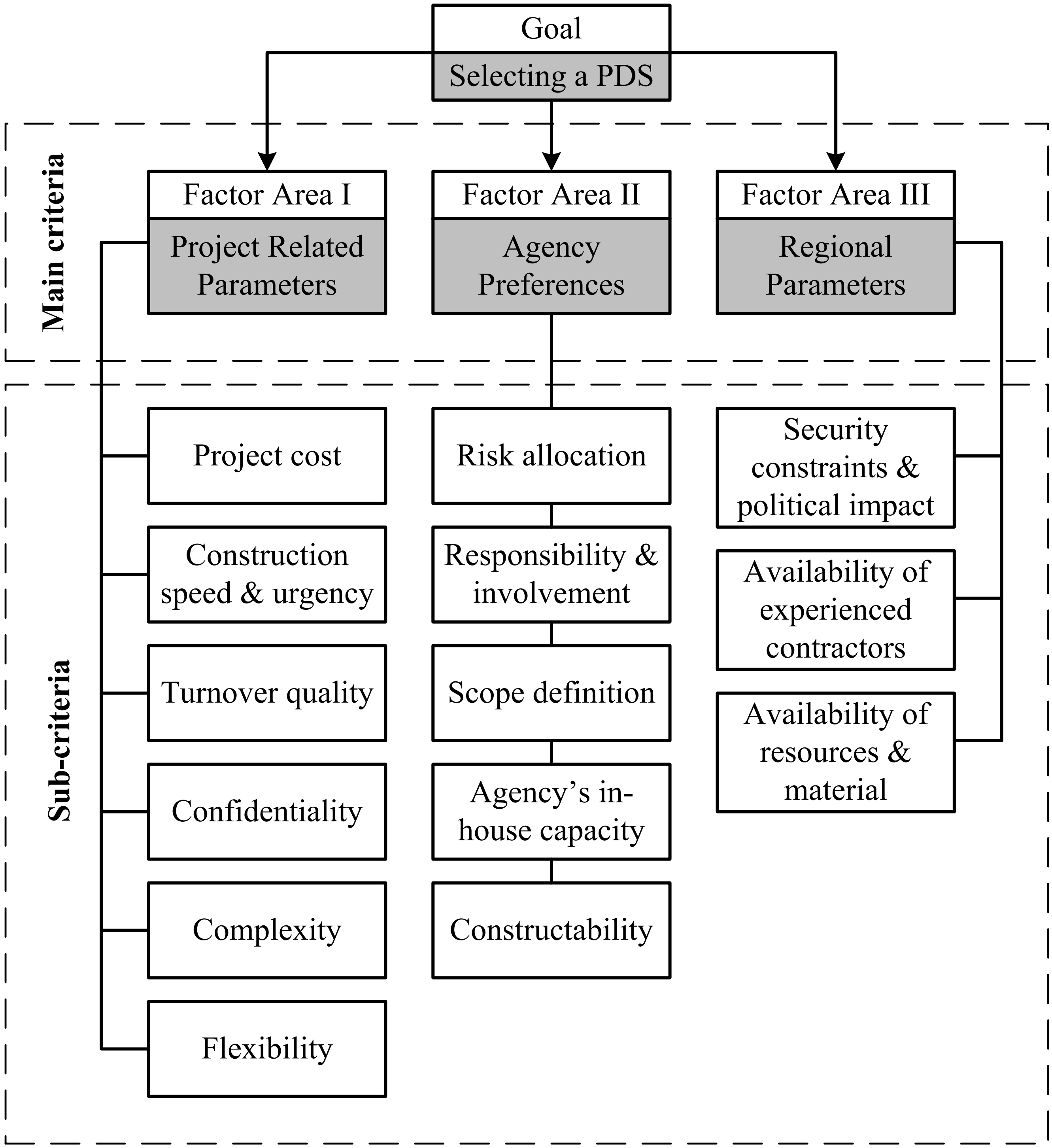


Figure 3.2 Hierarchical Structure of the PDS Selection Criteria

3.8.2 Measuring Relative Effectiveness Value (R.E.V) of the PDS Options

The selection models proposed in this research enable the decision makers to select a PDS by prioritizing the selection factors and ranking the PDS options based on how they align themselves with the selection factors. Measuring the relative effectiveness values should only be initiated after the PDS options were defined. The PDS options, as discussed earlier, were defined based on their feasibility and potential for successful application. This step was designed with the knowledge that PDS options vary in their ability to meet the measurement attributes of the selection factors. In this exercise, each PDS option was assigned a value from a predefined utility value scale with respect to the selection factors. In other words, it is possible to define a set of utility factors for each PDS option by indicating their relative utility against each selection factor. In order to assign an appropriate effectiveness value to a PDS option, decision makers should take cognizance about the advantages and disadvantages of the subject PDS. This is due to the influence that each PDS option is likely to have on the selection factors. This influence should be translated into an effectiveness value which will ultimately be used to determine the weighted score of a given PDS option with respect to each selection factor.

The relative importance values were obtained through a data collection exercise. To this end, a score sheet was prepared in form of a questionnaire and was disseminated to the sample population. This questionnaire was accompanied by a concise guideline to assist the respondents in assessing the R.E.V's. The R.E.V score sheet questionnaire is available in appendix I. The guideline stipulates the simple steps that respondents should follow in order to properly determine the relative effectiveness values. The respondents were advised that in order to assign a relative effectiveness value to a given PDS option, they should ask themselves the following question: "how effective/appropriate is the PDS option under consideration, relative to the other options, in terms of achieving or satisfying the selection factor". An Effectiveness Measure Scale (EMS) of 1-100 was designed to ascribe a score to each PDS option based on how they relate to the selection factors. Respondents were reminded that when assigning an effectiveness value to a PDS option, they should discuss its advantages and disadvantages and think in terms of the appropriateness of the subject PDS in meeting or satisfying the performance measures of the selection factor against which it's being assessed. That is, the relative effectiveness value should represent the suitability of the PDS option in aligning itself with the measurement attributes of the selection factors. Respondent would complete the questionnaire by scoring each PDS option for each selection factor, relative to the other options, before they move on to the next factor. Accordingly, each PDS option will end up with 14 R.E.V scores; one for each selection factor. In the aggregation process, these values will be multiplied by the relative importance weight of the respective selection factor. The product is then summed to determine the suitability index of each PDS option. Also, to facilitate the evaluation, respondents were provided with descriptions about the selection factors and their measurement attributes (see to table 5.2). To populate the score sheet with adequate values, respondents were instructed to assign a score of 100 to the most effective PDS option and a score of 1 to the least effective option with respect to a given selection factor. The intermediate PDS option should be assigned a value between 1 and 100 that best reflects its relative effectiveness. It was also asserted that the respondents should not have any reservation in assigning the highest or the lowest score to a PDS option. It is to say that, for instance, the score of “100” should not be reserved for the absolute best performance imaginable, but assigned to the PDS option that is most satisfactory between the PDS options that are subjected to evaluation. Similarly, the score “1” should not be kept for the worst performance possible, but for the least satisfactory performance among PDS options that are being evaluated. To reduce the subjectivity of evaluations, respondents were inhibited from assigning the same score to the PDS options when evaluated across the same selection factor.

In this research, The PDS options and the selection factors have been defined independent from any particular type of project. The only consideration was the presence of post-conflict behaviour and dynamics. Therefore, the relative effectiveness values could be determined regardless of an individual project. These independently assessed values are applicable to a wide range of projects as long as the same array of selection factors and PDS alternatives are applicable.

3.8.3 Score Aggregation and Analysis via Monte Carlo Simulation

The aggregate scores or the suitability indices of the PDS options are computed after the R.I.W’s R.E.V’s are determined. The aggregation rule applied in this case follows the additive model. The applicability of the additive model is warranted by the fact that the selection factors were assumed to have preferential independence amongst them. The suitability index is determined by summation of the weighted score for all selection factor. The suitability index is a sum product function of the importance weights and-effectiveness values of each PDS option over the set of selection factors. Based on the additive aggregation model, this procedure could be represented mathematically as follows:

$$U_j\,(a_{,}\,a_{2,}\ldots,a_{m)}= \sum_{i=1}^{n} W(c_i).V(a_jc_i) \quad (3.1)$$

Where U_j represents the suitability index or the aggregate score of PDS option j. In this equation, U_j is sum of the product of $W(c_i)$ and $V(a_jc_i)$; such that $W(c_i)$ represents the relative importance weight of selection factor i and $V(a_jc_i)$ denotes the relative effectiveness value of PDS option j over selection factor i. Also it should be noted that $\sum W(c_i) =1$.

The aggregate score, also called the suitability index is interpreted as an ordinal value that could only be used for identifying the most suitable PDS option. The PDS option with the highest score is selected as the most optimal choice. The calculations in table 3.2 pertain to one of the 36 respondents who participated in the survey. In a deterministic approach, the aggregate scores under each PDS from all 36 respondents can be averaged out to determine the suitability index of the PDS options. However, the individual-based assessment approach is based on a probabilistic model using Monte Carlo Simulation. The various steps involved in developing the simulation-based model is described in details under section 5.2.2 in chapter V.

Table 3.1 Sample Calculation of Aggregate Scores of PDS Options Based an Individual Response Set

Respondent # 8			DBB		DB		CM-R	
No.	SF	R.I.W	R.E.V	$W(c_i).V(a_jc_i)$	R.E.V	$W(c_i).V(a_jc_i)$	R.E.V	$W(c_i).V(a_jc_i)$
C1	PC	0.1350	70	9.4509	1	0.1350	100	13.5013
C2	CSU	0.0411	60	2.46755	100	4.1125	1	0.0411
C3	TQ	0.0411	90	3.7013	1	0.0411	100	4.1125
C4	CONF	0.1350	60	8.1008	1	0.1350	100	13.501
C5	COM	0.0351	60	2.1100	1	0.0351	100	3.5167
C6	FLX	0.0411	70	2.8788	100	4.1125	1	0.0411
C7	RA	0.1303	1	0.1303	90	11.7339	100	13.037
C8	RI	0.0322	100	3.2293	1	0.0322	80	2.5835
C9	SD	0.0391	1	0.0391	100	3.9189	90	3.5270
C10	AIHC	0.0391	70	2.7431	1	0.0391	100	3.9187
C11	CON	0.1303	1	0.1303	100	13.0379	60	7.8227
C12	SCPI	0.0200	60	1.2059	1	0.0201	100	2.0099
C13	AEC	0.0932	90	8.3958	1	0.0932	100	9.3287
C14	ARM	0.0866	70	6.0628	100	8.6611	1	0.0866
	$\sum W(c_i)$	1	**Score**	50.6466		46.1084		77.0295

3.8.4 Simulation and Sensitivity Analysis

The simulation is performed to identify a range for the suitability indices of the three PDS options. Through simulation, the probability density and probability distribution of the suitability indices can be defined for each PDS option. These distributions can be overlayed for all the PDS's to facilitae comparison of the aggregate scores and their distribution. Using simulation, the aggragte scores could also be plotted across the three PDS options. This plot can be used as a tool by decision makers to identify the most optimal PDS option at a glance. Also, the summary trend diagaram will specify a range for the PDS scores with the highest probability of occurance. This enables the decision makers to develop a better understanding as to the extent of suitability variation between the potentail PDS alternatives. The simulation command is executed from the @Risk menu. The user has to set the number of simulations as well as the number of iterations for each simulation. For this research, the number of iternations was set to 1000 and the model was simulated once. The simualtion starts upon executing the "Start Simulation" command and the simulation results and its relevant graphs can be viewd via " Browse Result" command on the main @Risk menu.

The @Risk menu also provides an option for sensitivity analysis. In this research, the sensitivty option is invoked to rank the selection factors based on their impact on the bottom line score of each PDS option. Through sensitivity analysis, decision makers will find an insight as to how the suiability index is affected due to a + 1 change in standard deviation in each of the inputs (weighted score of the selection factors). The sensitivity analysis aspect of this research is explained with examples and in more detail in chapter V.

3.9 Consensus-Based Assessment Model

As stated under the overview, the bottomline output of the PDS selection model could be reached using two different approaches. The first approach relies on individual assessment of the experts and draws on statistical means to aggregate the individual judgemetns. The aggregate judgements are then used to determine the suitability indices of the PDS options through simulation. The second approach, as its title connotes, aggregates judgments based on consenus and defines the suitablity indices through deterministic means. In brief, both approaches follow the same path in terms of eliciting relative importance weights and relative effectiveness values. The consensus based method similar to the indvidual-based approach, benefits from ANP as a mean to determine the R.I.W and MAUT to define the utility of the selection factors vis-à-vis the PDS options (R.E.V). An examination of the aptness of the two approaches revealed that consensus-based approach is more befitting in situations where logistical and operational constraints preclude an elaborate data collection scheme. In chapter V, the results obtained from both approaches are compared as mean to corroborate their utility and applicability.

As earlier discussed, the consensus-based assessment is hinged upon behavirol aggregation of judgements. This type of aggregation is based on the process of grouping a number of individual experts who collectively perform as a unit. Group consensus is also advantageous in terms filtering personal biases and making up for the lack of expereince among decision makers. The modality for obtaining the relative importance weights and the relative effectiveness as well as the details for execution of the consensus-based model are further discussed in chapter V.

CHAPTER IV

DATA COLLECTION AND CASE STUDY

4.1 Overview

This research drew on qualitative and quantitaive survey data, collected through first hand observation by the researcher. Data collection was carried out using a specifically designed two part questionnaire. The collected data consisted of three tiers. Tier one pertained to identification of the selection factors and was explained in details in the methodology chapter. It is the focus of this chapter to outline the procedures observed to obtain the data sets in tiers two and three. The latter tiers were geared towards obtaining the R.I.W of selection factors and the R.E.V of the PDS options by surveying the sample population. The questionnaire was put to trial to exclude the glitches and potential misinterpretations of the survey questions. The steps for data collection procedure are outlined in the following section. Also discussed are the particulars of the case study projects and the survey respondents.

4.2 Categories of the Case Study Projects

When the international community committed itself to the reconstruction of post-conflict Afghanistan, priority was given to the provision of, inter alia, schools and clinics, government and office buildings (Patel, 2007). Given the magnitude of funds and efforts invested in rehabilitation of these sectors, the researcher was drawn to selecting the case studies from amongst the health, educational, office and government buildings. These building types were grouped into two categories of health and educational vs. office and government buildings, herein referred to as H/E and O/G buildings. This categorization was on the basis of intended use, design properties and targeted beneficiaries. The data collected in this research reflects on some 90 individual projects from across 20 Afghan provinces. Table 4.1 displays the distribution of projects in the benchmarked provinces.

Table 4.1 Distribution of Projects by Province

Project Distribution			
No.	**Province**	**H/E**	**O/G**
1	Balkh	**	***
2	Bamyan	***	**
3	Farah	**	**
4	Faryab	***	**
5	Ghazni	**	**
6	Helmand	**	**
7	Herat	****	***
8	Kabul	****	****
9	Kandahar	**	**
10	Kapisa	**	***
11	Kunduz	***	**
12	Laghman	**	**
13	Nangarhar	**	*
14	Oruzgan	**	*
15	Paktia	**	**
16	Panjshir	**	**
17	Parwan	***	**
18	Samangan	**	**
19	Sar-e-Pol	**	**
20	Takhar	**	***

*Each asterisk represents one project

4.3 Categories of the Survey Respondents

The respondents were selected such to represent all the key concerns of post-conflict construction projects in Afghanistan. The respondent group was comprised of 36 experts in post-conflict construction operations. Their areas of expertise cover a wide variety of disciplines and positions including Head of Operation, Project Manager, Project Engineer and Roving Technical Engineer. The pie-chart in figure 4.1 demonstrates the breakdown of the respondents' population and their positions.

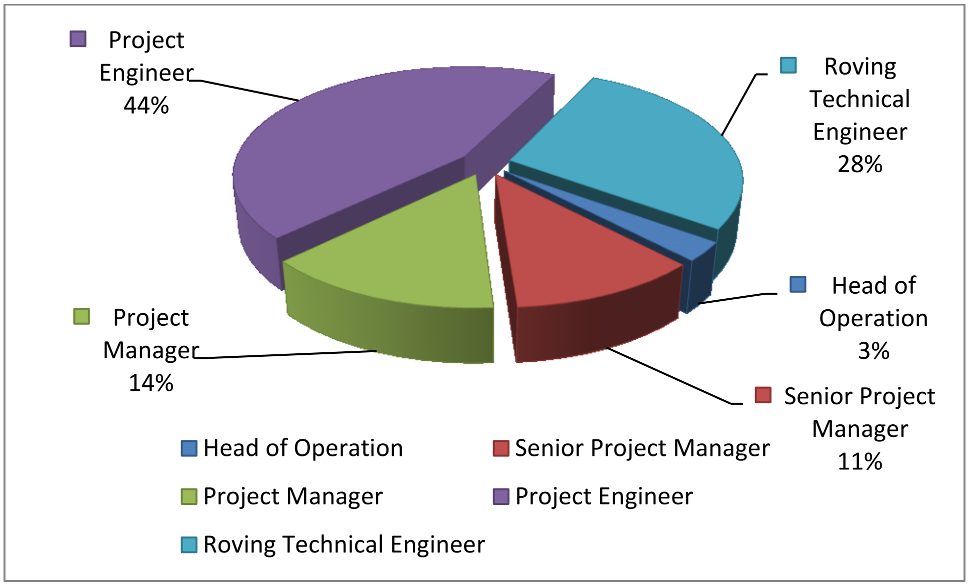


Figure 4.1 Composition of survey respondents

As the figure above shows, Project Engineers made up for a dominating 44% of the respondent population, followed by Roving Technical Engineers who represented 28% of the population. Project Managers, Senior Project Managers and Head of Operation respectively represented 14, 11 and 3 percent of the sample population. The Project Engineers had 6 years of experience on average basis. This number for Roving Technical Engineers was 10. Project Managers had 7 years of work experience on average compared to 8 years for Senior Project Managers and 11 for the Head of Operation.

4.4 Data Collection Method

The needful data on respondents' perception of PDS effectiveness and priorities of the selection factors, were collected directly from the respondents. This was materialized through conducting structured telephony interviews and the use of structured questionnaires. In view of the geographic distribution of the respondents across Afghanistan and their sporadic access to internet, the structured questionnaire forms in conjunction with timed follow-up email messages were used as the primary method of data collection. The questionnaire was forwarded to all the respondents on the same day. A preferred date of return was specified on the message to which the questionnaire package was enclosed. The package consisted of two separate questionnaires as available in appendix I. Part I of the questionnaire package was geared to elicit the effectiveness value of the PDS option relative to the selection factors listed under the column to the right of the questionnaire. Respondent were provided with a concise guideline as to how the effectiveness values were to be assigned. Part II of the questionnaire was designed to aggregate the respondents' judgment on the relative importance weight of the selection factors. The questions introduced in this section were adapted from the pair-wise comparison matrix questionnaire of the Super Decision software. Questionnaire part II consisted of three sections and was accompanied by a brief introduction to assist the respondents in producing consistent judgments.

4.4.1 Survey Procedure

The survey was designed and executed as such to have the maximum appeal to the respondents. Of the many techniques cited for enhancing the response turnover, the following key principles were applied to improve the attractiveness of the survey and increase the quality and quantity of the responses:

Throughout this survey, the respondents were reminded of the voluntary nature of this exercise and were reassured as to the confidentiality of their information and data. This was carried out in accordance to the protocol set forth by the Concordia University Human Research Ethics Committee (UHREC) of the Office of Research – Ethics and

Compliance Unit. Moreover, the purpose of this research was clearly stated and relayed to participants on the introduction page of the questionnaire package. The questionnaire was designed with concision in mind. The survey questions were formulated to be short, straightforward and focused. Given that in both parts of the questionnaire certain quantification techniques were used, simple and tangible rating scale were devised to facilitate assignment of quantitative values to qualitative data. Also, particular attention was given to logical ordering and sequencing of the questions in the survey. The questionnaires were then tested with a few members of the sample population to identify the bugs and rectify the potentially misleading content in terms of questions and framework. At different intervals, reminder massages were sent to the respondents to encourage timely feedback. The respondents were also provided with incentives such as formal acknowledgement of their contributions and a promise to share the outcome of the research.

4.4.2 Survey Pilot Test

The questionnaire package was tested before it was distributed to the sample population. To perform this test, a few members of the sample population as well as some experts in Canada were selected to participate in the pilot. This exercise was carried out to increase the overall credibility of the survey. In particular, the pilot test was performed to gather feedback on whether the survey is understandable and clear for everyone and to inhibit misinterpretations and misunderstandings of the survey questions. The pilot test also provided an opportunity to ensure the competency of the questions as well as the time required to complete it. Out of the 36 members of the sample population, 5 people (roughly 14%) were selected, one from each category of positions, in addition to 10 independent experts in Canada. The independent participants had an average of six years of work experience and possessed advanced university degrees in construction engineering and management.

4.4.3 Survey Questionnaire Modifications

During the pilot test, participants were asked to document their observations and remarks concerning design and content of the survey forms. The comments were collected upon completion of the test run. The questionnaire underwent four rounds of revision as a consequence of the comments received. Several sections of the questionnaires were affected by these revisions, namely as the completion guideline, the rating scale and the wording of the measurement attributes of some selection factors. These revisions helped to ensure that the questions were perceived the same way by all survey respondents.

4.4.4 Data Recording

A database was designed to keep track of respondents' information such as their duty station, degree, years of experience, position and email address. This information was used to maintain contact with the respondents during the stages of data collection and analysis. In a few cases where the response sets were incomplete or the consistency of judgments were off, the relevant respondents were easily identified for a follow-up using this tracking system. The data transcribed on the questionnaires were transferred into an Excel spreadsheet. Each respondent was assigned a unique table on the spreadsheet, marked with their name. The importance value ratings from the comparison matrices were fed into Super Decision to determine the Relative Importance Weights. These weights were then recorded in the appropriate cells in the spreadsheet. The Relative

Effectiveness Values were transferred directly from the questionnaires to the designated cells in the spreadsheet.

4.4.5 Data Screening and Preliminary analysis

To better coordinate the collection of filled-in questionnaires, respondents were instructed to forward their responses by electronic mail. There were however a few cases where the feedback had to be collected via telephone or online conversation.

Given the geographic barrier between the researcher and the respondents and the sensitive nature of the data being procured, verifying the accuracy of data was of paramount importance to ensure proper functioning of the selection model. Hence, each response set was thoroughly reviewed upon receipt. Part I of the received questionnaires was investigated for repetitive scores and inclusion of a best and worst score for the PDS options on each selection factor. Deviation from the guidelines were duly recorded and relayed to the respondents to instigate corrective actions.

The screening process of questionnaire part II was more elaborate as it involved a test of consistency. Although the questionnaire was designed such to yield maximum consistency in judgment, the test had to be performed to ascertain the accuracy of the output importance weights. The consistency test was carried out in Super Decision upon construction of the un-weighted supermatrix. The inconsistency index of the comparison matrices were checked for each response set. In case the index was outside the admissible range, the judgements were revised as to achieve desirable consistency.

CHAPTER V

RESULTS AND ANALYSIS

5.1 Overview

This chapter is primarily focused on recapitulating the execution results of the two models developed for selecting the most suitable project delivery system in post-conflict construction projects. The chapter also offers more detail on the procedures observed for obtaining these results and seeks out to explain the steps leading to the model development and implementation. The discussion on model development is followed by an overview of the outcomes as well as analysis of the results. The PDS selection results are revealed for each category of the case study projects, i.e. health/educational buildings and office/government buildings. As explained in chapter III, an aggregate score or the suitability index is a sum product function of the importance weights and effectiveness values of each PDS option over the set of selection factors (equation 3.1). In the next section, the calculation results for each component of the aggregate score are reviewed for each PDS option, under their respective category of case study project. This is followed by the simulation results of the aggregate scores for each PDS option. The analysis is concluded by choosing the PDS alternative with the highest suitability index. Also to provide a more in-depth analysis of the relationship between the aggregate scores and the selection factors, the results of regression mapped value analysis are reviewed and discussed and the selection factors are ranked based on their impact on the suitability indices of the PDS options for each category of the case study projects. Finally, the resulted outcome from both selection models is compared. This comparison aims to confirm the validity and robustness of the proposed model in choosing the most logically suitable project delivery system for post-conflict construction projects.

5.1.1 Selection Factor Identification Procedure

As stated in the methodology chapter, the selection factor identification procedure was carried out using Delphi method. A group of 36 practitioners were identified for this task. They were individually briefed on the modality of implementing the Delphi exercise. A one-pager guideline was prepared and disseminated to the participants highlighting the key components of this exercise. The guideline touched on the objectives of the exercise and contained a flowchart, detailing the three steps involved in establishing the exclusive set of PDS selection factors in post-conflict construction projects. The 36 members on the expert panel represented a wider population of post-conflict experts whose areas of expertise covers a vast variety of disciplines and executive positions including Head of Operation, Project Manager, Project Engineer and Roving Technical Engineer. Table 5.1 outlines the composition and profile of the expert panel.

The Delphi survey was set to stop at a predefined stop criterion of three survey rounds or achievement of consensus between the participants (whichever came first). The survey was designed so that by the end of the third round, the experts could produce a consolidated list of selection factors best capturing the various requirements of construction in post-conflict.

The literature review suggests that the majority of studies in this field have adopted a relatively large number of selection factors into the decision making framework. In practice, however, application of such large numbers of selection variables is met with hesitation and grimace. During the first round, experts were presented with the list of most frequently cited selection factors and were tasked to trim it down to a manageable number of factors. In this elimination exercise, experts were advised to retain only the most pertinent selection factors. The facilitator, at the end of round one, summarized the proceedings and furnished to participants, the factors derived from the first part of the Delphi exercise.

Table 5.1 Composition of the Panel Experts

No.	Category of Experts	Sample Size (Person)
1	Head of Operation	1
2	Senior Project Manager	4
3	Project Manager	5
4	Project Engineer	16
5	Roving Technical Engineer	10
Total		**36**

In the second round, the panel was instructed to classify the surviving selection factors under three factor areas of Project Related Parameters, Agency Preferences and Regional Parameters. It goes without saying that the selection factors were to be assigned to the foregoing factor areas on basis of their relevance. They were also advised to consolidate the selection factors if found to be redundant or interrelated. Given that certain underlying factors pertinent to the project, agency and the external environment (such as cost, time and security) are mutually shared between a number of selection factors, it is virtually impossible to entirely remove or consolidate the interrelated selection factors without damaging the integrity of the list produced by the end of round II. The existing interdependencies amongst the factor areas and their corresponding factors, further justifies the application of ANP in calculation of the Relative Importance Weights.

The third and final round of the Delphi survey consists of configuration of the selection factors based on their level of importance. It is to say that, the experts were advised only to keep the selection factors that they unanimously considered as significant to the PDS selection decision making process. The latter round resulted in retention of 7 selection factors under Project Related Parameters (factor area I), 4 selection factors under Agency Preferences (factor area II) and 3 selection factors under Regional Parameters (factor area III). Figure 3.2 displays the three factor areas with their corresponding selection factors in a hierarchical format.

5.1.2 Defining the Attributes of Measure

As mentioned in the earlier chapters, the proposed PDS selection model functions based on alignment of the attributes of the PDS options with the performance measures of the selection factors. In the previous section, the 14 selection factors were introduced. The description provided in appendix IV for each selection factor sets the tone for identifying the measurement attributes of every single factor versus the PDS options.

Table 5.2 provides an overview of the said attributes. The information contained in the following table was used by the survey respondents at a later stage to assign to each PDS option a relative effectiveness value on how they satisfy the measurement attributes ascribed to each selection factor.

5.2 Development of the ANP Model using the Super Decision Software

This process begins by conceptualizing the network model. Once the model has been thoroughly mapped out, it can be transferred to Super Decision for further processing. In order to conceptualize the model, a logical relationship between the elements should be visualized. This logical relationship will allow for grouping of the nodes and clusters to incarnate a structure for the model. This structure is shown in figure 5.1. As displayed in

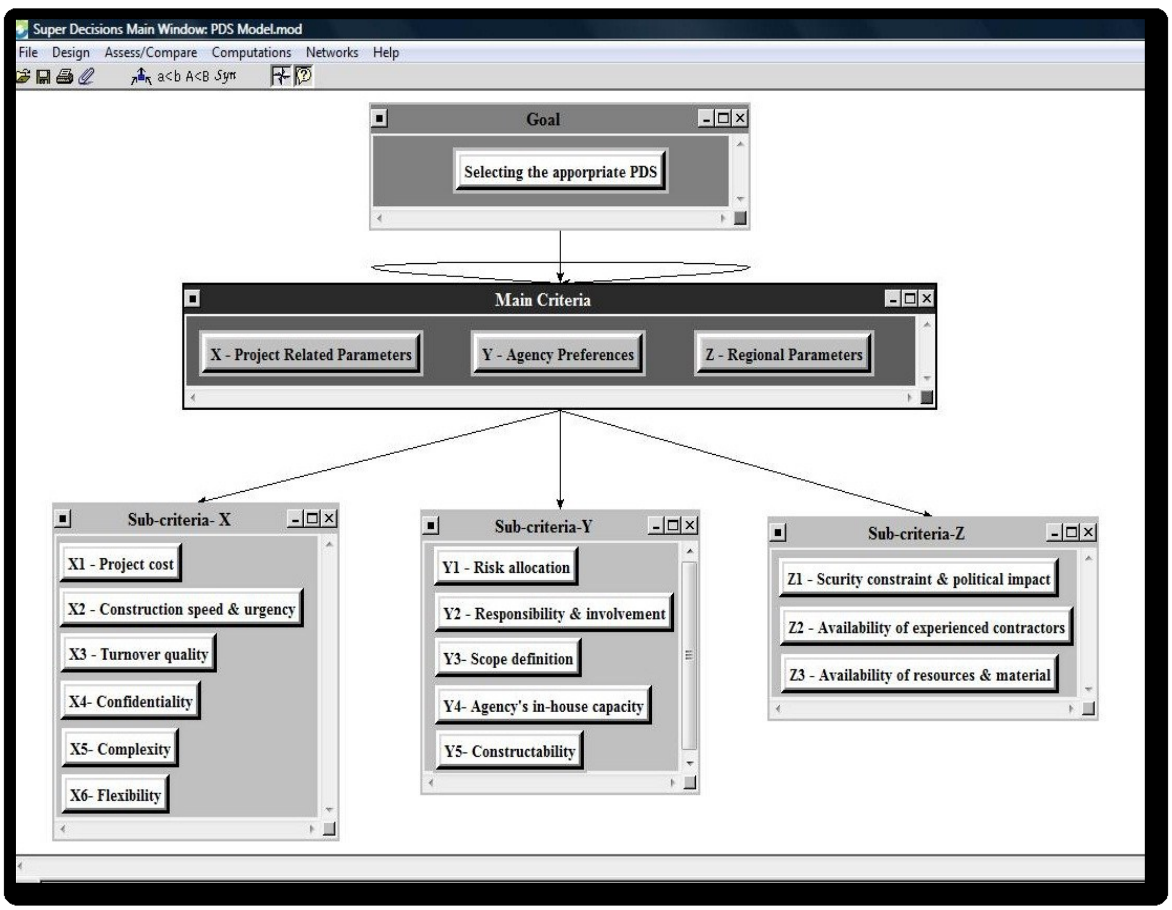


Figure 5.1 Screenshot of the ANP Model in Super Decision

Table 5.2 Measurement Attributes of the PDSSF

Selection Factors	Description	Measurement Attributes
Project Cost	Does your agency require a firm price before any commitment is made and is completion within original budget critical to project success?	Effectiveness of delivery system in controlling cost growth.
Construction Speed and Urgency	How important is early project completion to your agency and is completion within schedule critical to project success?	Securing the shortest reasonable schedule.
Turnover Quality	What level of turn-over quality does your agency seek to secure?	Effectiveness of delivery system in ease of start-up, reducing number of call backs, and lowering the operation and maintenance costs.
Confidentiality	How crucial is the confidentiality of project/engineering details to your agency?	Effectiveness of delivery system in concealing the project details and other proprietary matters.
Complexity	Is your project's design non-conventional, highly specialized and technologically advanced or is the construction complex, innovative and non-standard?	Effectiveness of delivery in effective orchestration and management of non-conventional project design/engineering and/or construction.
Flexibility	Does your agency anticipate an above normal level of change in the project and if so how important is it to retain the authority to effect change after cost estimate commitments are made?	Delivery system ability to smoothly incorporate changes to the project scope during detailed design and construction.
Risk Allocation	To what extent does your agency want to limit the amount of speculative cost, time and design liability?	Delivery system effectiveness in dividing and transferring risk between different project parties.
Responsibility and Involvement	To what extent does your agency wish to maintain control and exert influence over project design and execution and/or prefer direct professional responsibility?	Effectiveness of delivery system in accommodating agency's desire for involvement in managing design and construction.

Scope Definition	Availability and/or necessity of developing well defined project features by the award of the design and/or construction contract?	Flexibility of delivery system in efficiently using poorly defined scope before the award of design and/or construction.
Agency's in-house Capacity	To what extent is your agency dependant on outside assistance and does it have the wherewithal to get involved in detailed design and construction?	Delivery system effectiveness to promote agency's involvement in detailed design and construction commensurate with its capacity.
Constructability	To what extent is your agency keen on integrating construction knowledge into design process as a mean to achieve a better quality project, in a safe manner, within schedule and for the least cost?	Delivery system effectiveness to promote constructability and facilitate the interaction between construction knowledge of the design entity and the expertise of the construction party.
Security Constraints and Political Impact	To what extent is your project affected by security constraints, mobility restrictions and changing political considerations?	Delivery system effectiveness in adapting to the volatility of the situation on the ground and countering the negative effects (in terms of construction time and cost) resulting from security imposed restrictions and fast paced political and regulatory change.
Availability of experienced contractors	To what extent does your agency depend on local contractors/sub-contractors for execution of their projects?	Effectiveness of delivery system to address the shortage of contractors and/or subcontractors who have the expertise to fulfil project requirements and cope with its consequences (in terms of time, cost, risk allocation and quality) thereof.
Availability of Resources and Material	To what extent is material procurement and delivery critical to your project's success and is your agency inclined to promote early procurement of equipment and/or material to compensate for scarcity and/or long lead times of material and/or equipment?	Effectiveness of delivery system in permitting early design and purchase of equipment or material as well as offsetting the impact that availability of material would have on the construction speed in projects with a fast track or tight time schedule.

figure 5.1, the model consists only of one network. In this network all the clusters and their nodes are placed in a single window. Throughout this exercise, the comparisons are made with a notion that selecting the appropriate PDS is the overruling condition that should govern all judgements. The model consists of 5 clusters including the goal cluster, the main criteria cluster and the three clusters of sub-criteria. The main criteria cluster embodies three nodes, one for each of the factor areas earlier identified. These nodes include the project related parameters, the agency's preferences and the regional parameters. The criteria cluster is also connected to three clusters of sub-criteria. The nodes within each sub-criteria cluster are composed of the PDS selection factors. Another important aspect in developing an ANP model in Super Decision is to define the relationship between the clusters with respect to one another as well as the relationship between the clusters and nodes within and beyond the same cluster. In the present ANP model, there are no alternatives being considered. In other words, the model does not lead to selection of a particular PDS. The purpose of constructing the ANP model in Super Denison is solely to derive the relative priority or as it's called in this research, the relative importance weight of the selection factor. This information is then fed into the final PDS selection model to determine the weighted score of each selection factor. By aggregating the weighted score for all 14 selection factors, the suitability index of the PDS options will come to light.

In The present model, the straight arrows indicate the linkages between clusters. If an arrow is drawn from one cluster towards another, it signifies the outer dependence between the elements within the two clusters. This action can be performed using the Do

Connexions command menu in Super Decision. The looped arrow indicates inner dependence. This means that there are elements linked to one another within the same cluster. In the PDS selection model, the elements within the main criteria cluster are linked to each other to account for their inner dependence. This is signified by the loop as shown in figure 5.1. To summarize, the node in the goal cluster is connected to the three nodes in the main criteria cluster. This means that the "selection of the appropriate PDS" node will serve as the parent node in the comparison down the line. Similarly, given

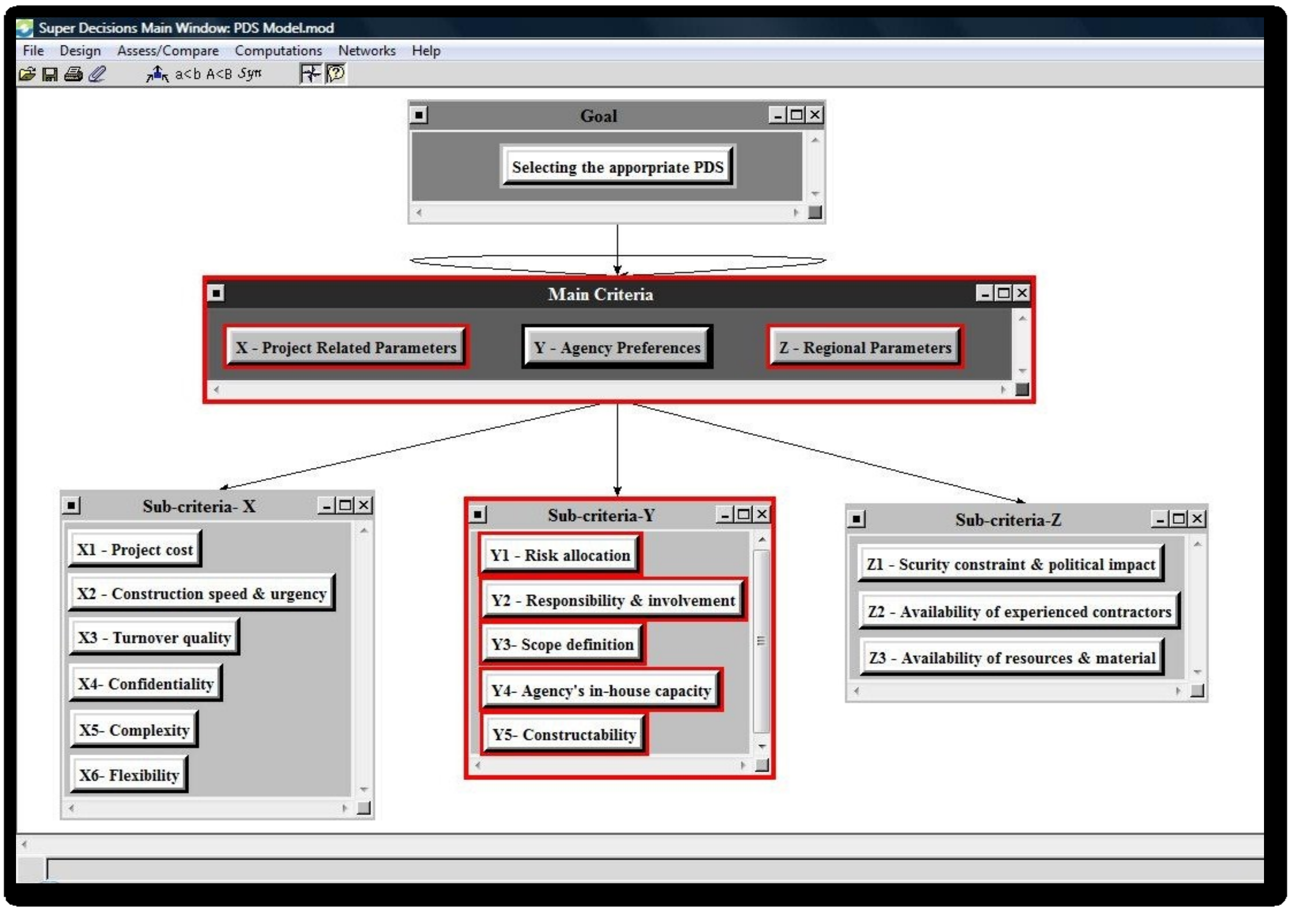


Figure 5.2 Visualization of outer and inner dependence for Node Y

the inherent inner dependence between the elements of the main criteria, the three nodes encased within this cluster are connected to one another as well as to the nodes encased within their corresponding -

sub-criteria cluster, i.e., node X is linked to Y and Z within the main criteria cluster as well as X1 through X6 within sub-criteria cluster X. Same order applies to nodes Y and Z. Figure 5.2 illustrates the connections in the case of node Y. The boxes outlined in this image denote that there is a connection to the said node.

The elements within each sub-criteria cluster are also pair-wise compared with respect to their corresponding parent node in main criteria cluster. The comparison stage began after the relationships between the clusters and nodes were defined. In this stage the clusters can be compared as well as the nodes within them to determine their weights. In this model, the clusters only act as benchmarks or references to allow for systematic comparison of the nodes within them. Therefore, they are not compared and the model assumes an equal weight of 1/n for each cluster where n corresponds to the number of clusters (the weights of clusters within a network add up to unity).

To initiate the node comparison, the element which is to serve as the parent node for the first set of comparison is selected. This could be done by depressing the Assess/Compare command menu from the Super Decision task bar and selecting the Node Comparison command. Once this command is selected, the program allows to change the parent node from the one already selected to the other parent nodes defined earlier in the model conceptualization stage. From the same screen, the user can select the cluster which contains the nodes considered for comparison with respect to the parent node. This action could be carried out alternatively by right-clicking on the parent node in the main screen and selecting the Node Compare Interface command from the drop-down menu that appears. By clicking this command, the cluster selector screen opens. From this screen the appropriate cluster which contains the nodes intended for comparison can be selected. Once the elements being compared are acknowledged, the comparison window in questionnaire mode opens. This action is repeated until all the intended nodes are compared. Figure 5.3 shows the comparison matrix screen in questionnaire mode for the nodes in the main criteria cluster with respect to the node in the goal cluster.

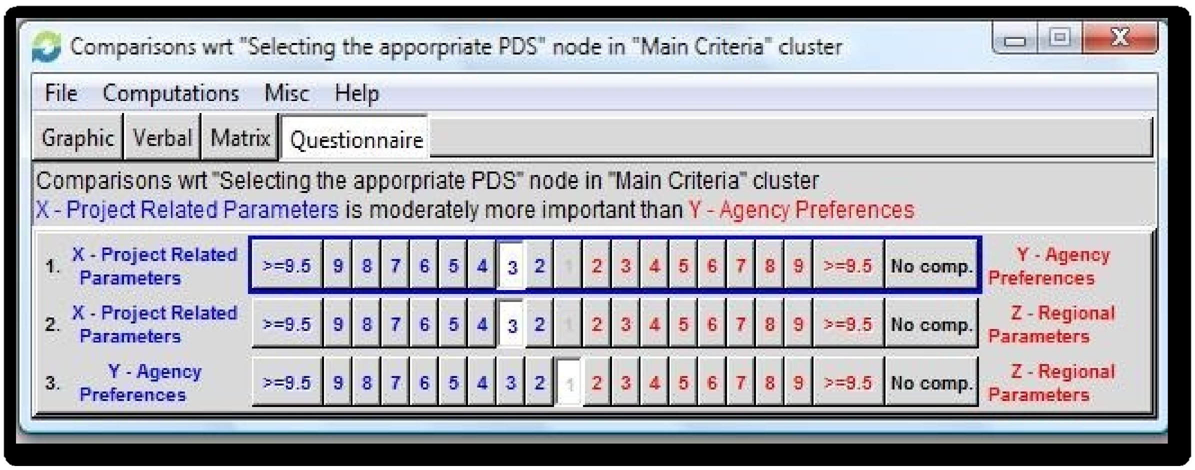


Figure 5.3 Comparison Questionnaire Matrix

The judgements should be entered as indicated by the user. In this research, to fill out the comparison questionnaires with adequate data, the researcher created an optimized questionnaire form and distributed it to the sample survey population. This questionnaire was accompanied by a brief introduction to guide the respondents in aggregating their judgments. This guideline as well as the sample questionnaire is included in appendix I. Once the comparison matrix is filled out, by selecting the Computation command menu from the task bar atop the questionnaire screen and selecting the Show New Priority Command, the local priorities of the nodes can be calculated. These local priorities correspond to the comparison judgements that were entered in the preceding step.

By calculating the local priorities, the program also displays the inconsistency index of the judgements. This index is visible at the top of the priorities screen as displayed in figure 5.4. As earlier stated, maintaining a consistent stream of judgment is of paramount importance to the accuracy of the weights derived from the ANP method. Saaty has defined an admissible range for the inconsistency index. In this study, given the size of comparison matrices, an inconsistency ratio of less than 0.1 is desirable. The desirable range is also annotated at the top of the priorities screen. If the inconsistency index falls beyond the admissible range, the judgements should be reviewed and accordingly modified to achieve a desirable inconsistency index. The Super Decision program offers an inconsistency improvement option. This option is accessible from the comparison window. The window should be viewed in the Matrix mode to allow access to the inconsistency improvement button.

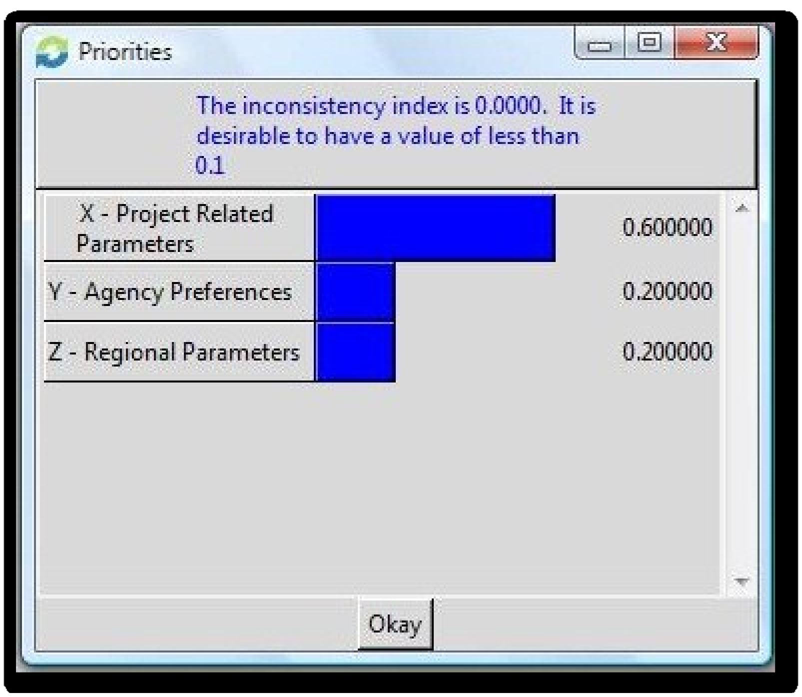


Figure 5.4 Local Priorities for the Nodes in the Main Criteria Cluster With Respect To the Node in the Goal Cluster

5.2.1 The Relative Importance Weights and the Super Matrix Computations

Once all the comparison matrices in the model have been filled out, the Computations command menu can be used to obtain the final priorities of the selection factors. The process of arriving at these priorities involves several levels of computation. These computations have been defined in the form of sub-commands under the Computation command menu. The model starts calculating the priorities by constructing the unweighted super matrix. This matrix contains the local priority vectors derived from every single comparison matrix that was built throughout the network. In the graphical

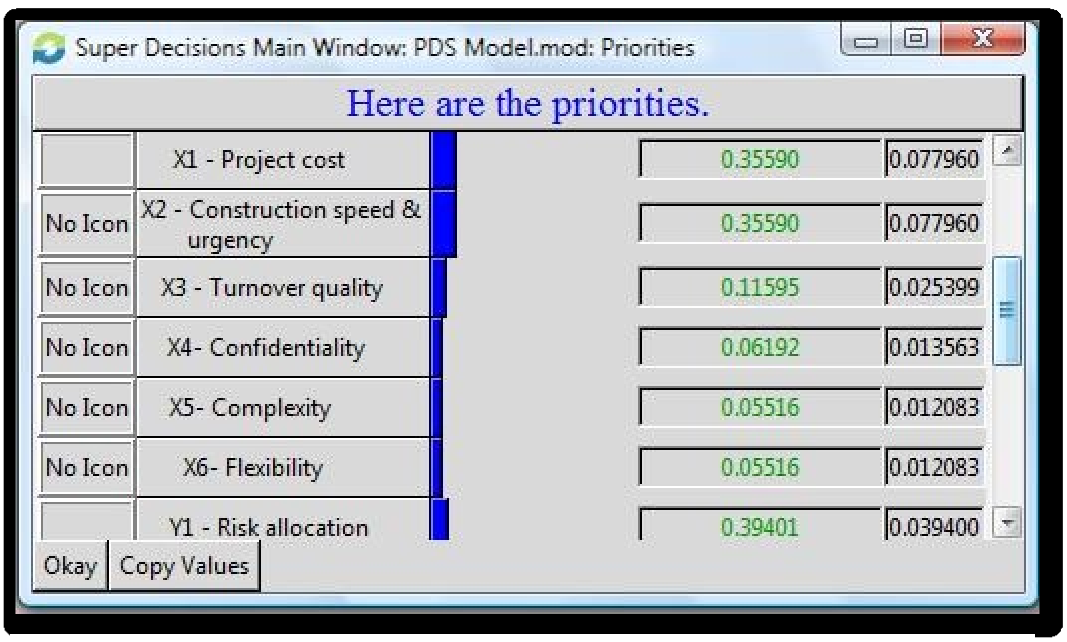


Figure 5.5 a Section from the Final Priorities Report

representation of the unweighted super matrix, the node situated on top of the column is the control criterion of the various comparison sets comprising of the nodes at the left. Next in the process is calculating the Weighted Super Matrix by multiplying the local priority vectors in the unweighted super matrix times the corresponding cluster weights. The cluster weights are determined by pair-wise comparing the connected clusters with respect to their importance over the parent cluster. When the clusters are assumed to have equal importance, the model enters equal values by default to form the cluster matrix. This will result in a column stochastic weighted supermatrix where the priority vectors in each column are weighted by the importance weight of their corresponding cluster. Lastly, to elicit the final priorities of the nodes, the Limit Super Matirx is computed by raising the weighted supermatrix to powers until it converges- that is when all the columns in the matrix have identical entries.

The entries in the limit super matrix represent the priorities of the nodes displayed on the left side of the matrix. The final priorities could also be retrieved using the Priorities sub-command. Figure 5.5 portrays the final priorities obtained by invoking the Priorities command. Applying this command will produce the priorities of all the nodes in the model. The priority values could be copied from the Priorities window and pasted into a spread sheet for further processing by simply depressing the copy values button at the bottom left corner of the screen.

5.2.2 Application of Monte Carlo Simulation and Score Aggregation in the Individual-Based Assessment Model

In the individual-based approach, the weighed scores [$W(c_i).V(a_jc_i)$] of each PDS are separately recorded in an Excel spread-sheet. In this manner, there will be total of 3 tables, each designated to a PDS option. Each table consists of 14 columns and 36 rows. The columns represent the weighted score of the subject PDS over the set of selection factors. The rows, on the other hand, represent the entries from each of the 36 respondents. Every respondent is assigned a row where the weighted scores are entered relative to each selection factor. These entries are based on the judgements elicited from that respondent in the R.I.W and the R.E.V determination stages. To initiate the probabilistic model in Excel, the @Risk component has to be activated. The process begins by defining a best-fit probability distribution for the inputted weighted scores of each selection factor. Given the availability of data (36 entries) this task can be performed with relative ease using the Distribution Fitting command from the @Risk menu. To execute this command for the range of data for which the best fit distribution is intended, the category of data has to be defined by clicking on the " Data" tab and selecting the appropriate data type from the drop-down menu in the "Fit Distribution to Data" screen. The numerical data used in this research falls in the continuous data category. This step is illustrated in figure 5.6.

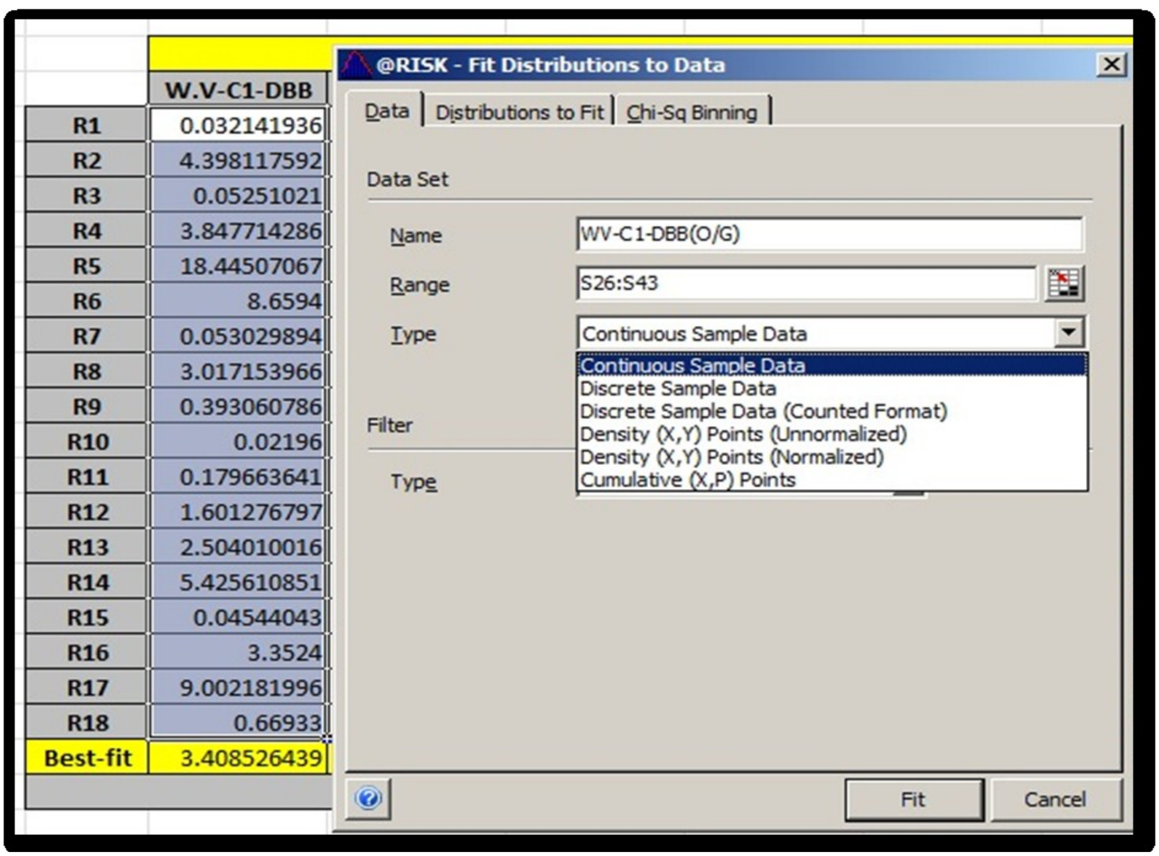


Figure 5.6 Selection of Data Category in @Risk

Subsequently, by clicking on the "Distributions to Fit" tab in the "Fit Distribution to Data" screen, the lower and upper limits of the data should be specified. It was established that the weighted scores are determined by multiplying the R.I.W which ranges from 0 to1 by the R.E.V that varies from 1-100. Therefore, the weighted score which is a product of these two should be bound between 0 and 100. By setting the lower and upper limits, the program automatically narrows down the list of applicable theoretical distributions to Beta General, Triangular and Uniform. This is shown in figure 5.7. By pressing the "Fit" button on the right bottom corner of the screen, @Risk points out the best fit distributions and ranks them based on their P-value. As shown in figure 5.8, the distribution with the lowest P-value is the best fit and is visible on top of the list. This fit-ranking is based on the Chi-Square goodness of fit test.

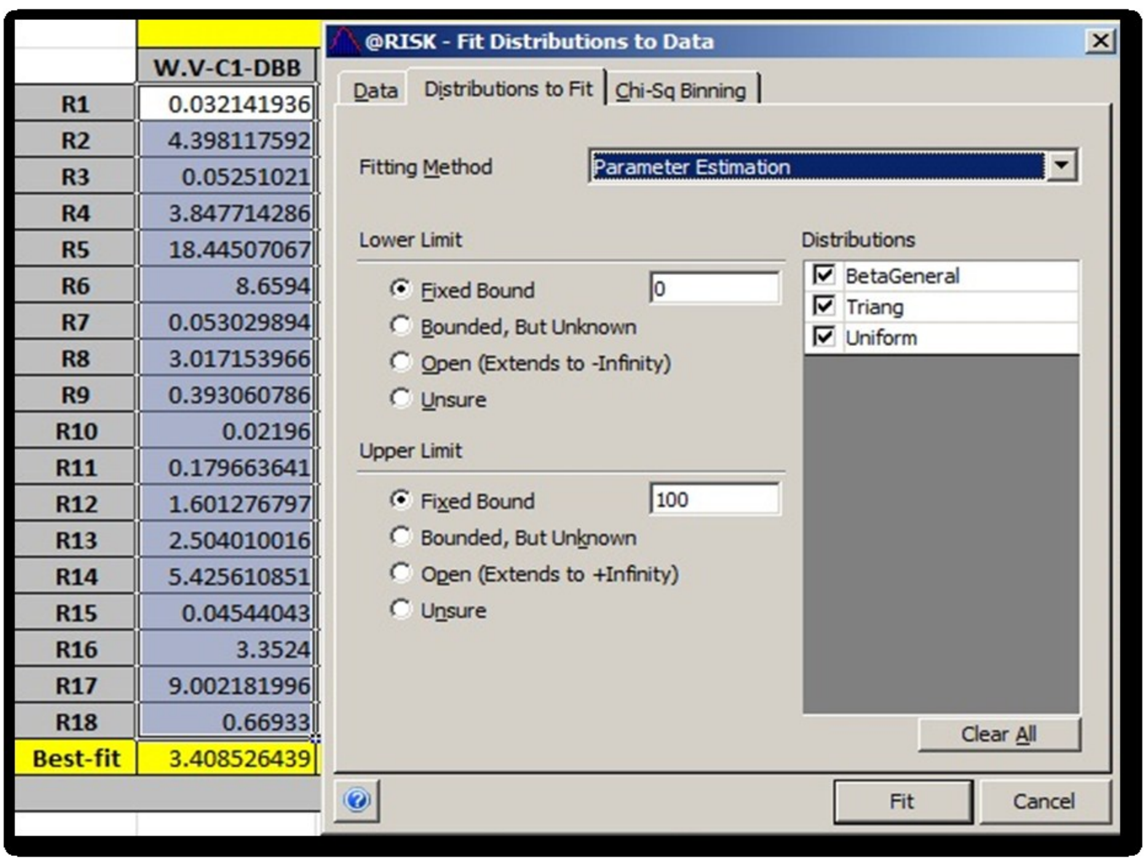


Figure 5.7 the Applicable Theoretical Distributions

After the best fit distribution is defined, the mean value of this distribution can be recorderd for future reference by pressing the “Write to Cell” button situated on the lower right corner of the “Fit Results” screen. These steps are repeated for all the 14 selection factors. The mean values for the best fit distriutions are similarly recorded. The suitability index is determined by summing the mean values of the weighted scores so far recorded. This formula is applied to an empty cell in the Excel spread-sheet. The resulted value is designated as the simulation output by applying the “Add Output” command from the @Risk menu. These steps are applied for all three PDS options. At the end of this process, the PDS option with the highest output value is regarded as the most suitable project delivery system for the project in mind.

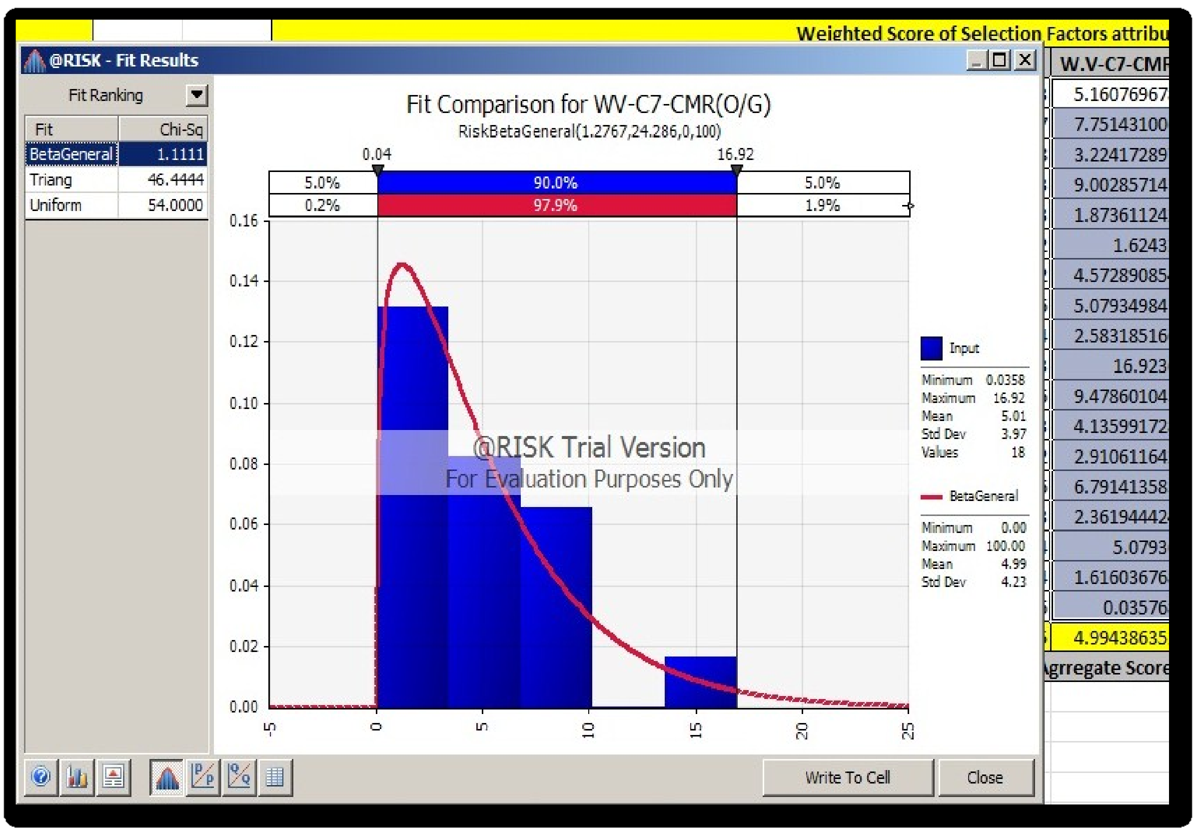


Figure 5.8 the Best-Fit Ranking Results

5.2.3 Measuring the Relative Importance Weight of Selection Factors in the Consensus-Based Model

The steps outlined for obtaining the relative importance weights under the individual assessment method are applicable to the consensus-based approach in its entirety. They are only distinguished in that instead of collecting individual response sets, a group judgement is reached by the members of the decision-making committee through communication and discussion. In this research, consensus was built through decision conferencing. In the decision conference meeting, particpants were selected to represent all the key concerns on the issue of post-conflict construction projects. The composition of the working group was the same as in the selection factor identification stage. The breakdown of participants is similar to that shown in table 5.1. The session started off by setting up a target and brainstorming the issue at hand. Next in the process, a model was built based on the participants judgements on the relative importance weights. To derive these judgemetns, participants were referred to the questionnaire form that was designed earlier for the individual-based assessment approach. The respondents were already familiar with the questionnaire. This familiarity proved advantageous in deriving the consensus-based judgements. Particiapnts discussed the questinnaire in their working group, one question at a time and moved on to the next question only after a consesnus answer was reached. In the process leading to a consensus answer, several revisions were made to ensure that the results are reflective of the broader consensus. Lastly, the results were summarized and recorded for the next setp.

5.2.4 Measuring the Relative Effectiveness Value of the PDS Options in the Consensus-Based Model

The process for measuring relative effectiveness values is entirely compatible with the one applied under the individual-based assessment. The same Effectiveness Measure Scale is used for the cosensus-based assessment. The modality of building consesus is similar to that explained under sectoin 5.2.3. Upon reaching consensus on the relative importance weights, particiapnts were directed to replicate the same procedure to determine the effectiveness values of the PDS options relative to set of selection factors defined for post-conflict construction projects. Through decision conferencing, the participants, tapped into their shared understanding of the decision problem and deteremined the R.E.V of the PDS options through consensus.

5.2.5 Defining the Utility Factors Based on the Relative Effectiveness Values in the Consensus-Based Model

The process of determining the relative effectiveness value is a prerequisite to defining the utility functions of the PDS options. Although the proposed consensus-Based model can consolidate a suitability index on the basis of R.I.W and R.E.V alone, this step is an additional effort for transforming the relative effectiveness values into utility functions and connecting the selection factors to the desirabiltiy of the PDS alternatives. The utility functions provide a uniform scale to compare the level of attainment of the PDS options. In this exercise, decision makers assigned a numerical index to varying levels of attainment for each PDS option based on the relative effectiveness values earlier assigned through direct scoring. The utility functions are developed through “standard gambling” technique. In this technique, the best and worst outcomes (PDS options) are identified based on their effectiveness score relative to each selection factor. The choice of the best and the worst outcome is governed by the lower and uppper limits of the EMS scale. Therefore, a score of 100 signifies the best outcome whereas the score of 1 defines the worst possible outcome. The range of 0 to 1 was selected to establish the utiliy value of the worst and the best outcomes respectively. In the standard gambling method (Hatush and Skitmore, 1998), the decision makers are offered two selection routes to determine the utlity of the intermediate values. The decisoin makers can choose between the "Certain Option" where a certain outcome with probaility of $p=1$ is warranted, or the "Risk Option" where the decision maker is faced with a probabilistic outcome in form of a lottery. In this lottery the decision maker can either end up with the best outcome which has the probability of p or the worst outcome with the probability of $1-p$. To determine the utility of an intermediate score, the decision maker has to assume a value for the indifference probability between the certain outcome route and the 50-50 route offered as per the Risk Option for the worst and the best outcomes. The utility of the intermediate values is then calculated based on the principles of expected value from equation 5.1.

Arriving at an idifference probabaility is a time consuming process that involves a great degree of subjectivity. Alternatively, in this research a linear interpolation method was employed to determine the utility of intermediate values. This task was carried out with relative ease due to the fact that respondentes were instructed to always include a best and a worst oucome while assigining the relative effectiveness values to the PDS options. Therefore, in the case of each selection factor, the three PDS options were scored in such a way that there were always two outcomes with respective scores of 1 and 100 and a third PDS option with an intermediate value score. Therfore, for each selection factor, the PDS option with the highest score was assigned the best utility of unity and the utility

p(utility of the best outcome) + (1-p)* (utility of the worst outcome)* (5.1)

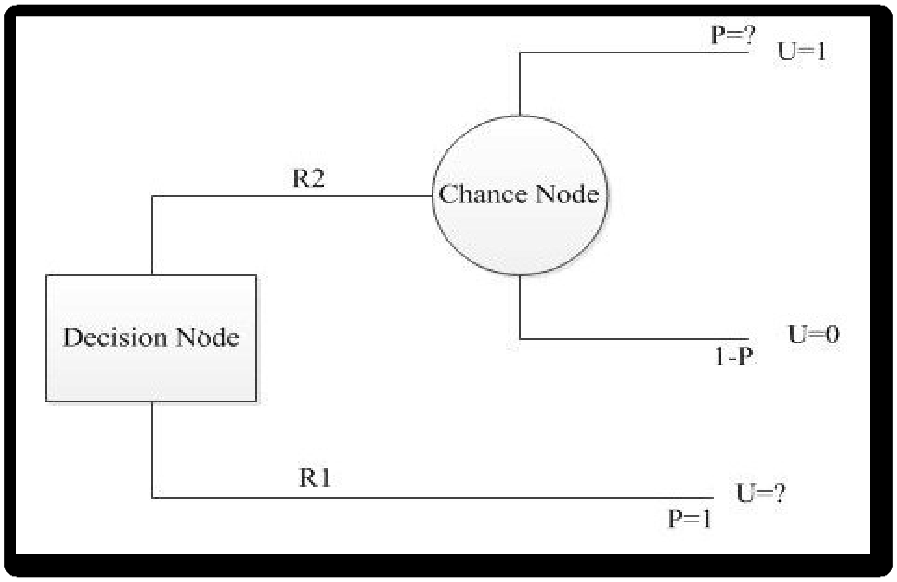


Figure 5.9 Visualization of the Standard Gambling Technique

of zero was reserved for the PDS option that was assigned a relative effectiveness value of 1. The utility of the PDS with an intermediate score was then calculated through linear interpolation. This linear interpolation is methematically described in the following equartion:

$$Y2 = \frac{(X2-X1)(Y3-Y1)}{(X3-X1)} + Y1 \qquad (5.2)$$

Where: Y_2 is the utility value of the PDS option with the intermediate score,

Y_1 and Y_3 represent the best and worst utility values respectively,

X_2 represents the effective value score of the intermediate PDS option and,

X_1 and X_3 resepectively represent the effectiveness values for the best and the worst PDS options.

5.2.6 Execution of Consensus-Based Model

The suitability indices of the PDS options are the sum product function of their utility and the R.I.W's of each selection factor. In other words, the aggregate score of each PDS is calculated by summing the multiplication results of their relative utility and the relative importance weight for each selection factor. This process could be tabulated on an Excel spread-sheet as shown in table 5.3.

Table 5.3 Tabulated Results of the Consensus-Based Approach

Consensus-based Approach			**DBB (Option 1)**			**DB (Option 2)**			**CM-R (Option 3)**		
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
No	S.F	R.I.W	R.E.V	Utility	Wi.Uji	R.E.V	Utility	Wi.Uji	R.E.V	Utility	Wi.Uji
1	PC	0.1474	1	0	0	50	0.49	0.0722	100	1	0.1474
2	CSU	0.1474	1	0	0	100	1	0.1474	60	0.59	0.0869
3	TQ	0.1021	100	1	0.1021	1	0	0	70	0.69	0.0704
4	CONF	0.0256	100	1	0.0256	1	0	0	50	0.49	0.0125
5	COM	0.0228	100	1	0.0228	1	0	0	50	0.49	0.0111
6	FLX	0.0228	100	1	0.0228	1	0	0	60	0.59	0.0134
7	RA	0.0746	1	0	0	60	0.59	0.0440	100	1	0.0746
8	RI	0.0746	100	1	0.0746	1	0	0	50	0.49	0.0365
9	SD	0.0139	1	0	0	100	1	0.0139	30	0.29	0.0040
10	AIHC	0.0139	100	1	0.0139	1	0	0	50	0.49	0.0068
11	CON	0.0122	1	0	0	100	1	0.0122	50	0.49	0.0059
12	SCPI	0.0374	1	0	0	100	1	0.0374	70	0.69	0.0258
13	AEC	0.1990	1	0	0	100	1	0.1990	60	0.59	0.1174
14	ARM	0.1057	1	0	0	100	1	0.1057	50	0.49	0.0518
$\sum$ **Wi** = 1			**Score** (R.I.W*Utility)		**0.2620**			**0.6321**			**0.6653**

As per table 5.3, the suitability index of PDS option 1 is the sum product of columns 1 and 3. Similarly, the aggregate score of PDS option 2 is the sum product of columns 1 and 6 and for option 3, the suitabality index is the sum product of columns 1 and 9. The PDS option with the highest suitability index is selected as the most suitable project delivery system for the intended project.

5.3 Results from the Individual-Based Assessment Model

This model is built upon individual assessment of the relative criteria weights and relative effectiveness value of the PDS options. The suitability indices were obtained via a statistical aggregation method. The relative importance weights of selection factors were determined through ANP. The suitability index for each PDS alternative was aggregated via Monte-Carlo simulation. The simulation is performed using Palisade's @Risk analysis software. Aggregation results collectively point out to CM-R as the most suitable PDS option for both categories of the case study projects. The second and third most suitable option are DB and DBB for both project groups.

5.3.1 Health and Educational Buildings

The following results were obtained from the respondents who were involved, to varying degrees in the decision making, design, construction and monitoring of projects in the health and educational building category. The geographic spread of these project is outlined in table 4.1.

I. Relative Importance Weights

The relative importance weights have been obtained independent from any particular PDS. Hence, these importance weights could be applied to a wide range of projects in post-conflict construction programs. Table 5.4 displays the relative importance weights of the selection factors for health and educational buildings. These weights have been generated via Super Decision software. The values listed in front of each selection factor are in fact the final priority values resulting from construction of the ANP limit supermatrix. Table 5.4 consists of 14 columns and 18 rows. Each column corresponds to a selection factor and the rows contain the relative importance weights as decided by the 18 respondents.

Table 5.4 Relative Importance Weights of Selection Factors for Health and Educational Buildings

Relative Importance Weight of Selection Criteria for Health and Educational Buildings														
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
W-1	0.1848	0.0601	0.0311	0.0293	0.0293	0.0300	0.1649	0.0527	0.0449	0.0945	0.0542	0.0518	0.1553	0.0173
W-2	0.1374	0.0350	0.0264	0.0222	0.0264	0.0228	0.1925	0.0391	0.0475	0.0391	0.0331	0.2270	0.0757	0.0757
W-3	0.0372	0.0333	0.0148	0.0107	0.0208	0.0208	0.1201	0.0612	0.1440	0.0336	0.0340	0.3705	0.0506	0.0484
W-4	0.1484	0.1484	0.0290	0.0262	0.0393	0.0230	0.0554	0.0526	0.2868	0.0151	0.0187	0.0122	0.0765	0.0684
W-5	0.1383	0.0434	0.0443	0.0483	0.0473	0.0568	0.0143	0.0755	0.1172	0.0489	0.0143	0.1121	0.0777	0.1616
W-6	0.2119	0.0428	0.0428	0.0408	0.0428	0.0475	0.0291	0.0214	0.0571	0.1029	0.1609	0.0389	0.0176	0.1434
W-7	0.0705	0.0967	0.0939	0.0824	0.0645	0.0621	0.1324	0.0604	0.1590	0.0385	0.0381	0.0669	0.0188	0.0159
W-8	0.1350	0.0411	0.0411	0.1350	0.0352	0.0411	0.1304	0.0323	0.0392	0.0392	0.1304	0.0201	0.0933	0.0866
W-9	0.1743	0.0312	0.1743	0.0279	0.0312	0.0279	0.0259	0.0703	0.1367	0.0079	0.0258	0.0242	0.1212	0.1212
W-10	0.2032	0.0568	0.0410	0.0344	0.0703	0.0410	0.1413	0.0468	0.0227	0.0265	0.1413	0.0159	0.0794	0.0794
W-11	0.1470	0.0391	0.1470	0.0300	0.0164	0.0233	0.1144	0.0216	0.0297	0.2575	0.0314	0.0156	0.0441	0.0831
W-12	0.1183	0.0610	0.0243	0.0168	0.0987	0.0987	0.0283	0.0137	0.1196	0.1523	0.1633	0.0018	0.0953	0.0080
W-13	0.2169	0.0731	0.0337	0.0252	0.0610	0.0489	0.0337	0.0337	0.1518	0.0139	0.1518	0.0096	0.0734	0.0734
W-14	0.1293	0.1293	0.0245	0.1293	0.0245	0.0208	0.0520	0.0520	0.0100	0.0187	0.0100	0.0437	0.2322	0.1234
W-15	0.0770	0.2150	0.0265	0.0770	0.0265	0.0161	0.0958	0.0343	0.0343	0.0178	0.0178	0.0517	0.1551	0.1551
W-16	0.0974	0.0974	0.0974	0.0974	0.0195	0.0195	0.0695	0.0695	0.0240	0.0240	0.0129	0.0743	0.0743	0.2229
W-17	0.0622	0.1155	0.1198	0.0631	0.0308	0.0286	0.0881	0.0957	0.0214	0.1404	0.0878	0.0978	0.0244	0.0244
W-18	0.0261	0.0883	0.0483	0.0131	0.0072	0.0170	0.0774	0.0613	0.0530	0.1103	0.0638	0.0547	0.1988	0.1807

The rows in the above table sum to unity. In other words, adding the values for C_1 to C_{14} yields the value of one for each response set. Using Palisade's @Risk analysis software, a best fit distribution for the weight of each selection factor was determined. Table 5.5 contains the mean values of the best fit distributions for each selection factor. The mean values are used to indicate the relative average weight of the selection factors.

Table 5.5 Average Relative Weights of Selection Factors for H/E Buildings

S.F.	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
A.R.W	0.1281	0.0784	0.0592	0.0506	0.0384	0.3387	0.0867	0.0496	0.0837	0.0661	0.0661	0.0734	0.0924	0.0932

The ARW table for H/E buildings reveals that C_1, which represents project cost is the most significant selection factor with the relative average weight of 0.1281, followed by $C_{14,}$ that is availability of resources and material with the relative weight of 0.0932 and C_{13} , availability of experienced contractors with the weight of 0.0924.

I. Relative Effectiveness Values

The relative effectiveness values were assigned by individual respondents to each PDS option relative to the selection factors. Table 5.6 contains the relative effectiveness values that correspond to DBB As per the questionnaire guideline, the respondents were advised to assign a value of 1 or 100 to PDS alternatives over the selection factors, respectively denoting the least and the most effective PDS option. The intermediate PDS option was expected to receive a value between 1 and 100 depending on its level of effectiveness in meeting the performance measures of the selection factors. Table 5.7 demonstrates the relative effectiveness values corresponding to DB.

Table 5.6 Relative Effectiveness Values pertaining to DBB for H/E buildings

Relative Effectiveness Value for DBB- Health and Educational Buildings														
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
V-DBB1	100	100	100	100	100	100	100	100	100	100	100	100	100	100
V-DBB2	1	1	100	1	1	1	1	100	1	100	1	1	1	1
V-DBB3	80	1	1	1	1	1	80	100	100	80	1	1	100	100
V-DBB4	1	70	80	1	1	100	100	100	50	70	100	100	100	60
V-DBB5	50	1	100	1	1	50	100	60	70	40	40	80	100	80
V-DBB6	80	1	1	1	1	1	1	1	1	100	1	100	100	1
V-DBB7	1	1	1	100	100	100	1	100	100	100	1	1	1	1
V-DBB8	70	60	90	60	60	70	1	100	1	70	1	60	90	70
V-DBB9	1	1	90	90	50	100	1	100	1	100	1	100	1	1
V-DBB10	100	1	100	100	1	1	1	50	1	100	1	1	1	1
V-DBB11	80	1	1	1	90	1	1	100	1	100	60	1	1	1
V-DBB12	1	1	1	100	100	1	1	100	1	100	1	100	100	1
V-DBB13	1	1	80	40	70	30	90	90	90	90	90	60	90	90
V-DBB14	1	1	100	100	100	100	1	100	1	100	1	1	1	1
V-DBB15	1	1	100	100	100	1	1	100	1	100	1	1	1	1
V-DBB16	1	1	100	100	80	1	1	100	1	100	1	1	1	1
V-DBB17	1	1	100	100	100	1	1	100	1	100	1	1	1	1
V-DBB18	60	1	1	1	70	1	1	100	1	100	60	1	1	1

Table 5.8 reflects on the effectiveness value of CM-R relative to the project delivery system selection factors in post-conflict health and educational building projects. A visual investigation of the REV tables reveals that DBB is relatively a less attractive option as compared to DB and CM-R. However, DBB has relatively scored the highest over C_8 (Responsibility & Involvement) and C_{10} (Agency's In-House Capacity). These findings are consistent with the properties of design-bid-build project delivery method. As for DB, the highest score are attributed from C_2 (Construction Speed & Urgency), C_{11} (Constructability), and C_{14} (Availability of Resources & Material). These are due to the inherent advantages of design build delivery method to fast track, allow for infusion of

design knowledge with construction expertise and its flexibility in early procurement of material.

Table 5.7 Relative Effectiveness Values pertaining to DB for H/E buildings

Relative Effectiveness Value for DB- Health and Educational Buildings														
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
V-DBB1	70	100	100	100	100	100	90	100	100	100	90	100	90	100
V-DBB2	100	100	1	100	100	90	90	1	100	1	100	100	100	100
V-DBB3	1	80	80	100	90	90	1	40	40	1	100	50	70	50
V-DBB4	90	100	100	100	100	1	1	40	100	1	1	1	1	100
V-DBB5	100	70	1	80	100	1	1	1	1	1	90	100	1	100
V-DBB6	1	80	70	80	60	100	60	90	70	70	70	60	70	100
V-DBB7	100	100	100	1	1	1	80	1	1	40	70	90	80	100
V-DBB8	1	100	1	1	1	100	90	1	100	1	100	1	1	100
V-DBB9	60	100	60	1	1	1	90	1	100	1	100	1	100	100
V-DBB10	1	100	40	1	100	100	100	1	100	1	100	100	100	100
V-DBB11	1	100	100	100	1	100	100	1	100	1	100	100	100	100
V-DBB12	100	100	100	1	1	100	100	1	100	1	100	1	1	100
V-DBB13	100	100	80	40	70	80	90	90	70	80	80	60	100	90
V-DBB14	80	100	1	1	1	1	100	1	100	1	100	100	60	100
V-DBB15	60	100	1	1	1	100	100	1	100	1	100	80	100	100
V-DBB16	90	100	1	1	1	100	100	1	100	1	100	70	100	100
V-DBB17	60	100	1	1	1	100	100	1	100	1	100	100	100	100
V-DBB18	1	100	100	100	1	100	100	1	100	1	100	100	100	100

Table 5.8 reveals that CM-R is a relatively more attractive option in terms of its effectiveness to meet the performance measures of the selection factors. CM-R is notably more appealing due its ability to satisfy factors C_1, C_2, C_6, C_7, C_9, C_{11} and C_{14}. This conclusion is merely based on the number of high scores (100's) that the PDS has been assigned with respect to a given selection factor. However, the choice of the most appropriate PDS is governed by their suitability index which takes into account the importance weights of the selection factors. This will be cross referenced with the simulation results at a later stage to corroborate the relative suitability of CM-R.

Table 5.8 Relative Effectiveness Values pertaining to CM-R for H/E buildings

Relative Effectiveness Value for CMR- Health and Educational Buildings														
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**
V-DBB1	100	70	90	60	30	30	100	50	20	20	100	90	100	90
V-DBB2	90	90	20	80	90	100	100	70	90	60	80	80	70	80
V-DBB3	100	100	90	100	100	100	100	1	1	100	100	100	1	1
V-DBB4	100	1	1	70	60	60	70	1	1	100	70	70	30	1
V-DBB5	1	100	70	100	80	100	50	100	100	100	100	1	40	1
V-DBB6	100	100	100	100	100	50	100	100	100	1	100	1	1	60
V-DBB7	80	50	90	60	80	80	100	80	30	1	100	100	100	60
V-DBB8	100	1	100	100	100	1	100	80	90	100	60	100	100	1
V-DBB9	100	60	100	100	100	90	100	60	80	80	80	60	80	70
V-DBB10	80	90	1	50	50	80	80	100	90	50	80	80	90	90
V-DBB11	100	90	90	90	100	80	90	70	90	70	90	80	80	90
V-DBB12	70	80	80	80	80	70	80	90	80	60	80	80	70	70
V-DBB13	50	70	80	40	70	80	90	90	70	70	70	60	80	80
V-DBB14	100	70	80	80	90	90	90	90	60	80	90	40	100	60
V-DBB15	100	80	90	60	90	20	80	60	50	30	90	100	70	80
V-DBB16	100	90	70	90	100	30	90	70	80	40	90	100	70	80
V-DBB17	100	80	40	60	60	60	90	60	40	60	60	80	70	60
V-DBB18	100	90	90	70	100	80	80	70	80	70	90	80	70	90

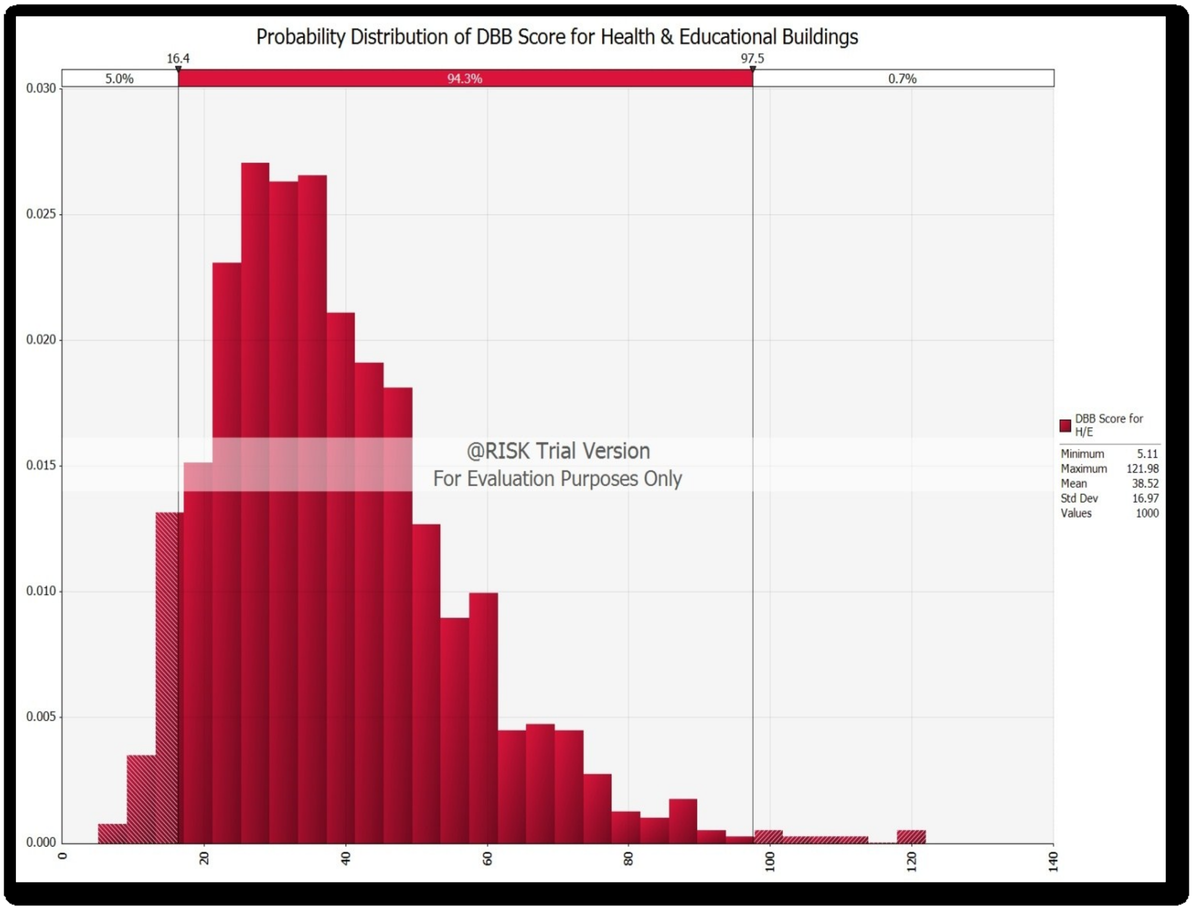
II. Suitability Index for DBB

The suitability index for each PDS is determined through summation of their weighted score with respect to each selection factor. As earlier stated, the suitability index is a sum product function of the importance weights and effectiveness values of each PDS option over the set of selection factors. The mathematical representation of this additive aggregation model is stated in equation 3.1.

Table 5.9 Weighted Scores corresponding to DBB in Health and Educational Buildings

	Weighted Score of Selection Factors attributed to DBB- Health and Educational Buildings													
	W.V-C1	W.V-C2	W.V-C3	W.V-C4	W.V-C5	W.V-C6	W.V-C7	W.V-C8	W.V-C9	W.V-C10	W.V-C11	W.V-C12	W.V-C13	W.V-C14
R1	18.475	6.006	3.105	2.930	2.930	3.003	16.490	5.267	4.494	9.449	5.422	5.176	15.528	1.725
R2	0.137	0.035	2.642	0.022	0.026	0.023	0.193	3.908	0.048	3.908	0.033	0.227	0.076	0.076
R3	2.974	0.033	0.015	0.011	0.021	0.021	9.604	6.121	14.398	2.690	0.034	0.371	5.063	4.842
R4	0.148	10.385	2.321	0.026	0.039	2.302	5.537	5.259	14.342	1.058	1.866	1.223	7.650	4.105
R5	6.914	0.043	4.434	0.048	0.047	2.840	1.434	4.530	8.202	1.957	0.573	8.964	7.769	12.929
R6	16.948	0.043	0.043	0.041	0.043	0.047	0.029	0.021	0.057	10.294	0.161	3.894	1.762	0.143
R7	0.070	0.097	0.094	8.239	6.448	6.210	0.132	6.036	15.898	3.848	0.038	0.067	0.019	0.016
R8	9.451	2.468	3.701	8.101	2.110	2.879	0.130	3.229	0.039	2.743	0.130	1.206	8.396	6.063
R9	0.174	0.031	15.688	2.507	1.559	2.785	0.026	7.028	0.137	0.794	0.026	2.424	0.121	0.121
R10	20.315	0.057	4.095	3.437	0.070	0.041	0.141	2.342	0.023	2.654	0.141	0.016	0.079	0.079
R11	11.757	0.039	0.147	0.030	1.472	0.023	0.114	2.159	0.030	25.747	1.883	0.016	0.044	0.083
R12	0.118	0.061	0.024	1.676	9.875	0.099	0.028	1.370	0.120	15.225	0.163	0.179	9.527	0.008
R13	0.217	0.073	2.693	1.008	4.270	1.468	3.030	3.030	13.661	1.251	13.661	0.578	6.605	6.605
R14	0.129	0.129	2.449	12.934	2.449	2.080	0.052	5.205	0.010	1.869	0.010	0.044	0.232	0.123
R15	0.077	0.215	2.655	7.698	2.655	0.016	0.096	3.430	0.034	1.779	0.018	0.052	0.155	0.155
R16	0.097	0.097	9.740	9.740	1.558	0.019	0.069	6.950	0.024	2.403	0.013	0.074	0.074	0.223
R17	0.062	0.115	11.980	6.307	3.082	0.029	0.088	9.567	0.021	14.045	0.088	0.098	0.024	0.024
R18	1.568	0.088	0.048	0.013	0.504	0.017	0.077	6.129	0.053	11.028	3.829	0.055	0.199	0.181
μ of best-fit	4.895	1.130	3.618	3.510	2.162	1.318	1.240	4.191	3.641	5.794	1.290	1.095	2.632	1.989
	Output (Agrregate Score)													38.505

Table 5.9 contains the weighted scores of the selection factors attributed to DBB for the health and educational buildings. The entry in each cell is resulted from multiplication of the selection factor's weight times the effectiveness value of DBB relative to that factor. The aggregate score is then calculated by adding up the mean values of the best fit distribution of the weighted scores across the 14 selection factors. As stated in the overview, the suitability index resulted from the individual-based assessment model is simulated using the @Risk analysis software trial version 5.7. By simulating the score with an iteration of 1000. The probability distribution of the suitability index for DBB is reflected in figure 5.10. The probability distribution indicates a value for the lower, the mean and the upper limits of the suitability index.



These values are as follows: Lower limit: 5.11, Mean: 38.5, Upper limit: 121.98. The mean value of the probability distribution is in fact the suitability index of the DBB project delivery system for health and educational buildings. After the SI values were simulated for the other PDS options, they were compared and the option with the highest mean value was selected as the most suitable option. The bar chart in figure 5.10 demonstrates that the aggregate score range between 20 and 40 has the highest probability density.

III. Suitability Index for DB

Table 5.10 contains the weighted scores of the selection factors relative to DB for the health and educational buildings. The suitability index probability distribution graph is displayed in figure 5.11. This graph is resulted by simulating the aggregate score of DB for H/E buildings as the risk output in @Risk analysis software.

Table 5.10 Weighted Scores corresponding to DB in Health and Educational Buildings

	Weighted Score of Selection Factors attributed to DB- Health and Educational Buildings													
	W.V-C1	W.V-C2	W.V-C3	W.V-C4	W.V-C5	W.V-C6	W.V-C7	W.V-C8	W.V-C9	W.V-C10	W.V-C11	W.V-C12	W.V-C13	W.V-C14
R1	12.933	6.006	3.105	2.930	2.930	3.003	14.841	5.267	4.494	9.449	4.880	5.176	13.976	1.725
R2	13.742	3.497	0.026	2.224	2.642	2.051	17.329	0.039	4.754	0.039	3.310	22.703	7.568	7.568
R3	0.037	2.666	1.186	1.066	1.871	1.871	0.120	2.448	5.759	0.034	3.399	18.526	3.544	2.421
R4	13.353	14.836	2.902	2.624	3.928	0.023	0.055	2.104	28.684	0.015	0.019	0.012	0.076	6.842
R5	13.828	3.035	0.044	3.866	4.728	0.057	0.014	0.075	0.117	0.049	1.290	11.205	0.078	16.161
R6	0.212	3.425	2.997	3.265	2.569	4.748	1.743	1.930	3.996	7.206	11.263	2.336	1.233	14.344
R7	7.049	9.671	9.395	0.082	0.064	0.062	10.590	0.060	0.159	1.539	2.666	6.022	1.505	1.587
R8	0.135	4.113	0.041	0.135	0.035	4.113	11.734	0.032	3.919	0.039	13.038	0.020	0.093	8.661
R9	10.459	3.117	10.459	0.028	0.031	0.028	2.327	0.070	13.674	0.008	2.583	0.024	12.121	12.121
R10	0.203	5.685	1.638	0.034	7.033	4.095	14.130	0.047	2.267	0.027	14.129	1.589	7.944	7.944
R11	0.147	3.909	14.696	2.995	0.016	2.328	11.437	0.022	2.974	0.257	3.138	1.564	4.414	8.308
R12	11.831	6.096	2.430	0.017	0.099	9.875	2.831	0.014	11.955	0.152	16.332	0.002	0.095	0.798
R13	21.688	7.313	2.693	1.008	4.270	3.913	3.030	3.030	10.625	1.112	12.143	0.578	7.338	6.605
R14	10.347	12.934	0.024	0.129	0.024	0.021	5.205	0.052	1.004	0.019	1.004	4.371	13.935	12.340
R15	4.619	21.495	0.027	0.077	0.027	1.610	9.580	0.034	3.430	0.018	1.779	4.136	15.510	15.510
R16	8.766	9.740	0.097	0.097	0.019	1.948	6.950	0.069	2.403	0.024	1.294	5.200	7.428	22.287
R17	3.733	11.545	0.120	0.063	0.031	2.865	8.807	0.096	2.137	0.140	8.779	9.778	2.444	2.444
R18	0.026	8.826	4.831	1.311	0.007	1.697	7.737	0.061	5.298	0.110	6.381	5.472	19.885	18.072
µ of best-fit	7.090	7.684	3.122	1.214	1.667	2.439	6.930	0.859	6.032	1.138	5.915	5.351	6.462	9.143
	Output (Agrregate Score)													65.045

According to the probability distribution chart in figure 5.11, the lower limit or the minimum value of the aggregate score is 15.87. The upper limit or the maximum value equals 172.47 and the mean value which is synonymous with the suitability index is 65.04. This value is the same as the output (aggregate score) calculated in table 5.10.

Figure 5.11 also indicates that while 90% of the suitability indices fall between 33.5 and 106.6, the highest probability density pertains to the score range between 40 and 80.

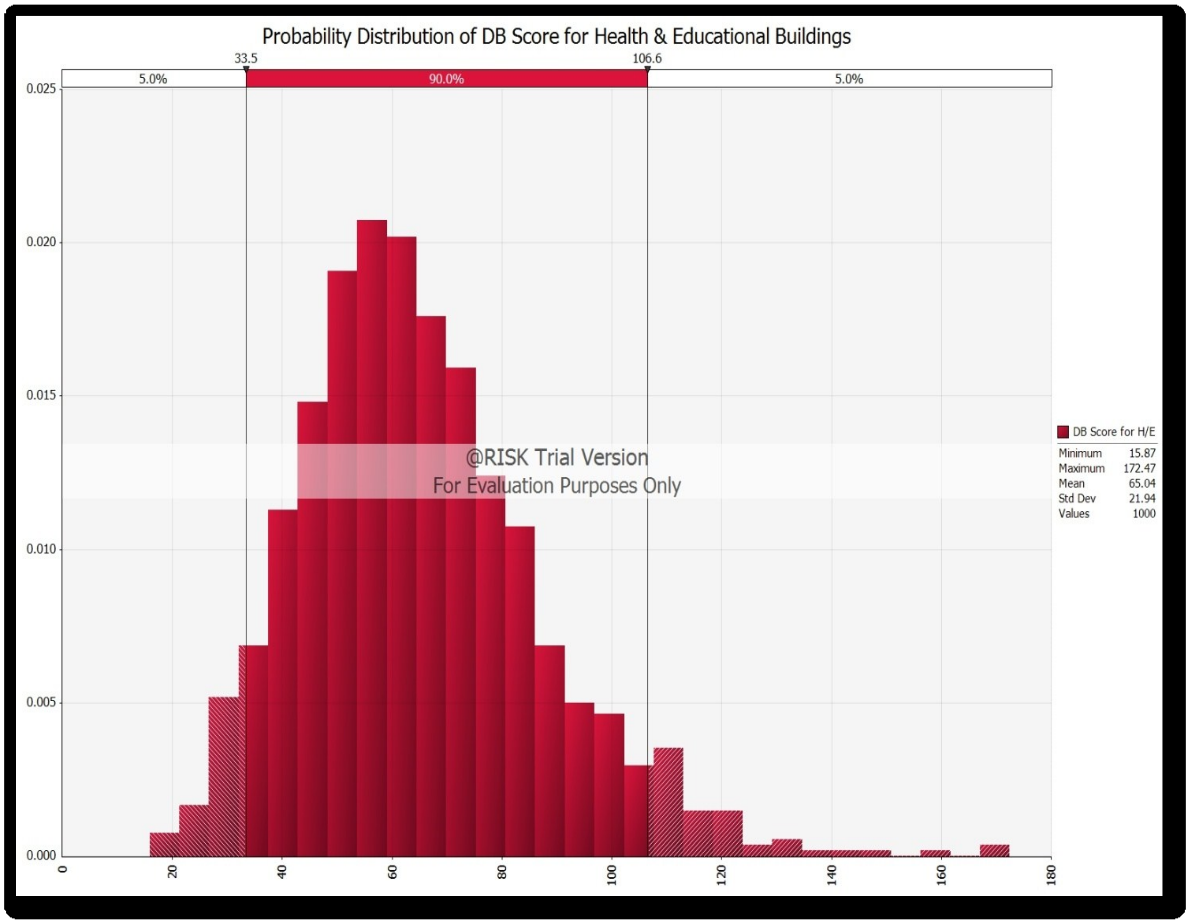


Figure 5.11 Probability Distribution of DB suitability Index for H/E buildings

V. Suitability Index for CM-R

The weighted scores for CM-R in health and educational building projects are captured in table 5.11. As the table demonstrates the suitability index of CM-R is 72.73 which is significantly higher than that of DBB and DB for this category of buildings. The probability distribution bar chart resulted from simulation of the CM-R aggregate score is displayed in figure 5.12. The probability distribution indicates that the lower and the upper limits of the suitability index equal to 29.28 and 141.68 respectively. The mean value of the probability distribution which indicates the suitability index for CM-R equals 72.73.

Table 5.11 Weighted Scores corresponding to CMR in Health and Educational Buildings

	Weighted Score of Selection Factors attributed to CMR- Health and Educational Buildings													
	W.V-C1	W.V-C2	W.V-C3	W.V-C4	W.V-C5	W.V-C6	W.V-C7	W.V-C8	W.V-C9	W.V-C10	W.V-C11	W.V-C12	W.V-C13	W.V-C14
R1	18.475	4.204	2.795	1.758	0.879	0.901	16.490	2.634	0.899	1.890	5.422	4.659	15.528	1.553
R2	12.368	3.147	0.528	1.780	2.378	2.278	19.255	2.736	4.279	2.345	2.648	18.162	5.297	6.054
R3	3.718	3.332	1.335	1.066	2.079	2.079	12.005	0.061	0.144	3.362	3.399	37.052	0.051	0.048
R4	14.836	0.148	0.029	1.837	2.357	1.381	3.876	0.053	0.287	1.511	1.306	0.856	2.295	0.068
R5	0.138	4.336	3.104	4.833	3.782	5.679	0.717	7.549	11.717	4.893	1.434	0.112	3.108	0.162
R6	21.185	4.281	4.281	4.081	4.281	2.374	2.905	2.144	5.709	0.103	16.091	0.039	0.018	8.607
R7	5.640	4.835	8.455	4.943	5.159	4.968	13.238	4.829	4.769	0.038	3.808	6.691	1.881	0.952
R8	13.501	0.041	4.113	13.501	3.517	0.041	13.038	2.584	3.527	3.919	7.823	2.010	9.329	0.087
R9	17.431	1.870	17.431	2.785	3.117	2.507	2.585	4.217	10.939	0.636	2.067	1.455	9.697	8.485
R10	16.252	5.116	0.041	1.718	3.516	3.276	11.304	4.685	2.040	1.327	11.303	1.271	7.149	7.149
R11	14.696	3.518	13.226	2.696	1.636	1.862	10.293	1.511	2.676	18.023	2.824	1.251	3.531	7.477
R12	8.281	4.877	1.944	1.341	7.900	6.912	2.265	1.233	9.564	9.135	13.065	0.143	6.669	0.559
R13	10.844	5.119	2.693	1.008	4.270	3.913	3.030	3.030	10.625	0.973	10.625	0.578	5.871	5.871
R14	12.934	9.054	1.959	10.347	2.204	1.872	4.684	4.684	0.602	1.495	0.903	1.748	23.224	7.404
R15	7.698	17.196	2.389	4.619	2.389	0.322	7.664	2.058	1.715	0.534	1.601	5.170	10.857	12.408
R16	9.740	8.766	6.818	8.766	1.948	0.584	6.255	4.865	1.922	0.961	1.165	7.429	5.200	17.829
R17	6.222	9.236	4.792	3.784	1.849	1.719	7.926	5.740	0.855	8.427	5.267	7.822	1.711	1.467
R18	2.614	7.944	4.348	0.918	0.720	1.358	6.190	4.290	4.238	7.719	5.743	4.378	13.919	16.264
μ of	10.745	5.344	4.441	4.002	2.999	2.441	7.960	3.249	4.236	3.749	5.370	5.770	6.850	5.575
best-fit	Output (Agrregate Score)													72.730

Figure 5.12 also indicates that the 90% confidence interval of the probability distribution accounts for the suitability indices ranging between 44.9 and 107.8. Yet, the highest probability density pertains to the score range between 60 and 80.

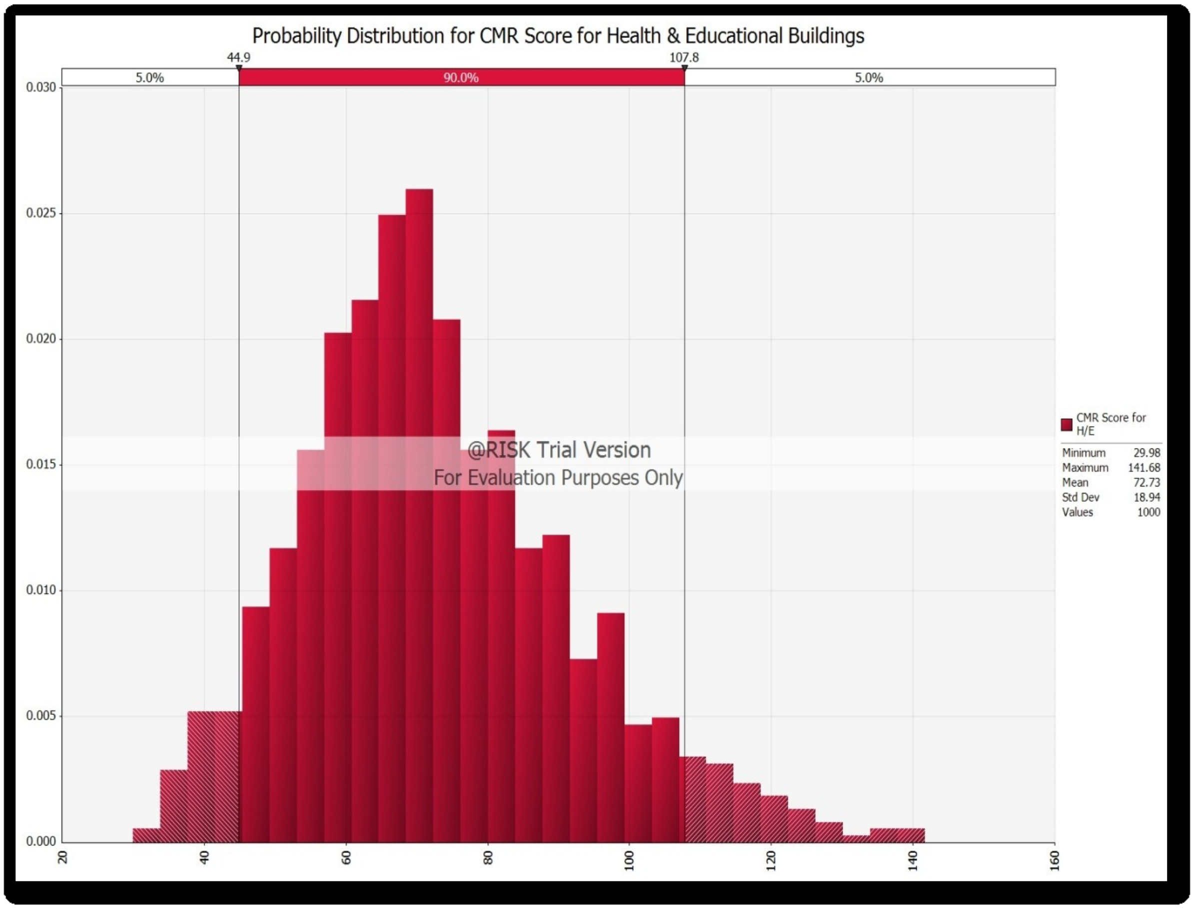


Figure 5.12 Probability Distribution of CMR suitability Index for H/E buildings

5.3.2 Analysis of the Suitability Indices based on the Simulation Results for H/E Buildings

Upon completion of the simulation, a suitability index summary trend is plotted. The plot demonstrates the trend of the suitability indices of the three PDS options as well as the probability of occurrence of a given SI over the range of output data (aggregate sore). This plot is a resourceful tool that could help the decision makers in identifying the most suitable PDS option at a glance. Figure 5.13 shows the aggregate score summary trend for the PDS's in health and educational building projects.

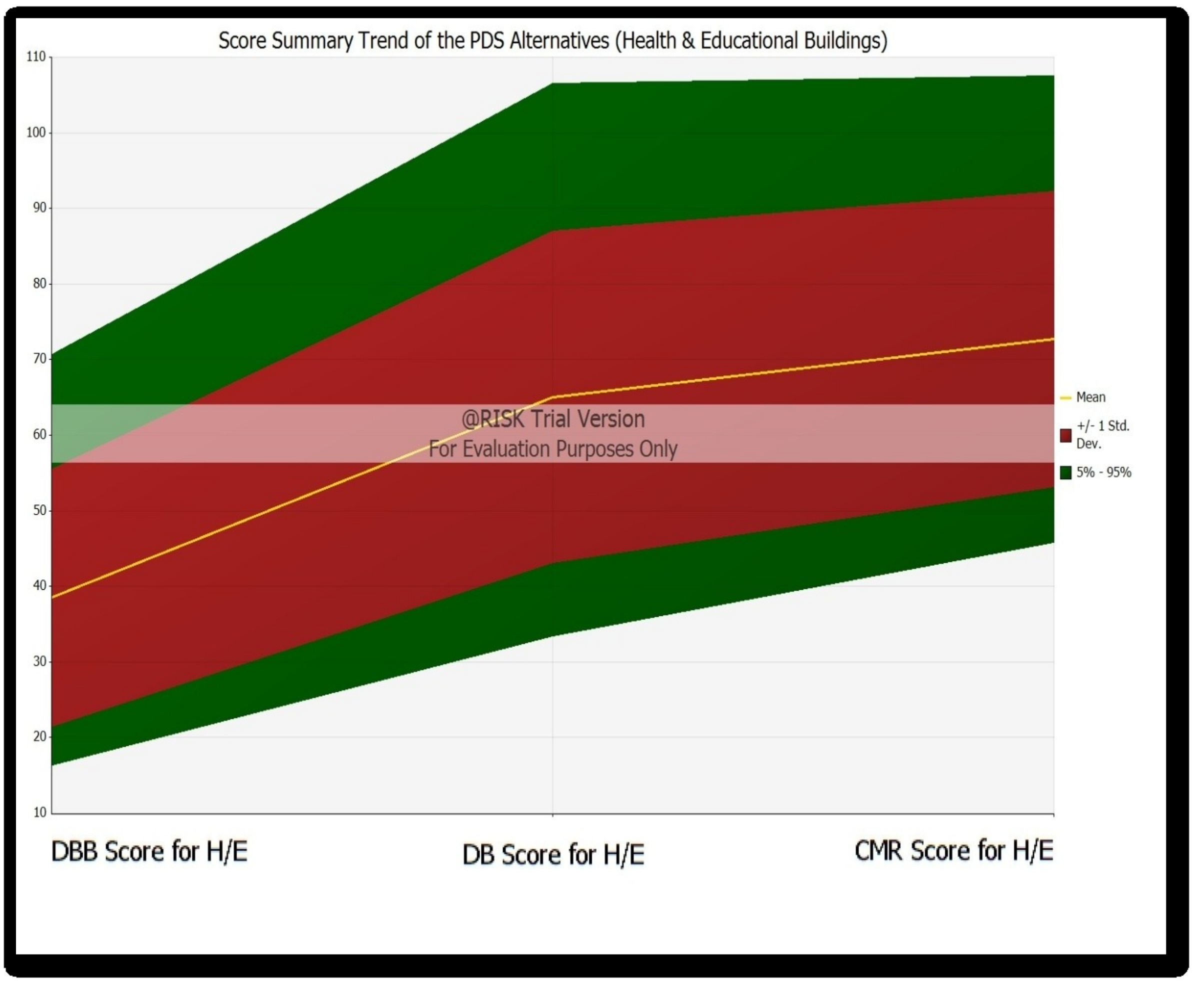


Figure 5.13 Summary Trend of the PDS Suitability Indices for H/E buildings

Figure 5.13 shows that CM-R has a higher probability density compared to DB and DBB. The narrow curve amidst the graph corresponds to the mean value of the suitability index. The area immediately to the top and bottom of the average curve indicate the score range with the highest probability. The very outer layers of the graph indicate the lower and upper limits of the probability distribution of the suitability indices. The final results reveal that CM-R, with the suitability index of 72.73, outperforms DB and DBB with the suitability indices of 65.04 and 38.5 respectively.

5.3.3 Sensitivity Analysis of the Suitability Indices for H/E Buildings

The sensitivity analysis was performed to determine the level of impact of each selection factor on the aggregate score (suitability index). This task was facilitated by the

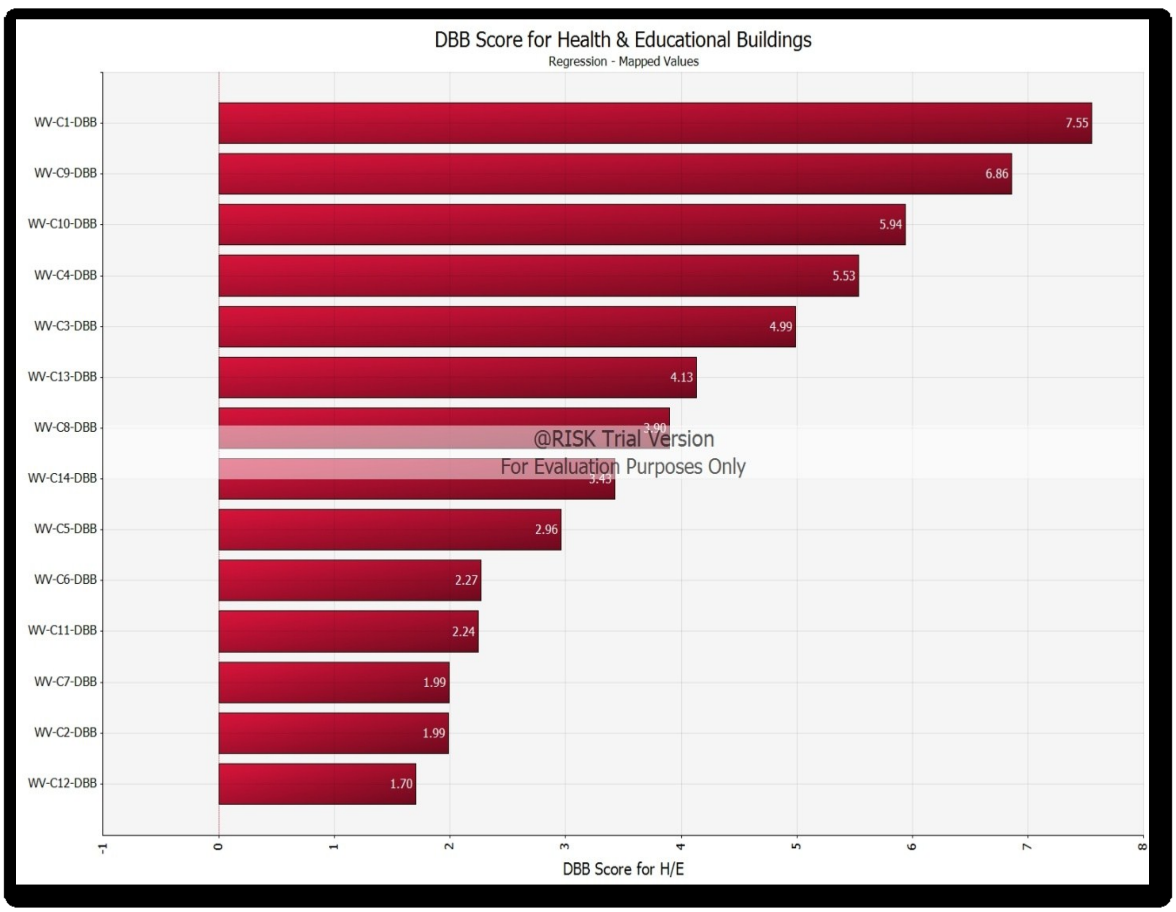


Figure 5.14 Sensitivity Analysis of DBB SI for H/E buildings

Regression Mapped Value Graph command in @Risk software. The resulted tornado graphs exhibit how much a change in an input (weighted score of the selection factors) can affect the bottom-line output (the suitability index). The X axis of the tornado graphs indicates the amount of change in the suitability index due to a +1 standard deviation change in each input.

Figure 5.14 illustrates the regression mapped value tornado graph for the DBB score. The graph has also ranked the selection factors in a descending order based on their level of impact on the suitability index of DBB.

Table 5.12 Ranking of Selection Factors based on their Impact on the SI of DBB (H/E Buildings)

Selection Factors Effect on DBB Suitability Index for H/E Buildings		
Rank	**Selection Factor**	**Change due to +1 σ**
1	Project Cost (C_1)	7.55
2	Scope Definition (C_9)	6.86
3	Agency's in-house Capacity (C_{10})	5.94
4	Confidentiality (C_4)	5.53
5	Turnover Quality (C_3)	4.99
6	Availability of Experienced Contractors (C_{13})	4.13
7	Responsibility and Involvement (C_8)	3.90
8	Availability of Resources and Material (C_{14})	3.43
9	Complexity (C_5)	2.96
10	Flexibility (C_6)	2.77
11	Constructability (C_{11})	2.24
12	Risk Allocation (C_7)	1.99
13	Construction Speed and Urgency (C_2)	1.99
14	Security Constraints and Political Impact (C_{12})	1.70

According to the analysis results, C_1 (project cost) has the highest impact on the suitability index of DBB option. This is followed by C_9 (scope definition) and C_{10} (agency's in-house capacity). The selection factors with the least impact are identified as C_7 (risk allocation), C_2 (construction speed & urgency) and C_{12} (security constraint & political impact). Table 5.12 shows the ranking of the entire set of selection factors.

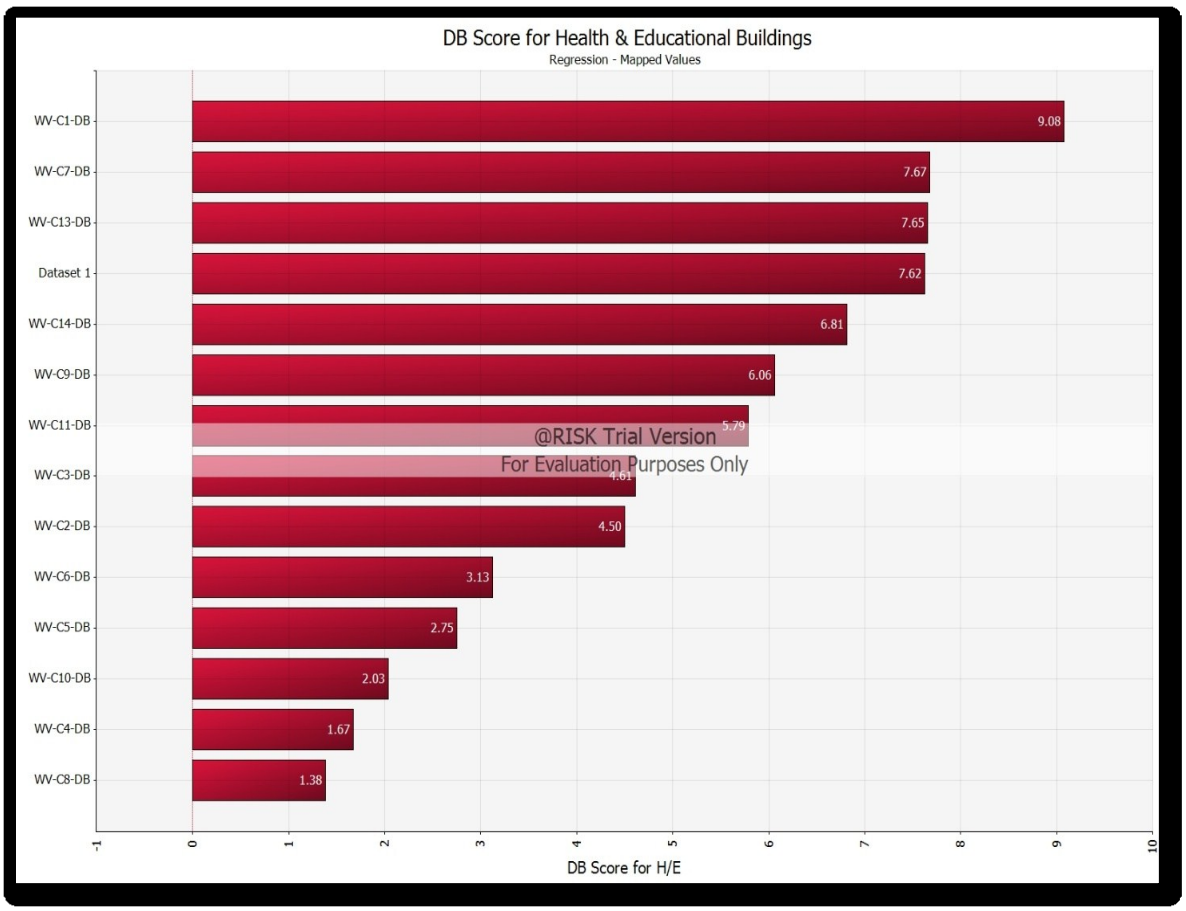


Figure 5.15 Sensitivity Analysis of DB SI for H/E buildings

Figure 5.15 illustrates the sensitivity analysis graph for the DB suitability index. The descending rank order of the selection factors reveals that C_1 (project cost) has the highest impact on the suitability index of DB option. This is followed by C_7 (risk allocation) and C_{13} (availability of experienced contractors). The selection factors with the least impacts are C_{10} (agency's in-house capacity), C_4 (confidentiality) and C_8 (responsibility & involvement). The selection factor ranking is provided in table 5.13. The selection factors' effect on SI decrease from top to bottom.

Table 5.13 Ranking of Selection Factors based on their Impact on the SI of DB (H/E Buildings)

Selection Factors Effect on Suitability Index of DB for H/E Buildings		
Rank	**Selection Factor**	**Change due to +1 σ**
1	Project Cost (C_1)	9.08
2	Risk Allocation (C_7)	7.67
3	Availability of Experienced Contractors (C_{13})	7.65
4	Security Constraints and Political Impact (C_{12})	7.62
5	Availability of Resources and Material (C_{14})	6.81
6	Scope Definition (C_9)	6.06
7	Constructability (C_{11})	5.79
8	Turnover Quality (C_3)	4.61
9	Construction Speed and Urgency (C_2)	4.50
10	Flexibility (C_6)	3.13
11	Complexity (C_5)	2.75
12	Agency's in-house Capacity (C_{10})	2.03
13	Confidentiality (C_4)	1.67
14	Responsibility and Involvement (C_8)	1.38

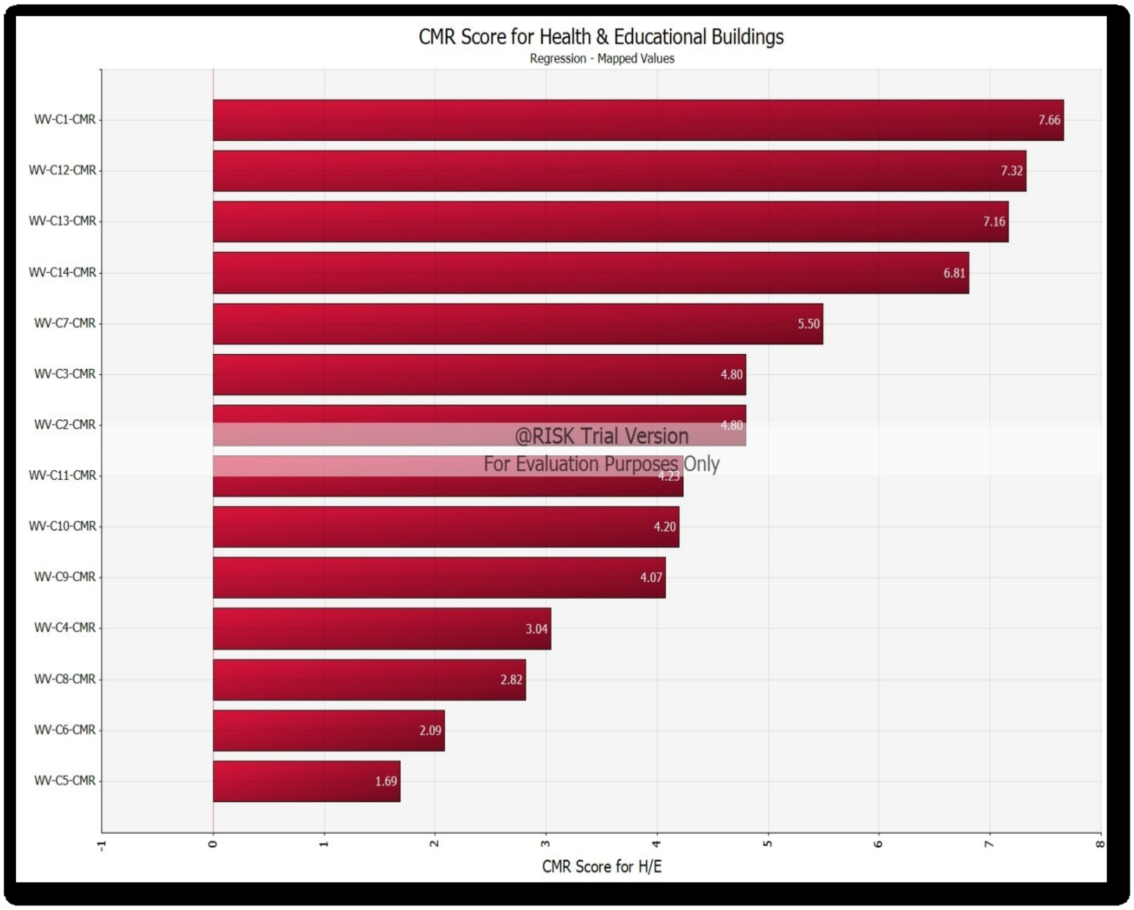


Figure 5.16 Sensitivity Analysis of CM-R SI for H/E buildings

The results of sensitivity analysis on the suitability index of CM-R reveal that C_1 (project cost), C_{12} (security constraints & political impact) and C_{13} (availability of experienced contractors) have the highest effect on the value of SI. Moreover, selection factors such as C_8 (responsibility & involvement), C_6 (flexibility) and C_5 (complexity) have the least effect on the suitability index of CM-R in health and educational building construction projects. The tornado chart in figure 5.16 displays the sensitivity analysis results pertaining to CM-R. Table 5.14 shows the ranking of selection factors based on the amount of change they inflict on the suitability of CM-R in the present category of project due to a +1 variation of standard deviation.

Table 5.14 Ranking of Selection Factors based on their Impact on the SI of CM-R (H/E Buildings)

Selection Factors Effect on Suitability Index of CM-R for H/E Buildings		
Rank	**Selection Factor**	**Change due to +1 σ**
1	Project Cost (C_1)	7.66
2	Security Constraints and Political Impact (C_{12})	7.32
3	Availability of Experienced Contractors (C_{13})	7.16
4	Availability of Resources and Material (C_{14})	6.81
5	Risk Allocation (C7)	5.50
6	Turnover Quality (C_3)	4.80
7	Construction Speed and Urgency (C_2)	4.80
8	Constructability (C_{11})	4.23
	Table 5.14 Continued	
9	Agency's in-house Capacity (C_{10})	4.20
10	Scope Definition (C_9)	4.07
11	Confidentiality (C_4)	3.04
12	Responsibility and Involvement (C_8)	2.82
13	Flexibility (C_6)	2.09
14	Complexity (C_5)	1.69

5.3.4 Office and Government Buildings

The results here forth stated pertain to the category of office and government building projects in post-conflict Afghanistan. Details on the location and the quantity of these projects are outlined in table 4.1.

I. Relative Importance Weights

Table 5.15 exhibits the relative importance weights of the selection factors for office and government buildings. The modality of extracting these weights and the properties of the table presented below are identical to those stated under the health and educational buildings category.

Table 5.16 contains the mean values of the best fit distributions for each of the 14 selection factors. The mean values are used to indicate the relative average weight of the selection factors. The best fit distributions and their mean values were obtained through @Risk analysis software.

Table 5.15 Relative Importance Weights of Selection Factors for O/G Buildings

Relative Importance Weight of Selection Criteria for Office and Government Buildings														
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
W-1	0.0321	0.1142	0.0606	0.0611	0.0611	0.0709	0.0573	0.0300	0.1557	0.1557	0.0138	0.0804	0.0804	0.0268
W-2	0.0628	0.0628	0.1212	0.0092	0.0092	0.0092	0.1550	0.0181	0.0355	0.0370	0.0191	0.3504	0.0664	0.0440
W-3	0.0525	0.0083	0.0525	0.0272	0.0525	0.0773	0.0358	0.1691	0.0134	0.0861	0.0469	0.2200	0.1169	0.0414
W-4	0.0550	0.0061	0.0192	0.0066	0.0153	0.0254	0.0900	0.0178	0.0185	0.2538	0.0185	0.0279	0.2230	0.2230
W-5	0.2049	0.0582	0.0559	0.0717	0.0369	0.0305	0.0187	0.0528	0.1004	0.1850	0.0568	0.0183	0.0549	0.0549
W-6	0.0866	0.0866	0.0200	0.0272	0.0250	0.0213	0.0180	0.0180	0.0558	0.1189	0.0558	0.0432	0.1364	0.2871
W-7	0.0530	0.0085	0.1037	0.0077	0.0258	0.0085	0.0508	0.1975	0.0172	0.1513	0.0122	0.2830	0.0404	0.0404
W-8	0.0335	0.0335	0.0670	0.1341	0.0168	0.1341	0.0635	0.0317	0.0635	0.1905	0.0317	0.0338	0.0775	0.0887
W-9	0.0131	0.0631	0.0422	0.0224	0.0037	0.0037	0.0287	0.1634	0.0942	0.1634	0.0118	0.0300	0.1802	0.1802
W-10	0.0220	0.0437	0.0868	0.0053	0.0053	0.0053	0.1880	0.0340	0.0340	0.0201	0.0940	0.3461	0.0577	0.0577
W-11	0.1797	0.0178	0.1691	0.0174	0.0264	0.0340	0.1053	0.0210	0.0079	0.0246	0.0079	0.0229	0.1830	0.1830
W-12	0.0534	0.0102	0.1135	0.0102	0.0102	0.0102	0.0827	0.1563	0.0269	0.0899	0.0129	0.3082	0.0385	0.0770
W-13	0.0313	0.1375	0.1991	0.0139	0.0670	0.0104	0.0291	0.1562	0.0129	0.1447	0.0867	0.0720	0.0255	0.0136
W-14	0.0543	0.0173	0.1257	0.0886	0.1643	0.0166	0.0679	0.0168	0.0679	0.0168	0.2355	0.0096	0.0760	0.0428
W-15	0.0454	0.1370	0.1558	0.0135	0.0145	0.0133	0.0472	0.0070	0.1040	0.0377	0.0449	0.0285	0.1265	0.2246
W-16	0.0335	0.0335	0.0670	0.1341	0.0168	0.1341	0.0635	0.0317	0.0635	0.1905	0.0317	0.0327	0.0594	0.1079
W-17	0.0900	0.0667	0.0323	0.0170	0.0328	0.0278	0.0180	0.0180	0.0818	0.0939	0.0551	0.0350	0.1555	0.2761
W-18	0.0149	0.0034	0.0060	0.0492	0.0492	0.0055	0.0358	0.1713	0.0159	0.1994	0.0358	0.3304	0.0434	0.0399

Judging by the average weights from table 5.16, selection factor C_{12} (security constraint & political impact) is the most significant factor with the relative average weight of 0.1268, followed by C_{10} (agency's in-house capacity) with the relative weight of 0.1188 and C_{14} (availability of resources & material) with the ARW of 0.1118.

These values reveal that the priority of selection factors in this category of buildings is slightly different than the health and educational building category. In the latter group, the three most significant selection factors were, in order of significance: C_1 (project cost), C_{14} (availability of resources & material), C_{13} (availability of experienced contractors).

Table 5.16 Average Relative Weights of Selection Factors for O/G Buildings

S.F.	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
A.R.W	0.0625	0.0503	0.0828	0.0400	0.0354	0.0357	0.0644	0.0729	0.0538	0.1188	0.0490	0.1268	0.0969	0.1118

II. Relative Effectiveness Values

Table 5.17 demonstrates the relative effectiveness values corresponding to DBB for O/G building category. The visual investigation of the REV's in table 5.17 reveals that DBB has received relatively low scores with respect to most selection factors with the exception of C8 (responsibility & involvement) and C_{10} (availability of in-house capacity). These observations are in line with the characteristics of the design-bid-build project delivery system. DBB requires maximal retention of responsibility by the agency and would subsequently call for a well-rounded capacity on the part of the agency (project owner). Table 5.18 demonstrates the RIV's for DB in O/G building project category. The visual inspection of table 5.18 reveals that DB has scored relatively higher than DBB with respect to the majority of the selection factors, particularly with regards to C_2 (construction speed & urgency), C_{11} (constructability), C_{13} (availability of experienced contractors) and C_{14} (availability of resources & material).

Table 5.17 Relative Effectiveness Values pertaining to DBB for O/G buildings

Relative Effectiveness Value for DBB- Office and Government Buildings														
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
V-DBB1	1	1	100	100	100	100	1	100	1	100	1	1	1	90
V-DBB2	70	1	100	1	1	60	100	100	80	90	1	70	100	60
V-DBB3	1	1	1	1	80	100	1	1	1	1	1	1	1	1
V-DBB4	70	1	100	100	100	100	1	100	1	100	100	100	100	1
V-DBB5	90	1	100	70	1	100	1	1	100	1	80	1	1	1
V-DBB6	100	1	100	80	1	1	1	90	100	100	100	70	1	1
V-DBB7	1	1	1	1	1	1	1	100	1	100	1	100	100	1
V-DBB8	90	1	1	1	1	1	100	1	1	100	60	1	1	1
V-DBB9	30	1	100	1	100	80	100	100	1	100	100	1	1	1
V-DBB10	1	1	90	100	100	100	1	1	1	1	1	1	1	1
V-DBB11	1	1	100	100	100	1	1	100	1	100	1	1	1	1
V-DBB12	30	1	100	1	100	60	1	100	60	70	100	70	100	60
V-DBB13	1	80	1	1	1	1	1	1	1	100	50	100	1	1
V-DBB14	1	80	1	100	1	10	1	1	100	90	1	70	90	100
V-DBB15	1	100	100	100	1	100	100	100	1	100	80	1	1	100
V-DBB16	1	40	1	1	1	1	1	100	100	100	1	1	1	1
V-DBB17	1	50	100	80	1	1	1	100	1	100	1	1	1	1
V-DBB18	1	1	80	90	1	80	90	100	1	90	1	100	90	100

Table 5.18 Relative Effectiveness Values pertaining to DB for O/G buildings

Relative Effectiveness Value for DB- Office and Government Buildings														
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
V-DBB1	80	100	1	1	1	1	100	1	100	1	100	80	100	90
V-DBB2	100	70	1	80	100	1	1	1	1	1	90	100	1	100
V-DBB3	90	100	100	100	1	1	100	100	100	100	90	100	90	100
V-DBB4	1	100	1	1	1	1	90	1	70	70	70	60	70	100
V-DBB5	1	100	1	1	100	1	90	90	1	100	100	100	100	100
V-DBB6	1	90	1	1	100	90	80	100	1	90	90	90	100	100
V-DBB7	80	90	80	80	60	100	100	1	70	70	70	70	60	100
V-DBB8	80	90	90	100	90	100	1	100	100	1	100	100	90	100
V-DBB9	100	50	1	60	1	1	1	1	100	1	90	100	100	100
V-DBB10	50	100	1	1	1	1	100	100	100	100	90	100	90	100
V-DBB11	80	100	1	1	1	100	100	1	100	1	100	90	100	100
V-DBB12	100	90	1	50	1	1	100	1	1	1	90	100	1	100
V-DBB13	50	1	100	70	80	100	50	100	100	1	1	1	100	100
V-DBB14	70	100	90	90	100	90	90	100	90	100	90	100	1	1
V-DBB15	100	1	1	1	100	1	1	1	100	10	1	90	100	1
V-DBB16	80	1	90	100	90	100	100	1	1	1	60	100	90	100
V-DBB17	80	1	1	1	100	90	100	1	100	1	90	100	100	80
V-DBB18	90	100	1	1	90	1	100	1	100	1	90	80	1	1

These observations are attributed to the fact that DB allows for fast tracking of the construction operation. The success of a DB delivery system is contingent upon availability of seasoned contractors. Also, given the possibility of phased construction, early procurement of material is a concern, therefore availability of material and resources should be taken into consideration before committing to a DB delivery system. Table 5.19 captures the RIV's corresponding to CMR. It is apparent from table 5.15 that CM-R has received better ratings compared to the other options for office and government building projects. Yet again the final decision is governed by the suitability indices derived based on the aggregation of the weighted scores.

Table 5.19 Relative Effectiveness Values pertaining to CMR for O/G buildings

Relative Effectiveness Value for CMR- Office and Government Buildings														
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
V-DBB1	100	90	60	40	70	80	90	60	90	70	100	100	80	80
V-DBB2	1	100	70	100	80	100	50	50	100	100	100	1	80	1
V-DBB3	100	90	90	50	100	40	90	30	70	40	100	60	100	90
V-DBB4	100	90	90	90	90	80	100	70	100	1	100	1	1	80
V-DBB5	90	90	90	100	90	90	100	100	90	90	90	90	90	90
V-DBB6	90	90	90	100	90	100	90	1	90	1	100	100	90	90
V-DBB7	100	100	100	100	100	70	90	80	100	1	100	1	1	70
V-DBB8	1	90	100	80	100	90	80	90	80	90	90	85	100	90
V-DBB9	1	100	90	100	80	100	90	70	50	60	100	20	90	80
V-DBB10	100	90	100	80	90	50	90	40	40	40	100	80	100	80
V-DBB11	100	70	80	70	50	30	90	30	70	40	90	100	80	80
V-DBB12	1	100	90	100	80	100	50	30	100	100	100	1	40	1
V-DBB13	100	100	80	100	100	50	100	50	80	60	100	90	90	90
V-DBB14	100	1	110	1	90	100	100	90	1	1	100	1	100	90
V-DBB15	90	100	90	60	60	20	50	50	90	40	100	100	80	70
V-DBB16	100	100	100	80	100	90	80	90	80	80	100	80	100	90
V-DBB17	100	100	90	100	90	100	90	90	90	90	100	90	90	100
V-DBB18	100	90	100	100	100	100	1	80	90	100	100	1	80	90

III. Suitability Index for DBB

Table 5.20 contains the weighted scores of the selection factors attributed to DBB for the office and government buildings. The aggregate score was calculated by summing the average values from the best fit distribution of the weighted scores. Figure 5.17 exhibits the probability distribution of the DBB suitability index as determined through simulation of the aggregate score. The probability distribution indicates a lower limit of 7.67, a Mean of 44.22 and an upper limit: 140.98. The mean value of the probability distribution is in effect the suitability index of the DBB project delivery system for office and government buildings. The chart in figure 5.17 demonstrates that the aggregate score range between 30 and 50 has the highest probability density.

Table 5.20 Weighted Scores corresponding to DBB in Office and Government Buildings

	Weighted Score of Selection Factors attributed to DBB- Office and Government Buildings													
	W.V-C1	W.V-C2	W.V-C3	W.V-C4	W.V-C5	W.V-C6	W.V-C7	W.V-C8	W.V-C9	W.V-C10	W.V-C11	W.V-C12	W.V-C13	W.V-C14
R1	0.032	0.114	6.057	6.112	6.112	7.086	0.057	3.003	0.156	15.566	0.014	0.080	0.080	2.411
R2	4.398	0.063	12.119	0.009	0.009	0.553	15.503	1.809	2.839	3.333	0.019	24.526	6.639	2.642
R3	0.053	0.008	0.053	0.027	4.201	7.730	0.036	0.169	0.013	0.086	0.047	0.220	0.117	0.041
R4	3.848	0.006	1.924	0.661	1.529	2.539	0.090	1.778	0.018	25.377	1.848	2.788	22.301	0.223
R5	18.445	0.058	5.590	5.016	0.037	3.054	0.019	0.053	10.042	0.185	4.544	0.018	0.055	0.055
R6	8.659	0.087	1.996	2.177	0.025	0.021	0.018	1.624	5.584	11.889	5.584	3.022	0.136	0.287
R7	0.053	0.008	0.104	0.008	0.026	0.008	0.051	19.751	0.017	15.132	0.012	28.304	4.043	0.040
R8	3.017	0.034	0.067	0.134	0.017	0.134	6.349	0.032	0.063	19.048	1.905	0.034	0.077	0.089
R9	0.393	0.063	4.216	0.022	0.367	0.294	2.870	16.342	0.094	16.342	1.177	0.030	0.180	0.180
R10	0.022	0.044	7.808	0.529	0.529	0.529	0.188	0.034	0.034	0.020	0.094	0.346	0.058	0.058
R11	0.180	0.018	16.910	1.740	2.643	0.034	0.105	2.099	0.008	2.455	0.008	0.023	0.183	0.183
R12	1.601	0.010	11.351	0.010	1.019	0.611	0.083	15.626	1.614	6.293	1.289	21.571	3.852	4.623
R13	0.031	11.004	0.199	0.014	0.067	0.010	0.029	0.156	0.013	14.475	4.333	7.204	0.026	0.014
R14	0.054	1.380	0.126	8.859	0.164	0.166	0.068	0.017	6.791	1.514	0.235	0.675	6.838	4.278
R15	0.045	13.701	15.577	1.348	0.015	1.334	4.724	0.702	0.104	3.773	3.594	0.028	0.126	22.460
R16	0.034	1.341	0.067	0.134	0.017	0.134	0.063	3.175	6.349	19.048	0.032	0.033	0.059	0.108
R17	0.090	3.337	3.234	1.359	0.033	0.028	0.018	1.796	0.082	9.387	0.055	0.035	0.155	0.276
R18	0.015	0.003	0.482	4.425	0.049	0.438	3.219	17.128	0.016	17.946	0.036	33.045	3.908	3.992
µ of best-fit	2.300	1.755	4.797	1.798	0.938	1.376	1.878	4.704	1.867	9.691	1.370	6.601	2.756	2.398
	Output (Agrregate Score)													44.229

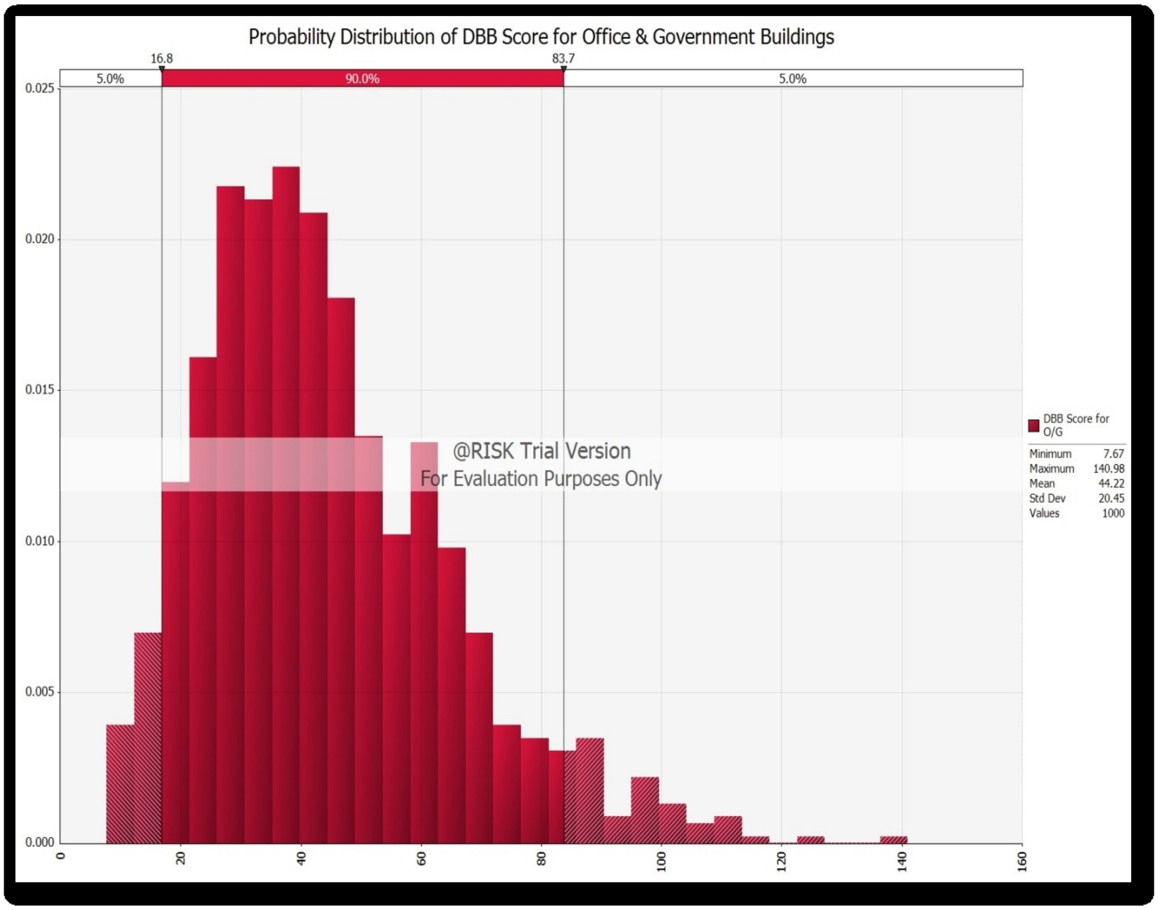


Figure 5.17 Probability Distribution of DBB suitability Index for O/G buildings

IV. Suitability Index for DB

Table 5.21 contains the weighted scores of the selection factors relative to DB for the office and government buildings. Figure 5.18 depicts the suitability index probability distribution graph. The graph is resulted by simulating the aggregate score of DB for O/G buildings as a risk output in @Risk analysis software. As per figure 5.18, the minimum value assumed for the aggregate score is 8.10. The maximum value equals 157.13 and the mean value that represents the suitability index is 62.36. The distribution mean value is the same as the output (aggregate score) calculated in table 5.21. According to figure 5.18, while 90% of the suitability indices fall between 29.4 and 102.4, the highest probability density pertains to the score range between 40 and 80.

Table 5.21 Weighted Scores corresponding to DB in Office and Government Buildings

	Weighted Score of Selection Factors attributed to DB- Office and Government Buildings													
	W.V-C1	W.V-C2	W.V-C3	W.V-C4	W.V-C5	W.V-C6	W.V-C7	W.V-C8	W.V-C9	W.V-C10	W.V-C11	W.V-C12	W.V-C13	W.V-C14
R1	2.571	11.419	0.061	0.061	0.061	0.071	5.734	0.030	15.566	0.156	1.381	6.429	8.036	2.411
R2	6.283	4.398	0.121	0.737	0.922	0.009	0.155	0.018	0.035	0.037	1.716	35.037	0.066	4.403
R3	4.726	0.828	5.251	2.715	0.053	0.077	3.582	16.914	1.339	8.608	4.222	22.005	10.523	4.141
R4	0.055	0.607	0.019	0.007	0.015	0.025	8.103	0.018	1.293	17.764	1.293	1.673	15.611	22.301
R5	0.205	5.815	0.056	0.072	3.693	0.031	1.686	4.751	0.100	18.505	5.679	1.830	5.489	5.489
R6	0.087	7.793	0.020	0.027	2.499	1.919	1.444	1.805	0.056	10.700	5.026	3.886	13.637	28.711
R7	4.242	0.764	8.294	0.613	1.546	0.849	5.081	0.198	1.202	10.593	0.852	19.813	2.426	4.043
R8	2.682	3.017	6.034	13.410	1.509	13.410	0.063	3.175	6.349	0.190	3.175	3.384	6.975	8.866
R9	1.310	3.156	0.042	1.342	0.004	0.004	0.029	0.163	9.422	0.163	1.059	3.003	18.018	18.018
R10	1.098	4.370	0.087	0.005	0.005	0.005	18.804	3.401	3.401	2.012	8.462	34.615	5.192	5.769
R11	14.373	1.785	0.169	0.017	0.026	3.401	10.532	0.021	0.790	0.025	0.790	2.059	18.301	18.301
R12	5.338	0.917	0.114	0.509	0.010	0.010	8.272	0.156	0.027	0.090	1.160	30.816	0.039	7.704
R13	1.565	0.138	19.909	0.976	5.361	1.036	1.455	15.619	1.292	0.145	0.087	0.072	2.552	1.356
R14	3.798	1.726	11.311	7.973	16.430	1.492	6.112	1.682	6.112	1.682	21.192	0.964	0.076	0.043
R15	4.544	0.137	0.156	0.013	1.450	0.013	0.047	0.007	10.398	0.377	0.045	2.564	12.648	0.225
R16	2.682	0.034	6.034	13.410	1.509	13.410	6.349	0.032	0.063	0.190	1.905	3.268	5.345	10.792
R17	7.202	0.067	0.032	0.017	3.278	2.502	1.796	0.018	8.176	0.094	4.962	3.503	15.550	22.091
R18	1.339	0.340	0.006	0.049	4.425	0.005	3.577	0.171	1.591	0.199	3.219	26.436	0.043	0.040
μ of best-fit	3.549	2.623	3.177	2.335	2.375	2.130	4.547	2.688	3.697	3.949	3.718	11.145	7.513	8.921
	Output (Agrregate Score)													62.366

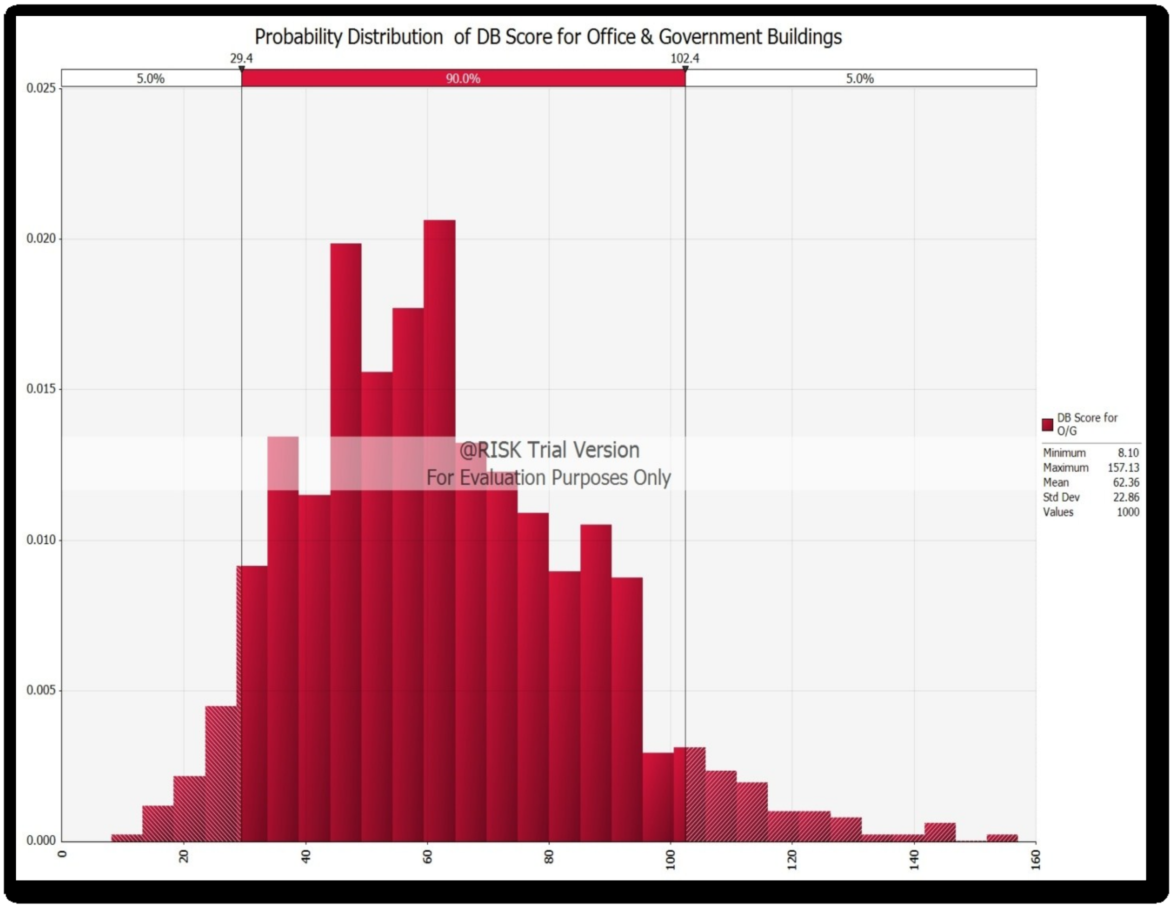


Figure 5.18 Probability Distribution of DB suitability Index for O/G buildings

V. Suitability Index for CM-R

The weighted scores for CM-R in office and government building projects are presented in table 5.22. The average value of the aggregate score probability distribution which represents the suitability index of CM-R reads as 71.31 which is significantly higher than DBB and DB for this category of buildings. The suitability index probability distribution bar chart is illustrated in figure 5.19. The chart indicates that the lower and the upper limits of the suitability index equal to 22.45 and 155.30 respectively.

Table 5.22 Weighted Scores corresponding to CMR in Office and Government Buildings

	Weighted Score of Selection Factors attributed to CMR- Office and Government Buildings													
	W.V-C1	W.V-C2	W.V-C3	W.V-C4	W.V-C5	W.V-C6	W.V-C7	W.V-C8	W.V-C9	W.V-C10	W.V-C11	W.V-C12	W.V-C13	W.V-C14
R1	3.214	10.277	3.634	2.445	4.278	5.669	5.161	1.802	14.009	10.896	1.381	8.036	6.429	2.143
R2	0.063	6.283	8.483	0.922	0.737	0.922	7.751	0.904	3.549	3.704	1.907	0.350	5.311	0.044
R3	5.251	0.746	4.726	1.358	5.251	3.092	3.224	5.074	0.938	3.443	4.691	13.203	11.692	3.727
R4	5.497	0.546	1.732	0.595	1.376	2.031	9.003	1.245	1.848	0.254	1.848	0.028	0.223	17.841
R5	18.445	5.234	5.031	7.166	3.324	2.749	1.874	5.279	9.038	16.654	5.111	1.647	4.940	4.940
R6	7.793	7.793	1.797	2.721	2.249	2.132	1.624	0.018	5.026	0.119	5.584	4.318	12.273	25.840
R7	5.303	0.849	10.368	0.766	2.576	0.594	4.573	15.801	1.718	0.151	1.217	0.283	0.040	2.830
R8	0.034	3.017	6.705	10.728	1.676	12.069	5.079	2.857	5.079	17.143	2.857	2.876	7.750	7.980
R9	0.013	6.312	3.795	2.236	0.294	0.367	2.583	11.440	4.711	9.805	1.177	0.601	16.216	14.414
R10	2.196	3.933	8.675	0.423	0.476	0.264	16.924	1.360	1.360	0.805	9.402	27.692	5.769	4.615
R11	17.966	1.249	13.528	1.218	1.321	1.020	9.479	0.630	0.553	0.982	0.711	2.288	14.641	14.641
R12	0.053	1.019	10.216	1.019	0.815	1.019	4.136	4.688	2.689	8.989	1.289	0.308	1.541	0.077
R13	3.130	13.755	15.927	1.394	6.701	0.518	2.911	7.810	1.033	8.685	8.667	6.483	2.296	1.220
R14	5.426	0.017	13.824	0.089	14.787	1.658	6.791	1.514	0.068	0.017	23.547	0.010	7.597	3.851
R15	4.090	13.701	14.019	0.809	0.870	0.267	2.362	0.351	9.359	1.509	4.493	2.849	10.118	15.722
R16	3.352	3.352	6.705	10.728	1.676	12.069	5.079	2.857	5.079	15.238	3.175	2.615	5.939	9.713
R17	9.002	6.674	2.911	1.699	2.950	2.780	1.616	1.616	7.358	8.448	5.513	3.152	13.995	27.613
R18	1.487	0.306	0.602	4.916	4.916	0.548	0.036	13.702	1.432	19.940	3.577	0.330	3.473	3.593
µ of best-fit	5.046	4.681	7.339	2.859	3.146	2.787	4.994	4.377	4.148	6.849	4.850	4.340	7.113	8.785
	Output (Agrregate Score)													71.313

Figure 5.19 also indicates that the 90% confidence interval of the probability distribution accounts for the suitability indices ranging between 40.8 and 108.5. However, the score range between 50 and 80 has the highest probability density.

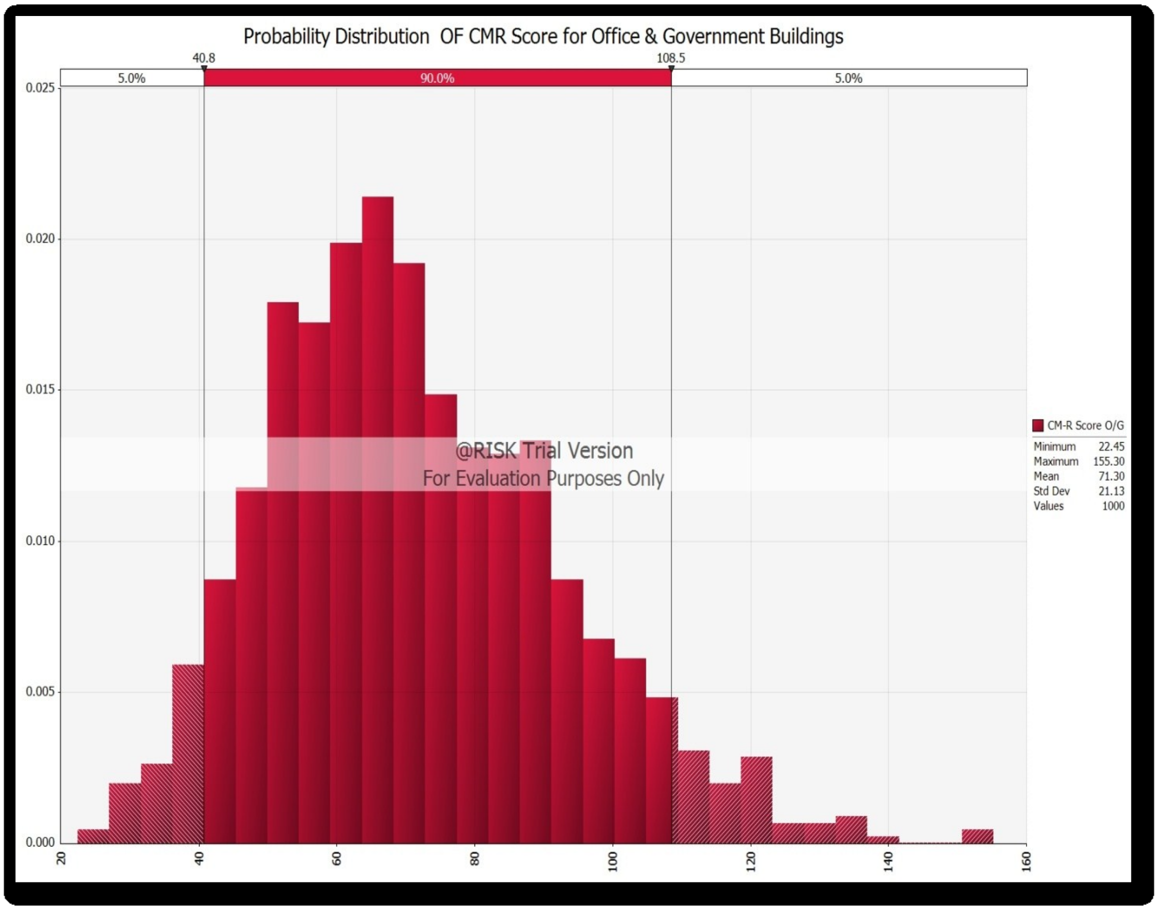


Figure 5.19 Probability Distribution of DB suitability Index for O/G buildings

5.3.5 Analysis of the Suitability Indices based on the Simulation Results for O/G Buildings

The suitability index summary trend in figure 5.20 demonstrates how the aggregate scores are plotted across the three PDS options. The figure indicates that CM-R has a higher probability density compared to DB and DBB. The narrow curve in the middle section of the graph trends the mean value of the suitability index. This curve signifies the suitability indices of the three options and could be used for visual demonstration of the most suitable PDS option. A comparison of the suitability indices reveal that CM-R with the SI of 71.31 outranks DB and DBB with the suitability indices of 62.36 and 44.22 respectively.

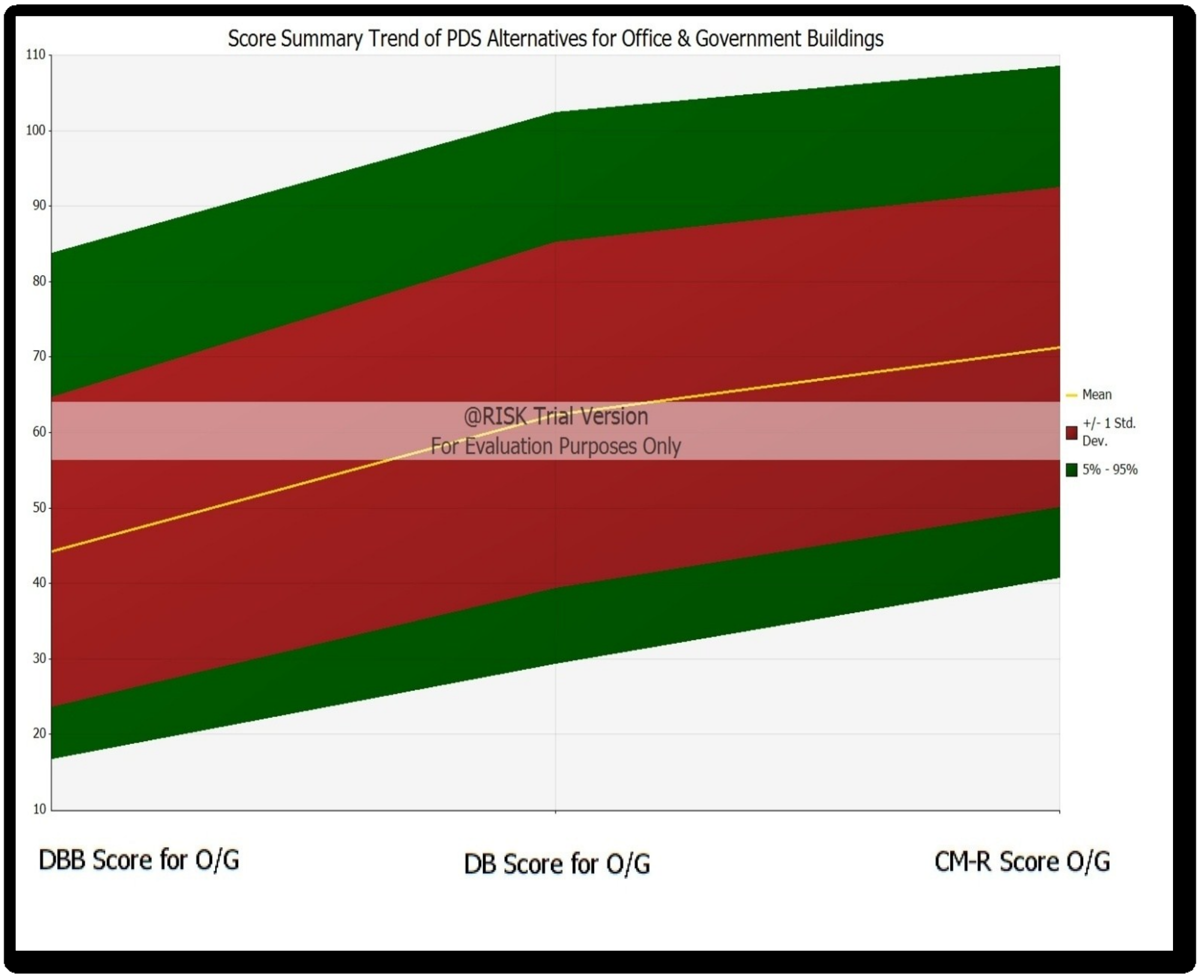


Figure 5.20 Summary Trend of the PDS Suitability Indices for O/G buildings

5.3.6 Sensitivity Analysis of the Suitability Indices for O/G buildings

The sensitivity analysis results allow for better understanding of the PDS's characteristics. Similar to the results reported under the H/E building category, sensitivity analysis was performed on the suitability indices of the PDS options to provide the decision makers with an opportunity to gain a better insight into the significance of the

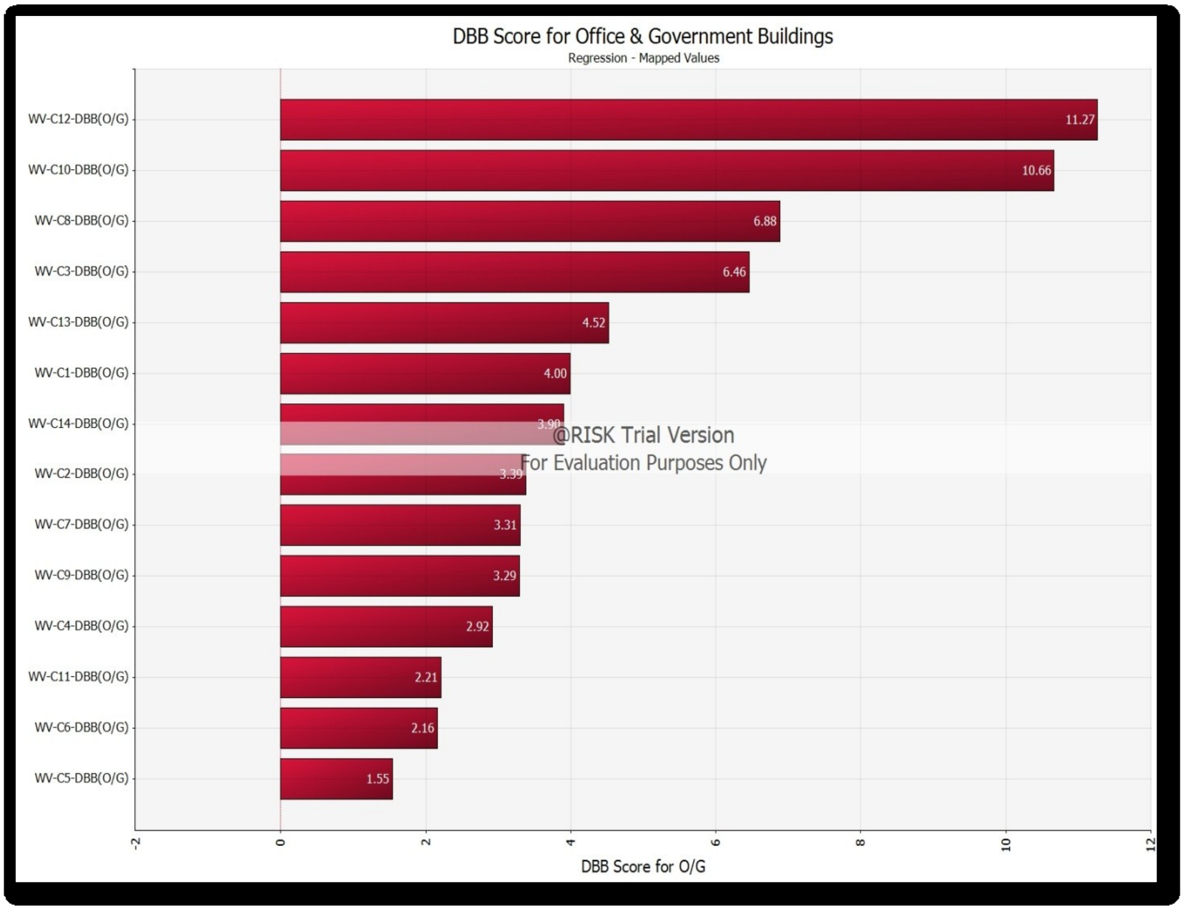


Figure 5.21 Sensitivity Analysis of DBB SI for O/G buildings

selection factors with respect to each PDS option in the case of office and government building projects. Figure 5.21 depicts the sensitivity results pertaining to DBB. In this chart the selection factors are ranked in a descending order based on their level of impact on the suitability index of DBB. The results reveal that, C_{12} (security constraint & political impact) has the most significant factor in determining the suitability index of DBB. Second most significant factor is C_{10} (agency's in-house capacity) followed by C_8

(responsibility & involvement). The selection factors least affecting the SI are identified as C_{11} (risk allocation), C_6 (flexibility) and C_5 (complexity). Table 5.23 presents the ranking of the entire selection factors with respect to the suitability index of DBB in O/G building projects. The sensitivity analysis results strongly corroborate with the realities of the construction projects in post-conflict. As an example, in O/G building projects, more significance is attached to selection factor C_{12} (security constraint & political impact) due to the fact that construction of office and government buildings has direct implications on the stability of the government, democratization process and security.

Table 5.23 Ranking of Selection Factors based on their Impact on the SI of DBB (O/G Buildings)

Selection Factors Effect on DBB Suitability Index for O/G Buildings		
Rank	**Selection Factor**	**Change due to +1**
1	Security Constraints and Political Impact (C_{12})	11.27
2	Agency's in-house Capacity (C_{10})	10.66
3	Responsibility and Involvement (C_8)	6.88
4	Turnover Quality (C_3)	6.46
5	Availability of Experienced Contractors (C_{13})	4.52
6	Project Cost (C_1)	4.00
7	Availability of Resources and Material (C_{14})	3.90
8	Construction Speed and Urgency (C_2)	3.39
9	Risk Allocation (C_7)	3.31
10	Scope Definition (C_9)	3.29
11	Confidentiality (C_4)	2.92
12	Constructability (C_{11})	2.21
13	Flexibility (C_6)	2.16
14	Complexity (C_5)	1.55

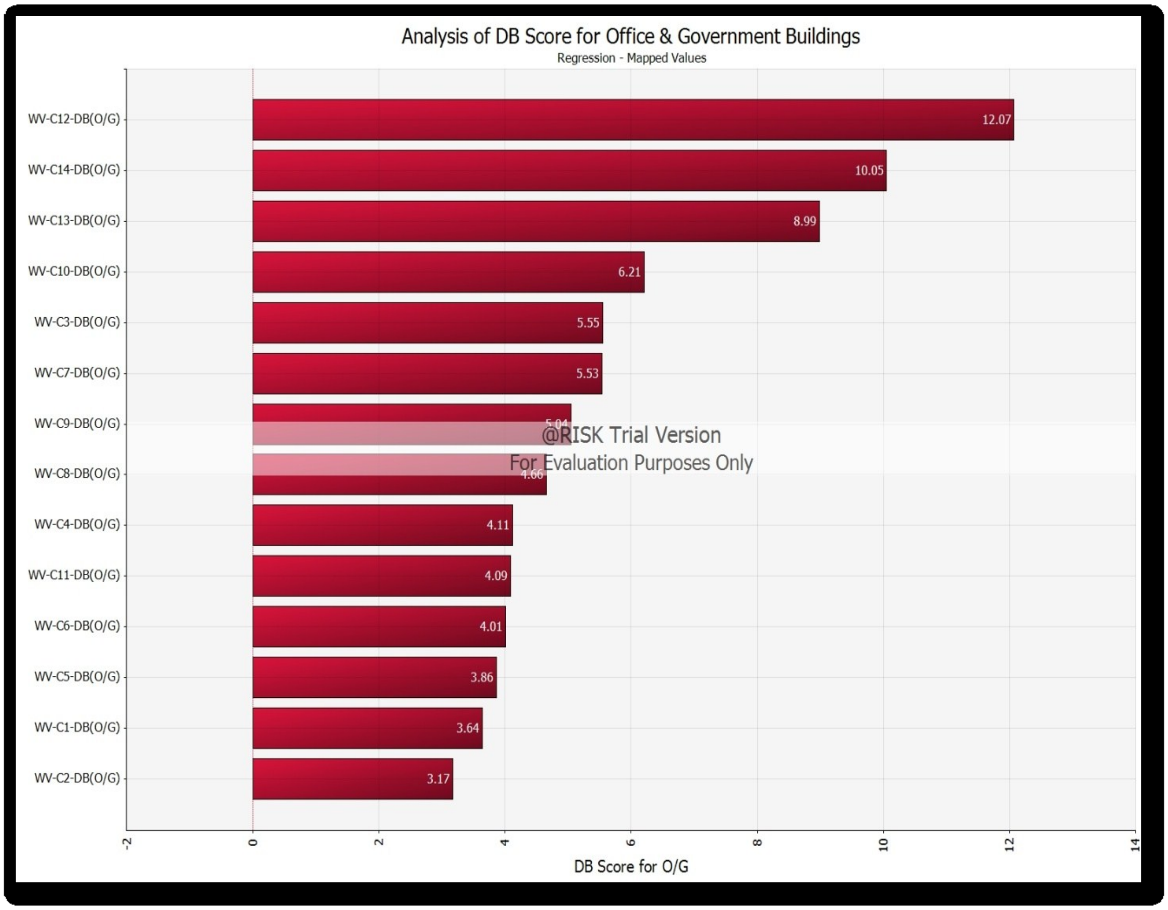


Figure 5.22 Sensitivity Analysis of DB SI for O/G buildings

Figure 5.22 displays the sensitivity analysis graph for DB. The ranking of the selection factors reveals that C_{12} (security constraint & political impact) has the highest impact on the suitability index of DB. This is followed by C_{14} (availability of resources & material) and C_{13} (availability of experienced contractors). The selection factors with the least impacts are C5 (complexity), C_1 (project cost) and C_2 (construction speed & urgency). Table 5.24 presents the ranking of the selection factor ranking in a descending order.

Table 5.24 Ranking of Selection Factors based on their Impact on the SI of DB (O/G Buildings)

Selection Factors Effect on Suitability Index of DB for O/G Buildings		
Rank	**Selection Factor**	**Change due to +1 σ**
1	Security Constraints and Political Impact (C_{12})	12.07
2	Availability of Resources and Material (C_{14})	10.05
3	Availability of Experienced Contractors (C_{13})	8.99
4	Agency's in-house Capacity (C_{10})	6.21
5	Turnover Quality (C_3)	5.55
6	Risk Allocation (C_7)	5.53
7	Scope Definition (C_9)	5.04
8	Responsibility and Involvement (C_8)	4.66
9	Confidentiality (C_4)	4.11
10	Constructability (C_{11})	4.09
11	Flexibility (C_6)	4.01
12	Complexity (C_5)	3.86
13	Project Cost (C_1)	3.64
14	Construction Speed and Urgency (C_2)	3.17

For CM-R, the sensitivity analysis results (figure 5.23) indicate that the selection factors with- the highest effect are C_{14} (availability of resources & material), C_{10} (availability of in-house capacity) and C_{13} (availability of experienced contractors). On the other hand, selection factors C_6 (flexibility), C_4 (confidentiality) and C_5 (complexity) have the least impact on the suitability index of CM-R in office and government building construction projects. Table 5.25 displays the ranking of selection factors based on their impact on the suitability of CM-R in office and government building projects.

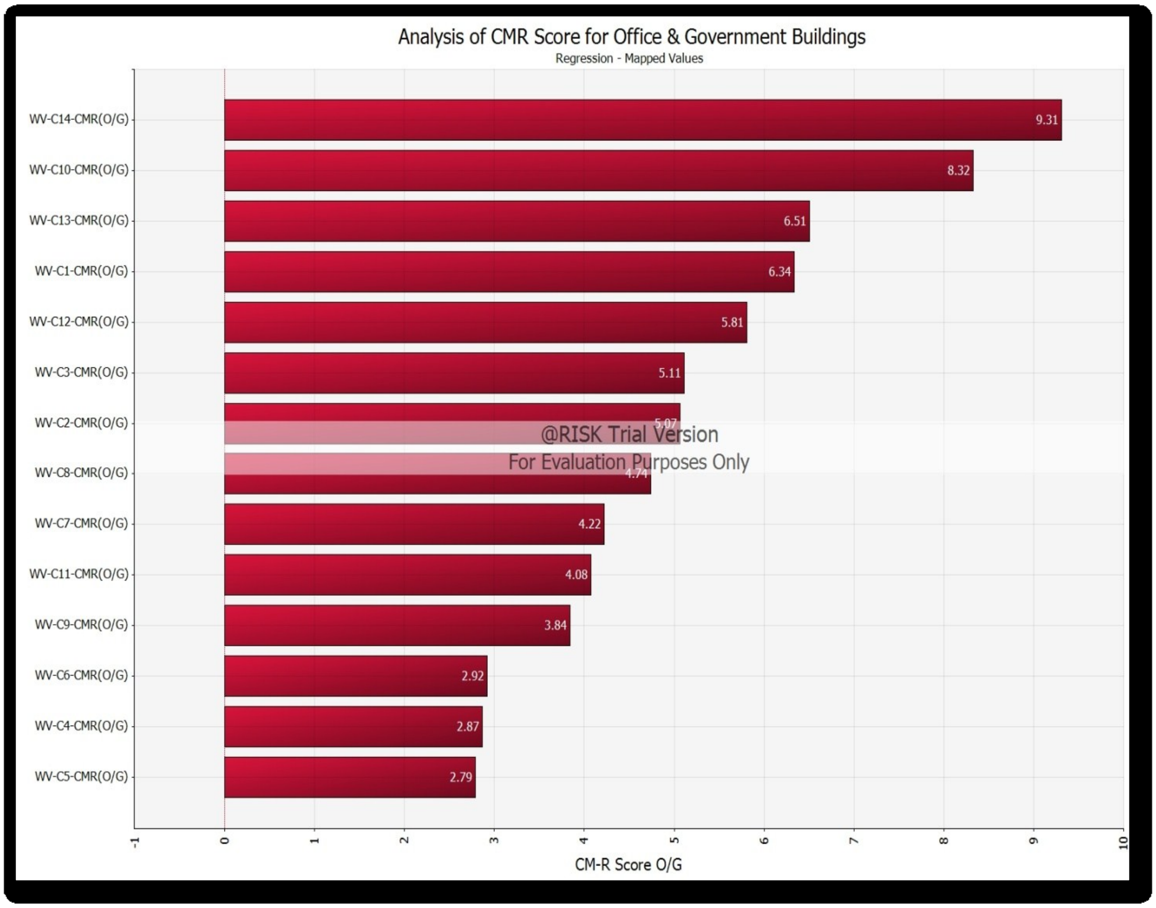


Figure 5.23 Sensitivity Analysis of CMR SI for O/G buildings

Table 5.25 Ranking of Selection Factors based on their Impact on the SI of CM-R (O/G Buildings)

Selection Factors Effect on CM-R Suitability Index for O/G Buildings		
Rank	Selection Factor	Change due to +1 σ
1	Availability of Resources and Material (C_{14})	9.31
2	Agency's in-house Capacity (C_{10})	8.32
3	Availability of Experienced Contractors (C_{13})	6.51
4	Project Cost (C_1)	6.34
5	Security Constraints and Political Impact (C_{12})	5.81
6	Turnover Quality (C_3)	5.11
7	Construction Speed and Urgency (C_2)	5.07
8	Responsibility and Involvement (C8)	4.74
9	Risk Allocation (C_7)	4.22
10	Constructability (C_{11})	4.08
11	Scope Definition (C_9)	3.84
12	Flexibility (C_6)	2.92
13	Confidentiality (C_4)	2.87
14	Complexity (C_5)	2.79

5.4 Comparison of the Results between H/E and O/G buildings

The suitability indices of the PDS options are compared between the two categories of building types. This information is presented in table 5.26. As the table demonstrates, CM-R is the most suitable PDS option for both project types. DB is the second most suitable while DBB has received the least suitability score.

Table 5.26 Comparison of the PDS Suitability Indices for O/G and H/E building types

Rank	PDS Option	SI for H/E buildings	SI for O/G
1	**CM-R**	72.73	71.31
2	**DB**	65.04	62.36
3	**DBB**	38.50	44.22

Table 5.27 provides a comparative view of the most and the least effective selection factors with respect to each PDS option for the two categories of case study projects.

Table 5.27 Comparison of the SI –Selection Factor Nexus

Health and Educational		**Office and Government**	
	DBB		
Most Effective	PC (C_1)	SCPI (C_{12})	**Most Effective**
	SD (C_9)	AIHC (C_{10})	
	AIHC (C_{10})	RI (C_8)	
Least Effective	RA (C_7)	CON (C_{11})	**Least Effective**
	CSU (C_2)	FLX (C_6)	
	SCPI (C_{12})	COM (C_5)	
	DB		
Most Effective	PC (C_1)	SCPI (C_{12})	**Most Effective**
	RA (C_7)	ARM (C_{14})	
	AEC (C_{13})	AEC (C_{13})	
Least Effective	AIHC (C_{10})	COM (C_5)	**Least Effective**
	CONF (C_4)	PC (C_1)	
	RI (C_8)	CSU(C_2)	

Table 5.27 Continued

Health and Educational		Office and Government	
CM-R			
Most Effective	PC (C_1)	ARM(C_{14})	**Most Effective**
	SCPI (C_{12})	AIHC (C_{10})	
	AEC (C_{13})	AEC (C_{13})	
Least Effective	RI (C_8)	FLX (C_6)	**Least Effective**
	FLX (C_6)	CON (C_4)	
	COM (C_5)	COM (C_5)	

5.5 Results from the Consensus-Based Assessment Model

The consensus-based assessment model relies on aggregation of judgements furnished by the panel of experts. This method is advantageous in that it guards against personal biases. Also, the results determined through this method are quite versatile since they reflect on the collective judgements of a larger, more diverse pool of respondents. The following section elaborates on the outcome of applying the consensus-based model. The data was collected from the same sample population as in the individual-based model. This model was conducted after completion of the former model; therefore the respondents were already familiar with the process. This proved very instrumental in procurement of data and consensus building. The results herein recorded pertain to a larger group of building projects and is applicable to the both categories of H/E and O/G buildings. This is partly due to the fact that the sample population was a conglomerate of practitioners from both categories of the case study projects who shared similar concerns and experience with respect to post-conflict rehabilitation endeavours.

5.5.1 Relative Importance Weights

Table 5.28 displays the importance weights of the selection factors computed through ANP. The values contained in this table are derived from the ANP comparison matrices. These matrices were constructed based on the group consensus judgements on the relative importance of the selection factors.

Table 5.28 Consensus-Based Relative Importance Weights

Consensus-Based Group Response		
No.	**SF**	**R.I.W**
C1	PC	0.1474
C2	CU	0.1474
C3	TQ	0.1021
C4	CONF	0.0256
C5	COM	0.0229
C6	FLX	0.0229
C7	RA	0.0747
C8	RI	0.0747
C9	SD	0.0139
C10	AIHC	0.0139
C11	CON	0.0122
C12	SCPI	0.0375
C13	AEC	0.1990
C14	ARM	0.1057
∑ Wi		1

A visual inspection of the relative importance weights reveals that selection factor C_{13} (availability of experienced contractors) has received the highest importance weight. Selection factors C_1 (project cost) and C_2 (construction speed & urgency) have jointly received the second highest importance weight, closely followed by C_9 (scope definition) and C_{10} (agency's in-house capacity) in the fourth place. Given that the importance weights are determined irrespective of any particular project, it may be surmised that availability of experienced contractors in post-conflict Afghanistan is a major concern considered by majority of decision makers.

5.5.2 Relative Effectiveness Values

The consensus-based relative effectiveness values of the PDS options are presented in table 5.29. These values have been determined through consensus according to the procedures described in section 5.2.4. Table 5.29 also contains the utility values of the PDS options relative to each selection factor. The methodology for obtaining the utility values has been expressed in full details earlier in this chapter (5.2.5)

Table 5.29 Consensus- Based Relative Effectiveness/ Utility Values

PDS Options					
DBB		DB		CM-R	
Effectiveness Value	Utility	Effectiveness Value	Utility	Effectiveness Value	Utility
1	0	50	0.49	100	1
1	0	100	1	60	0.59
100	1	1	0	70	0.69
100	1	1	0	50	0.49
100	1	1	0	50	0.49
100	1	1	0	60	0.59
1	0	60	0.59	100	1
100	1	1	0	50	0.49
1	0	100	1	30	0.29
100	1	1	0	50	0.49
1	0	100	1	50	0.49
1	0	100	1	70	0.69
1	0	100	1	60	0.59
1	0	100	1	50	0.49

The utility values suggest that on average basis, CM-R has received higher effectiveness value. DB and DBB are respectively second and third in terms of their average effectiveness value.

5.5.3 Consensus-Based suitability Indices of the PDS Options

In the consensus-based model, the suitability indices are determined based on an additive aggregation model. The suitability indices are in effect, the sum product function of the utility values and the relative importance weights of the selection factors. Table 5.30 displays the aggregation process and the suitability indices of the three PDS options.

Table 5.30 Aggregation of the Suitability Indices for the PDS Options

PDS Options														
Group Response			DBB				DB				CM-R			
No.	SF	R.I.W	R.E.V	Utility	$W(c_i).U(a_jc_i)$	$W(c_i).V(a_jc_i)$	R.E.V	Utility	$W(c_i).U(a_jc_i)$	$W(c_i).V(a_jc_i)$	R.E.V	Utility	$W(c_i).U(a_jc_i)$	$W(c_i).V(a_jc_i)$
1	PC	0.1474	1	0	0	0.147	50	0.49	0.072	7.3718	100	1	0.147	14.744
2	CU	0.1474	1	0	0	0.147	100	1	0.147	14.7436	60	0.59	0.087	8.846
3	TQ	0.1021	100	1	0.102	10.210	1	0	0	0.1021	70	0.69	0.070	7.147
4	CONF	0.0256	100	1	0.026	2.565	1	0	0	0.0256	50	0.49	0.013	1.282
5	COM	0.0229	100	1	0.023	2.285	1	0	0	0.0229	50	0.49	0.011	1.143
6	FLX	0.0229	100	1	0.023	2.285	1	0	0	0.0229	60	0.59	0.013	1.371
7	RA	0.0747	1	0	0	0.075	60	0.59	0.044	4.4809	100	1	0.075	7.468
8	RI	0.0747	100	1	0.075	7.468	1	0	0	0.0747	50	0.49	0.037	3.734
9	SD	0.0139	1	0	0	0.014	100	1	0.014	1.3930	30	0.29	0.004	0.418
10	AIHC	0.0139	100	1	0.014	1.393	1	0	0	0.0139	50	0.49	0.007	0.697
11	CON	0.0122	1	0	0	0.012	100	1	0.012	1.2228	50	0.49	0.006	0.611
12	SCPI	0.0375	1	0	0	0.037	100	1	0.037	3.7457	70	0.69	0.026	2.622
13	AEC	0.1990	1	0	0	0.199	100	1	0.199	19.9017	60	0.59	0.117	11.941
14	ARM	0.1057	1	0	0	0.106	100	1	0.106	10.5745	50	0.49	0.052	5.287
	∑ Wi	1	Score		0.262	26.945			0.632	63.696			0.665	67.312

5.5.4 Analysis of the Consensus- Based Suitability Indices

The bottom line results in table 5.30 indicate the aggregate scores of each PDS option. The results show that CM-R (SI= 0.66) outperforms DB (SI= 0.63) and DBB (0.26). Therefore based on the input provided by the respondents, the consensus-based model distinguishes CM-R as the most suitable project delivery system in post conflict construction projects in Afghanistan.

5.6 Comparison of the Outcomes of the Two Models and Testing

The results under each of the proposed models are compared to corroborate the outcomes and establish that these decision tools could be applied beyond the perimeter formed by the case study projects. The proposed models were also subjected to testing to confirm their utility and applicability. A fraction of the sample population was asked to apply the proposed models to a number of upcoming projects. This was aimed at confirming the utility of the models by comparing the choice of PDS suggested by the models to the ones intuitively favoured by the respondents prior to their engagement in this exercise. The testing result indicated a 100% match.

5.7 Results Summary

Table 5.31 provides a comparative view of the suitability indices gathered from the two models proposed in this research. As the results show, both models have flagged CM-R as the most suitable project delivery system.

Table 5.31 Suitability Indices Results Summary

	SI from the Individual-Based Assessment Model		**SI from the Consensus-Based Assessment Model**	
PDS Options	**Health and Educational Buildings**	**Office and Government Buildings**	**Based on Utility Functions**	**Based on Value Functions**
DBB	**38.50**	**44.22**	**0.26**	**26.94**
DB	**65.04**	**62.36**	**0.63**	**63.69**
CM-R	**72.73**	**71.31**	**0.66**	**67.31**

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary and Conclusions

Studies show that the choice of project delivery system has a direct impact on the outcome of the project. The literature review reveals that there has been no structured framework designed for the selection of project delivery systems in post-conflict construction projects. A careful review of the construction efforts in post-conflict indicates that decisions are merely based upon preconceived advantages and disadvantages of each PDS. In many cases, project owners and development agencies resort to informal procedures in selecting a project delivery approach. There is an oversimplification of the decision making process in such a way that conclusions are often drawn in absence of careful review, without consideration of alternatives or all the determinant factors.

The overall objective of this research was to develop a well-rounded framework for rational and structured selection of the most suitable project delivery system in post-conflict construction projects. This objective was secured through establishing a customized methodology for identifying the most pertinent selection factors in post-conflict projects and prioritizing them in relation to the properties of the applicable PDS options. As a result, a multi criteria decision making model was designed to help development agencies in choosing the project delivery system that is best suited to their projects on the basis of project objectives, priorities and specific agency and location conditions. The model development was pursued through aggregating the preferences of a broad sample of experienced practitioners through survey and structured interviews.

The results of this research were sufficient to warrant the conclusion that:

- The results obtained from execution of the two proposed models are unanimous and consistent,
- The proposed models are effective in securing objective, well-informed decisions concerning PDS selection,
- The methodology employed in this research will enhance the decision maker’s understating of the multi criteria decision making problem,
- The proposed methodology, emphasizes on consideration of the selection factors and their relation with the PDS options to garner a logical solution for PDS selection,
- CM-R is a comparatively more attractive PDS option for construction of health/educational and office/government projects in post-conflict Afghanistan.
- DB is more accommodating than DBB for construction of health/educational and office/government projects in post-conflict Afghanistan.
- Project cost, security constraints and political impact and availability of experienced contractors are the three most significant selection factors affecting the suitability index of CM-R in H/E building projects.
- Availability of resources and material, agency’s in-house capacity and availability of experienced contractors are the factors with highest impact on the suitability index of CM-R for O/G building projects.

- Application of the individual-based model will enable decision makers to gain a better insight into the level of importance their selection criteria.

6.2 Contributions

The novelty of this research lies in its innovative approach in bringing some degree of objectivity to an otherwise subjective area of construction management. The most considerable contribution of this research is the simplistic yet sophisticated methodology devised to select a suitable PDS in post-conflict construction projects. Other contributions could be categorized as follows:

- Developing a methodology for identification of the most pertinent selection factors in post-conflict construction projects.
- Developing a list of most important selection factors in post-conflict construction projects and defining their performance measures.
- Developing an innovative mixed-method approach to determine the suitability indices of the PDS options.
- Ranking the selection factors for the two categories of case study projects based on their influence on the suitability indices of the PDS options.
- Provision of two project delivery system selection models based on a unique quantification approach.

6.3 Limitations

This research was developed to address a basic yet fundamental gap in post-conflict construction projects. However, the model was designed using the data collected from post-conflict practitioners in Afghanistan alone. The sample population who participated in this research was not randomly selected. However, the diverse background and extensive experience of the participants in conjunction with their sizable number minimized the impact of biased outcomes.

Also, the data collected in this research only correspond to two categories of buildings and does not cover major capital projects. As such, the applicability of the model to certain infrastructures is subject to testing.

Moreover, in the ANP model, assumptions were made in determining the dependence between selection factors. The assumption was such that only the main criteria were deemed as interdependent. In other words, only the top level criteria were assumed to be dependent and the dependencies between the selection factors (sub-criteria) were taken out of consideration. This assumption was made only to facilitate execution of the ANP model and to avert confusion and frustration on the part of respondents.

6.4 Recommendations for Future Research

The PDS selection models proposed in this research have the potential of being adopted as standard practice tools by the development agencies involved in post-conflict rehabilitation in Afghanistan. The following recommendations are made to improve the present work and also to build on its potentials for future research:

Areas of Improvement:

- To fully exploit the potentials of the ANP model, assumption of dependence amongst the sub-criteria within and beyond each sub-criteria cluster should be incorporated- this will enhance the quality of judgments on the relative importance weights of the selection factors,

- Other methods of quantification can be used to obtain the relative effectiveness values,
- In the consensus-based model, the utility values were determined via linear interpolation; this could be revised in the future through application of the standard gambling technique as explained in chapter V.

Extension of Current Work:

- The models should be further developed and extended to suit the particular conditions of other post-conflict countries,
- It is also recommended to customize the models to meet the requirements of construction efforts in disaster relief projects by identifying disaster relief specific selection factors,
- As discussed in chapter II, the PDS options selected for evaluation in this research are mainly suited for public funded construction projects. The proposed models could be modified to accommodate other types of project delivery system particularly those that accommodate public-private-partnership.

REFERENCES

Affleck, R. T., and Freeman, R. (2010). *Challenges for engineering design, construction, and maintenance of infrastructure in afghanistan.* (Special Report 10-2 No. EDRC/CRREL SR-10-2). Washington DC: US Army Corps of Engineers.

Airport Owner's guide to Project delivery system (Oct, 2006), prepared by the joint committee of ACI-NA, ACC and AGC, [Online] Available at http://www.acconline.org [Retrieved May 1, 2011].

Al Khalil, M. I. (2002). Selecting the appropriate project delivery method using AHP. *International Journal of Project Management, 20*(6), 469-474.

Alhazmi, T., and McCaffer, R. (2000). Project procurement system selection model. *Journal of Construction Engineering and Management, 126*(3), 176-184.

Almazroa, D. A. (2004). *Project delivery system decision frameworks using the weighting factors and analytic hierarchy process methods.* University of Pittsburgh). *ProQuest Dissertations and Theses*, 205 p. http://search.proquest.com/docview/305147176?accountid=10246

Ang, AH-S. , Tang, WH. ; *Probability Concepts in Engineering Planning and Design*, Vol. 2 John Wiley and Sons, New York (1984).

Associated General Contractors of America (2004). *Project Delivery Systems for Construction*, Washington DC.

Banwell, H. (1964) *The Placing and Management of Contracts for Building and Civil Engineering work*, A report of the Committee under the chairmanship of Sir Harold Banwell, HMSO, London.

Barfield, T., (2010), *Afghanistan: A Cultural and Political History*. Princeton University Press, Princeton.

Beard, J. L., Loulakis, M. C., and Wundram, E. C. (2001). *Design-build: Planning through development* McGraw-Hill Professional.

Belton V, Steward T. (2002). *Multiple criteria decision analysis: An integrated approach*. Boston (MA), USA: Kluwer.

Bennett, J. and Flanagan, R. (1983). For the good of the client. *Building*, 1 April, 26-27.

Borcherding, K., Eppel, T., and Von Winterfeldt, D. (1991). Comparison of weighting judgements in multiattribute utility measurement. *Management Science,* , 1603-1619.

Bowers, D. D., (2001). "*Integrated Project Delivery and Contract Strategy Options.*" M.S. Thesis, Dept. Of Civ. Engrg, Texas A and M University, College Station, TX.

Bu-Qammaz, A. S. (2007). *Risk Assessment of International Construction Projects using the Analytic Network Process,* Canadian Journal of Civil Engineering, 36(7): 1170-1181.

Chan, A. P. C., Scott, D., and Lam, E. W. M. (2002). Framework of success criteria for design/build projects. *Journal of Management in Engineering, 18*, 120.

Chan, C. T. W. (2007). Fuzzy procurement selection model for construction projects. *Construction Management and Economics, 25*(6), 611-618.

Chang, C. Y., and Ive, G. (2002). Rethinking the multi-attribute utility approach based procurement route selection technique. *Construction Management and Economics, 20*(3), 275-284.

Chen, Z., Li, H., and Wong, C. T. C. (2005). EnvironalPlanning: Analytic network process model for environmentally conscious construction planning. *Journal of Construction Engineering and Management, 131*, 92.

Cheng, E. W. L., and Li, H. (2004). Contractor selection using the analytic network process. *Construction Management and Economics, 22*(10), 1021-1032.

Cheng, E. W. L., Li, H., and Yu, L. (2005). The analytic network process (ANP) approach to location selection: A shopping mall illustration. *Construction Innovation: Information, Process, Management, 5*(2), 83-97.

Cheung, S. O., Lam, T. I., Wan, Y. W., and Lam, K. C. (2001). Improving objectivity in procurement selection. *Journal of Management in Engineering, 17*, 132.

Cheung, S. O., Ng, T. S. T., Wong, S. P., and Suen, H. C. H. (2003). Behavioral aspects in construction partnering. *International Journal of Project Management, 21*(5), 333-343.

Construction Industry Institute (1997). "Project Delivery Systems: CM at Risk, Design-build, Design-bid-build", Executive Summary, RS133-1, Construction Industry Institute, Austin, TX.

Construction Round Table (1995). *Thinking about Building, The Business Round Table*, London.

Dagdeviren, M., Eraslan, E., Kurt, M., and Dizdar, E. (2005). An alternative approach for supplier selection problem with analytical network process. *Technology Journal, 8*(2), 115-122.

Danert, K., Carter, R. C., Rwamwanja, R., Ssebalu, J., Carr, G., and Kane, D. (2003). The private sector in rural water and sanitation services in Uganda: Understanding the context and developing support strategies. *Journal of International Development, 15*(8), 1099-1114.

Davies, P. T. (2004). Is evidence-based government possible? Jerry lee lecture. *Fourth Annual Campbell Collaboration Colloquium, Washington, DC, 18–20 February 2004.,*

De Silva, A. (2002). *A Model for Optimizing the Selection of Project Delivery Systems using Analytic Hierarchy Process (AHP),*

Dell'Isola, M., Licameli, J., and Arnold, C. (1998). How to form a decision matrix for selecting a project delivery system. *Design-Build Strategies, 4*(2)

Diderich, J. (2007), The challenges of rebuilding Afghanistan. *The Maple Leaf*, 10(38).

Dikmen, I., Birgonul, M. T., and Gur, A. K. (2007a). A case-based decision support tool for bid mark-up estimation of international construction projects. *Automation in Construction, 17*(1), 30-44.

Dikmen, I., Birgonul, M. T., and Han, S. (2007b). Using fuzzy risk assessment to rate cost overrun risk in international construction projects. *International Journal of Project Management, 25*(5), 494-505.

Dyer, J. (2005). MAUT—Multiattribute utility theory. *Multiple Criteria Decision Analysis: State of the Art Surveys,* , 265-292.

Eccles, S., O.Reilly, M. and Stovin, V. (1997). Numerical modeling of contract strategy evaluation, *ARCOM 1997 Conference Proceedings, Cambridge, Association Researchers in Construction Management*, Cambridge, 103-111.

Edwards, W., and Barron, F. H. (1994). SMARTS and SMARTER: Improved simple methods for multi-attribute utility measurement. *Organizational Behavior and Human Decision Processes, 60*(3), 306-325.

Emmerson, H. (1962). Survey of problems before the construction industries. HMSO. EPSRC. (1998) Engineering and Physical Sciences Research Council. http://www.epsrc.ac.uk

Eriksson, M., Jianchu, X., Shrestha, A. B., Vaidya, R. A., Nepal, S., and Sandström, K. (2009). *The changing himalayas: Impact of climate change on water resources and livelihoods in the greater himalayas.* International centre for integrated mountain development (ICIMOD).

Fellows, R., Langford, D., Newcombe, R., and Urry, S. (2002). *Construction management in practice* Wiley-Blackwell.

Fellows, R., and Langford, D. (1980). Decision theory and tendering. *Building Technology and Management, 18*(9), 36-39.

Franks, J., and Harlow, P. A. (1984). *Building procurement systems: A guide to building project management* Chartered Institute of Building.

Freeman, R. (2008). Challenges of road construction in Afghanistan. *Transportation Systems 2008 Workshop*, 21-24 April, Phoenix, AZ.

Goiciechea, A., D. R. Hansen and L. Duckstein, *Multi-objective Decision Analysis with Engineering and Business Application*s, Wiley, New York, 1982.

Goodwin, P., and Wright, G. (2004). *Decision analysis for management judgment* John Wiley and Sons Inc.

Gordon, C. M. (1994). Choosing appropriate construction contracting method. *Journal of Construction Engineering and Management, 120*(1), 196-210.

Gorton, J.P. and Smith G.A. (1998). Weighing the options. *Journal of Management in Engineering*, *ASCE*, November/December, 69-72.

Gransberg, D. D., Koch, J. A., and Molenaar, K. R. (2006). *Preparing for design-build projects: A primer for owners, engineers, and contractors* Amer Society of Civil Engineers.

Guitouni, A., and Martel, J. M. (1998). Tentative guidelines to help choosing an appropriate MCDA method. *European Journal of Operational Research, 109*(2), 501-521.

Hamilton, I. (1987). Developing expert systems for management applications. *Building Cost Modelling and Computers,* , 441-451.

Hatush, Z., and Skitmore, M. (1998). Contractor selection using multicriteria utility theory: An additive model. *Building and Environment, 33*(2), 105-115.

Her Majesty's Treasury, Central Unit on Purchasing (1992). *Guidance Document No. 36: Contract Strategy Selection for Major Projects*, HMSO, London.

Hibberd, P., and Djebarni, R. (1996). Criteria of choice for procurement methods. *Proceedings of COBRA, , 96*

Ibbs, C.W. and Crandall, K.C. (1982). "Construction risk: multi-attribute approach", Journal *of the Construction Division*, Vol. 108, C02, pp. 187-200.

Ibbs, C. W., Kwak, Y. H., Ng, T., and Odabasi, A. M. (2003). Project delivery systems and project change: Quantitative analysis. *Journal of Construction Engineering and Management, 129*, 382.

Jaselskis, Edward J., Talukhaba, Alfred. (1998). "Bidding Considerations in Developing Countries." *Journal of Construction Engineering and Management*.

Karsak, E. E., Sozer, S., and Alptekin, S. E. (2003). Product planning in quality function deployment using a combined analytic network process and goal programming approach. *Computers and Industrial Engineering, 44*(1), 171-190.

Kasturi, S. P., and Gransberg, D. D. (2002). Time management-A design-build builder's perspective. *COST ENGINEERING-ANN ARBOR THEN MORGANTOWN-, 44*(9), 16-25.

Keeney, R. L., and Raiffa, H. (1993). *Decisions with multiple objectives: Preferences and value tradeoffs* Cambridge Univ Pr.

Kluenker, C. H. (1996). The construction manager as project integrator. *Journal of Management in Engineering, 12*(2), 17-20.

Konchar, M. (1998). Comparison of US project delivery systems. *Journal of Construction Engineering and Management, 124*, 435.

Konchar, M., Sanvido, V., and Moore, S. (1997). The benefits of design-build contracting in the united states. construction process re-engineering. *Proceedings of the International Conference on Construction Process Re-Engineering. Gold Coast,* 14-15.

Kumaraswamy, M., Palaneeswaran, E., and Humphreys, P. (2000). Selection matters–in construction supply chain optimisation. *International Journal of Physical Distribution and Logistics Management, 30*(7/8), 661-680.

Kumaraswamy, M. M., and Dissanayaka, S. M. (2001). Developing a decision support system for building project procurement. *Building and Environment, 36*(3), 337-349.

Lee, J. W., and Kim, S. H. (2000). Using analytic network process and goal programming for interdependent information system project selection. *Computers and Operations Research, 27*(4), 367-382.

Linstone, H. A., and Turoff, M. (1976). *The delphi method: Techniques and applications* Addison-Wesley.

Love, P. E. D., Skitmore, M., and Earl, G. (1998). Selecting a suitable procurement method for a building project. *Construction Management and Economics, 16*(2), 221-233.

Luu, D. T., Ng, S. T., and Chen, S. E. (2005). Formulating procurement selection criteria through case-based reasoning approach. *Journal of Computing in Civil Engineering, 19*, 269.

Luu, D. T., Ng, S. T., and Chen, S. E. (2003). Parameters governing the selection of procurement system–an empirical survey. *Engineering, Construction and Architectural Management, 10*(3), 209-218.

Luu, D. T., Ng, S. T., Chen, S. E., and Jefferies, M. (2006). A strategy for evaluating a fuzzy case-based construction procurement selection system. *Advances in Engineering Software, 37*(3), 159-171.

Mahdi, I. M., and Alreshaid, K. (2005). Decision support system for selecting the proper project delivery method using analytical hierarchy process (AHP). *International Journal of Project Management, 23*(7), 564-572.

Markowitz, H., and Markowitz, H. M. (1991). *Portfolio selection: Efficient diversification of investments* Wiley.

Masterman, J. W. E. (2002). *An introduction to building procurement systems* Taylor and Francis.

McCommon, C., D. Warner and D. Yohalem. "*Community Management of Rural Water Supply and Sanitation Services - UNDP-World Bank Water and Sanitation Program - Water and Sanitation Discussion Paper, WASH Technical Report No. 667*." Washington, DC: The World Bank, 1990.

McIntyre, C., and Parfitt, M. K. (1998). Decision support system for residential land development site selection process. *Journal of Architectural Engineering, 4*, 125.

Meade, L. M., and Presley, A. (2002). R&D project selection using the analytic network process. *Engineering Management, IEEE Transactions on, 49*(1), 59-66.

Miller, G. A. (1994). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review, 101*(2), 343.

Miller, J. (1999). Applying multiple project procurement methods to a portfolio of infrastructure projects. *Procurement Systems: A Guide to Best Practice in Construction, E&N Spon,*

MIT OpenCourseWare, *The Impact of Globalization on the Built Environment.*

Mitropoulos, P., and Tatum, C. (2000). Forces driving adoption of new information technologies. *Journal of Construction Engineering and Management, 126*, 340.

Molenaar, K. R. (1998). Model for public sector design-build project selection. *Journal of Construction Engineering and Management, 124*, 467.

Momoh, J. A., and Zhu, J. (2003). Optimal generation scheduling based on AHP/ANP. *Systems, Man, and Cybernetics, Part B: Cybernetics, IEEE Transactions on, 33*(3), 531-535.

Morgenstern, O., and Von Neumann, J. (1953). Theory of games and economic behavior.

Moselhi, O., and Martinelli, A. (1990). Analysis of bids using multiattribute utility theory. *Transactions,* , 335-345.

Mustafa, M. A., and Ryan, T. C. (1990). Decision support for bid evaluation. *International Journal of Project Management, 8*(4), 230-235.

National Institute of Standards and Technology (2002), *Measuring the Impacts of Delivery System on Project Performance: Design-build and Design-bid-build, US Department of Commerce, Technology Administration*, available at: www.bfrl.nist.gov/oae/publications/gcrs/02840. pdf (accessed 10 May 2011).

NEDO (1983) *Faster Building for Industry*, National Economic Development Office, HMSO, London.

Naoum, S. (1989). An investigation into the performance of management contracts and the traditional methods of building procurement.

Ng, S. T., and Cheung, S. O. (2007). Virtual project delivery system adviser. *Journal of Professional Issues in Engineering Education and Practice, 133*, 275.

Ng, S. T., Luu, D. T., Chen, S. E., and Lam, K. C. (2002). Fuzzy membership functions of procurement selection criteria. *Construction Management and Economics, 20*(3), 285-296.

Ng, S. T., and Skitmore, R. M. (1995). CP-DSS: Decision support system for contractor prequalification. *Civil Engineering Systems, 12*(2), 133-159.

Nystrom, P. C., Ramamurthy, K., and Wilson, A. L. (2002). Organizational context, climate and innovativeness: Adoption of imaging technology. *Journal of Engineering and Technology Management, 19*(3), 221-247.

Oyetunji, A. A., and Anderson, S. D. (2006). Relative effectiveness of project delivery and contract strategies. *Journal of Construction Engineering and Management, 132*, 3.

Ozorhon, B., Dikmen, I., and Birgonul, M. T. (2007). Using analytic network process to predict the performance of international construction joint ventures. *Journal of Management in Engineering, 23*, 156.

Patel, S., and Center for Strategic and International Studies (Washington, DC). (2007). *Breaking point: Measuring progress in afghanistan* CSIS.

Ratnasabapathy, S. and Rameezdeen. R. (2006). A Multiple Decisive Factor Model for Construction Procurement System Selection, *Proceedings of the Annual Research Conference of the Royal Institution of Chartered Surveyors.*

Ratner, B. D., and Rivera, A. (2004). Reasserting community: The social challenge of wastewater management in panajachel, guatemala. *Human Organization, 63*(1), 47-56.

Ribeiro, F. L. (2001). Project delivery system selection: A case-based reasoning framework. *Logistics Information Management, 14*(5/6), 367-376.

Rubin, R.A. and Wordes, D. (1998), ``Risky business'', *Journal of Management in Engineering*, November/December, pp. 36-43.

Rwelamila, P. D., and Meyer, C. (1999). Appropriate or default project procurement systems? *Cost Engineering, 41*(9), 40-44.

Saaty, T. L. (2005). *Theory and applications of analytic network process* RWS publications Pittsburgh, PA.

Saaty, T. L. (2004). Decision making—the analytic hierarchy and network processes (AHP/ANP). *Journal of Systems Science and Systems Engineering, 13*(1), 1-35.

Saaty, T. L. (1996). *Decision making with dependence and feedback: The analytic network process: The organization and prioritization of complexity* RWS publications Pittsburgh, PA, US.

Saaty, T. L. (1980). *Analytic hierarchy process* Wiley Online Library.

Sargand, S. (2009). *Unofficial report regarding on challenges and training of new Afghan engineers*. June 2009

Sarkis, J. (1999). A methodological framework for evaluating environmentally conscious manufacturing programs. *Computers and Industrial Engineering, 36*(4), 793-810.

Sanvido V. and Konchar, M. (2005). *Selecting project delivery systems: comparing design-build,design-bid-build and construction management at risk.* The Project Delivery Institute, VA,USA.

Spainhour, L. K., Mtenga, P. V., and Sobanjo, J. (1999). Multicriteria DSS with historical database for attenuator selection. *Journal of Computing in Civil Engineering, 13*, 187.

Special Inspector General for Afghanistan Reconstruction (SIGAR). (2010). *Quarterly report to the United States Congress*. Arlington, VA, 30 January, 2010.

Silver, E. (2003). Design-builders pass muster in Afghanistan. *ENR, 251*, 17-20.

Simon (1944) *The placing and management of building contracts*: *Report of the Central Council for Works and Buildings*, (Chairman: Lord Simon) HMSO: London.

Singh, S. (1990). Selection of appropriate project delivery system for construction projects. *Proceedings of CIB W-90 International Symposium on Building Economics and Construction Management,* 469-480.

Skitmore, M., and Love, P. E. D. (1995). Construction project delivery systems: An analysis of selection criteria weighting.

Skitmore, R., and Marsden, D. (1988). Which procurement system? towards a universal procurement selection technique. *Construction Management and Economics, 6*(1), 71-89.

Songer, A. D., and Molenaar, K. R. (1996). ‘‘Selecting design-build: Public and private sector owner attitudes.’’ *J. Mgmt. Engrg*., ASCE,12(6), 47–53.

Songer, A. D., Molenaar, K. R., and Robinson, G. D. (1996). Selection factors and success criteria for design-build in the US and UK. *Journal of Construction Procurement, 2*(2), 69-82.

Talukhaba, A. (1998). Bidding considerations in developing countries. *Journal of Construction Engineering and Management, 124*, 185.

Touran, A., Molenaar, K. R., Gransberg, D. D., and Ghavamifar, K. (2009). Decision support system for selection of project delivery method in transit. *Transportation Research Record: Journal of the Transportation Research Board, 2111*(-1), 148-157.

Ueki, M., Haas, C. T., and Seo, J. (1999). Decision tool for microtunneling method selection. *Journal of Construction Engineering and Management, 125*, 123.

Von Winterfeldt, D., and Edwards, W. (1986). *Decision analysis and behavioral research* Cambridge University Press Cambridge.

Yu, R., and Tzeng, G. H. (2006). A soft computing method for multi-criteria decision making with dependence and feedback. *Applied Mathematics and Computation, 180*(1), 63-75.

Ziara, M. M., and Ayyub, B. M. (1999). Decision analysis for housing-project development *Journal of Urban Planning and Development, 125*, 68.

APPENDICES

APPENDIX I

SURVEY QUESTIONNAIRE

GUIDELINE FOR COMPLETING QUESTIONNAIRE PART I: SELECTING RELATIVE EFFECTIVENESS VALUES OF PDS ALTERNATIVES

Introduction: The thrust of this exercise is to determine the performance (attainment) level of each project delivery system alternative on the measurement attributes of the Selection Factors **(SF)**. Respondents are encouraged to refer to this guideline for better understanding of the properties and attributes of the Project Delivery System **(PDS)** alternatives. Also, the tables illustrated in this guideline should be referred to for information concerning the measurement attributes of each selection factor.

Instructions for completing the questionnaire: Respondents should select the appropriate value from the Effectiveness Measure Scale **(EMS)** depicted on the questionnaire, and assign it to each project delivery system, relative to other PDS alternatives on the basis of its effectiveness in meeting the measurement attributes of the selection factors. In conferring the relative effectiveness values, respondents should bear in mind the question that "how effective/appropriate is the PDS option under consideration, relative to other alternatives, in terms of achieving or satisfying the selection factor?"

The Effectiveness Measure Scale ranges from 1 to 100. As such, the most effective/appropriate PDS option compared to others in satisfying the selection factor should receive a score of 100 and the least effective/appropriate PDS option a score of 1. The PDS option that falls between the most and least effective should be assigned a score that reflects its relative effectiveness.

Respondents should not have any reservation in assigning the highest or the lowest score to a PDS option. It is to say that, for instance, the score of "100" should not be reserved for the absolute best performance imaginable, but assigned to the PDS option that is most satisfactory between the PDS alternatives that are being examined. Similarly, the score "1" should not be kept for worst performance possible, but for the least satisfactory performance among PDS options that are being evaluated. Respondents should also refrain from assigning duplicate scores to the PDS options being evaluated over the same factor in the same set of comparison.

Table 1. Description of PDS Alternatives

Project Delivery System alternatives in brief	
DBB	***Design-Bid-Build*** is marked by sequential sequencing of design and construction. Agency enters into contract separately with designer and constructor
DB	***Design-Build*** is recognized by overlapped sequencing of construction. Procurement commence during design. Agency deals with a single point of contract (design build contractor).
CM-R	***Construction Manager at Risk*** entails overlapped sequencing of design and construction. Procurement begins during design. Agency contracts separately with designer and CM (at risk). It helps by supplementing in-house staff and saving time by fast tracking construction. The performance risk is transferred to CM.

Table2. Description of Project Delivery System Selection Factors

Factor No.		Selection Factors (SF)	Description	Measurement Attributes
Factor Area 1 (Project Related Parameters)	1	**Project Cost**	Does your agency require a firm price before any commitment is made and is completion within original budget critical to project success?	Effectiveness of delivery system in controlling cost growth.
	2	**Construction Speed and Urgency**	How important is early project completion to your agency and is completion within schedule critical to project success?	Securing the shortest reasonable schedule.
	3	**Turnover Quality**	What level of turn-over quality does your agency seek to secure?	Effectiveness of delivery system in ease of start-up, reducing number of call backs, and lowering the operation and maintenance costs.
	4	**Confidentiality**	How crucial is the confidentiality of project/engineering details to your agency?	Effectiveness of delivery system in protecting the secrecy of projects and other proprietary matters.
	5	**Complexity**	Is your project's design non-conventional, highly specialized and technologically advanced or is the construction complex, innovative and non-standard?	Effectiveness of delivery in effective orchestration and management of non-conventional project design/engineering and/or construction.
	6	**Flexibility**	Does your agency anticipate an above normal level of change in the execution of the project and if so how important is it to retain the authority to effect change after cost estimate commitments are made?	Delivery system ability to smoothly incorporate changes to the project scope during detailed design and construction.
Factor Area 2(Agency Preferences)	7	**Risk Allocation**	To what extent does your agency want to limit the amount of speculative cost, time and design liability?	Delivery system effectiveness in dividing and transferring risk between different project parties.
	8	**Responsibility & Involvement**	To what extent does your agency wish to maintain control and exert influence over project design and execution and/or prefer direct professional responsibility?	Effectiveness of delivery system in accommodating agency's desire for involvement in managing design and construction.
	9	**Scope Definition**	Availability and/or necessity of developing well defined project features by the award of the design and/or construction contract?	Flexibility of delivery system in efficiently using poorly defined scope before the award of design and/or construction.
	10	**Agency's in-house Capacity**	To what extent is your agency dependant on outside assistance & does it have the wherewithal to get involved in detailed design and construction?	Delivery system effectiveness to promote agency's involvement in detailed design and construction commensurate with its capacity.

Table2. Description of Project Delivery System Selection Factors

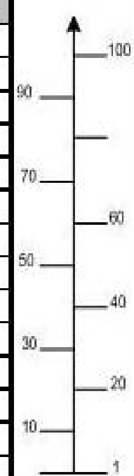
Cont'd from previous page:

Factor No.		Selection Factors (SF)	Description	Measurement Attributes
Factor Area 2(Agency Preferences)	11	**Constructability**	To what extent is your agency keen on integrating construction knowledge into design process as a mean to achieve a better quality project, in a safe manner, within schedule and for the least cost?	Delivery system effectiveness to promote constructability and facilitate the interaction between construction knowledge of the design entity and the expertise of the construction party.
Factor Area 3 (Regional Parameters)	12	**Security Constraints & Political Impact**	To what extent is your project affected by security constraints, mobility restrictions and changing political considerations?	Delivery system effectiveness in adapting to the volatility of the situation on the ground and countering the negative effects (in terms of construction time and cost) resulting from security imposed restrictions and fast paced political and regulatory change.
	13	**Availability of experienced contractors**	To what extent does your agency depend on local contractors/sub-contractors for execution of their projects?	Effectiveness of delivery system to address the shortage of contractors and/or subcontractors who have the expertise to fulfil project requirements and cope with its consequences (in terms of time, cost, risk allocation and quality) thereof.
	14	**Availability of Resources and Material**	To what extent is material procurement and delivery critical to your project's success and is your agency inclined to promote early procurement of equipment and/or material to compensate for scarcity and/or long lead times of material and/or equipment?	Effectiveness of delivery system in permitting early design and purchase of equipment or material as well as offsetting the impact that availability of material would have on the construction speed in projects with a fast track or tight time schedule.

QUESTIONNAIRE PART I

"RELATIVE EFFECTIVENESS VALUE SCORE SHEET"

Respondent's Information	
Name	
Position	
Date	
Duty Station	

Factor No.	Selection Factor	Relative Effectiveness Value			EMS
		DBB	DB	CM-R	
1	Project Cost				
2	Construction Speed and Urgency				
3	Turnover Quality				
4	Confidentiality				
5	Complexity				
6	Flexibility				
7	Risk Allocation				
8	Responsibility & Involvement				
9	Scope Definition				
10	Agency's in-house Capacity				
11	Constructability				
12	Security Constraints & Political Impact				
13	Availability of experienced contractors				
14	Availability of Resources and Material				

Remarks:

GUIDELINE FOR COMPLETING QUESTIONNAIRE PART II: RELATIVE IMPORTANCE WEIGHTS

The purpose of this questionnaire is to extrapolate relative importance weights of PDS selection factors through pair-wise comparison. The outcome from this exercise is entered into "Super Decision" software; the software incorporates the inner and outer dependence among the selection factors in its calculation and synthesizes the judgements to produce a relative priority weight for each selection factor.

Respondents are invited to use the rating scale (also known as the fundamental scale of absolute numbers) provided below to assign a numerical value to their judgements. Judgements are made by comparing two elements (either from the main criteria or the sub-criteria cluster) with respect to a third element also known as the control criterion. For instance, when comparing between factors **A** and **B** with respect to factor **C** as the control criterion, the respondents should answer the following question: What is the relative importance of factor **A** on factor **B** (or vice versa, should you feel that B is more important than A) with respect to factor **C**. If your comparison indicates that **A** is equally or more important than **B**, mark your answer by choosing an appropriate value ***from left to right*** of the score range. Alternatively, if you find that **B** is more important than **A**, please indicate your answer by choosing a value from ***right to left*** of the score range.

Saaty's Fundamental Scale of Absolute Numbers		
Intensity of Importance	**Definition**	**Explanation**
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
A note on assigning intermediate values (2,4,6 & 8) in the judgment of relative importance		
2,4,6,8	Intermediate values between adjacent cell values	Sometimes one needs to interpolate a compromise judgment numerically because there is no good word to describe it.

As already explained under part I of this questionnaire, there are three main factor areas (main criteria) identified for PDS selection decision making. Each factor area is broken down into a number of criterion (selection factors). To assist the respondents in better visualising the relationships between the factor areas and their corresponding criterion, the hierarchical structure of PDS selection criteria considered in this research is illustrated in the following page.

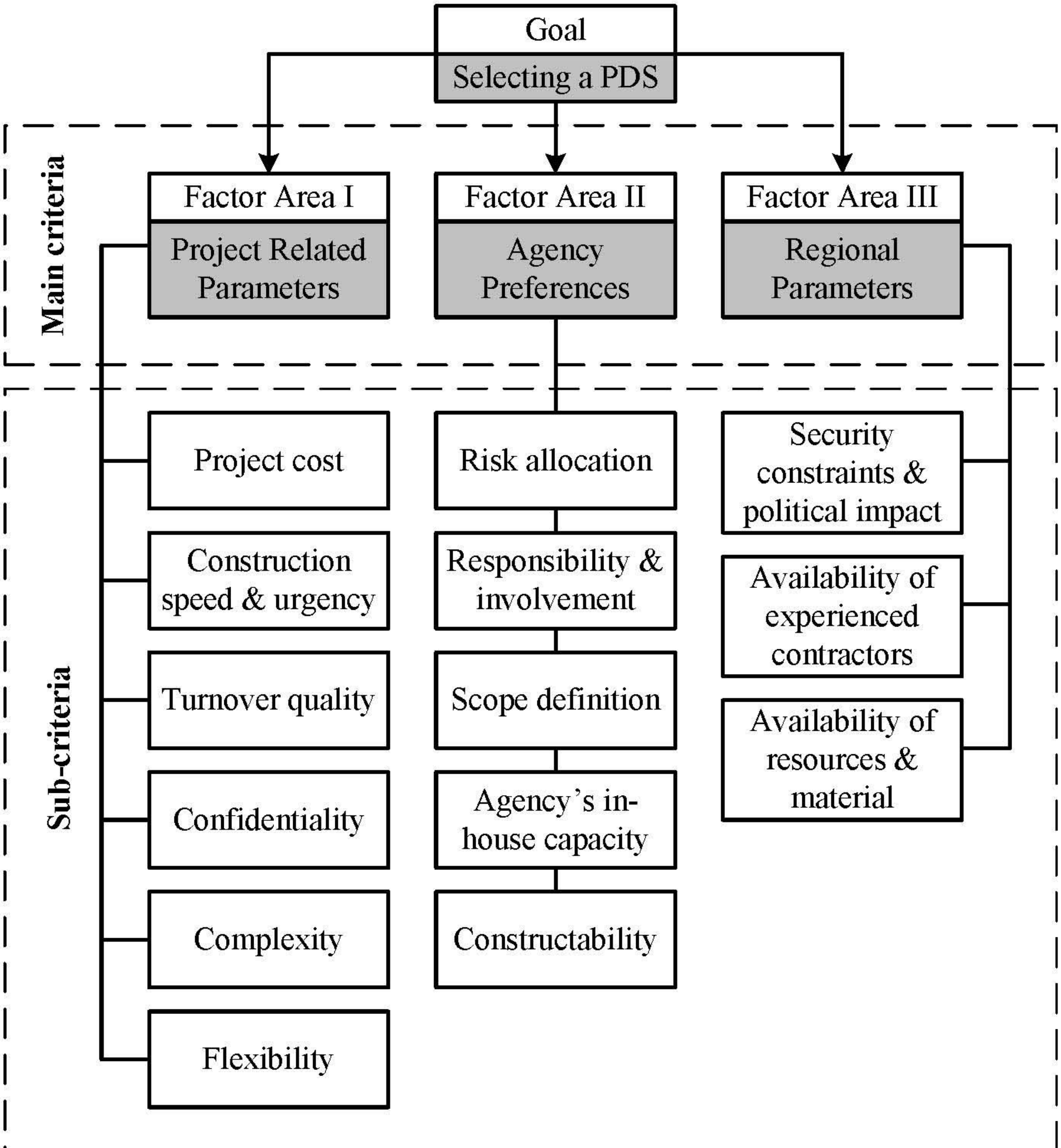


Figure 1. Hierarchical structure of project delivery system selection criteria

౩ QUESTIONNAIRE PART II ଓ

"RELATIVE IMPORTANCE WEIGHTS"

Respondent's Information	
Name	
Position	
Date	
Duty Station	

Please read the questions and choose an integer value from 1 to 9, as per Saaty's fundamental scale, and mark your answer in the appropriate cell.

1. **Section I)** Comparison between the main criteria with respect to the goal:

Section I	With respect to (C): " selecting an appropriate Project Delivery System"										
		Indicate the **relative importance** of **A** on **B** or vice versa									
	(A)	Extreme	Very strong	Strong	Moderate	Equal	Moderate	Strong	Very strong	Extreme	(B)
	Project related parameters	⑨	⑦	⑤	③	①	③	⑤	⑦	⑨	Agency preferences
		⑨	⑦	⑤	③	①	③	⑤	⑦	⑨	Regional parameters

2. **Section II)** Comparison between the sub-criteria with respect to the parent criteria:

Section II. (a)	With respect to (C): "Project related parameters"										
		Indicate the **relative importance** of **A** on **B** or vice versa									
	(A)	Extreme	Very strong	Strong	Moderate	Equal	Moderate	Strong	Very strong	Extreme	(B)
	Project cost	⑨	⑦	⑤	③	①	③	⑤	⑦	⑨	Construction speed & urgency
		⑨	⑦	⑤	③	①	③	⑤	⑦	⑨	Turnover quality
		⑨	⑦	⑤	③	①	③	⑤	⑦	⑨	Confidentiality
		⑨	⑦	⑤	③	①	③	⑤	⑦	⑨	Complexity
		⑨	⑦	⑤	③	①	③	⑤	⑦	⑨	Flexibility

Continued from section II:

Section II. (b)	With respect to (C): "Agency preferences"										
	(A)	Extreme	Very strong	Strong	Moderate	Equal	Moderate	Strong	Very strong	Extreme	(B)
	Risk allocation	⑨	⑦	⑤	③	①	③	⑤	⑦	⑨	Responsibility & involvement
		⑨	⑦	⑤	③	①	③	⑤	⑦	⑨	Scope definition
		⑨	⑦	⑤	③	①	③	⑤	⑦	⑨	Agency's in-house capacity
		⑨	⑦	⑤	③	①	③	⑤	⑦	⑨	Constructability

Indicate the **relative importance** of A on B or vice versa

Section II. (c)	With respect to (C): "Regional parameters"										
	(A)	Extreme	Very strong	Strong	Moderate	Equal	Moderate	Strong	Very strong	Extreme	(B)
	Security constraints & political impact	⑨	⑦	⑤	③	①	③	⑤	⑦	⑨	Availability of experienced contractors
		⑨	⑦	⑤	③	①	③	⑤	⑦	⑨	Availability of resources & material

Indicate the **relative importance** of A on B or vice versa

3. **Section III)** Comparison between the main criteria to elicit their interdependencies:

Section III. (a)	With respect to (C): "Project related parameters"										
	(A)	Extreme	Very strong	Strong	Moderate	Equal	Moderate	Strong	Very strong	Extreme	(B)
	Agency preferences	⑨	⑦	⑤	③	①	③	⑤	⑦	⑨	Regional parameters

Indicate the **relative importance** of A on B or vice versa

Section III. (b)	With respect to (C): "Agency preferences"										
	(A)	Indicate the **relative importance** of A on B or vice versa									(B)
		Extreme	Very strong	Strong	Moderate	Equal	Moderate	Strong	Very strong	Extreme	
	Project related parameters	⑨	⑦	⑤	③	①	③	⑤	⑦	⑨	Regional parameters
Section III. (c)	**With respect to (C): "Regional parameters"**										
	(A)	Indicate the **relative importance** of A on B or vice versa									(B)
		Extreme	Very strong	Strong	Moderate	Equal	Moderate	Strong	Very strong	Extreme	
	Project related parameters	⑨	⑦	⑤	③	①	③	⑤	⑦	⑨	Agency preferences

Observations & Remarks:

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APPENDIX II

RESULTS ANALYSIS GRAPHS FROM @RISK SIMULATION

DBB

1.1 Health and Educational Buildings

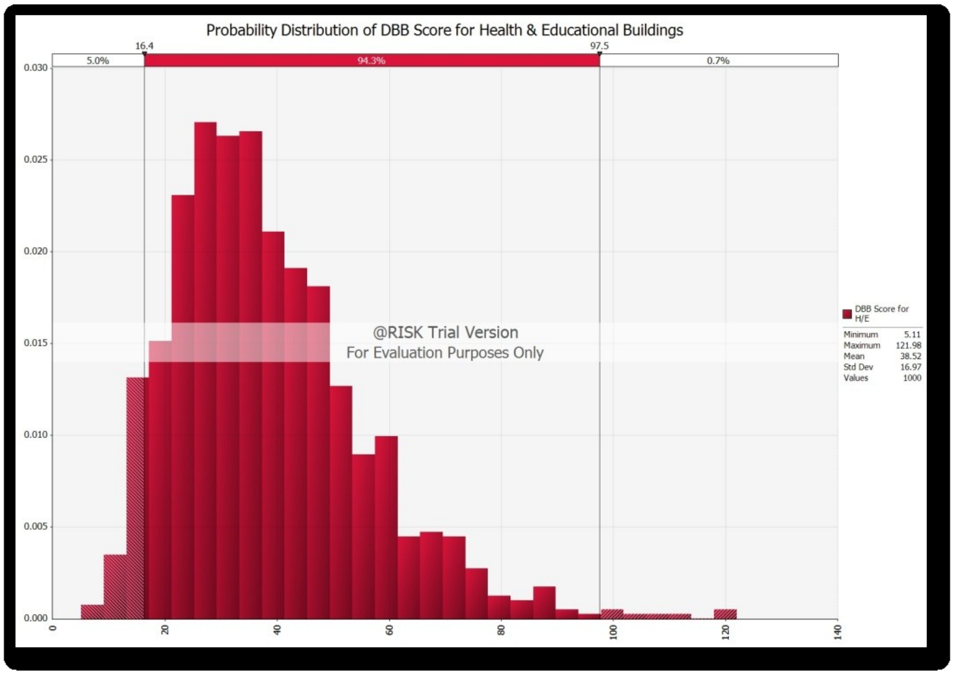

Figure 3 Probability Distribution of DBB Score for Health and Educational Buildings

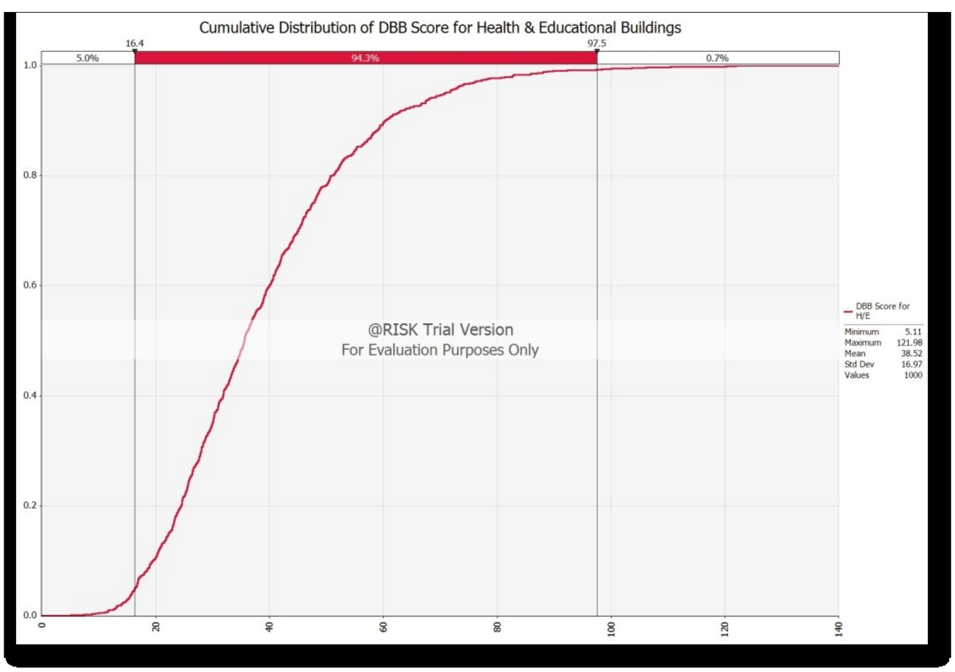

Figure 2 Cumulative Distribution of DBB Score for Health and Educational Buildings

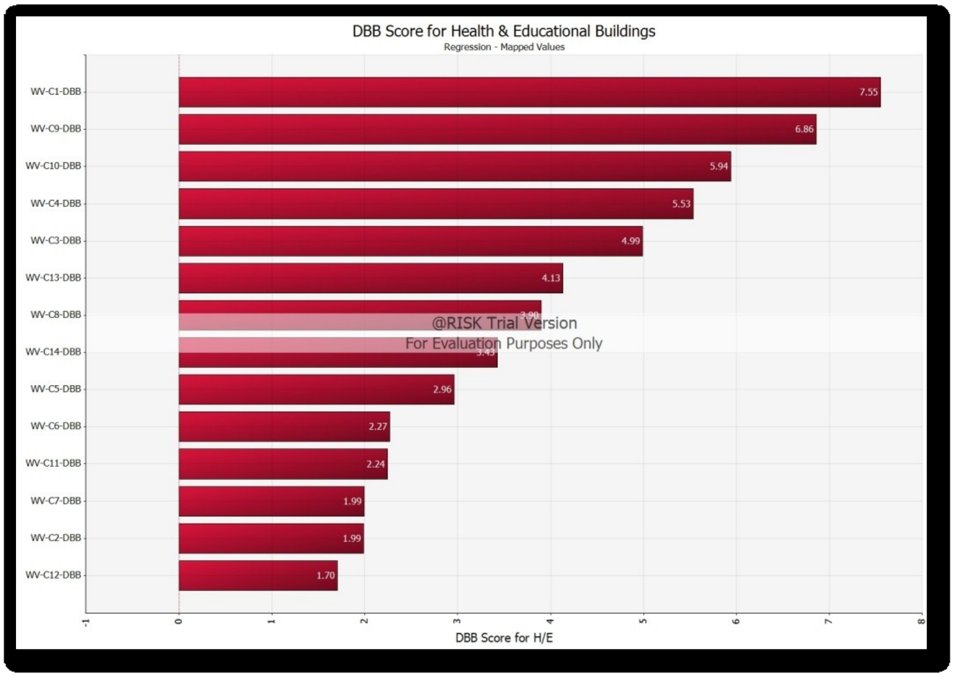

Figure 5 Sensitivity Tornado Graph of DBB Score for Health and Educational Buildings

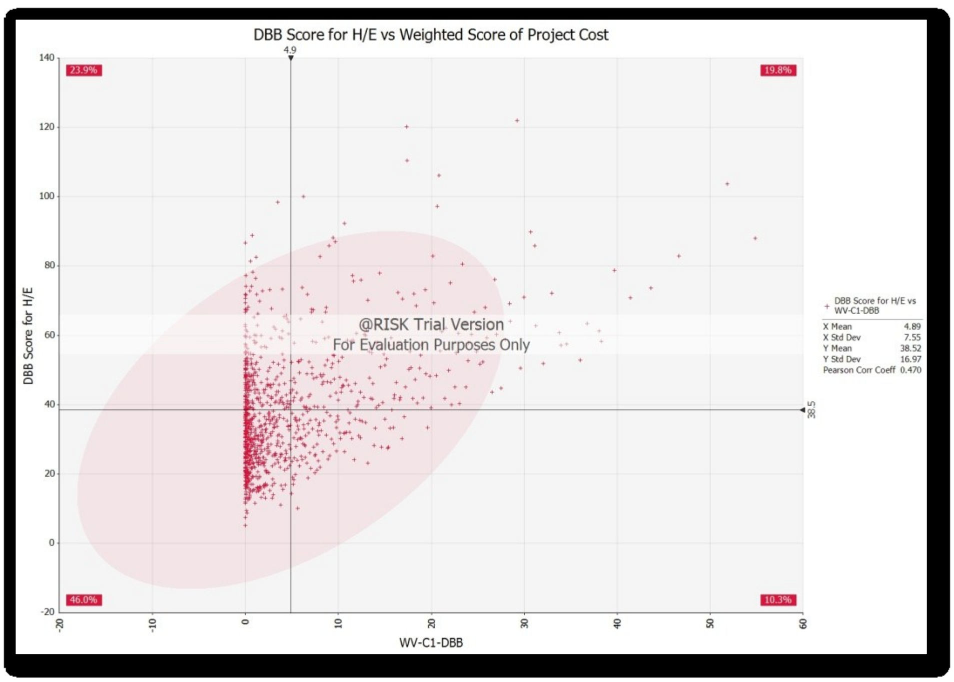

Figure 4 Selection Factor with most impact on DBB for Health and Educational Buildings

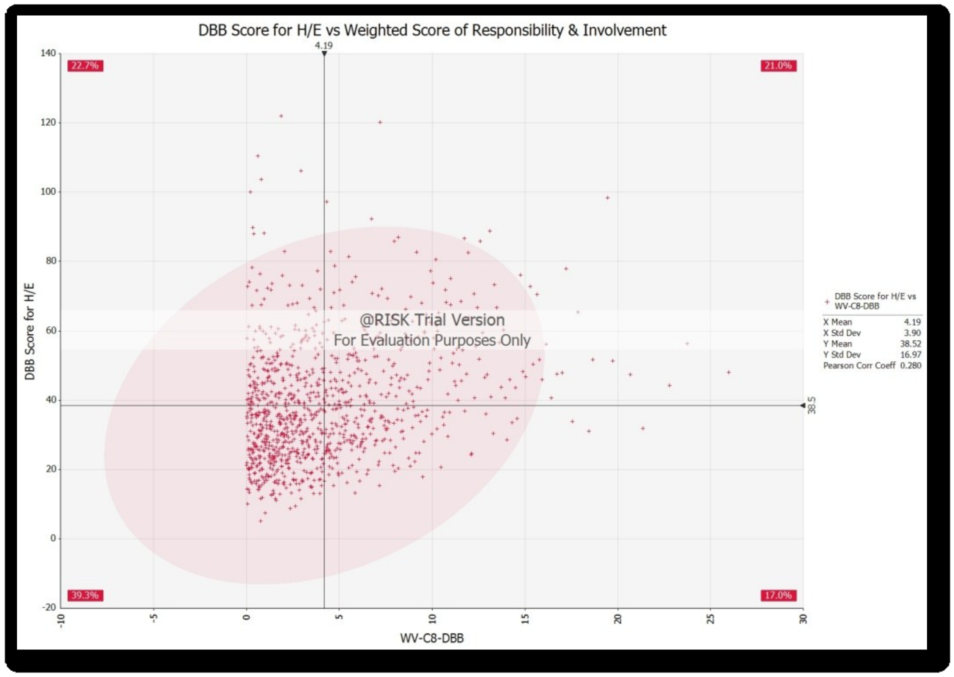

Figure 5 Selection Factor with medium impact on DBB for Health and Educational Buildings

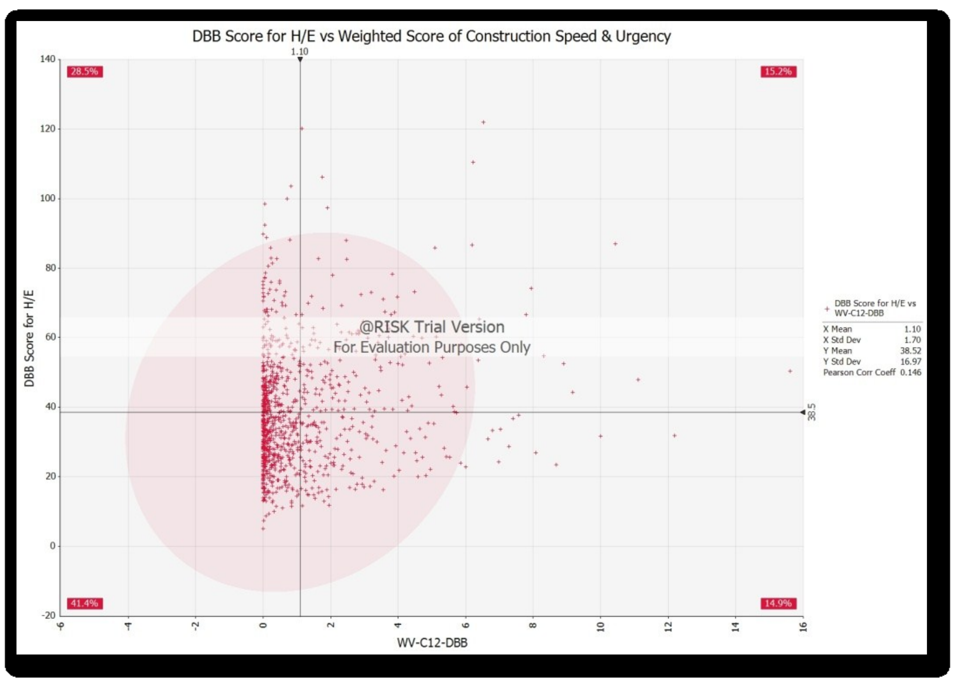

Figure 6 Selection Factor with least impact on DBB for Health and Educational Buildings

1.2 Office and Government Buildings

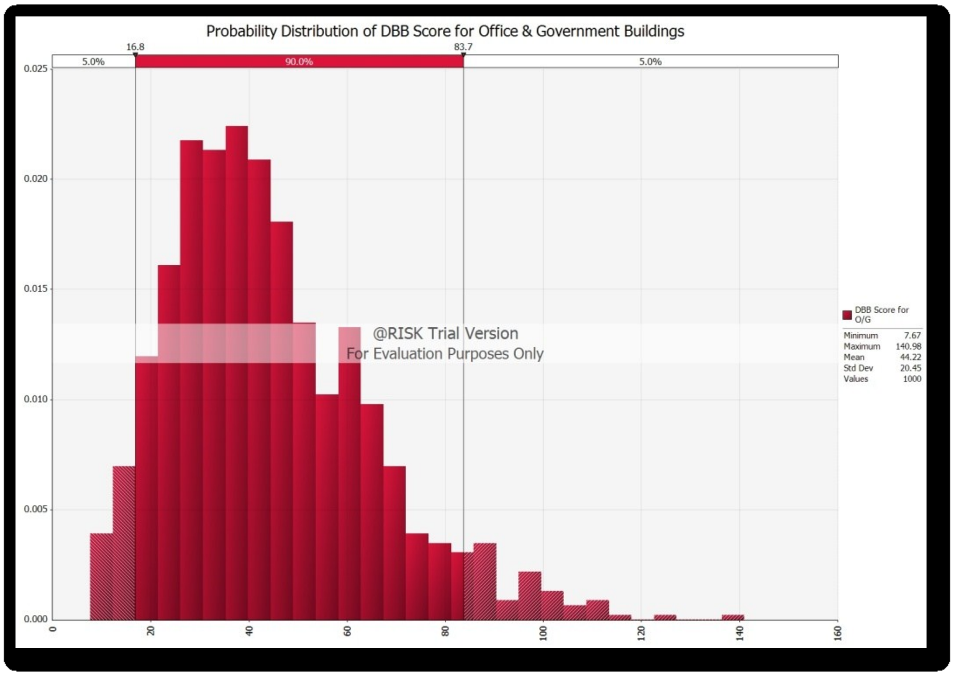

Figure 7 Probability Distribution of DBB Score for Office and Government Buildings

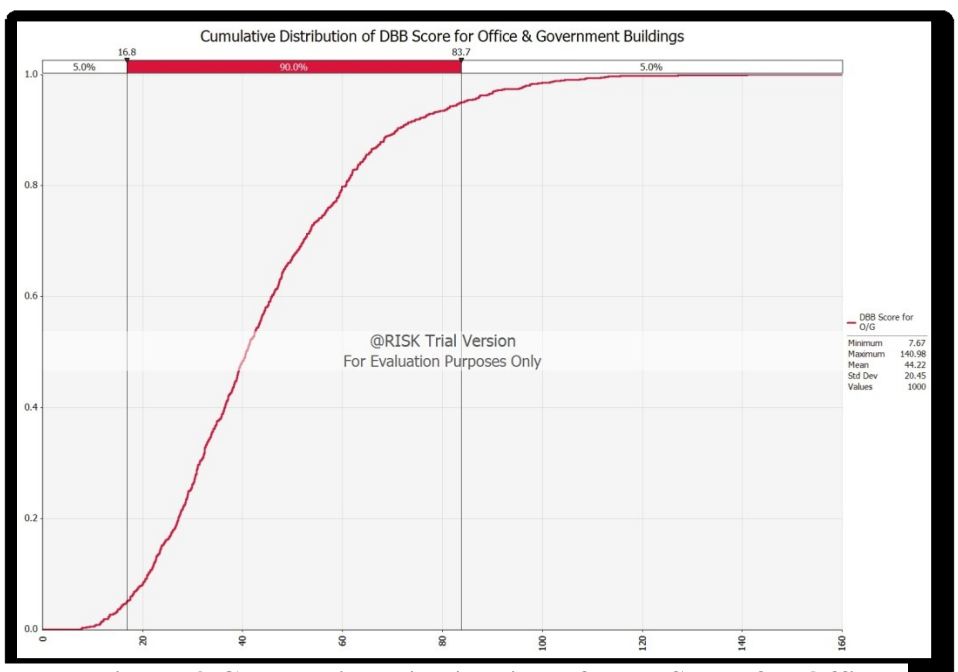

Figure 8 Cumulative Distribution of DBB Score for Office and Government Buildings

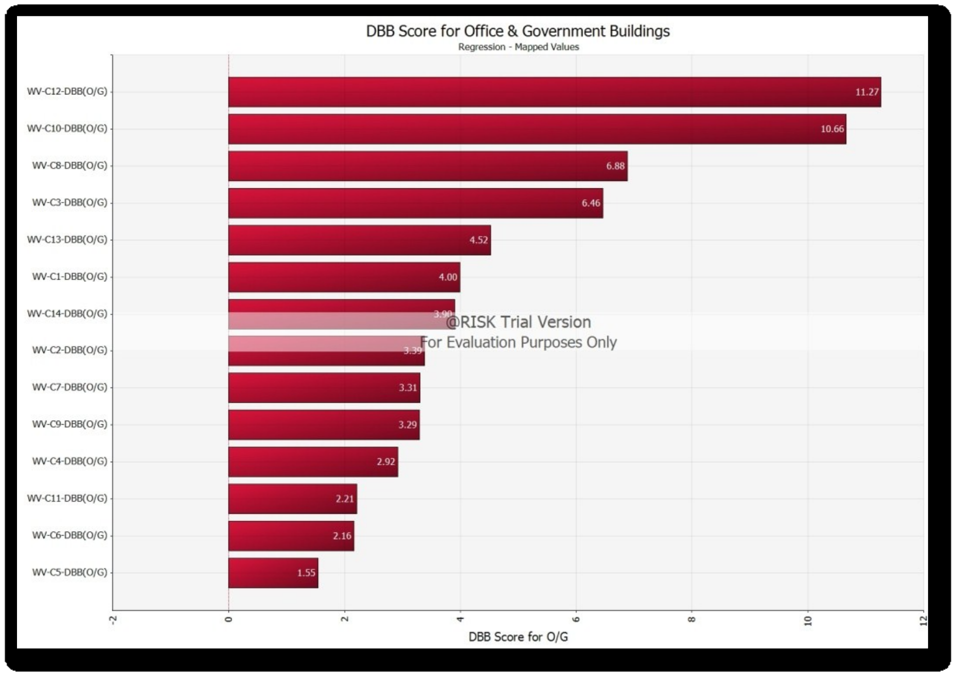

Figure 9 Sensitivity Tornado Graph of DBB Score for Office and Government Buildings

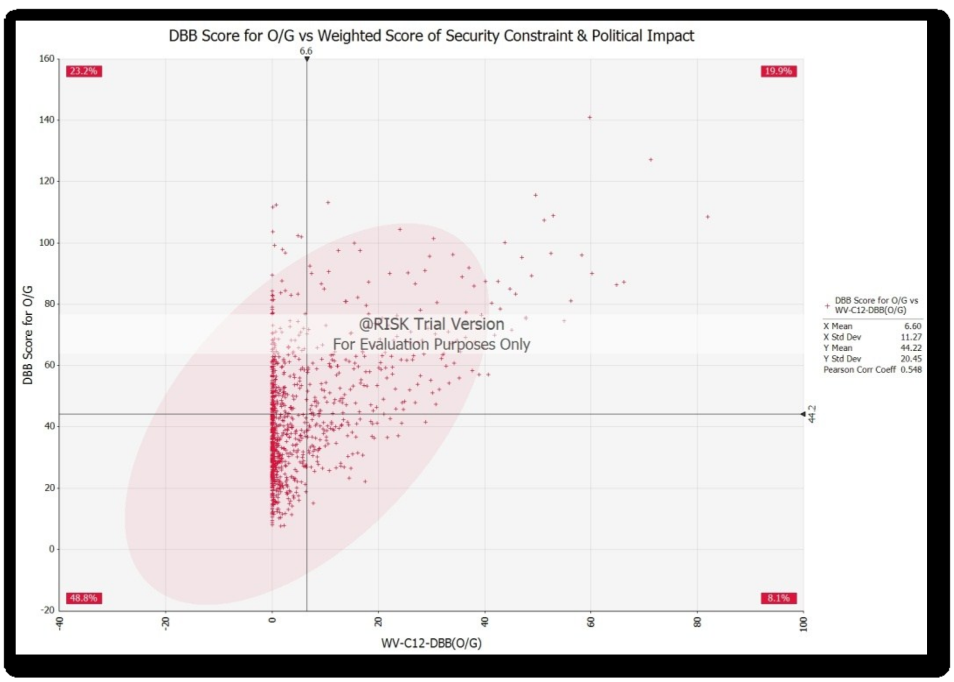

Figure 10 Selection Factor with most impact on DBB for Office and Government Buildings

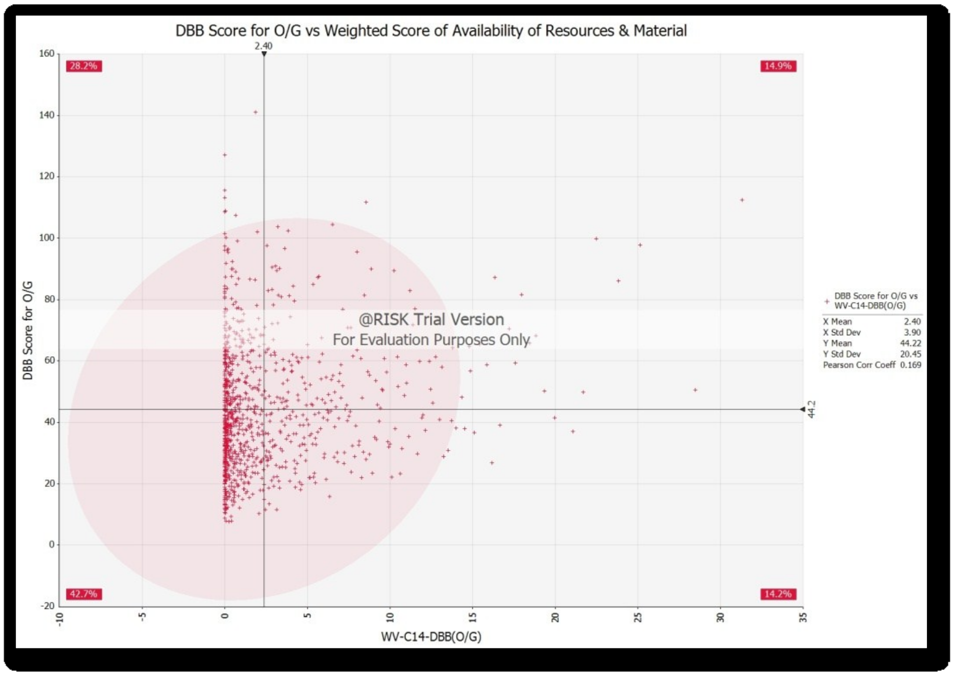

Figure 11 Selection Factor with medium impact on DBB for Office and Government Buildings

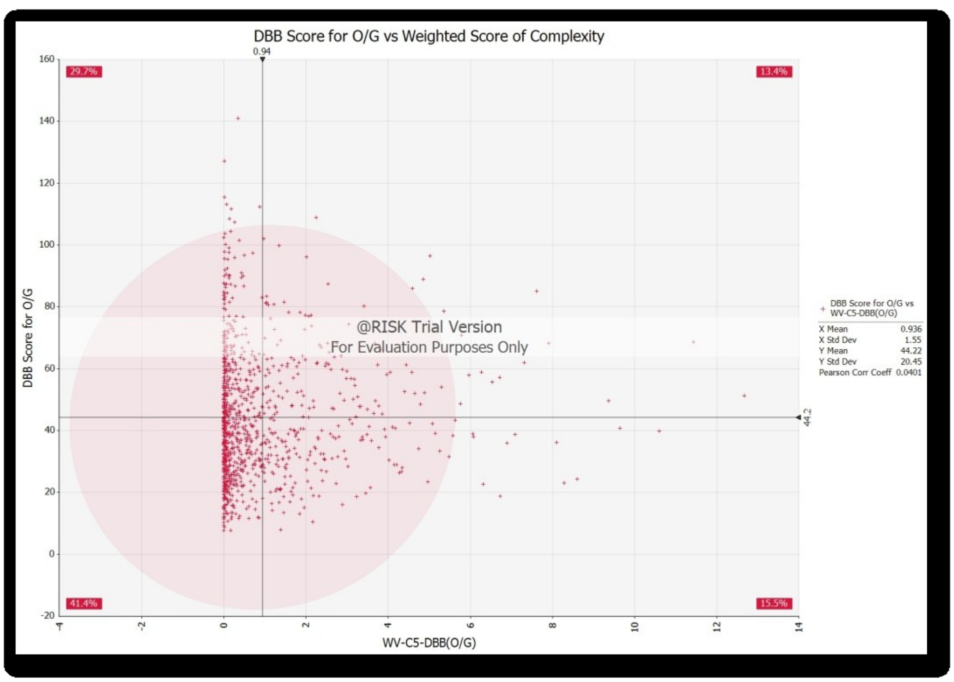

Figure 12 Selection Factor with least impact on DBB for Office and Government Buildings

2. DB

2.1 Health and Educational Buildings

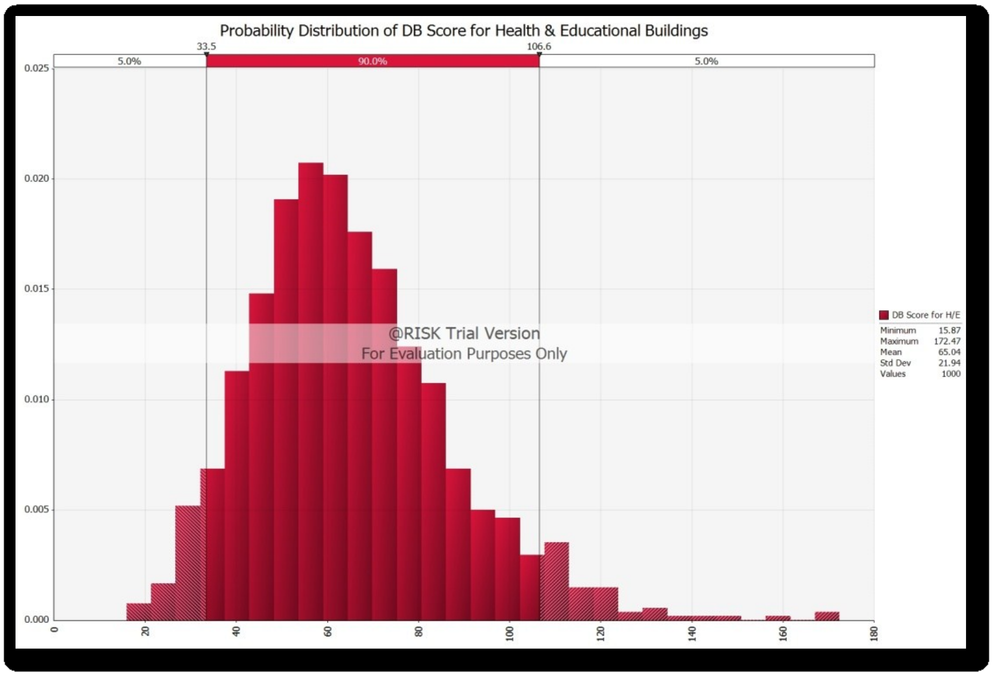

Figure 13 Cumulative Distribution of DB Score for Health and Educational Buildings

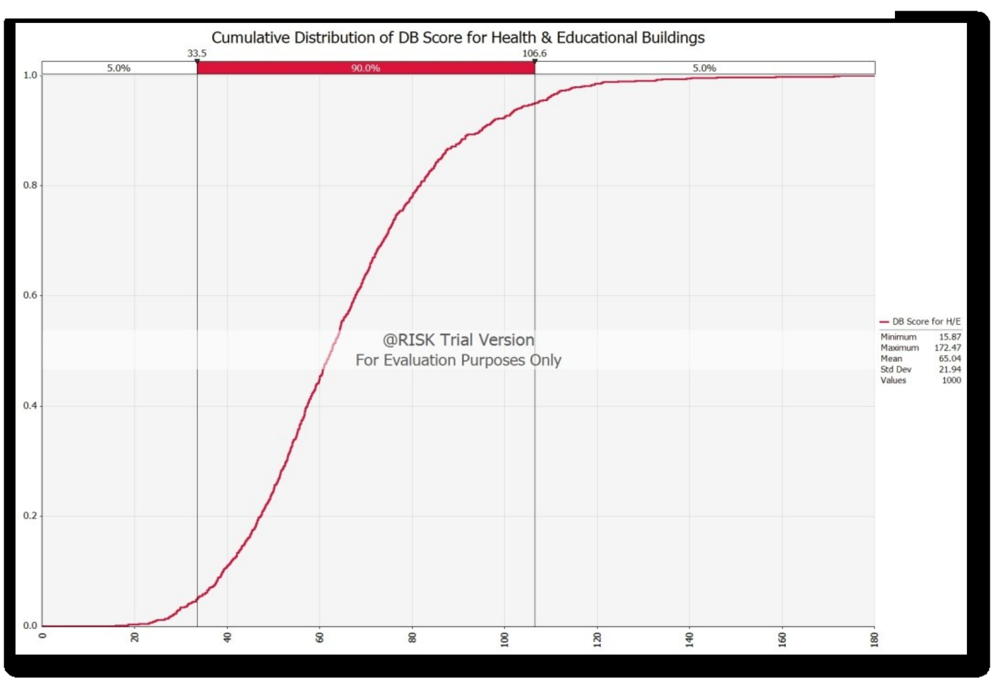

Figure 14 Cumulative Distribution of DB Score for Office and Government Buildings

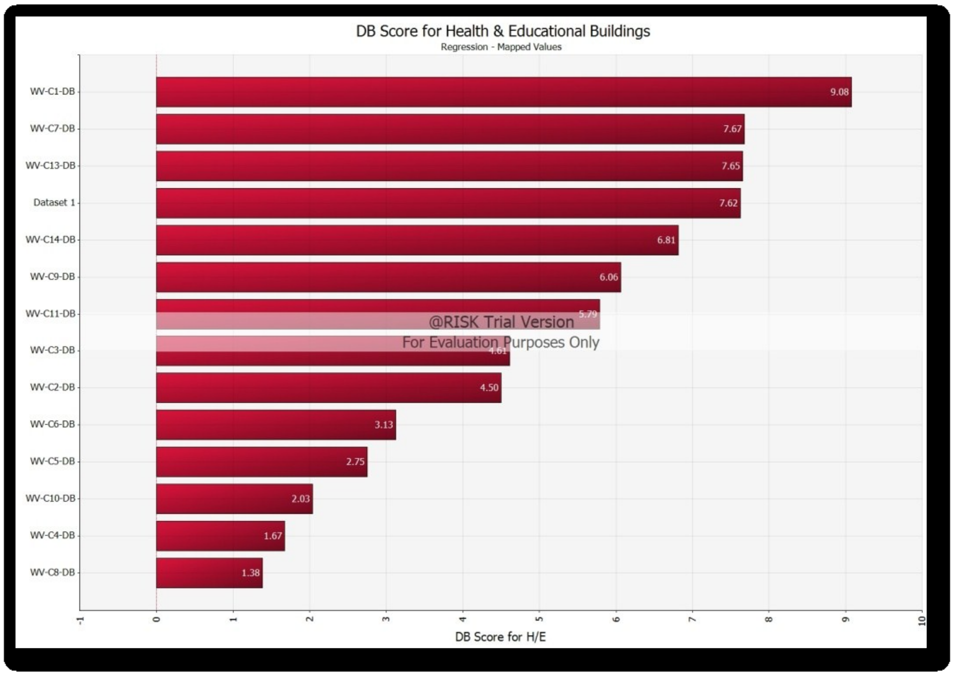

Figure 15 Sensitivity Tornado Graph of DBB Score for Health and Educational Buildings

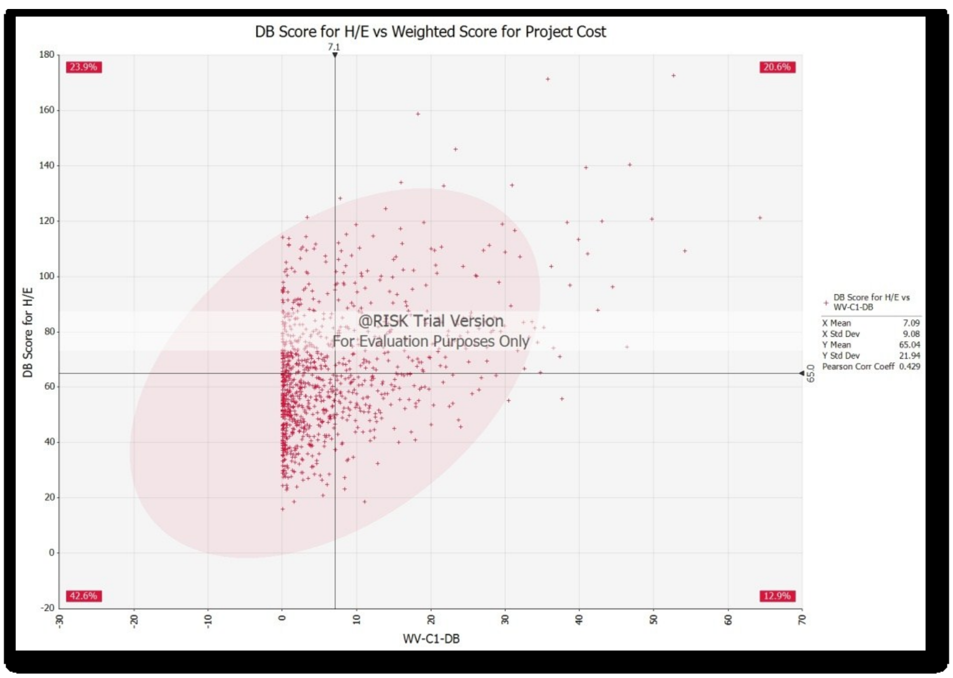

Figure 16 Selection Factor with most impact on DB for Health and Educational Buildings

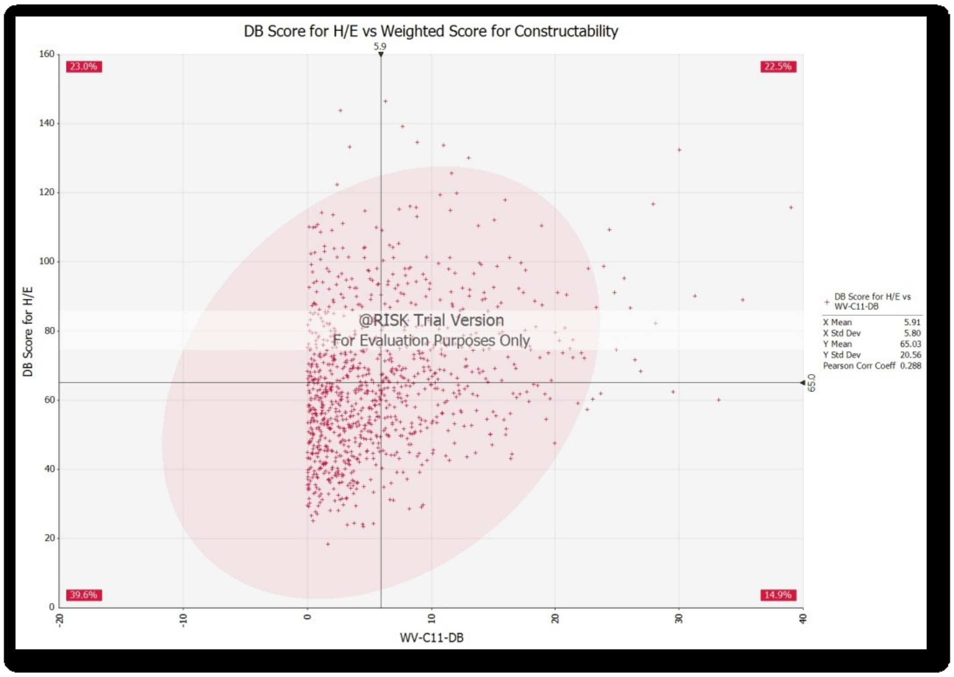

Figure 17 Selection Factor with medium impact on DB for Health and Educational Buildings

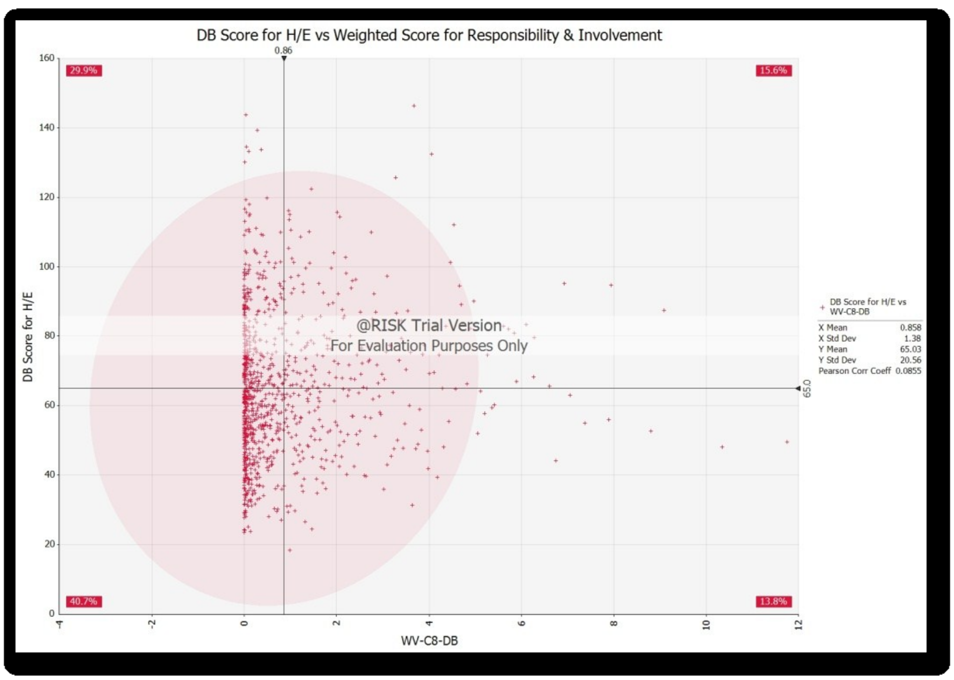

Figure 18 Selection Factor with least impact on DB for Health and Educational Buildings

2.2 Office and Government Buildings

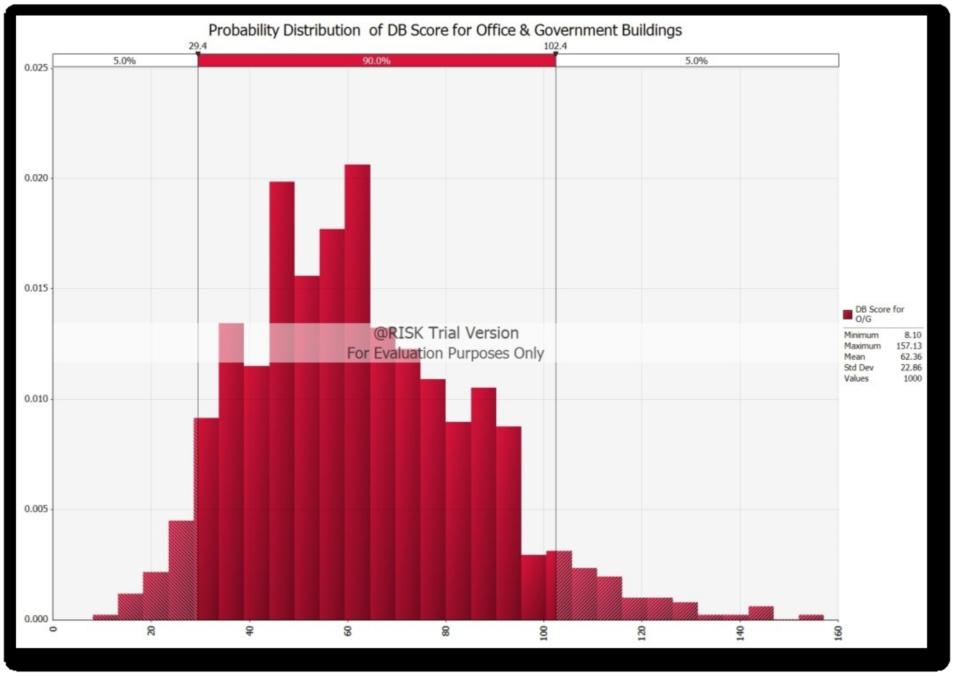

Figure 19 Probability Distribution of DB Score for Office and Government Building

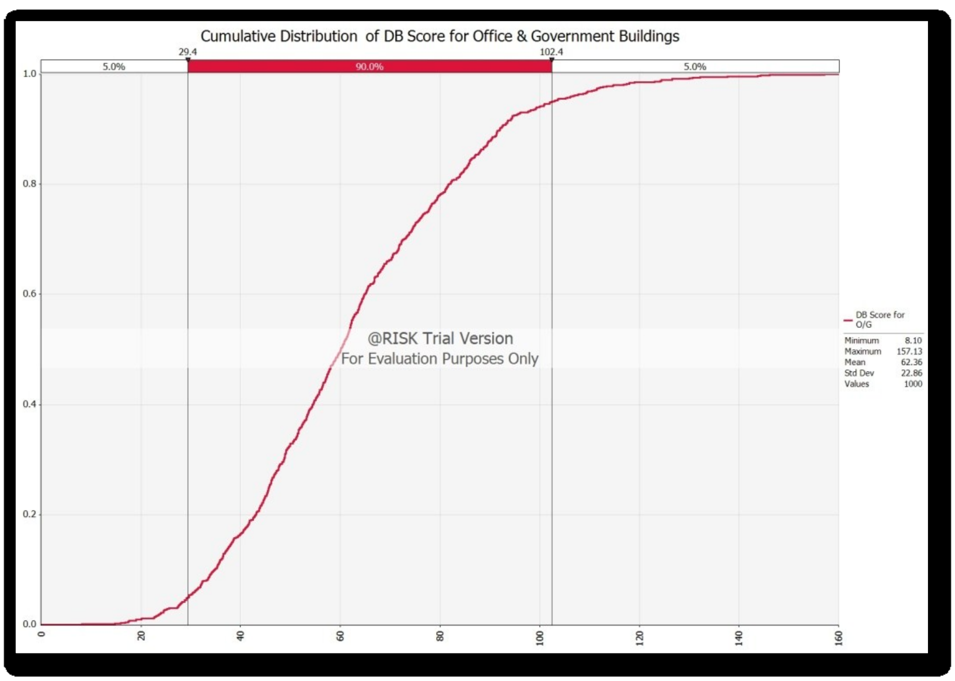

Figure 20 Cumulative Distribution of DB Score for Office and Government Building

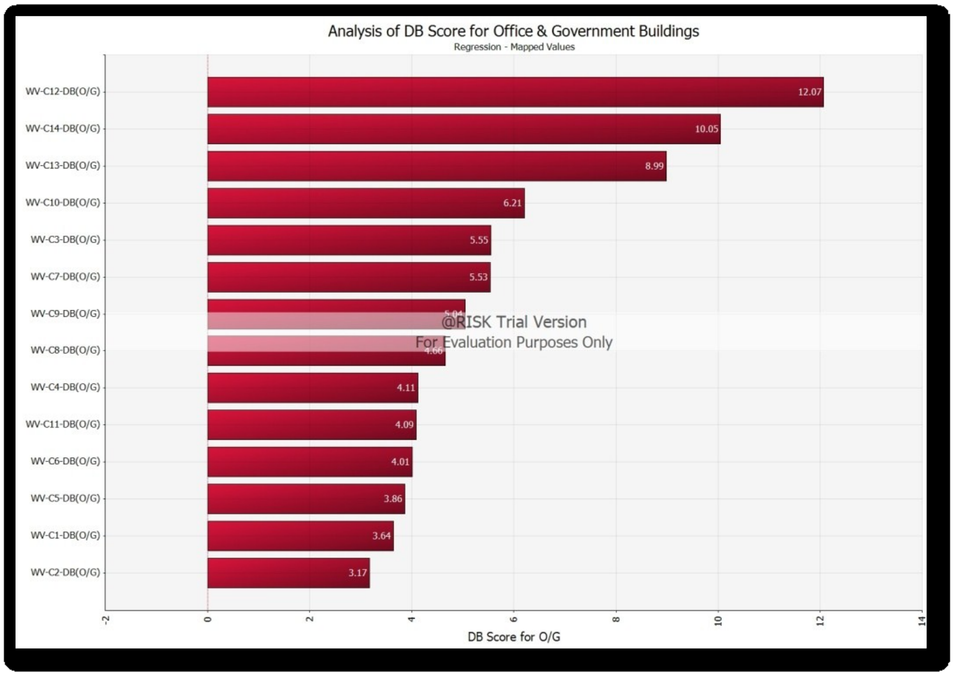

Figure 21 Sensitivity Tornado Graph of DB Score for Office and Government Buildings

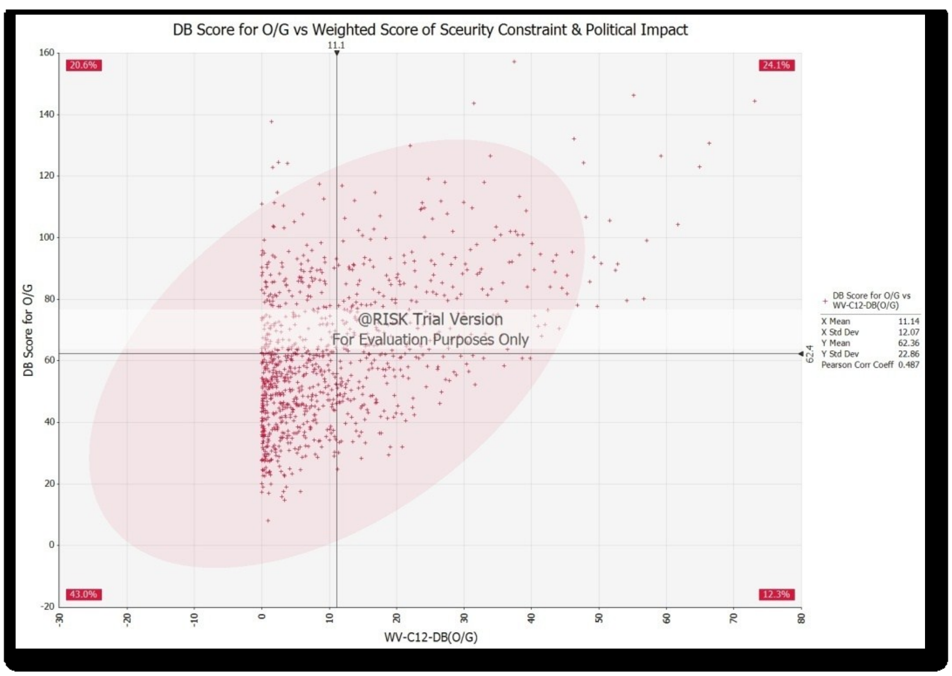

Figure 22 Selection Factor with most impact on DB for Office and Government Buildings

Figure 23 Selection Factor with medium impact on DB for Office and Government Buildings

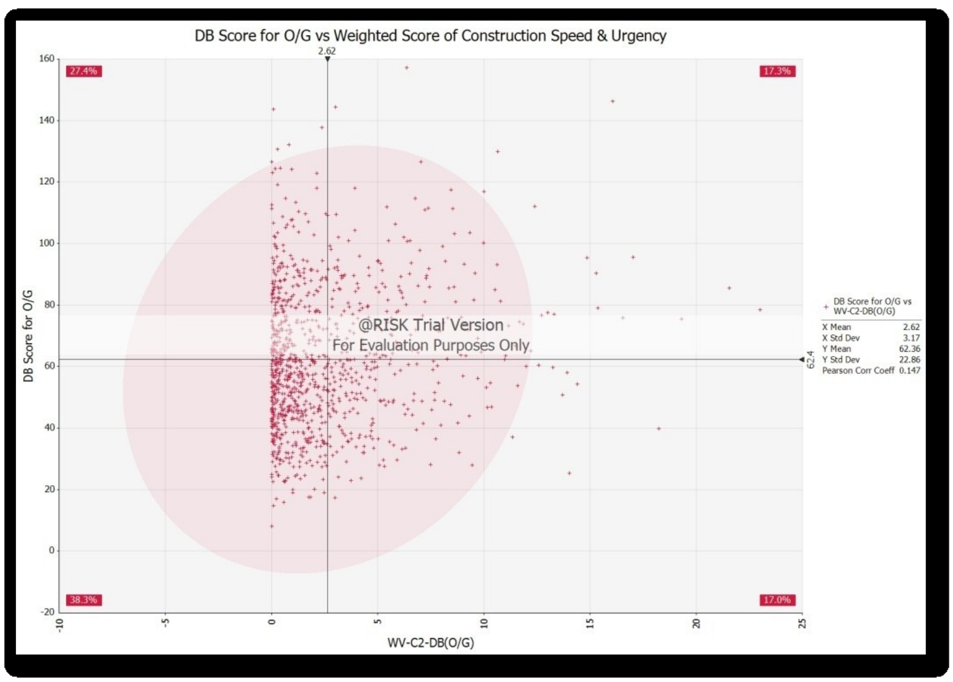

Figure 24 Selection Factor with least impact on DB for Office and Government Buildings

3. CM-R

3.1 Health and Educational Buildings

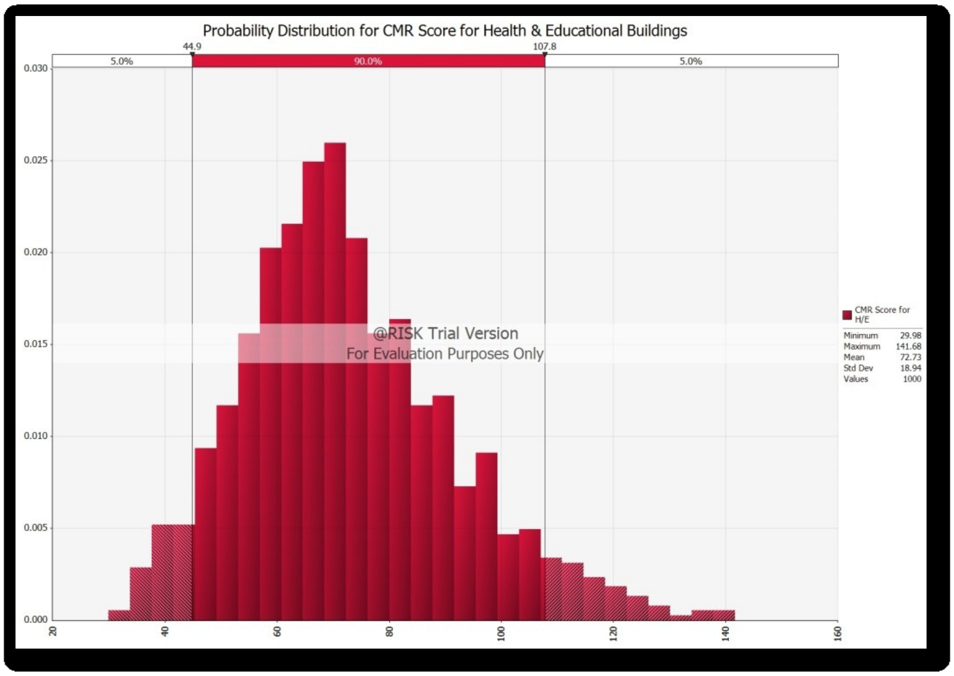

Figure 25 Probability Distribution of CMR Score for Health and Educational Buildings

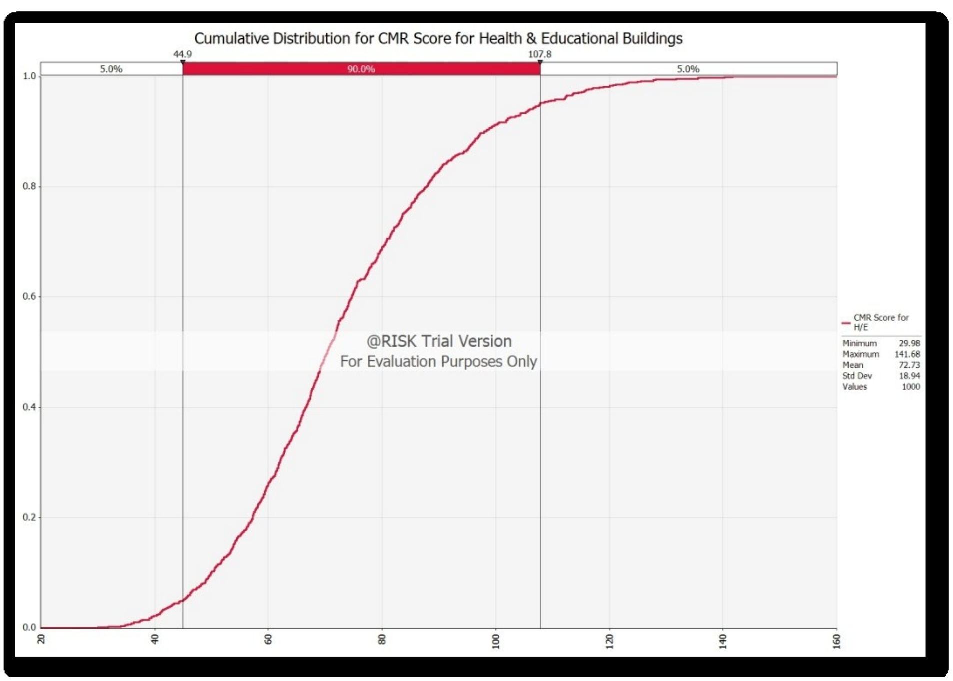

Figure 26 Cumulative Distribution of CMR Score for Health and Educational Buildings

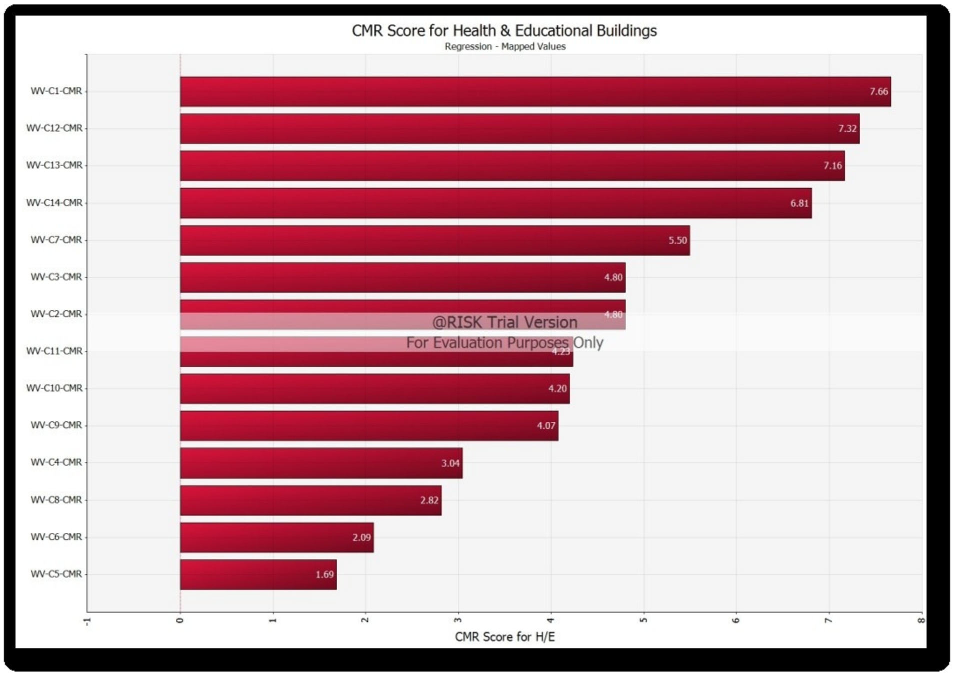

Figure 27 Sensitivity Tornado Graph of CMR Score Factors for Health and Educational Buildings

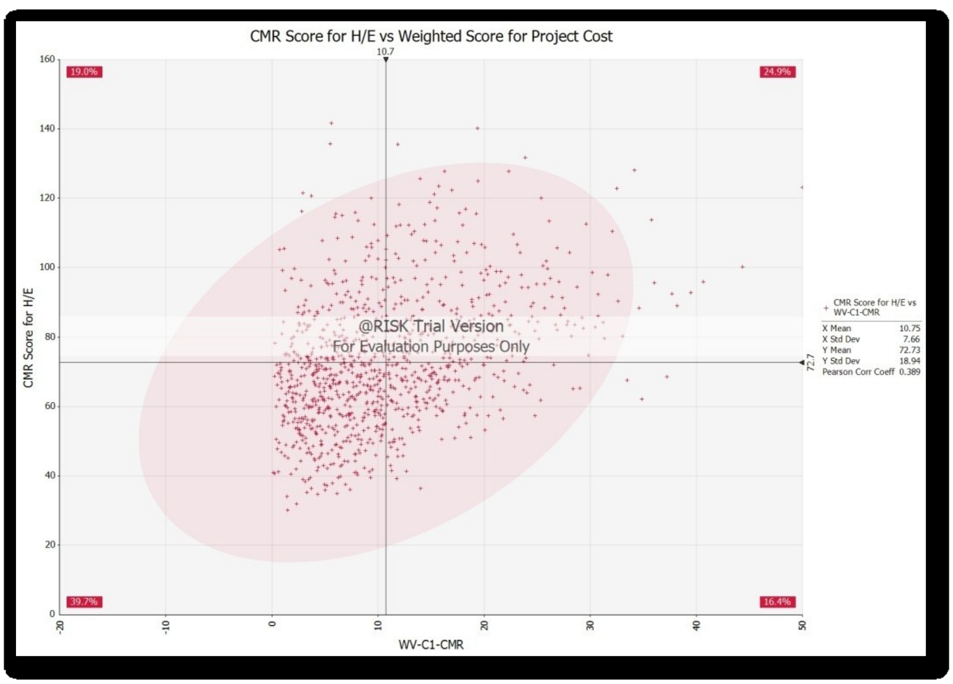

Figure 28 Selection Factor with most impact on CMR for Health and Educational Buildings

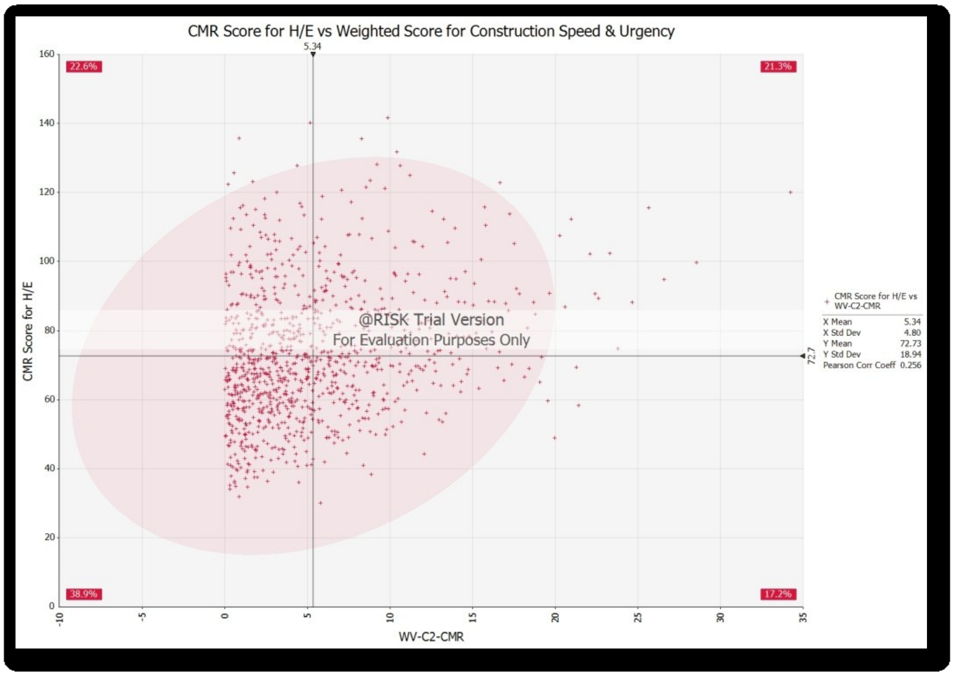

Figure 29 Selection Factor with least impact on CMR for Health and Educational Buildings

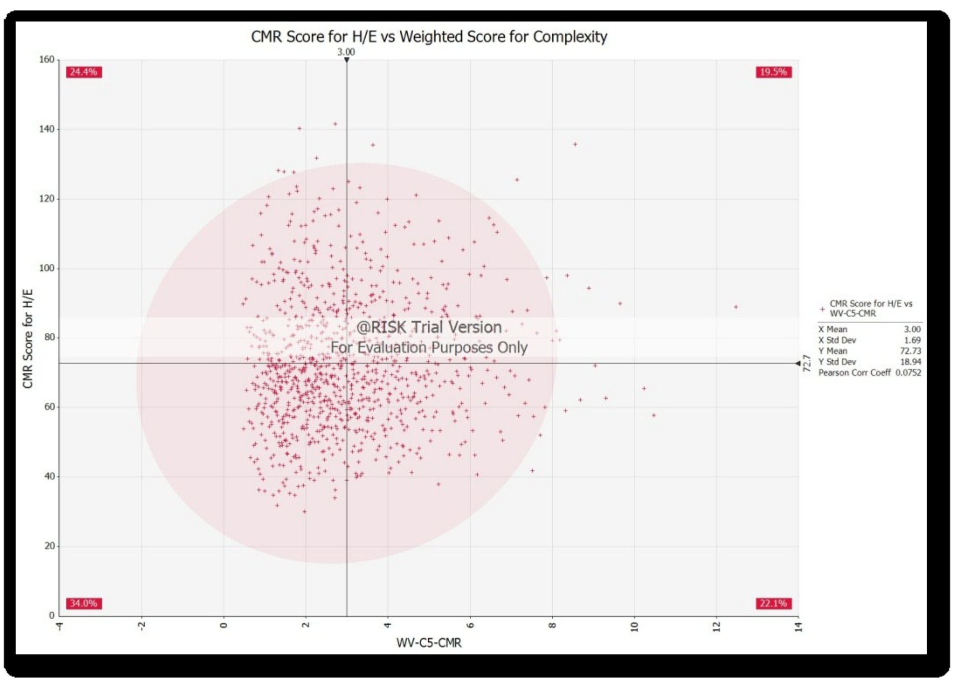

Figure 30 Selection Factor with medium impact on CMR for Health and Educational Buildings

3.2 Office and Government Buildings

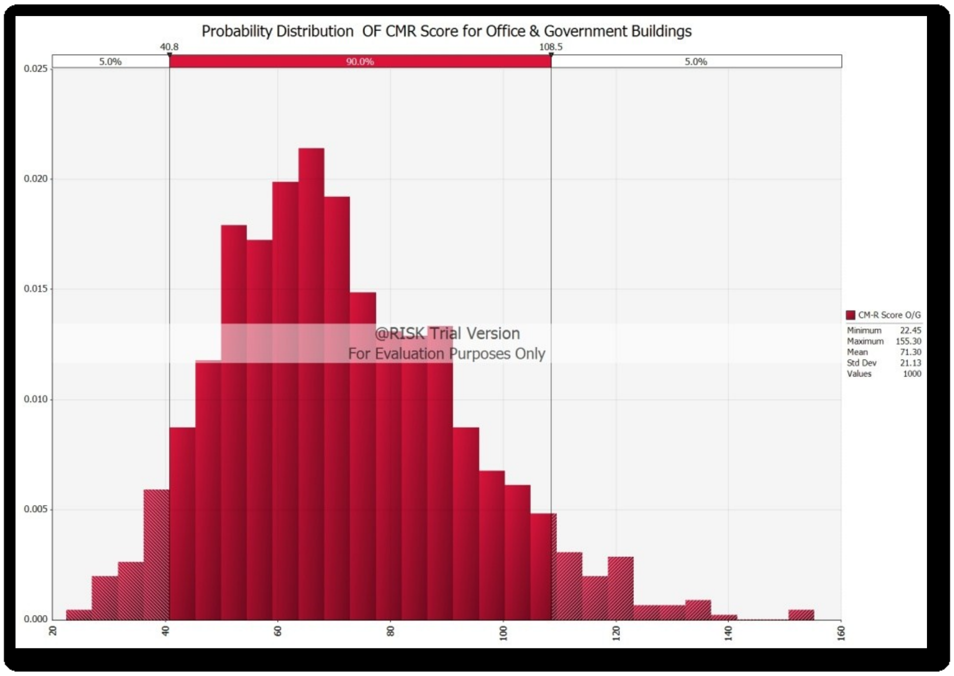

Figure 31 Probability Distribution of CMR Score Office and Government Buildings

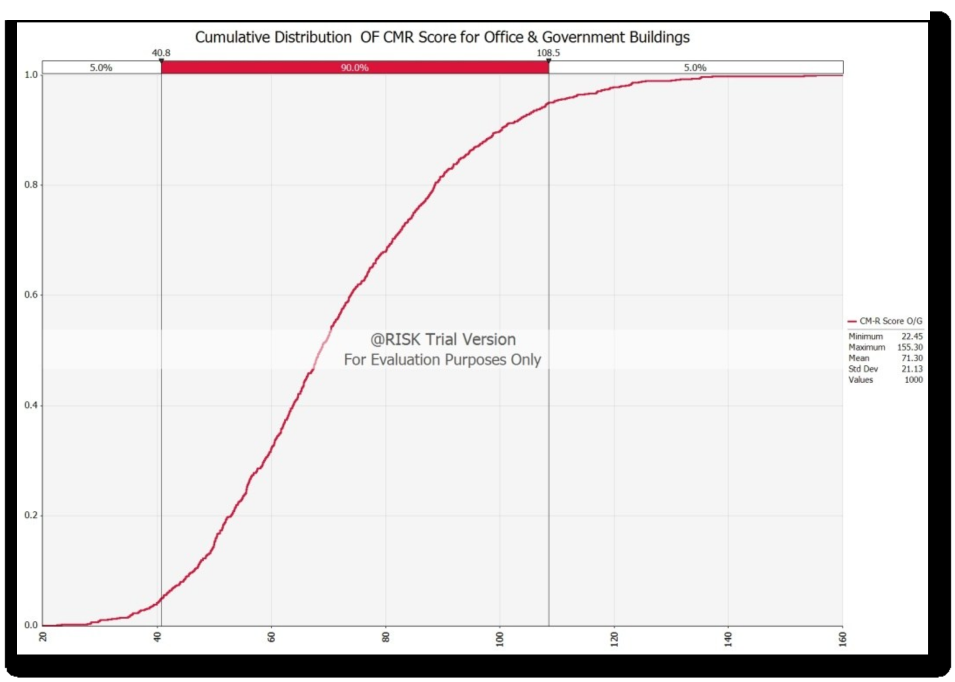

Figure 32 Cumulative Distribution of CMR Score for Office and Government Buildings

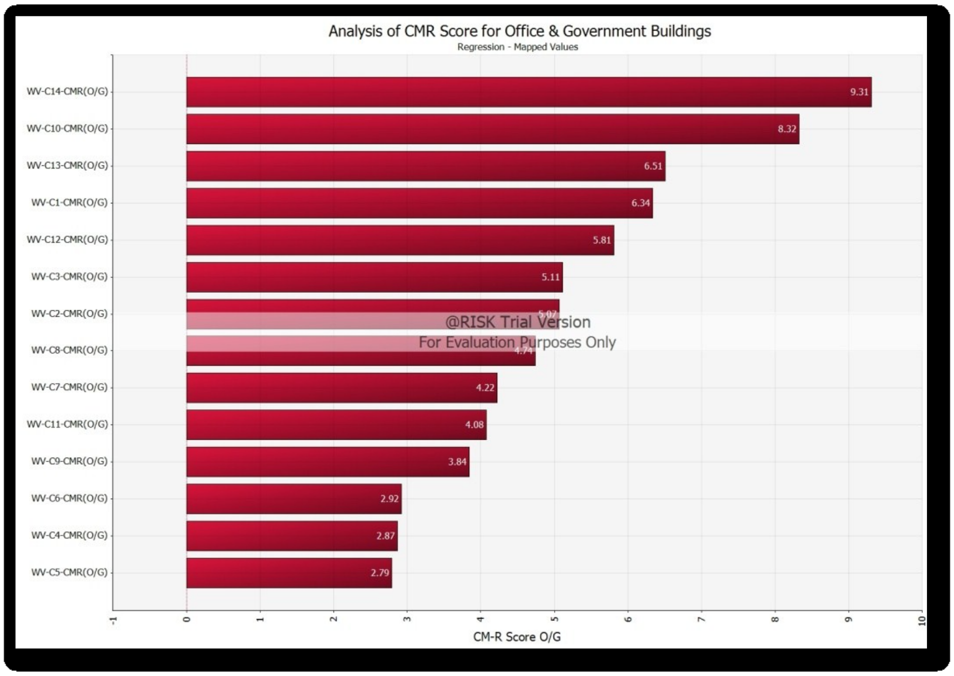

Figure 33 Sensitivity Tornado Graph of CMR Score for Office and Government Buildings

Figure 34 Selection Factor with most impact on CMR for Office and Government Buildings

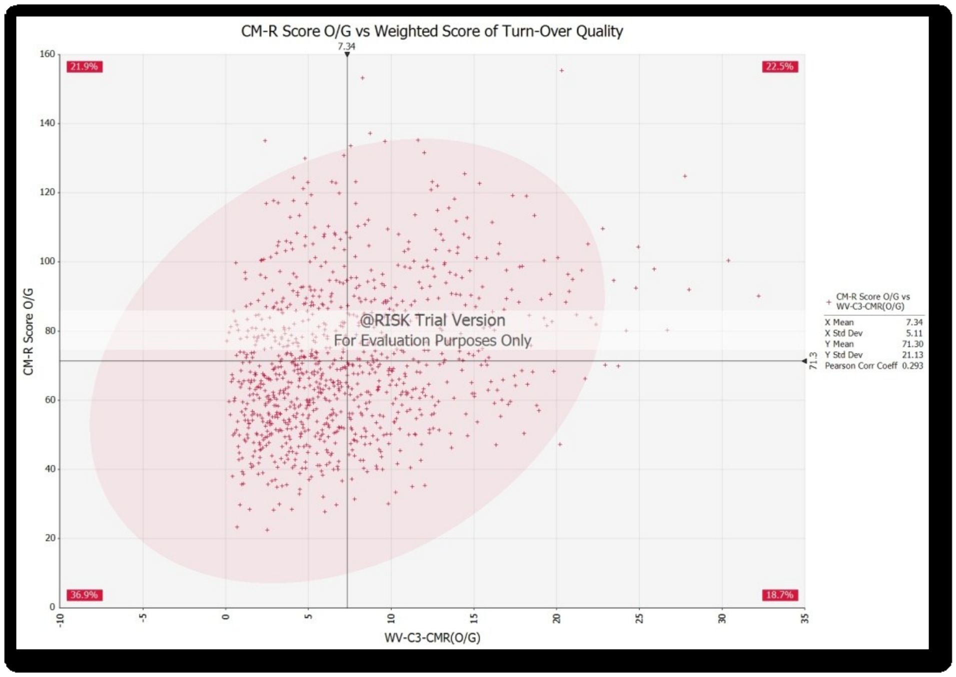

Figure 35 Selection Factor with medium impact on CMR for Office and Government Buildings

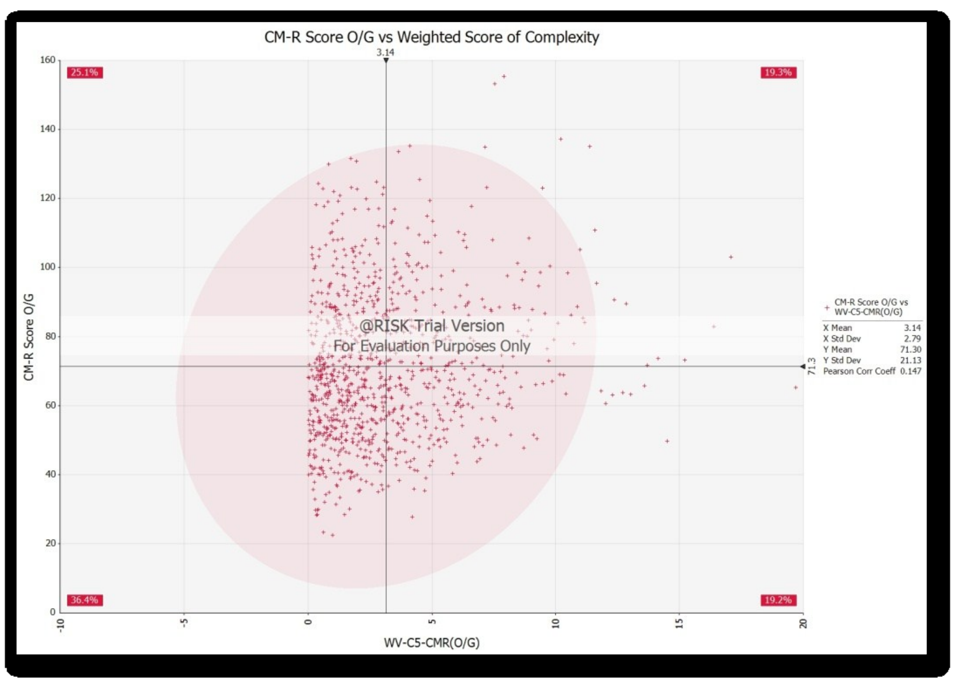

Figure 36 Selection Factor with medium impact on CMR for Office and Government Buildings

4. Comparative Distribution of PDS Score

4.1 Health and Educational Buildings

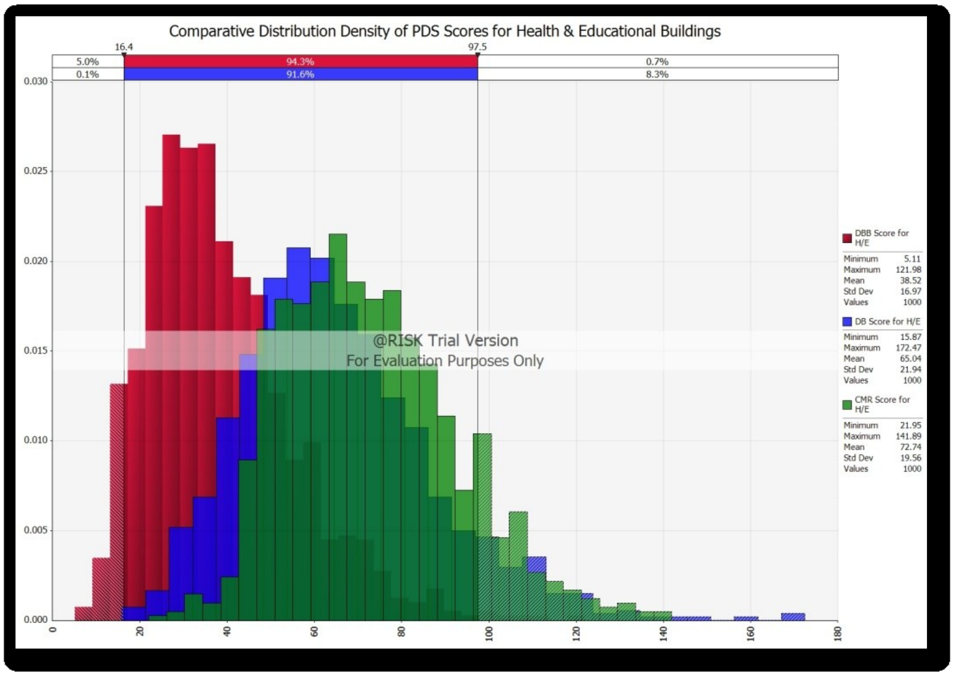

Figure 37 Comparative Distribution Density of PDS Score for Health and Educational Buildings

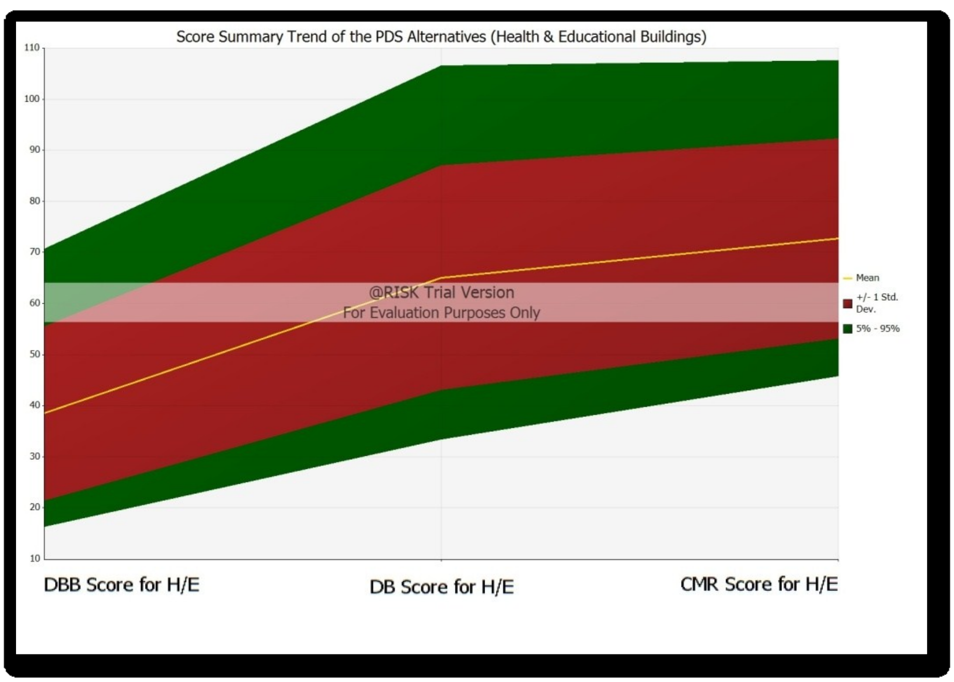

Figure 38 Summary Trend for PDS Scores-Health and Educational Buildings

4.2 Office and Government Buildings

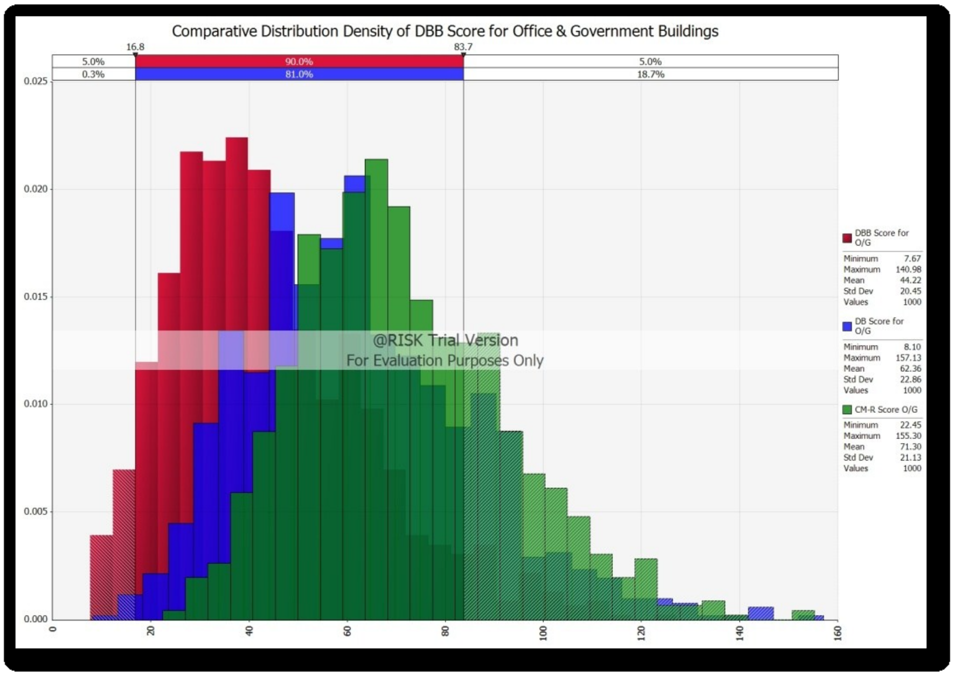

Figure 39 Comparative Distribution Density of PDS Score for Office and Government Buildings

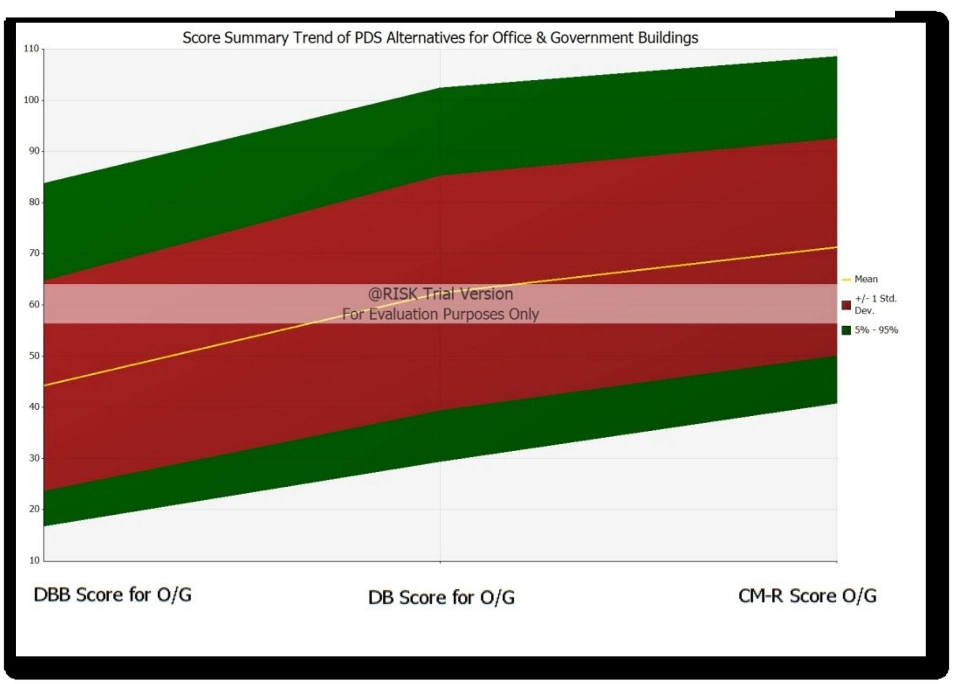

Figure 40 Summary Trend for PDS Scores- Office and Government Buildings

APPENDIX III

ALTERNATIVE PROJECT DELIVERY SYSTEMS

1.1 The Traditional Project Delivery Process

Also referred to as the "design-bid-build" process, features a prevalent role by the owner. Much of the risk is retained by the owner who orchestrates the process in a series of sequential steps. This is by many accounts the most appropriate for repetitive, recurrent commodity types of construction such as roads, earth-moving warehouses and the like, as well as most public buildings and medium-sized projects.

What follows include a brief look at some of the key attributes of the traditional (design-bid-build) approach:

• **Project financing:** Determining the source of finance is handled by the owner; in the case of public owners the available options range from the direct appropriations to revenue or general obligation bonds. Finding and securing project funding is solely the responsibility of the owner.

• **Operation and maintenance:** The owner operates and maintains the facility and may use in-house staff or contract support or some combination of the two.

• **Ownership:** Usually the site ownership rests with the owner and title of the constructed facility vests in the owner at completion by the builder.

The traditional project delivery (DBB) process became the go-to delivery process for public owners in the latter half of the last century.

1.2 The Rise of Alternative Delivery Systems

The discontent with the traditional design bid build process surmounted during the 80's. Litigations were often the result of the adversarial relationships between the project parties (architect, engineer and constructor). Owners were becoming increasingly distraught having to arbitrate between the parties and cost overruns and schedule delays were becoming all too common. Consequently, alternative delivery systems began to emerge in the public sector.

I. **Fast-Track:** is a system in which some of the design, procurement and construction phases are executed in parallel--but in contrast to design-build, independently—as a mean to delivery time reduction. This approach is used to expedite construction where investors/owners anticipate to quickly start generating revenue from the facility (quick return, e.g., during a real estate boom). It is also used when a functional facility or space is need by a particular deadline namely as an Olympic site, or where high-value, short life-cycle products such as computer chips (Intel), require specialized facilities which are often only a small percentage of total product costs.

II. **Multiple-Primes:** is a variation of either design-bid-build or design-build where an owner divides the project into discrete sub-projects and selects contractors to independently and often simultaneously construct them. The multi-prime approach can potentially reduce costs and the risk of reliance on a single contractor by bidding smaller packages. However, practicing Multi-Prime requires that the owner or his appointed program manager should have sufficient knowledge and the necessary skill set to effectively coordinate and supervise the activities of a multitude of primes and avert job site and scheduling conflicts and confusion. Multiple primes are widely used by the U.S. Department of Defense, state transportation agencies and airport authorities in the United States.

III. **Design-Build:** Is a method that has come to prominence in Europe and many parts of Asia, it eliminates the separate responsibilities for the designer and the contractor altogether. Design build provides the owner with a single point of contract since in most cases the designer is a partner, a subcontractor or an employee of the contractor.

IV. **Turnkey:** “Turnkey,” often referred to as EPC, is essentially design-build plus operation start-up to ensure the provision of a properly working facility. Turnkey is widely exercised in the chemical, petrochemical, and power sectors where long lead time equipment procurement is often a critical component of construction. In recent years the turnkey method has expanded to water and sewage treatment works, and specialized buildings such as laboratories, manufacturing plants, prisons and hospitals.

1.3 Inclusion of the Private Sector

There is no single “model” of a “standard” public private partnership. Each one is devised to align with the parameters of the project, and more importantly, meet the risk tolerance of the partners. As the name suggests, there are three components in any PPP undertaking:

A. **The Owner or the Public Partner:** The Public partner may be any public owner who has a facility need. This may be a city, a county, a highway department, or the Corps of Engineers.

B. **The Private Partner:** The private partner may be a single company, but more often it is a team of companies who have come together to undertake the partnership. The team is usually arranged to cover all the disciplines and expertise necessary to deliver the partnership. The team may take a number of legal forms-a special purpose corporation, a joint venture, etc.

C. **The Partnership Agreement:** The agreement between the parties is often complex and involves numerous documents, particularly if there is a private financing dimension to the project. It encompasses much more than a design and a construction agreement. Both partners need to involve legal experts when structuring the PPP agreements.

In order for a PPP to be a viable option, the following conditions must apply:

- **There has to be a crisp and sustained urgency for the project:** The project must have a strong public need and that need must be in existence for a foreseeable future. If the funding is expected to be derived from the revenue generated by the facility or product being catered by the project, the continuity of the need into the future is essential to justify funding.
- **A solid project scope definition:** The project scope must be fully developed and detailed -at least in terms of performance. Agreement on project performance requirements by the partners must be absolute.
- **The project must produce a quantifiable product or a service:** Project financing is almost always derived from the product or service produced by the project. Whether financing is provided by the public partner or the private partner,

it is required that the revenue stream from the project be quantifiable so that an appropriate financing mechanism can be set up. If private financing is to be an option, the public partner must be willing to enter into a long term agreement to take the product or service provided by the project and to pay for it-a so-called "take-or-pay" agreement. The partners must be able to agree on how to share the project risk. The partners must negotiate and agree on "The Deal". The roles and responsibilities of the partners must be clear and complete for both sides and must be reduced to writing.

- **The project must have a strong political champion willing to confront the interest groups who may be opposed:** PPP's are different. There will be opposition from various interest groups who see the PPP as an infringement on their normal rights and responsibilities, and there must be a strong political champion willing to work with these groups to reduce their concerns.

V. **Build-Operate-Transfer (BOT):** BOT similar to turnkey, couples design-build with an operating period. In recent years, it has been adopted, often together with independent project financing (structural financing), for complex infrastructure such as mass transit, airports, pipelines and power.

VI. **Super Turnkey:** A contemporary variation of turnkey construction where a company designs and constructs a facility to meet often demanding performance specifications and/or parameters defined by the client and initially operates the facility under contract. Super turnkey development places increased technical and financial risk on the contractor and typically requires additional expertise often accompanied by proprietary technology.

VII. **Build-Transfer-Operate (BTO):** A private developer finances and builds a facility and, upon completion, transfers legal ownership to the sponsoring government agency. The owner then leases the facility back to the developer under a long-term lease, during which the developer operates the facility and has the opportunity to recover the investment and a reasonable profit. This arrangement is similar to the BOT model previously described, but can avoid some of the legal, regulatory, and liability issues that can arise from private ownership and, in the U.S. and a number of other countries.

VIII. **Build-Own-Operate-Transfer (BOOT):** In effect, a concession that at the completion of the concession period, is “returned” to the original owner, either at an agreed-upon price, or as payment for the concession.

IX. **Design-Build-Operate-Maintain (DBOM):** A variation of BOOT, designed to take advantage of governments’ (especially in the U.S.) access to lower cost or “tax free” funding, but is also increasingly popular as a legal way to “lease” government-owned/government-built facilities to a concessionaire for a fixed time period.

X. **Wraparound Addition:** A private developer finances and constructs an addition at an existing public facility. The private developer then operates both the existing facility and the addition for either a set period of time, or until the developer recovers costs plus a reasonable return on investment.

XI. **Lease-Develop-Operate (LDO):** A developer is given a long-term lease to operate and expand an existing facility. The developer agrees to invest in facility improvements, and can recover the investment plus a reasonable return over the term of the lease under the lease-develop-operate model.

XII. **Build-Own-Operate (BOO):** The classic concession where a private developer finances, builds, owns, and operates a facility in perpetuity. The developer/owner may be subject to regulatory constraints on operations, toll and service levels, etc. The long-term right to operate the facility ideally provides the developer with sufficient financial incentive to maintain and improve it.

XIII. **Buy-Build-Operate (BBO):** An existing facility, often public, is sold or transferred to a new owner who renovates or expands the facility, and then continues to own and operate the facility in perpetuity.

XIV. **Operate and Maintain:** A company operates a public facility under contract with the sponsoring government or private owner (computer and electronic data processing services, toll collection, water and sewage plant operation, and janitorial services, etc). Operation of a facility under such arrangements, typically termed “outsourcing,” can result in improved service and efficiency and are commonly used by local government to provide municipal services such as solid waste removal.

APPENDIX IV

DESCRIPTION OF THE PDSSF'S IN POST-CONFLICT

I. **Project Cost:** is amongst the chief factors that respondent will consider as a precursor to the decision making process. In order to measure the level of attainment or desirability of a given PDS option vs. this factor, the decision maker, or the survey respondents in the present research, will not gauge the project cost on its own. What is in question is the importance or the weight that is attached to this factor due to its influence on the PDS selection process, as well as the degree to which it can affect the choice of best PDS option. The text book definition of cost (budget) stipulates that, the project owner has to determine a realistic budget prior to design in order to evaluate project feasibility, secure financing, and as a “tool to choose from among alternative designs or sites”. Once the budget is determined, the owner requires that the project be completed at or close to the figure set out in the budget without excessive overruns. On the other hand, PDS alternatives (DBB, DB and CM-R) react differently to the issue of cost, both in terms of how effective they are in preventing cost overruns or in other words leveraging a within budget completion and how well they can cope with the absence of an accurate or wholesome cost estimate. An example would be the lump sum contracts in the traditional (DBB) delivery approach. It’s almost impossible to go ahead with a DBB without knowing the project cost. This is due to its sequential nature of design-tender-construction. Whereas In a DB approach, the design package could evolve while construction is already underway; therefore cost determination has a lesser impact on the selection of PDS.

II. **Construction Speed and Urgency:** Similar to cost, it is not the schedule in itself that the respondent should assess. The aim is to elicit the importance of construction speed and the agency’s anticipation of urgency in the construction process and exploiting the alignment of these concerns with the attributes of the PDS options in order to run the selection model. The construction speed could also be seen as speedy procurement process and agency's desire to have the project completed as soon as possible. The literature suggests that DB is 7% faster than CM-R and 12% faster than DBB (Konchar 1997). Given the agency's preference for expeditious completion of the project and anticipation of circumstances beyond control (the urgency, like an up-coming election, etc.) the choice of PDS will be affected.

III. Turn-Over Quality:

This selection factor touches on turnover quality alone which is a subset of quality. Quality in this context is synonymous with "Agency's satisfaction". Quality in its broader sense is divided into two subsets (some researchers have envisaged a third subset as being "process equipment and its layout"). These subsets include:

- **Turnover quality:** which investigates quality indices such as:
    - Ease of start-up: indicates the difficulty of facility startup process.
    - Call backs: reflects the number and magnitude of call backs during the turnover process.
    - O&M cost: indicates the achievement of expected operation and maintenance costs for the facility.
- **System quality:** includes quality indices such as:
    - Quality of envelope, roof, structure and foundation.
    - Quality of interior space and layout.
    - Quality of environmental systems: such as HVAC systems.

With the above classification in mind, the three quality indices that respondent should aggregate into the selection process are those classified under “turnover quality”. The literature suggests that the latter subset, i.e. system quality does not play as major a role as turnover quality in the decision leading to selection of a project delivery system.

The literature (Konchar 1997) suggests that each project delivery method results in different level of turnover quality. DB and CM-R outperform DBB in terms of startup quality. DB and CM-R also outweigh DBB in terms of callbacks and DB outperforms DBB and CM-R in terms of O&M quality.

IV. **Confidentiality:** is a key consideration that affects the choice of funding agencies in delegating design and oversight aspects of a project to a third party. For instance in Design-Build contracts, the owner benefits from having to deal with a single point of contract (the designer-constructor entity) that saves the owner from the headache of dealing with too many parties. On the other hand, the owner must have utmost confidence in the work of DB contractor or alternatively, the project should not be marked as classified, otherwise the owner will have certain reservations in terms of choosing a DB contract. In such cases, selection of Design Build or CM-R is met with reluctance and the owner is inclined toward the Traditional DBB system. Owners with highly specialized program needs find it unsuitable to turn over responsibility to an outside team, without ensuring adequate level of confidence and oversight. Therefore, in post-conflict construction, elucidation of owner's position on confidentiality is an important factor that in conjunction with other considerations could implicate the outcome of the PDS decision making process.

V. **Complexity:** is seen as the adequacy of the PDS option to deal with complex (type and size) projects. The complexity could stem from the project size or type or could be associated with owner's desire for innovative design and/or technologically advanced facility that would require particular contractor and constructability analysis. Every PDS option responds differently to this criterion, for instance, DB is best suited to conventional projects for which project requirements could be clearly defined and the expertise is widely available.

VI. **Flexibility:** is the ability and/or authority of the agency to effect change after construction cost estimate commitment to the contractor. Depending on the chosen PDS, owner will have varying latitude in terms of accommodating design changes throughout the design and construction process. The behavior of each PDS with respect to flexibility has been further discussed in the project delivery method pros and cons section under chapter II. To determine which PDS best serves this selection factor, the respondent have to determine the extent to which they can anticipate altering the project, one way or another, once the work has begun on site.

VII. **Risk Allocation:** is defined as the risk proclivity of the agency and its preference for shifting some of the traditional risk (design errors and omissions, cost and time) to design/constructor party. More specifically, to establish a reference between this factor and the PDS options, respondents should specify the extent to which the agency (funding/development) wishes to limit the speculative risk and transfer the risk of time, cost and design liability. Conversely, project owners fall into two categories of risk averse and risk prone in terms of their strategy versus risk. Meanwhile, one of the overriding differences between project delivery options lies in their ability to distribute risk. In DBB for instance, the delivery method can help the project owner divide the risks between the designer and the contractor, but the risks of additional construction costs resulting from design errors are almost entirely retained by the owner. In DB however, the owner is in a position where he can decide about the type of risks he wishes to transfer to the DB contractor. In DB the risk is transferred to the design-builder entity for the most part. CM-R on the other hand, facilitates the risk management but is not ideal in terms of risk allocation given the number of parties involved directly in the project. The extant of the guaranteed maximum price (GMP) clause in CM-R, as a mean for risk allocation, alleviates the overall risk to the owner; yet it's reaching an agreement on the GMP and the degree of CM's involvement in the design review process that determine the extent to which the risk is shared by either party. The interface between owner's risk taking strategy and the behavior of a particular PDS towards risk determines the suitability of a given PDS for a particular project owner.

VIII. **Responsibility and Involvement:** This selection factor reflects of the agency's desire to be directly involved in the project details. The agency's decision on the extent of their involvement in project will directly impact the choice of project delivery system.

The traditional method (DBB) is structured in such a way that calls for active presence and participation of the project owner throughout the design and construction process. In DB, however, the owner adopts a more relaxed stance and in CM-R, owner exerts its influence on the project through the construction manager.

IX. **Scope Definition:** This selection factor relates to the clarity, quality and precise understanding of the project scope before it's submitted to the designer. Certain project delivery systems like the traditional design-bid-build require a fully detailed scope definition before the design phase could begin. Obviously, in such cases the owner's preference weighs in favor of DBB approach. On the contrary, there are circumstances where a fully detailed scope is not a prerequisite and its lack thereof will not hamper the procurement process. In such a case, a DB approach is more appealing as it would allow for phased construction where the project scope and design continue to evolve while the construction work is moving forward.

X. **Agency's In-House Capacity:** This sub-criterion looks at whether the agency has the HR capacity to dedicate to their projects. It also investigates the staff size and the technical capacity/equipment of the agency to guide them in choosing a project delivery method that is more compatible with the wherewithal of the agency. The agency's in-house capability has considerable influence over how much outside assistance is required during the design and construction process.

XI. **Constructability:** is perceived in terms of effectiveness and constructability of design as well as the Integration of construction knowledge with expertise. It involves a formal process of allowing contractors to add their input to the project design before the bidding starts. This process determines the level of difficulty of the construction and to provide design modifications that facilitate the construction process resulting in cost and time savings, as well as alleviating the disputes. Various studies confirm that integrating construction knowledge into design process greatly improves the chances of achieving a better quality project, in a safe manner, within schedule and for the least cost. Different project delivery methods, given their inherent features, could pose barriers to the timing of constructability implementations and the degree to which they facilitate the interaction between construction knowledge of the design entity and the expertise of the construction party. The latter objective is achieved by bringing key project players together for partnering and goal setting. This integration is most effective when contractor input is incorporated during the preliminary design phase, not just prior to when the construction starts. Obviously, a PDS with the least potential for adversarial relationship like DB will outrank those such as DBB with the most potential for conflict. Also, as per the definition of constructability, timing of constructability implementation is another key factor. Those PDS options that allow for an earlier inclusion of constructability into design phase are looked upon more favorably.

XII. **Security Constraints and Political Impact:** this selection factor is unique to post-conflict re-construction endeavors. It touches on the limiting effect of political considerations and security related constraints on project procurement and execution. Its bearing on the outcome of project delivery selection decision is based on its underlying factors and the extent to which these factors are affected by security and political instability. The factors influenced by security constraints and political impact are namely as speed, time and cost certainty. Decision makers should remain focused on the ability of PDS options in offsetting the unfavorable impact of this criterion on the underlying factors mentioned above.

XIII. **Availability of Experienced Contractors:** is concerned with the availability of local designers/contractors and sub-contractors with the needful expertise to meet project requirements. It's needless to say that contractors are essential party to the entire construction process. Shortage or inadequacy of the contractors will significantly jeopardize the project's success. This criterion influences a number of underlying factors such as speed, time, cost, risk allocation and turnover quality. The scarcity of experienced contractors will send the traditional DBB approach to the bottom of the list. This is due to the fact that in DBB approach, competitive bidding is a prerequisite for quality-based contractor selection. This will lead the decision makers to consider alternative delivery options where competitive bidding is not a concern.

XIV. **Availability of Resources and Material:** is also a major concern affected by the economy and trade conditions of the location in which the project is being built. In post-conflict situations, the scarcity of material and resources due to years of unrest and embargo is a ubiquitous problem. This problem has an impact on the factors which determine a project's success, such as speed, time, cost, risk and quality. The availability of material may greatly influence the schedule particularly in projects with a fast track or very tight schedule. Therefore, efforts should be made to select a PDS with the capability to contain and reverse the undesirable consequences and delays stemming from the shortage of material and resources.

APPENDIX V

DESCRIPTION OF THE SPECIFIC TECHNICAL CONSTRAINTS IN POST-CONFLICT CONSTRUCTION PROJECTS

1. Physical Environment

In Afghanistan, there is a systematic lack of records and awareness about the physical environment, climate, terrain, environmental processes (frost, floods, droughts, etc.), as well as the seasonal conditions that affect infrastructure (Eriksson et al. 2009). A significant portion of the construction must be performed in remote mountainous or deserted areas with extreme climatic conditions.

2. Hostile Geographic Terrain

High elevations and isolated mountainous roads contribute to severity of living and working conditions in Afghanistan. In most mountainous areas of Afghanistan, trails are found along the edges of the cliffs. In other parts, where presence of seasonal or permanent waterways separates the land, traffic becomes virtually impossible. These roads are typically narrow and are prone to rock slides due to lack of consideration about slope stability and other design factors during construction. Roads become impassable due to rock slides- a typical problem for steep mountainous areas. Although roads are being designed and constructed, the scarcity of resources at remote locations disrupts the delivery of quality construction materials needed for sustainable and long-term infrastructure solutions (Eriksson et al. 2009; Freeman 2008).

3. Construction standards

The wide ranging cultural diversity in Afghanistan has lead to a wide range of construction practices (e.g., building a dwelling) in the country. It is customary, particularly in rural areas for inhabitants to build their own dwellings or living quarters with a complete disregard to construction norms and techniques and without the supervision of construction specialists (Barfield 2010).

The Afghan construction methods are primitive and limited to various regions and villages. The locally available materials are often selected and used in the construction.

4. Brain drain

As mentioned earlier, Reconstruction efforts in Afghanistan are met by many challenges including shortage of qualified human resources. The lack of trained Afghans in technical domains such as engineering, geology, and construction management is a major hindrance in advancing reconstruction efforts. The United Nations High Commissioner for Refugees (UNHCR) statistics indicate that approximately 6 million Afghans have left their homeland since the Russian invasion in 1979. Despite continuous efforts to incentivize the qualified Afghan Diaspora to return, the emigrants are hesitant and show little interest to repatriate; henceforth, the international community's role in meeting the engineering needs and filling the construction knowledge gaps is further accentuated.

5. The Impact of Tribal social structure on Construction Projects

Afghanistan has a tribal sociological structure. The fundamental disparities and differences between Afghan citizens are attributed in part to the tribal composition of the Afghan society. These disparities are well witnessed in terms of cultural and linguistic dissimilarities in different Afghan provinces. The persistence of the tribal nature in this country is by large the result of inadequate communications and restrictive transportation infrastructure. This tribal nature has certain implications on construction projects. This means that citizens in different provinces will have different skills and different set of expectations for structures. Moreover, the prevalent nepotism will prevent contractors with a different tribal background to work as freely in a particular province. In other words, the local population will be more accommodating to contractors from their own province.

6. Challenges in Quality Control and Monitoring of Projects

Reaching out to remote construction sites throughout Afghanistan has forever been a ubiquitous problem. In an effort to marginalize insurgency and to usher in economic development, there has been an increase in the number of construction projects taking place in remote areas with alarming security conditions (Diderich 2007). The ever-present security concerns limit the mobility of engineers and reduce project oversight and inspection. Therefore, there is growing demand for adoption of situation specific construction methods that would ensure quality of construction and reduce the need for permanent on-site supervision.

7. Corruption

In post-conflict countries, high costs of living, limited resources, poverty and financial distress have lead many professionals to seek irregular means of income. This phenomenon exacerbates corruption and gives rise to further conflict and is detrimental to the trust between the stakeholders. Stringent bureaucratic rules and regulations area introduced to the system as a mean to curb rampant corruptions. Yet corruption finds a way to nestle in the nooks and crannies of complex bureaucratic procedures (Danert et al., 2003).

8. Security Related concerns

The insurgency and war is still brewing in large parts of Afghanistan. Given the magnitude of reconstruction efforts in this country, it is inevitable that many construction sites are located in insurgent infested areas with higher security threats to the international development agencies, contractors and the beneficiaries. It is imperative that safety and security of construction personnel must be incorporated into the planning process. As earlier discussed, geo-climatic conditions of Afghanistan are diverse and replicating prototype designs would require site specific information, which in light of said security concerns, could be very difficult to procure. In such cases extraordinary measures must be taken to access site information such as coordination with military or security providing companies. Furthermore, vandalism and destruction of construction equipment, abduction of personnel and other disruptive behavior are common acts of insurgency that delay construction.

9. Design-build challenges

Design-Build is a form of project delivery system that is often preferred by many project owners. In Design-Build construction project delivery systems, two cardinal aspects of the work, the design and construction, will be carried out under a single contract, which makes it more manageable for the project owner. This type of construction project delivery system is governed by a very tight timeline. Success of a Design-Build project delivery method is contingent upon the capacity and capability of the various project elements. Insurgency, shortage of skilled workforce, sub-par management, socio-economic and political instability restrict Afghanistan's capacity to undertake construction and development projects (silver 2003), diminishing the allure of Design-Build as the project delivery method of choice.

10. Quality the of Construction Materials

As earlier outlined, transportation network in Afghanistan is under-developed. Lack of corridors and proper connection intensifies the problem of delivering construction materials to remote locations. Construction materials, in often cases, are imported from neighboring countries and supply chain is inconsistent with market needs. Due to Poor road conditions, inadequate means of transportation and inconsistency in supply chain, material procurement should take place with proper planning, ahead of time and in anticipation of contingencies such fluctuation of Material costs due to lack cost control measures and rising inflation rates (Jaselskis and Talukhaba, 1998). Cement for instance, is a commodity which is always in short supply. Additionally, there is great inconsistency between contractors using patchy materials and their construction methods (Freeman 2008). Generally, contactors have a tendency to procure locally available materials. There are very limited construction material laboratories that can assess and test properties of local construction materials. There are generous deposits of aggregates across Afghanistan. Conversely, in post-conflict countries, cost of construction material runs high and their quality is inferior in comparison to the developed countries. Designers are compelled to compensate for low-end quality in their designs. Assessing the quality of material will only be made possible after they are delivered to the job site. Upon inspection, they are either returned or if that is not an option, the inferior quality material is put to use as is resulting in a poor quality of construction. Procurement of construction material requires significant pre-planning Moreover; Local contractors have a tendency to save on costs by cutting corners and compromising on the quality of material. Also, application of knockoff construction materials is common and conflicts with desired material specifications.