INVESTIGATING THE CHALLENGES FOR THE IMPLEMENTAION OF CONSTRUCTABILITY PRACTICES IN CONSTRUCTION INDUSTRY

By

RAO UMAIR ASGHAR

(00000118688)

A synopsis submitted in partial fulfillment of

the requirements for the degree of

Masters of Science

in

Construction Engineering and Management

Department of Construction Engineering and Management

Post Graduate Wing - SCEE

School of Civil and Environmental Engineering (SCEE)

National University of Sciences and Technology (NUST),

Islamabad, Pakistan

(2019)

THESIS ACCEPTANCE CERTIFICATE

Certified that final copy of MS thesis written by Rao Umair Asghar (Registration No. 00000118688) of Post Graduate Wing – SCEE has been vetted by undersigned, found complete in all respects as per NUST Statutes/Regulations, is free of plagiarism, errors, and mistakes and is accepted as partial fulfillment for award of MS/M Phil degree. It is further certified that necessary amendments as pointed out by GEC members of the scholar have also been incorporated in the said thesis.

Signature: ___________________________________

Name of Supervisor: Dr. Khurram Iqbal Ahmad Khan

Date: _______________________________________

Signature (HOD): _____________________________

Date: _______________________________________

Signature (Dean/Principal): _____________________

Date: _______________________________________

This is to certify that the

thesis titled

INVESTIGATING THE CHALLENGES FOR THE IMPLEMENTAION OF CONSTRUCTABILITY PRACTICES IN CONSTRUCTION INDUSTRY

Submitted by

Rao Umair Asghar

(00000118688)

has been accepted towards the partial fulfillment
of the requirements for the degree of
Master of Science in Construction Engineering and Management

Dr. Khurram Iqbal Ahmad Khan

Assistant Professor, Head of Department (HOD)

Department of Construction Engineering and Management

School of Civil & Environmental Engineering (SCEE)

National University of Sciences & Technology (NUST), Islamabad

ACKNOWLEDGEMENTS

In the name of Almighty Allah, the most Merciful, the Beneficent. All praise is only for Allah who created us and always planned the best for us. I am grateful to the Almighty Allah for His countless blessings and mercy bestowed upon me through the difficulties of life and I seek His guidance, and pray to Him for blessings and ease throughout this life and the life to come.

I am in debt of gratitude to my research supervisor Dr. Khurram Iqbal Ahmad Khan for his guidance, motivation and constant encouragement throughout this journey. I sincerely appreciate the valuable time and personal support accorded by him. I am also extremely grateful to the committee members, Dr. Abdur Rehman Nasir and Mr. Muhammad Hasnain for their sincere guidance to complete this research work.

I am very grateful to all the respondents for their valuable contribution to this research. And at the end, I would like to pay my earnest and honest gratitude to my family, especially my husband for his unconditional support, encouragement and patience.

ABSTRACT

Constructability lays the foundation of effective design and execution of a project which results in cost savings as well completion of project without any delays in schedule. It involves in improving projects internal and external factors that enhances performance of a project. Implementation of constructability practices is a great challenge to its practitioners since it necessitates putting all of the vital concepts identified into a feasible package. Efficient project delivery and performance heavily relies on the inter-stakeholder relation. Nonetheless, the current practices and traditional procurement methods in Pakistan's construction industry do not provide a viable environment for the implementation of constructability practices in construction industry. The lack of implementation of constructability practices results in project delay, cost overrun and reworks on most projects. Smooth and cordial working relationships among contractor, consultant and the client can be achieved by implementing constructability practices. This study conducted a survey with 108 construction industry professionals, which revealed the barriers in the implementation of constructability practices construction sites in Pakistan. A formal approach is also proposed to facilitate in adoption of constructability practices based on the construction sector by overcoming the barriers through experienced personnel. This research strives to standardize the management of project's internal and external constraints and give access to real-time information for improving the overall project performance.

Table of Contents

ACKNOWLEDGEMENTS iii
ABSTRACT iv
List of Figures vii
List of Tables 8
List of Acronyms 9
Chapter - 1 10
INTRODUCTION 10
1.1. Study Background 10
1.2. Problem Statement 10
1.3. Research Objectives 11
1.4. Research Significance 11
1.5. Advantages 12
1.6. Scope of Research 12
Chapter - 2 13
LITERATURE REVIEW 13
2.1. Introduction 13
2.2. Construction Industry: Importance in Pakistan 13
2.3. Constructability- Overview 14
2.3.1. Constructability-Definitions 14
2.3.2. Constructability-Perceptions 14
2.3.3. Constructability-Concepts 15
2.4. Constructability Practices- Approach Selection 16
2.4.1. Constructability Methods 16
2.4.2. Constructability Programs 18
2.4.3. Constructability Approach Selection 20
2.5.1. Constructability Implementation: 23
2.5.2. Implementation Challenges: 24
2.5.2.1. Implementation Challenges: General Contractors 24
2.5.2.2. Implementation Challenges: Designers 25
Chapter - 3 26
RESEARCH METHODOLOGY 26
3.1. Introduction 26

3.2. Research Design 26
3.3 Questionnaire Survey 28
3.4 Sample Size 28
3.5 Data Analysis 29
3.5.1 Cronbach's Coefficient Alpha Method 29
3.5.2 Shapiro-Wilk Test 29
3.5.3 Kruskal Wallis test 29
Chapter - 4 30
DATA ANALYSIS AND RESULTS 30
4.1. Introduction 30
4.2. Characteristics of Respondents to Questionnaire Survey 30
4.2.1 Academic Qualification 32
4.2.1 Professional Experience 32
4.2.1 Organization Role 32
4.2.2 Size of Project 32
4.2.3 Awareness about constructability 33
4.3. Statistical Analysis 34
4.3.1 Reliability of the Sample Cronbach's Coefficient Alpha Method 34
4.3.2 Measurement of Normality of Data 35
4.3.3 Test for Non-Parametric Data 37
Kruskal Wallis 37
4.3.4 Relative Importance Index (RII) 39
4.3.4.1. General Group 43
4.3.4.2. Owner Group 43
4.3.4.3. Contractor Group 43
4.3.4.4. Designer Group 43
4.3.4.5. Project Group 43
Chapter - 5 49
CONCLUSIONS AND RECOMMENDATIONS 49
5.1 Conclusions 49
5.2 Recommendations 50
References 51
Annexure-A (Questionnaire Survey) 56

List of Figures

Figure 1: Constructability Approach Selection Descision Model 21

Figure 2: Heirarchical Framework :Owner Characteristics 22

Figure 3: Heriarichal Framework:Project Characteristics 22

Figure 4: Flowchart of Research Design 27

Figure 5: Academic Qualification of Respondents...31

Figure 6: Professional Experience of Respondents 31

Figure 7: Organization Role of Respondents...32

Figure 8: Size of Project 33

Figure 9: Awareness about construcatbility..33

Figure 10: Relative Importance Index of Barriers 42

Figure 11: Relative Importance Index of General Barriers 44

Figure 12: Relative Importance Index of Owner Group Barriers 45

Figure 13: Relative Importance Index of Contractor Barriers 46

Figure 14: Relative Importance Index of Design Group Barriers..47

Figure 15: Relative Importance Index of Project Barriers..48

List of Tables

Table 1: Benefits of Construcatbility 15

Table 2: Results of Shapiro Wilk Test 35

Table 3: Results of Kruskal Wallis Test 37

Table 4: Relative Importance Index of Barriers 40

Table 5: Relative Importance Index of General Barriers 43

Table 6: Relative Importance Index of Owner Barriers 44

Table 7: Relative Importance Index of Contractor Barriers 45

Table 8: Relative Importance Index of Designer Barriers 46

Table 9: Relative Importance Index of Project Barriers 47

List of Acronyms

- ASCE American Society of Civil Engineers
- ACI American Concrete Institute
- BIM Building Information Modelling
- BRT Business Roundtable
- CI Construction Industry
- CII Construction Industry Institute
- CIIA Construction Industry Institute Australia
- CIRIA Construction Industry Research and Information Association
- CPEC China-Pakistan Economic Corridor
- CAD Computer Aided Designs
- ISO International Organization for Standardization
- KPIs Key Performance Indicators
- MCDM Multi-criterion decision making
- PEC Pakistan Engineering Council
- VE Value Engineering

Chapter - 1

INTRODUCTION

1.1. Study Background

Constructability is defined as “the optimum use of construction knowledge and experience in planning, design, procurement, and field operations to achieve overall project objectives” (Institute 1986). Constructability application suggests that projects where impact of construction in different phases of project, a considerable savings can be achieved. The implementation of constructability practices during initial phases of a project delivers the superlative prospect for project costs (Jergeas and Put 2001). To assimilate this information efficiently, it must be recognized in a required framework to its employers. Improvement in constructability implementation requires, a sound system is needed to seizure and transference experience from construction and engineering projects to impending projects. Constructability analysis is very important because the potential problems may be found before the construction. The main function of BIM is to enhance constructability analysis thought simulating construction operations by 3D model (Yang, LEE et al. 2013). Professionals of construction sector have competencies and knowledge that can be beneficial in developing sustainable project design and provide efficient completion of project without delays. This research will examine detailed constructability practices that can benefit in management of construction work and building information throughout the project delivery process. Identifying the challenges in the implementation of Constructability practices will be assessed to enhance or improve project delivery performance. Different methods are required to utilize in implementing constructability practices and knowledge throughout the planning and execution phase.

1.2. Problem Statement

1. Construction is a highly fragmented industry, as different project stakeholders and participants from different organizations are involved, with varied skills, interests and objectives in construction industry causes delays, claims and excessive operational costs

2. As traditional procurement methods prevail which doesn’t allow the contractor to give information to other stakeholders and creates a hurdle in the application of constructability concepts during life cycle of project.
3. Construction industry lags behind in terms of adoption of modern tools and methods for different phases of project which results in low project performance

1.3. Research Objectives

- To identify the applications of constructability practices in the construction sector
- To identify the challenges for the implementation of constructability practices in construction industry
- To provide recommendations in the adoption of constructability practices for improved performances in the construction sector

1.4. Research Significance

A major incentive to boost construction potency is that the doubtless important edges related to higher levels of construction capability. Value or Cost savings as a recognized profit. Within the industry, profits play a decisive role in maintaining business. Every company makes an effort to spot a replacement plan which will facilitate in increase their saving margins to stay in competition with other companies. Building capability could be a strategic advantage that industrialists will use to realize price savings. Implementing constructability could be a major challenge for professionals because it needs swing all the mandatory ideas into one sensible package. Building capability could be a project plus that has driven consideration of many academic and engineering establishments over last thirty years. Concept of "constructability" in America, or "buildability" in Britain, came out in end of Seventies. These studies represent that the dearth of incorporation between execution and design was basic reason behind value and quality problems by the development trade. several studies are exhausted his space and several other researchers have created necessary recommendations. Today, construction methods square measure being enforced wide within the industry associate degreed became an essential part of the project progress.

1.5. Advantages

Business round-table conference (BRT) calculates reduction in construction prices a minimum of 10–20 times. It's common that once we cite profit, we have a tendency to think about value savings to be the sole profit. However, there square measure several alternative advantages besides value savings. The study will provide following benefits to the construction industry and enhance deliverance of construction projects through refined constructability framework:

a. Improvement in safety measures,
b. Amount of rework reduced, improved communication, improved assurance from crew member.
c. Reduced engineering cost
d. Schedule critical path reduced
e. Reduced execution cost

1.6. Scope of Research

The study will be initiated through a literature review process for determining the level of research carried out on constructability practices and constructability applications. Thereafter, key constructability practices and their applications in different phases of the project will be identified. Afterwards, factors effecting the implementation of constructability in construction industry will be identified. A questionnaire survey will be carried to identify and categorize key barriers for implementing constructability practices and ascertain key performance indicators (KPIs) for constructability practices. Afterwards these responses will be reviewed and integrate with framework to evaluate possible benefits of project deliverance in constructability practices implementation in Pakistan’s construction industry using a statistical software. This information will be utilized for achieving the refined framework for challenges in implementing constructability practices.

Chapter - 2

LITERATURE REVIEW

2.1. Introduction

The current chapter provides review of literature related to the benefits of implementation of constructability practices. It also discusses the research carried out on adoption of constructability tools and practices to reduce delays, cost overruns and errors during pre-design and execution phase in the construction industry. Moreover, it summarizes the efforts to develop framework for implementation of constructability practices in construction industry.

2.2. Construction Industry: Importance in Pakistan

CI plays a crucial part in the social and financial progress of a country. It not only provides the livelihood, but also the access to energy, transportation, infrastructure, housing, health and water to a large and diverse classes of society. It is observed that output of construction industry has a valuable share of around 40-60% in GDP. Also, more than 60 other industries are linked with construction industry. Pakistan's CI has remained a substantial driver in fiscal and social hoist of economy. Economic Survey of Pakistan (Force and Research 1987, Murray 2003, 2017) reported that contribution of Pakistan's CI was 2.74% in the country's GDP with a growth rate of 9.05%. Country's CI also absorbs 7.31% of labor force directly(2017), and overall 30-35% of population relies upon CI(Farooqui and Ahmed 2008). CI's manifold backward and forward linkages with other industries pave the way for country's survival, development, and growth(Farooqui and Ahmed 2008). Pakistan's construction sector has a great potential to play a substantial role in the national growth and development, especially after the inception of China-Pakistan Economic Corridor (CPEC), which is expected to boost the market for the construction industry. However, the construction industry remains one of the most neglected sectors in Pakistan. The government bodies have failed to make policies and reforms to incorporate the modern constructability practices in the CI. Pakistan Engineering Council (PEC) and the respective ministries have made some strides, but with ineffective implementation. Nevertheless, to satisfy the national needs, CI needs an efficient and proactive management of projects to increase the performance and hence the profitability.

2.3. Constructability- Overview

2.3.1. Constructability-Definitions

Construction Industry Institute (CII 1986) defines constructability as “The optimum use of construction knowledge and experience in planning, design, procurement and field operations to achieve overall project objectives” (Gambatese, Pocock et al. 2007). Also constructability can be stated as “the ease with which a project can be built and the quality of its construction documents” (Gambatese et al. 2003). CIRIA in 1983 defines buildability as “The extent to which the design of a building facilitates ease of construction, subject to the overall requirements for the completed building.”(Raviv, Shapira et al. 2012). Constructability can also be outlined as:

- “the capability of being constructed”(Division 1991)
- “a measure of the ease or expediency with which a facility can be constructed”(Hugo, O'Connor et al. 1990)
- “the integration of construction knowledge, resources, technology and experience into the engineering and design of a project”(Anderson, Fisher et al. 1995)
- “a process that utilizes construction personnel with extensive construction knowledge early in the design stages of projects to ensure that the projects are buildable, while also being cost-effective, biddable, and maintainable” AASHTO (2000)

2.3.2. Constructability-Perceptions

Fisher and Tatum (1997) claims that architects mostly didn’t taken into account the influence of execution limitations and also disintegration of construction and design delayed current data discussion. In a study conducted by Touran, he came to a conclusion that “A lack of communication between designer and builder frequently results in designs that are unnecessarily difficult and expensive to build.” (Touran 1988)

2.3.3. Constructability-Concepts

Constructability ideas documented and / or listed during this section embrace some key ideas known by researchers and people being employed in numerous states. CII brought about construction task force to put down the ideologies / ideas that might be want to advance construction potency at every stage of a plan: (1) Conceptual planning, (2) Design and procurement, and (3) Field operations. The task force directed three studies for this persistence (Institute 1986, John Thomas, Rusch et al. 1986, Tatum and Vanegas 1986). In the first study (John Thomas, Rusch et al. 1986). CII coveted to see methods that will help in building enhancements throughout the abstract coming up with section of a venture. Three characteristics are important: to develop whole of a project pathway; Extension website outline; And in view of different major construction ways. Further studies (Griffith and Sidwell 1997) examines however construction information and skill can be used most effectively throughout the engineering and procurable phases. The findings are stated as follows:

- Procurement, design and execution ought to be construction motivated
- Project must be designed as it allows economical construction
- Project design ought to allow the employment of obtainable capitals
- Design must aid in execution under adversative climate situations and
- Specifications must allow to modify construction processes

2.3.4. Benefits of Constructability (Importance)

Table 1: Benefits of Constructability

Domain	Impact	References
Cost	Savings 1-14% Of Capital Cost	(Gray 1983)
	Saving on total project cost	(Elgohary, Fairclough et al. 2003, Trigunarsyah 2004)
	Reduced Site Labor	(Lam 2002)
	Increased cost effectiveness	(Pheng Low 2001)

	Better resources utilization	(Eldin 1999)
Time	Early Completion	(Griffith and Sidwell 1997, Eldin 1999, Pheng Low 2001, Trigunarsyah 2004)
	Increased productivity	(Griffith and Sidwell 1997, Poh and Chen 1998, Pheng Low 2001)
	Reduced outage duration	(Eldin 1999)
Quality	Higher quality of built products	(Eldin 1999, Elgohary, Fairclough et al. 2003)
Safety	Safer environment on site	(Eldin 1999, Trigunarsyah 2004)

2.4. Constructability Practices- Approach Selection

2.4.1. Constructability Methods

The means for constructability knowledge transfer have been defined using different terms in the literature.(Radtke and Russell 1993) dealt with "approaches to implementation of constructability." (Fisher, Anderson et al. 2000) used the term "constructability tools" and defined them as mechanisms that are used to perform a function; in that context tools include documents, procedures, persons, entities, or software programs. (Pocock, Kuennen et al. 2006) discussed "mechanisms" that are used to address constructability. (Arditi, Elhassan et al. 2002) also used the term "constructability tools." The current study used the term "constructability methods," which appears more appropriate when measures such as employment of a constructability champion are considered. One can see the benefit of constructability methods as a way of preventing constructability problems from becoming constructability failures. Following are the main constructability methods identified in the literature. The methods were sorted and are grouped by families that are characterized by different approaches or ways of implementations:

(1) Formal corporate policy statements: statements that elaborate on the intention of the organization in implementing constructability.

(2) Checklists: Checklists covering corporate procedures, lessons learned, technical issues, etc. Checklists are specified to ensure a comprehensive performance of tasks without overlooking vital issues. Among the constructability methods they list, (Pocock, Kuennen et al. 2006) counted checklists aimed to avoid common construction errors as well as the International Organization for Standardization (ISO) certified quality system.

(3) Organizational measures: these are administrative measures taken by the organization in order to establish management teams that are bound to be dedicated to implementing constructability. (Fisher 2007) described the team building process, constructability team, constructability champion, and constructability engineering role.

(4) Contractual measures: measures taken within prevalent procurement methods or innovative procurement methods, such as design-build, partnering or the Integrated Project Delivery (IPD) method, through which all parties involved (owners, general contractors, sub-contractors, etc.) share risk and reward (Kent and Becerik-Gerber 2010).

(5) System modeling and analysis methods: procedures and methods used to prefer or analyze actions related to the project. Typical such methods are Value Engineering (VE), which focuses on function/performance; cost-benefit analysis within the VE process; and the use of the Critical Path Method (CPM) to define and schedule formal constructability review process steps (Fisher, Anderson et al. 2000, Dunston, Gambatese et al. 2003, Fisher 2007)

(6) Reviews: a review is a step of a quality assurance method performed during design and construction. (Radtke and Russell 1993) described constructability design reviews at set percentages of design completion using formal design checklists. Peer reviews are popular within design firms (Arditi, Elhassan et al. 2002, Pocock, Kuennen et al. 2006).

(7) Advanced technology methods: these methods take the advantage of the remarkable progress in project modeling in recent years. They include Building Information Modeling (BIM)(Eastman, Teicholz et al. 2011), multimedia, virtual reality, geographic information systems, databases, analytical-simulation tools such as artificial intelligence, decision support systems, and expert systems. (Sacks, Koskela et al. 2010) described the interaction of BIM and lean construction as two approaches effecting fundamental change in the construction industry.

2.4.2. Constructability Programs

ASCE (1991) defines a constructability program as "the application of a disciplined, systematic optimization of the construction related aspects of a project during the planning, design, procurement, construction, test, and start-up phases by knowledgeable, experienced construction personnel who are part of a project team." A useful tool in the constructability program implementation process is the constructability implementation roadmap developed by CII (CII 1993). The roadmap offers guidance in the planning, development, and implementation of a constructability program, and is intended to be used by owners, designers, and contractors.

Owners or contractors can choose to implement constructability programs at the corporate (company) level and/or the project level depending on several factors. These factors include: commitment and support from top management, budget, resources, etc. CII (1987) documents the ideas, steps, and procedures that have worked best in implementing constructability programs at both the corporate and project levels. Important elements of both of these types of programs are discussed below.

Company Level Program: Large companies that realize the benefits of a high level of constructability and possess sufficient resources may choose to implement a corporate level constructability program. In order to develop a successful company level constructability program, a company should consider the following steps: self-assessment; corporate policy; organization and procedures; executive sponsor; constructability database; training; and appraisal. Companies should start by assessing where they are with regards to constructability. An individual who holds a top position in the company should be appointed as the executive sponsor for the program. His/her responsibilities toward the program should include: financial support, timely and effective supervision, and management of the program's continuous operation. The program implementation procedure should be clearly outlined by the company and made available to the responsible players. On successful implementation of these steps, a thorough and periodic appraisal of the program is required. Any shortcomings should be addressed with improvements immediately. The report also suggests the maintenance of a corporate "lessons learned" database through the appointment of a database custodian (Force and Research 1987).

Project Level Program. Project level programs can be a result of two situations. One, a company will have an in-place corporate program and will address constructability on each of its projects.

The other case would be a contractor who does not have a corporate program in place but is required by the owner to have a project level constructability program as part of the contract. These contractors might find this program guideline to be a useful tool to implement constructability at the project level. In either case, the project owner has a significant role in the implementation of a project-level constructability program. The project manager should issue a simple policy statement on behalf of the owner that outlines the program goals and the owner's commitment to constructability. The use of multiparty (designer, builder, and owner) constructability teams is essential in project-level constructability programs. An organization chart should be published which reflects the constructability participants and their roles (CII 1987). The Project Manager, assisted by the Senior Project Engineer, Senior Construction Representative, and Project Constructability Coordinator, should conduct constructability training at the project level. Integration of constructability specialists into the planning and design process from day one is critical in the success of the program. This practice is especially important for contractors implementing constructability programs for just a single project as it will help the construction firm's top management realize that constructability is a profit center and prompt them to develop a corporate-level program. The project constructability coordinator or others in charge holds the responsibility to prepare "lessons learned" for the project manager on an ongoing basis. The lessons should be forwarded to the database custodian for inclusion in the corporate "lessons learned" data file (Force and Research 1987) . (Radtke and Russell 1993) developed a tool for implementing a project level constructability program. The tool consisted of a process model to aid owners in the implementation of constructability programs at the project level. The model is based on the data obtained from the CII Constructability Implementation Task Force (1989) and various constructability implementation programs that were used in the industry during the time of the study. The researchers cite eight approaches from (Russell, Gugel et al. 1992) to implement constructability programs ranging from construction management practices to constructability services and programs for comprehensive constructability tracking. Out of these eight approaches the model process was created from the strengths of primarily three approaches:

1. constructability contract documents – provided insight on how to secure constructability input from other project participants;

2. specialized formal constructability programs – provided example constructability procedures, team organization, and cost benefit analysis that were project specific; and

3. comprehensive constructability tracking – provided example means to document savings and lessons learned over several projects.

The model consists of milestones, steps, and activities. Three milestones are described as: (1) obtaining constructability capabilities; (2) planning constructability implementation; and (3) implementing constructability. Within each milestone specific steps are described, and each step is further described by activities. The model process provides a benchmark for owners to use on their projects for the purpose of enhancing the constructability on their projects and in turn gaining the maximum benefits from the constructability improvement program (Radtke and Russell 1993).

2.4.3. Constructability Approach Selection

Constructability programs can be implemented in varying degrees of formality. Informal constructability approaches, usually indistinguishable from other construction management activities, may include design reviews and construction coordinators. Formal programs, usually having a documented corporate philosophy and budgeted resources, may involve tracking of lessons learned on past projects, team-building exercises, and construction personnel participating in project planning. A formal constructability approach may yield greater benefits than informal approaches (Russell, Gugel et al. 1994). The decision on what approach to implement, depends on several factors including the owner and project characteristics. A tool such as the constructability approach selection model developed by (Russell, Gugel et al. 1994) assists owners in efficiently determining the appropriate means by which to incorporate construction knowledge and experience into the designs of their projects. The model consists of three approaches to implement a constructability program: one informal and two formals (formal project level and comprehensive tracking). The model consists of a hierarchy of decision levels. Within these levels, there exists three steps: (1) individual assessment of owner and project characteristics resulting in a single conclusion of a formal or informal approach; (2) combining owner and project characteristics into a single conclusion of an informal or formal approach; and (3) if a formal approach is concluded, a decision is needed as to whether it is formal project level or comprehensive tracking. To assess the above-mentioned owner and project characteristics, a framework of variables described by parameters was also developed by (Russell, Gugel et al. 1994).

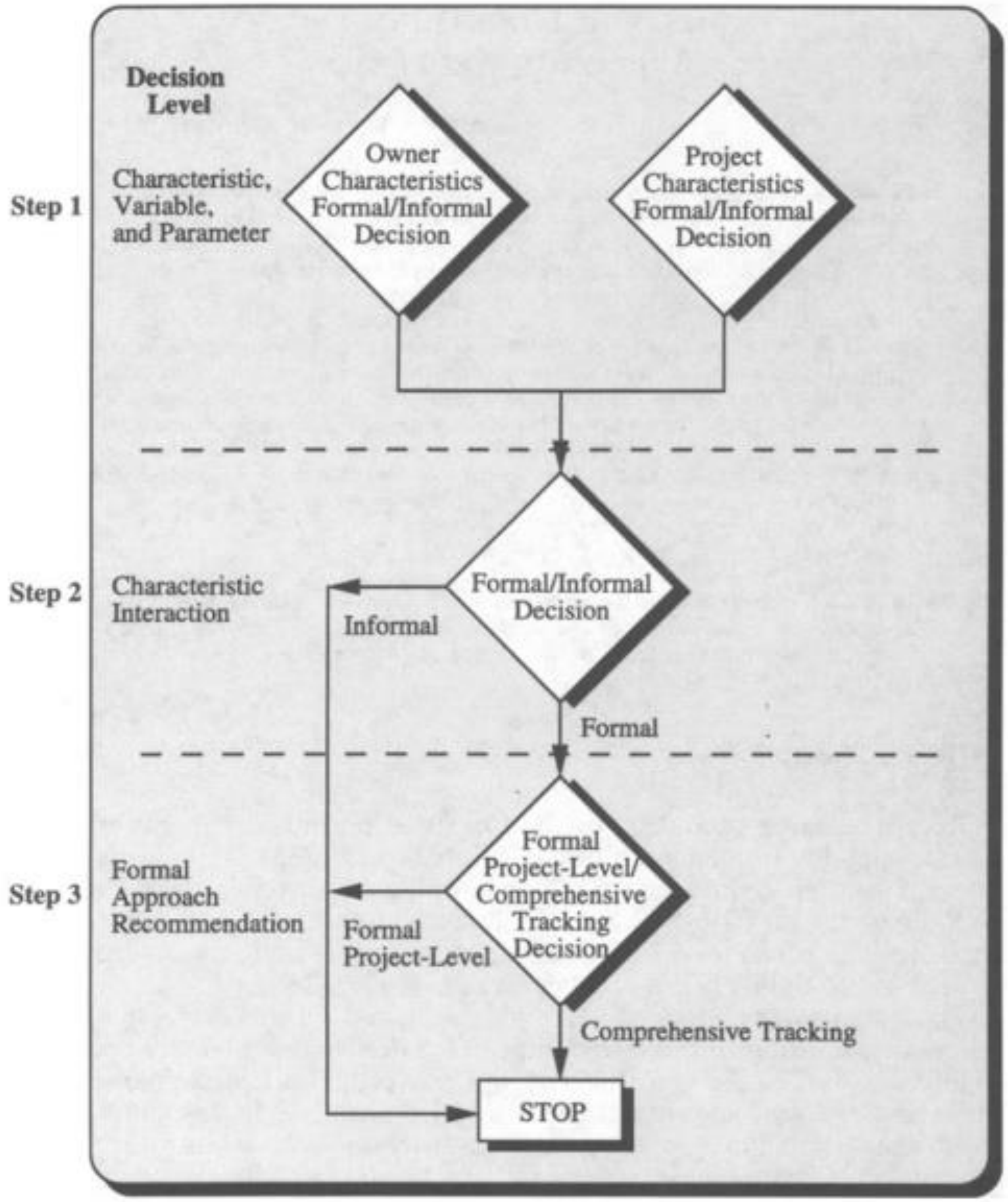

FIG. 1. Constructability Approach Selection Decision Model

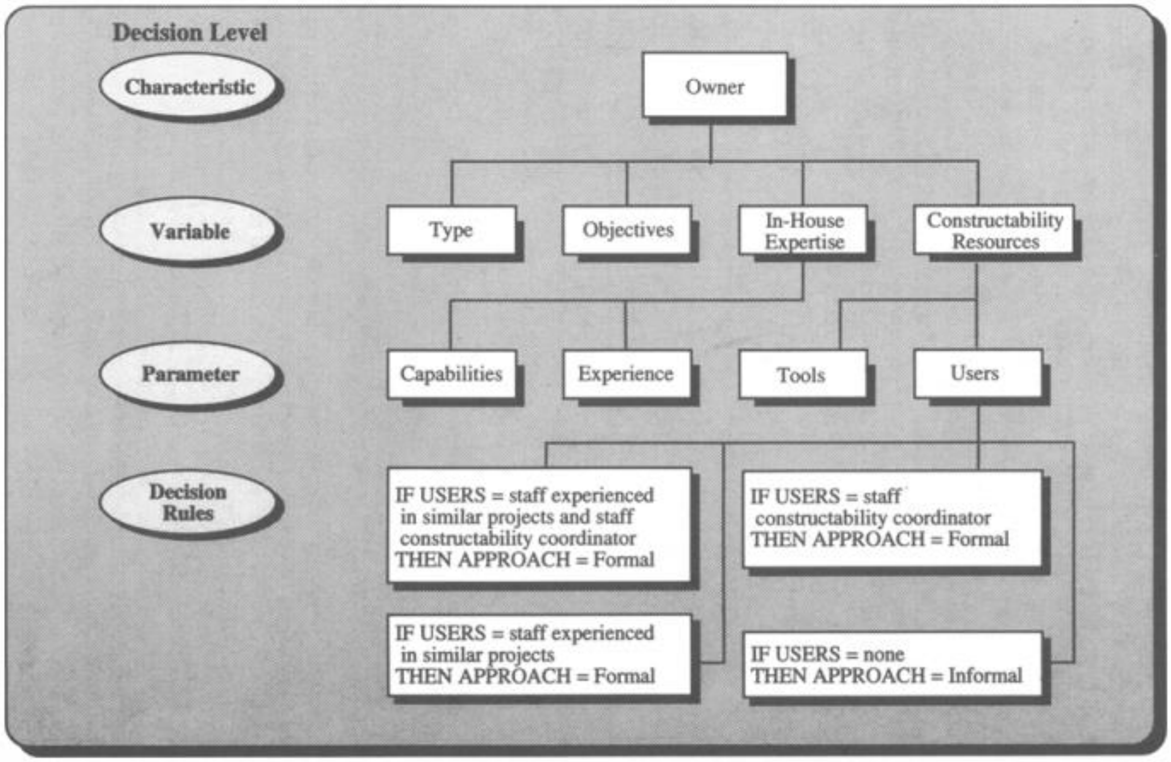

FIG. 2. Hierarchical Framework: Owner Characteristics

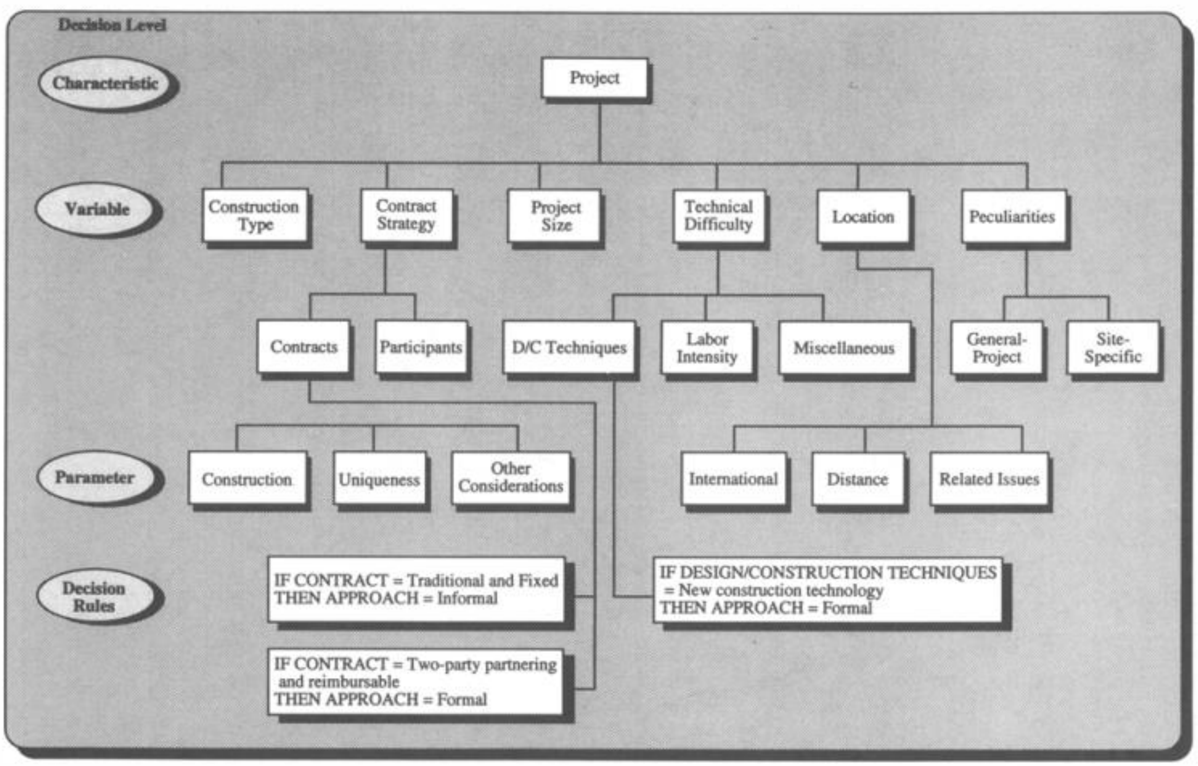

FIG. 3. Hierarchical Framework: Project Characteristics

2.5. Implementation of Constructability: Barriers and Challenges

2.5.1. Constructability Implementation:

Constructability implementation is a great challenge to the practitioners since it requires putting all of the essential concepts identified into a workable package. The Construction Management Committee of the American Society of Civil Engineers (ASCE 1991) states that, for any project to maximize its savings in terms of time, cost, and quality, the construction input or constructability, has to be started during the conceptual planning stage and continue during the entire life of the project. The great benefits of utilizing constructability input already at the early stages of a project, where in most cases the general contractor has not yet been nominated, have been recognized by many (Institute 1986, Hanlon and Sanvido 1995, Jergeas and Put 2001, Pulaski and Horman 2005, Song, Mohamed et al. 2009). The ability to influence cost is high during this stage and reduces as the project reaches the start-up stage. The constructability team should constitute personnel from different fields with varied expertise. Experienced construction personnel need to be involved with the project from the earliest stages to ensure that the construction focus and experience can properly influence owners, planners, and designers, as well as material suppliers. The construction personnel should come from the staff of the owner, a separate construction management firm, or possibly the designer or constructor (ASCE 1991). The construction person should be a full-fledged member of the project team, with access to, and participation in, the early decisions that affect the project. In certain cases, a full-time manager should be recruited to manage constructability reviews. Individuals managing constructability reviews should be knowledgeable engineers, must have the background of construction experience, be able to speak with authority, and have the team and people skills required to clearly put forth their ideas without alienating the rest of the team. In addition, to broaden the constructability focus, specialists should be brought in to look at specific tasks (transportation, structural, welding, rigging, piping, coatings, instrumentation, etc.) during the project development process (ASCE 1991).

The state of practice regarding constructability implementation has drawn some attention in recent years. (Arditi, Elhassan et al. 2002) stated that a little over half of design firms indicated that they have a formalized philosophy about constructability in their organization. Among other conclusions, he found that faulty working drawings and incomplete specifications were the major constraints working against the constructability of design, and that deficiency of design was one of the major challenges facing the construction industry. (Dunston, Gambatese et al. 2003) reported that the implementation of CRP had been rather slow due, in part, to lack of clarity regarding related costs and benefits and a perception that CRPs are resource intensive. (Pocock, Kuennen et al. 2006) described constructability tools that were used in practice; although a wide variety of constructability techniques were implemented, many areas of constructability practice could still be improved.

2.5.2. Implementation Challenges:

Constructability barriers can be defined as any significant inhibitor that prevents effective implementation of the constructability program (O'Connor and Miller 1994). Constructability barriers are evident in almost all organizations at both corporate and project levels. A constructability program can be efficient only when these barriers are identified and controlled effectively. Another research study that examined the barriers to improving constructability was conducted by (Jergeas and Put 2001)They reported several gaps between the potential benefits of applying constructability principles and those benefits actually realized in practice. These gaps are in the following areas:

- Up-front involvement of construction personnel;
- Achieving efficiency in the construction effort; and
- Use of informative construction methods and advanced technology.

2.5.2.1. Implementation Challenges: General Contractors

One of the major goals of the study by (Uhlik and Lores 1998) was to detect the prevalence of common barriers to improving constructability as perceived by general contractors. They found that general contractors had a common opinion on the topic of barriers regardless of the type of work, volume of work, or arrangement of contract used. The most common barriers identified by general contractors were that design without construction input is the traditional form of contracting and that designers lack construction experience and knowledge of construction technologies. Recurring barriers identified by the authors were the limitation of lump-sum competitive contracting and the adversarial attitude between designers and contractors. A new barrier to constructability was found to be designers' reluctance to include contractors in constructability review for fear of marring their reputation.

2.5.2.2. Implementation Challenges: Designers

(Arditi, Elhassan et al. 2002) reported that

- faulty, ambiguous, or defective working drawings,
- incomplete specifications, and
- adversarial relationships

were found to be the three major factors that cause constructability problems among design firms. On the other hand, owner resistance and budget limitations are perceived by designers as having a trivial effect on constructability. This finding does not agree with the generally held belief that owners are usually reluctant to allow their designers to conduct formal constructability programs because of the highly visible extra cost to their projects.

Chapter - 3

RESEARCH METHODOLOGY

3.1. Introduction

This chapter explains a detail methodology for achieving research objectives of this study mentioned in Chapter 1. A detailed literature review was conducted to get a vast knowledge on the subject topic which will be followed by questionnaire surveys to highlight critical factors and to categorize the significant factors into decision-support or decision oppose groups for the challenges investigated in implementation of constructability followed by pairwise comparison of critical factors and data collected through these phases will be analyzed using statistical and MCDM techniques. In the end, framework will be developed for investigating the challenges encounter in the implementation of constructability in construction projects.

3.2. Research Design

Research design refers to the general plan of addressing the research questions(Saunders, Lewis et al. 2009). It involves deciding among research strategies for data collection and analysis, validation and output of results. It is a roadmap which guides the researchers throughout for completion of the research program.

The study will be divided into four phases. In first phase, after development of research proposal, extensive literature review will be done to understand those barriers or challenges which effects the implementation of constructability. In second phase, questionnaire survey will be developed from extensive literature review, and then it will be floated to professionals. In third phase data collected from literature and interviews will be analyzed using statistical and MCDM techniques. In fifth phase, frame work will be proposed.

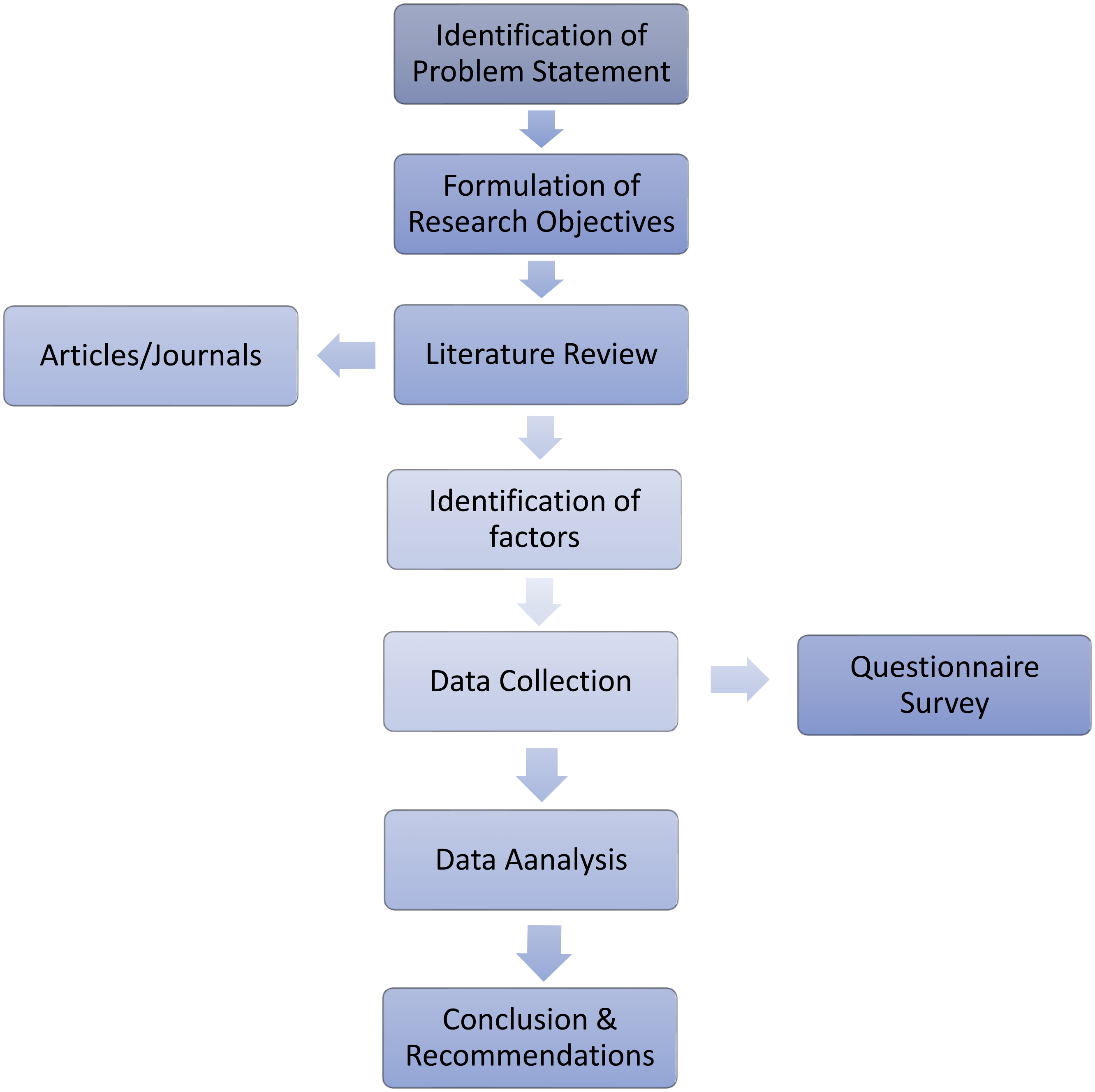

Figure 4: Flowchart of the Research Design

3.3 Questionnaire Survey

Questionnaire was developed by extensive literature review. In questionnaire survey 35 factors were identified. Questionnaire survey was distributed to 280 respondents, out of which 108 responses were received. Questionnaire survey was based on Likert scale. Questionnaire survey is attached in Annexure I.

3.4 Sample Size

As the population size for data collection is 40000. Registered engineer with Pakistan Engineering council are about 40000. For this population sample size is 96 according to (Dillman 2000). Equation (3-1) provides formula to calculate the sample sizes.

$$Ns = [(Np)(P)(1-P)] [(Np-1)(B/C)^2 + (P)(1-P)] \quad \ldots\ldots\ldots\ldots\ldots \text{(3-1)}$$

Where;

Ns: sample size for the desired level of precision

Np: population size i.e. 40,000

P: proportion of the population that is expected to choose one of the responses

Categories (yes/no); P = 0.5

B: acceptable sampling error; (±10% or ±0.10)

C: Z statistic associated with the confidence level

(1.96 corresponds to 95% confidence level)

The sample sizes which were acceptable for various populations with different sampling errors for 95% confidence level are given as per (Dillman 2000). These sample sizes can also be calculated by using the formula given in equation (3-1). There were 108 replies out of 280 showing an overall response rate of 38.5%. As per (Black et al., 2000), “in the construction enterprises, a good response rate is around 30%”. Hence, the response rate for this research is adequate.

3.5 Data Analysis

3.5.1 Cronbach's Coefficient Alpha Method

For the checking of reliability of the data collected on Likert scale Cronbach's Alpha method is used. If the value of Cronbach's Alpha is greater than .7, the data is reliable. Further, if the value is greater than .9, the data is highly consistent for use (Liew 2007). The value of Cronbach's Alpha is .937 so the data was highly consistent for further analysis.

3.5.2 Shapiro-Wilk Test

Before using other test first normality of data was checked. It is important to check the normality of the data because if the data is not normal than further tests are different for non-parametric data. As the sample size was less than 2000 Shapiro-Wilk test was used to check the normality of the data. After the data analysis it was found that the data was non-parametric, so the Kruskal- Wallis test was applied.

3.5.3 Kruskal Wallis test

If three or more independent groups (client, consultant and contractor) are identical or diverse on some variable of interest then the Kruskal-Wallis test and one-way analysis-of variance are used to determine the variation in the response of each group. It is most suitable to find the statistical indication of variation or dissimilarities in the perceptions of the stakeholders such as client, consultant and contractor, using average values or indices of the various groups. If the data is nonparametric the Kruskal-Wallis test is used whereas if the data is parametric in nature, then one-way ANOVA is used for further analysis. The data that was collected for this questionnaire-based research was not able to be validated by the normality test that's why Kruskal-Wallis test was used for further analysis to check the variations in the perceptions of the stakeholders. It is very less sensitive to outliers. The Ho for the test is that the means of variables are same and is rejected if the result is meaning full. The results are tested against the difficulty of significance of 0.05. All the stakeholders will have same perception if the significance value is above 0.05 and vice versa.

Chapter - 4

DATA ANALYSIS AND RESULTS

4.1. Introduction

In this chapter the data analysis and the results are discussed. The objectives of this research, as set forth in the beginning, encompasses the determination of, in relation to construction projects, the existing constructability practices and barriers to implementation of constructability practices. The questionnaire survey was floated to rank the barriers which affect the implementation of constructability. This study aims at reducing the barriers in the adoption of constructability practices on construction sites for maximizing the collaboration and thus the productivity and performance.

4.2. Characteristics of Respondents to Questionnaire Survey

The questionnaire was circulated on the web using email and professional networking site LinkedIn among client, contractor, consultant and other related construction professionals. Later on, the site visits were made to reach out to the construction experts. A total of 108 responses were obtained with a suitable mix of different sub-sector experts with various types of qualification, associated organizations and nature of experiences. The details of the respondents are as follows:

4.2.1 Academic Qualifications

Responses were made by construction professionals having different academic backgrounds. *Figure 6* explains the respondents' highest academic qualification: Construction professionals having professional engineering degree were 30.6%, with further masters were 62%. Moreover, those having doctorate level of engineering education were 5.6%. The construction professionals at senior positions but with only Diploma of Civil Engineering 1.8% of the total 104 respondents.

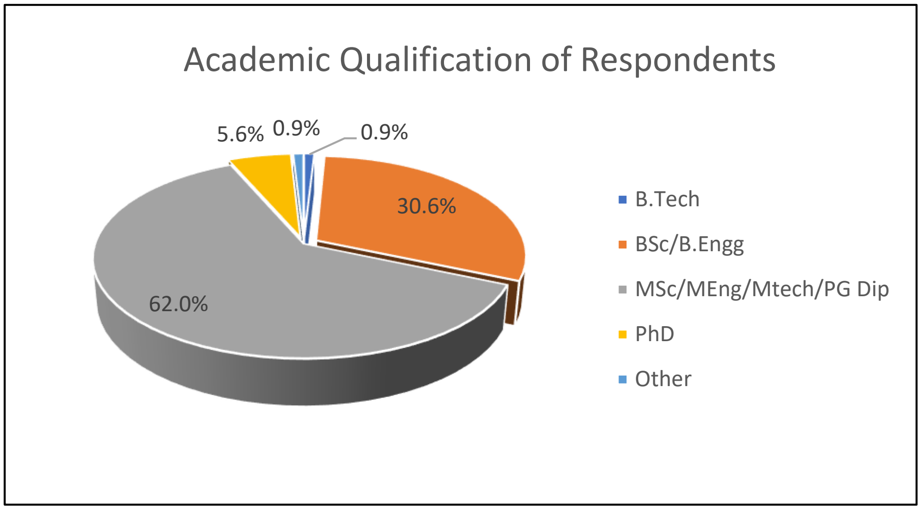

Figure 5: Academic Qualification of Respondents

4.2.2 Professional Experience

The respondents had varying years of professional experience. Fig. 7 demonstrates that 64.8% of respondents carried up to 5 years of experiences, while the next majority 23.1% had between 6-10 years of experience. Moreover, 9.33% respondents had 11-15 years, 0.98% respondents had 16-20 years, and 1.9% respondents had more than 20 years of professional experience in the construction industry.

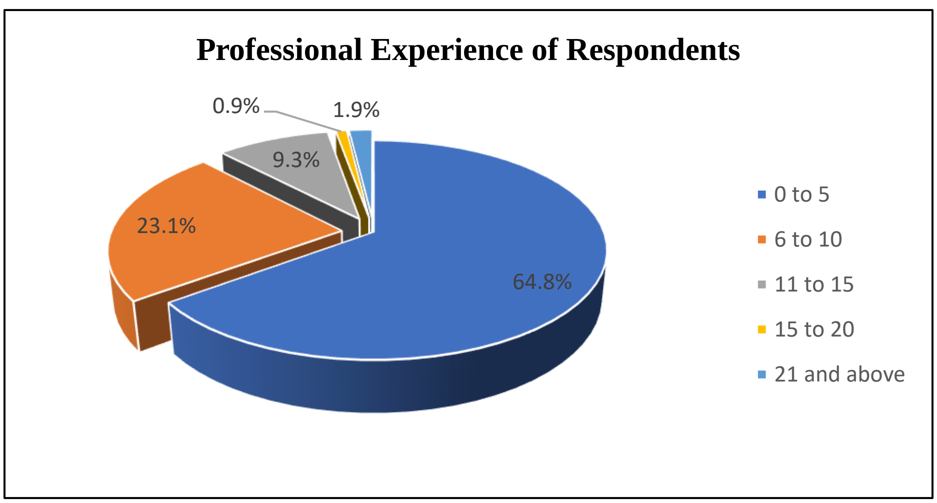

Figure 6: Professional Experience of Respondents

4.2.3 Organization Role

Another classification considered for the 104 respondents was their organization's role in the construction industry. Fig 9 shows that 20.4% respondents belong to client organizations, 29.6% to consultant, and 28.7% to contractor organizations. Remaining respondents are material suppliers 6.5% and academicians 14.8%.

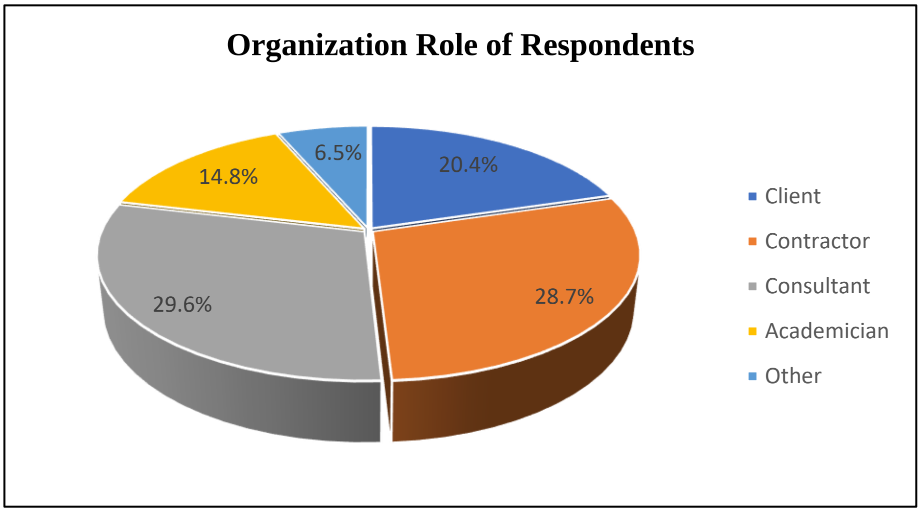

Figure 7: Organization Role of Respondents

4.2.4 Size of Project

Fig. 10 gives the classification of respondents based on the size of the project they worked. Out of total 104 construction industry professionals, 18.5% had a project budget less than 10 million, 20.4% had a project budget from 10 to 100 million, 23.1% had a project budget from 100 to 500 million, 17.6% had a project budget from 500 to 1000 million and 20.4% had a project budget from more than 1000 million.

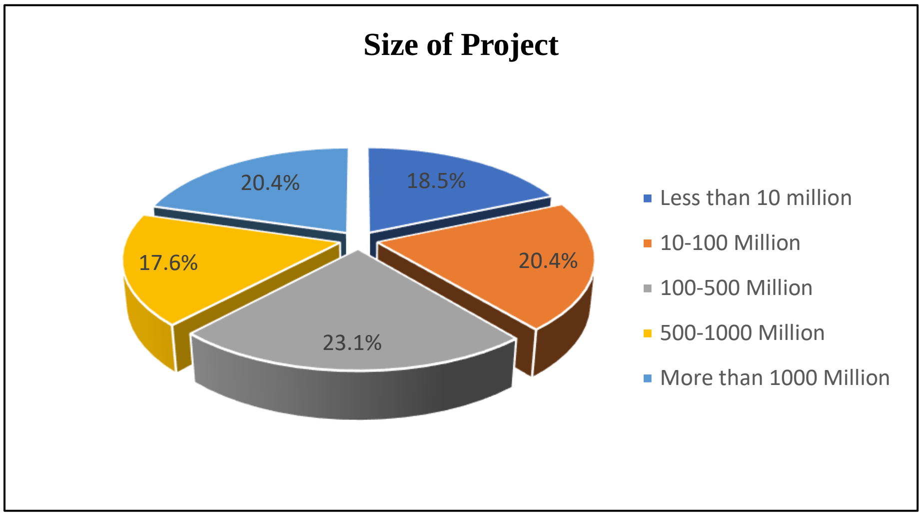

Figure 8: Size of Project

4.2.5 Awareness about constructability

Figure 11 shows the respondents awareness about the term and definition of constructability.88% of the respondents were familiar with the term constructability and 12% were unfamiliar with the term.

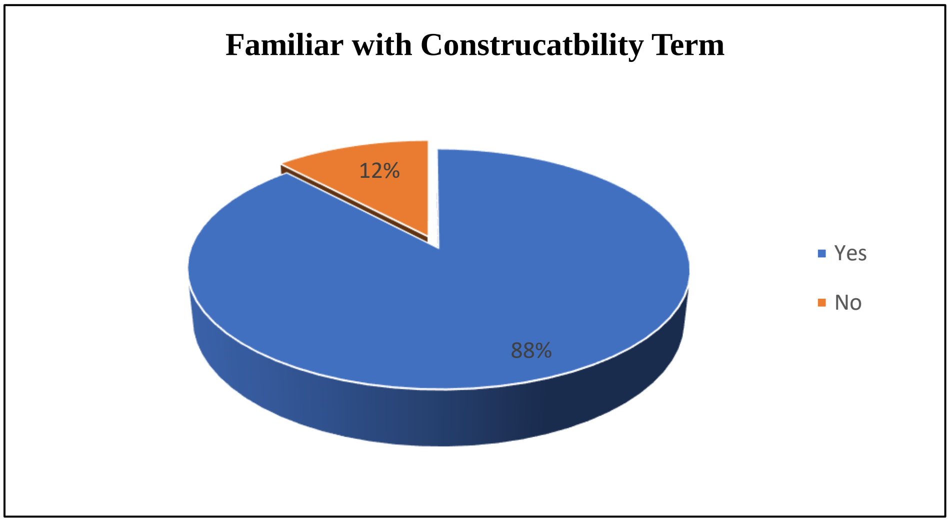

Figure 9: Familiar with constructability term

4.3. Statistical Analysis

To statistically validate the collected data, various tests were conducted for which the details are discussed below.

4.3.1 Reliability of the Sample

Cronbach's Coefficient Alpha Method

For the checking of reliability of the data collected on Likert scale, Cronbach's Alpha method is used. If the value of Cronbach's Alpha is greater than .7, the data is reliable. Further, if the value is greater than .9, the data is highly consistent for use (Liew 2007). The value of Cronbach's Alpha is .937 so the data is highly consistent for further analysis.

Case Processing Summary

		N	%
Cases	Valid	104	100.0
	Excluded[a]	0	.0
	Total	104	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.937	.937	35

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
131.92	424.712	20.609	35

4.3.2 Measurement of Normality of Data

Shapiro-Wilk test

For checking the normality of data, Shapiro-Wilk test was carried out as the sample size was less than 2000. This test was conducted to evaluate whether the collected data was normally distributed or not, i.e. the data was parametric or nonparametric. As per the results of normality test, the data is not normally distributed and non-parametric test are needed to further analysis.

Table 2: Results of Shapiro Wilk Test

S.No	Parameters	Mean	St. Deviation	N
1	Reluctance for additional early project-stage investments	3.36	1.07	104
2	Owner insistence in separating design and construction management operations	3.60	1.18	104
3	Lack of team-building and partnering abilities	3.76	0.88	104
4	Lack of resources	4.05	1.14	104
5	Dis-regard of constructability in selecting contractors and/or consultants	3.76	0.92	104
6	Contracting difficulties in the constructability scope definition	3.61	0.97	104
7	Limitations of lump-sum competitive contracting	3.34	0.95	104
8	Inappropriate contracting	3.83	1.08	104
9	Stakeholder complacency regarding the efficiency of the project management procedures	3.38	1.01	104
10	Lack of communication among designer, contractor and consultant	4.21	1.02	104
11	Disbelief in the potential utility of a constructability program	3.63	0.88	104
12	Lack of expert personnel	4.14	1.04	104
13	Inappropriate project delivery method	3.79	1.05	104
14	Lack of involvement of stakeholders in early phases of project	3.82	1.15	104

15	False and ambiguous information	3.81	1.18	104
16	Failure to search out problems and opportunities	3.51	1.05	104
17	False perceptions of constructability	3.61	1.06	104
18	Lack of concept awareness	3.98	1.11	104
19	Designer lacks construction expertise and awareness for construction technologies/software's	4.02	1.17	104
20	Incomplete specifications	3.97	1.09	104
21	No standardization of design	3.90	1.13	104
22	Faulty, ambiguous, or defective working designs	3.99	0.93	104
23	Perception of increased designer liability	3.48	1.11	104
24	Untimely knowledge feedback	3.44	0.93	104
25	Untimely involvement in the early project-lifecycle phases	3.75	1.13	104
26	Contractor outdated knowledge of construction methods and techniques	3.99	0.93	104
27	Low availability of qualified and skilled labor	3.93	1.04	104
28	Low work backlog	3.38	1.07	104
29	Inadequate contractor experience (work) causing error	3.91	1.05	104
30	Adversarial stakeholders' relationships	3.70	1.04	104
31	Extreme project size and complexity	4.04	0.99	104
32	Construction Sequence	3.90	1.06	104
33	Site and facility congestion	3.76	1.04	104
34	Strict time constraints/unrealistic schedule	4.00	0.96	104
35	Difficulty in proving the economics of constructability	3.59	1.03	104

4.3.3 Test for Non-Parametric Data

Kruskal Wallis

Since the data collected for this research was non-parametric, Kruskal-Wallis test was used to check whether all respondents including academia, owners/clients, consultants and contractors had similar perception regarding the factors affecting the implementation of constructability practices.

Table 3: Results of Kruskal Wallis Test

S.No	**Parameters**	**Sig.**
1	Reluctance for additional early project-stage investments	0.105
2	Owner insistence in separating design and construction management operations	0.467
3	Lack of team-building and partnering abilities	0.737
4	Lack of resources	0.194
5	Dis-regard of constructability in selecting contractors and/or consultants	0.913
6	Contracting difficulties in the constructability scope definition	0.062
7	Limitations of lump-sum competitive contracting	0.693
8	Inappropriate contracting	0.369
9	Stakeholder complacency regarding the efficiency of the project management procedures	0.286
10	Lack of communication among designer, contractor and consultant	**0.001**
11	Disbelief in the potential utility of a constructability program	0.366
12	Lack of expert personnel	**0.000**
13	Inappropriate project delivery method	0.113
14	Lack of involvement of stakeholders in early phases of project	0.316
15	False and ambiguous information	0.258

16	Failure to search out problems and opportunities	0.567
17	False perceptions of constructability	**0.001**
18	Lack of concept awareness	0.054
19	Designer lacks construction expertise and awareness for construction technologies/software's	0.102
20	Incomplete specifications	0.506
21	No standardization of design	**0.020**
22	Faulty, ambiguous, or defective working designs	0.187
23	Perception of increased designer liability	0.155
24	Untimely knowledge feedback	0.109
25	Untimely involvement in the early project-lifecycle phases	0.107
26	Contractor outdated knowledge of construction methods and techniques	0.143
27	Low availability of qualified and skilled labor	**0.006**
28	Low work backlog	0.097
29	Inadequate contractor experience (work) causing error	**0.033**
30	Adversarial stakeholders' relationships	**0.009**
31	Extreme project size and complexity	0.134
32	Construction Sequence	0.155
33	Site and facility congestion	0.481
34	Strict time constraints/unrealistic schedule	**0.004**
35	Difficulty in proving the economics of constructability	0.073

For most of the factors, the stakeholder’s perception was same but for the following factors difference in perception was observed

a) Lack of communication among designer, contractor and consultant
b) Lack of expert personnel
c) False perceptions of constructability
d) No standardization of design
e) Low availability of qualified and skilled labor
f) Inadequate contractor experience (work) causing error
g) Adversarial stakeholders’ relationships
h) Strict time constraints/unrealistic schedule

4.3.4 Relative Importance Index (RII)

The data collected through the questionnaire survey was analyzed and ranked using the RII as per {Kometa, 1994 #6}Using equation 4.1, RII was calculated for each factor available in the questionnaire by transforming the scale and assigning weighting. It was then used to determine the ranks of each factor.

$$\mathbf{RII = \sum w/(A * N) \ldots\ldots\ldots\ldots.. (0 \leq RII \leq 1)} \qquad \mathbf{(4.1)}$$

Where:

w = Weight given to each factor by the respondents and ranges from 1 to 5 where '1' is 'Not Applicable' and '5' is 'Directly Affect it'

A = Highest weight (i.e. 5 in this case)

N = Total number of respondents (i.e. 104 in this case)

RII ranges between 0 and 1

On the basis of the analysis, the results of the findings are presented and discussed in Table

Table 4: Results of Relative Importance Index

S.No	Barrier	Group	RIF
1	Lack of communication among designer, contractor and consultant	General	0.8423
2	Lack of expert personnel	General	0.8288
3	Lack of resources	Owner	0.8096
4	Extreme project size and complexity	Project	0.8077
5	Designer lacks construction expertise and awareness for construction technologies/software's	Designer	0.8038
6	Strict time constraints/unrealistic schedule	Project	0.8000
7	Faulty, ambiguous, or defective working designs	Designer	0.7981
8	Contractor outdated knowledge of construction methods and technique	Contractor	0.7981
9	Lack of concept awareness	Designer	0.7962
10	Incomplete specifications	Designer	0.7942
11	Low availability of qualified and skilled labor	Contractor	0.7865
12	Inadequate contractor experience (work) causing error	Contractor	0.7827
13	No standardization of design	Designer	0.7808
14	Construction Sequence	Project	0.7808
15	Inappropriate contracting	Owner	0.7654
16	Lack of involvement of stakeholders in early phases of project	General	0.7635
17	False and ambiguous information	General	0.7615

18	Inappropriate project delivery method	General	0.7577
19	Lack of team-building and partnering abilities	Owner	0.7519
20	Dis-regard of constructability in selecting contractors and/or consultants	Owner	0.7519
21	Site and facility congestion	Project	0.7519
22	Untimely involvement in the early project-lifecycle phases	Contractor	0.7500
23	Adversarial stakeholders' relationships	Project	0.7404
24	Disbelief in the potential utility of a constructability program	General	0.7250
25	Contracting difficulties in the constructability scope definition	Owner	0.7212
26	False perceptions of constructability	Designer	0.7212
27	Owner insistence in separating design and construction management operations	Owner	0.7192
28	Difficulty in proving the economics of constructability	Project	0.7173
29	Failure to search out problems and opportunities	General	0.7019
30	Perception of increased designer liability	Designer	0.6962
31	Untimely knowledge feedback	Contractor	0.6885
32	Stakeholder complacency regarding the efficiency of the project management procedures	General	0.6769
33	Low work backlog	Contractor	0.6750
34	Reluctance for additional early project-stage investments	Owner	0.6712
35	limitations of lump-sum competitive contracting	Owner	0.6673

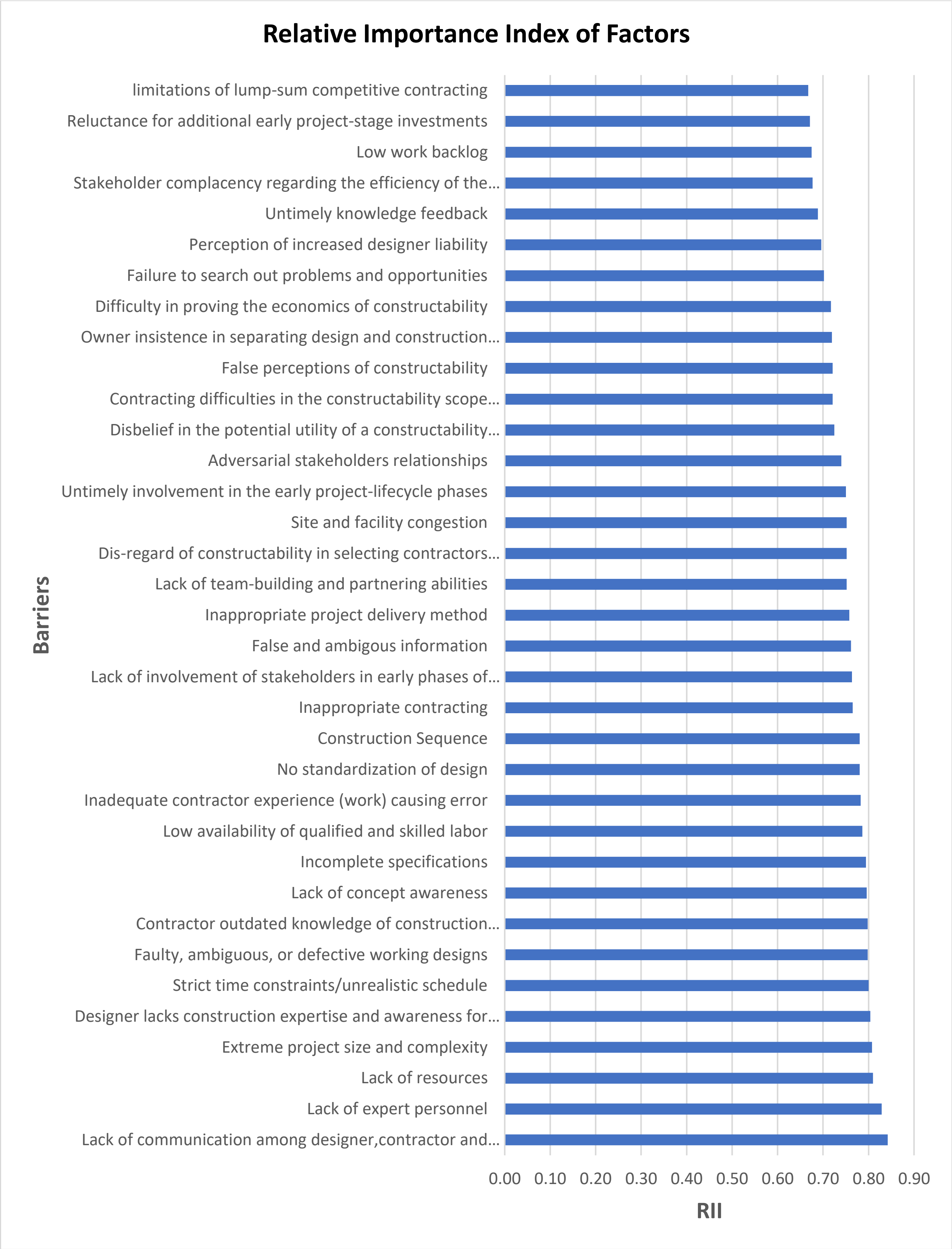

Figure 10: Relative Importance Index of Barriers

As evident from the Table, the top factor which affects implementation of constructability practices is lack of communication among designer, contractor and consultant. Second factor is lack of expert personnel and on third is work lack of resources by owner.

Respondents give the lowest weight to limitations of lump-sum competitive contracting.

As 35 factors was divided into five groups, their ranking according to groups is discussed in following tables.

4.3.4.1. General Group

In this group the respondents ranked “Lack of communication among designer, contractor and consultant” with RIF 0.8423 highly affecting factor while “Stakeholder complacency regarding the efficiency of the project management procedures” with RIF 0.6769 is least affecting factor. The ranking of factors according to RIF is shown in Table.

Table 5: Results of Relative Importance Index of General Group

S.No	Barrier	Group	RIF
1	Lack of communication among designer, contractor and consultant	General	0.8423
2	Lack of expert personnel	General	0.8288
3	Lack of involvement of stakeholders in early phases of project	General	0.7635
4	False and ambiguous information	General	0.7615
5	Inappropriate project delivery method	General	0.7577
6	Disbelief in the potential utility of a constructability program	General	0.7250
7	Failure to search out problems and opportunities	General	0.7019
8	Stakeholder complacency regarding the efficiency of the project management procedures	General	0.6769

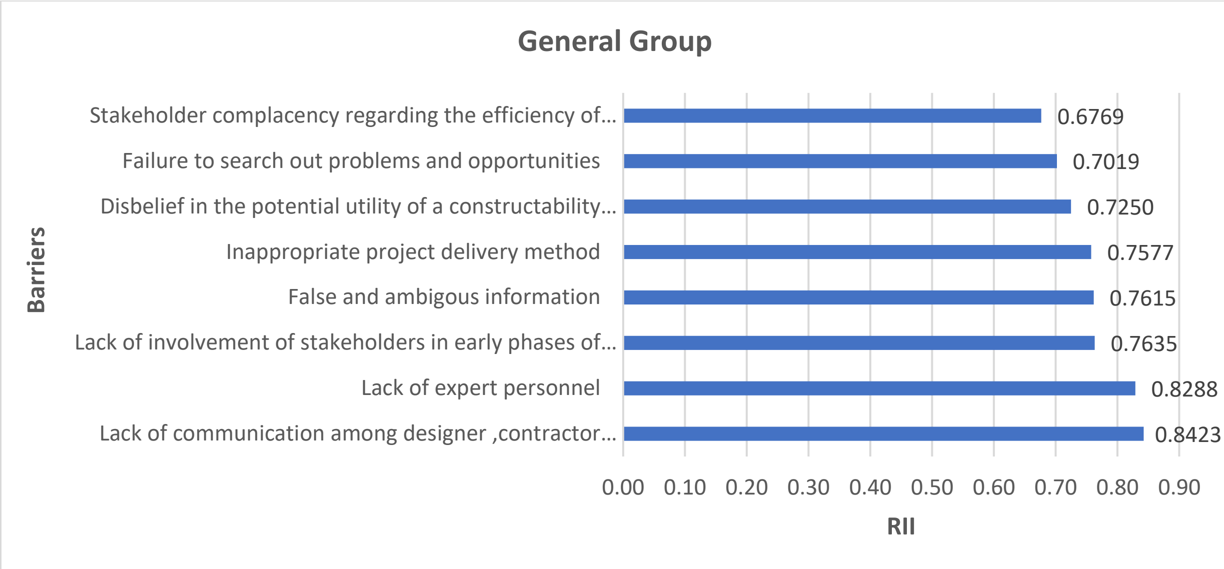

Figure 11: Relative Importance Index of General Barriers

4.3.4.2. Owner Group

In this group the respondents ranked "Lack of resources" with RIF 0.8096 highly affecting factor while "Limitations of lump-sum competitive contracting" with RIF 0.6673 is least affecting factor. The ranking of factors according to RIF is shown in Table.

Table 6: Results of Relative Importance Index of Owner Group

S.No	Barrier	Group	RIF
1	Lack of resources	Owner	0.8096
2	Inappropriate contracting	Owner	0.7654
3	Lack of team-building and partnering abilities	Owner	0.7519
4	Dis-regard of constructability in selecting contractors and/or consultants	Owner	0.7519
5	Contracting difficulties in the constructability scope definition	Owner	0.7212
6	Owner insistence in separating design and construction management operations	Owner	0.7192
7	Reluctance for additional early project-stage investments	Owner	0.6712
8	limitations of lump-sum competitive contracting	Owner	0.6673

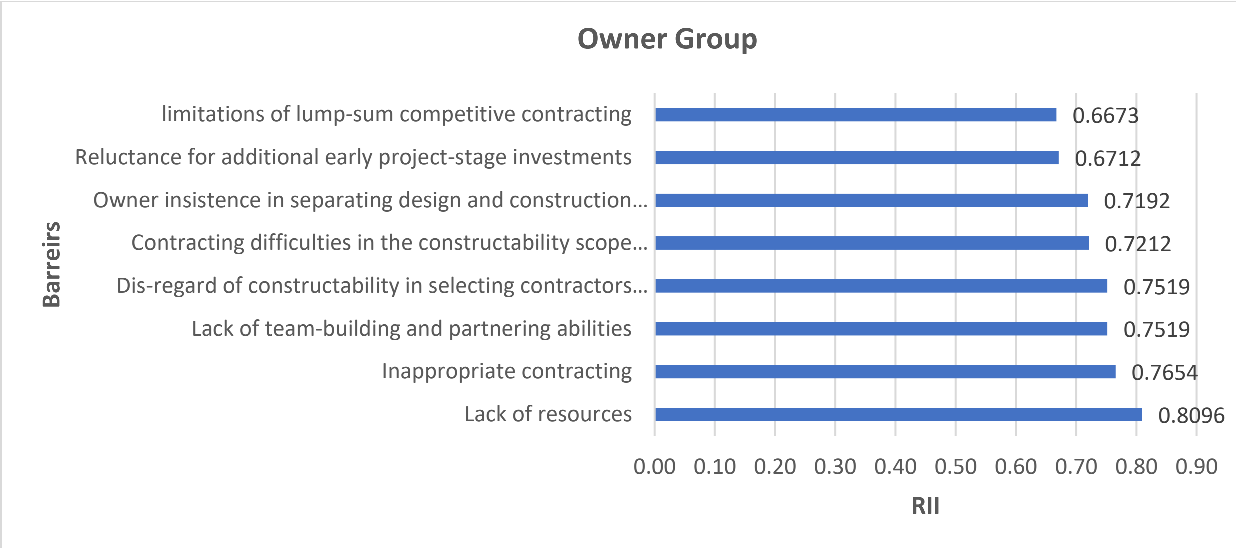

Figure 12: Relative Importance Index of Owner Group Barriers

4.3.4.3. Contractor Group

In this group the respondents ranked "Contractor outdated knowledge of construction methods and techniques" with RIF 0.7981 highly affecting factor while "Low work backlog" with RIF 0.6750 is least affecting factor. The ranking of factors according to RIF is shown in Table.

Table 7: Results of Relative Importance Index of Contractor Group

S.No	Barrier	Group	RIF
1	Contractor outdated knowledge of construction methods and techniques	Contractor	0.7981
2	Low availability of qualified and skilled labor	Contractor	0.7865
3	Inadequate contractor experience (work) causing error	Contractor	0.7827
4	Untimely involvement in the early project-lifecycle phases	Contractor	0.7500
5	Untimely knowledge feedback	Contractor	0.6885
6	Low work backlog	Contractor	0.6750

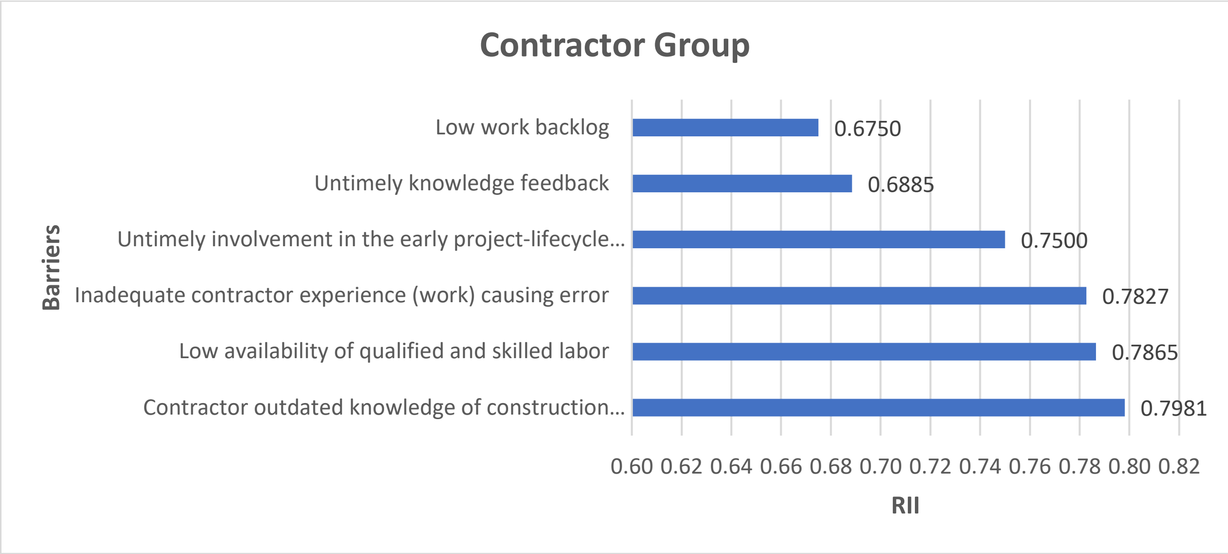

Figure 13: Relative Importance Index of Contractor Group Barriers

4.3.4.4. Designer Group

In this group the respondents ranked "Designer lacks construction expertise and awareness for construction technologies/software's" with RIF 0.8038 highly affecting factor while "Low work backlog" with RIF 0.6962 is least affecting factor. The ranking of factors according to RIF is shown in Table.

Table 8: Results of Relative Importance Index of Designer Group

S.No	Barrier	Group	RIF
1	Designer lacks construction expertise and awareness for construction technologies/software's	Designer	0.8038
2	Faulty, ambiguous, or defective working designs	Designer	0.7981
3	Lack of concept awareness	Designer	0.7962
4	Incomplete specifications	Designer	0.7942
5	No standardization of design	Designer	0.7808
6	False perceptions of constructability	Designer	0.7212
7	Perception of increased designer liability	Designer	0.6962

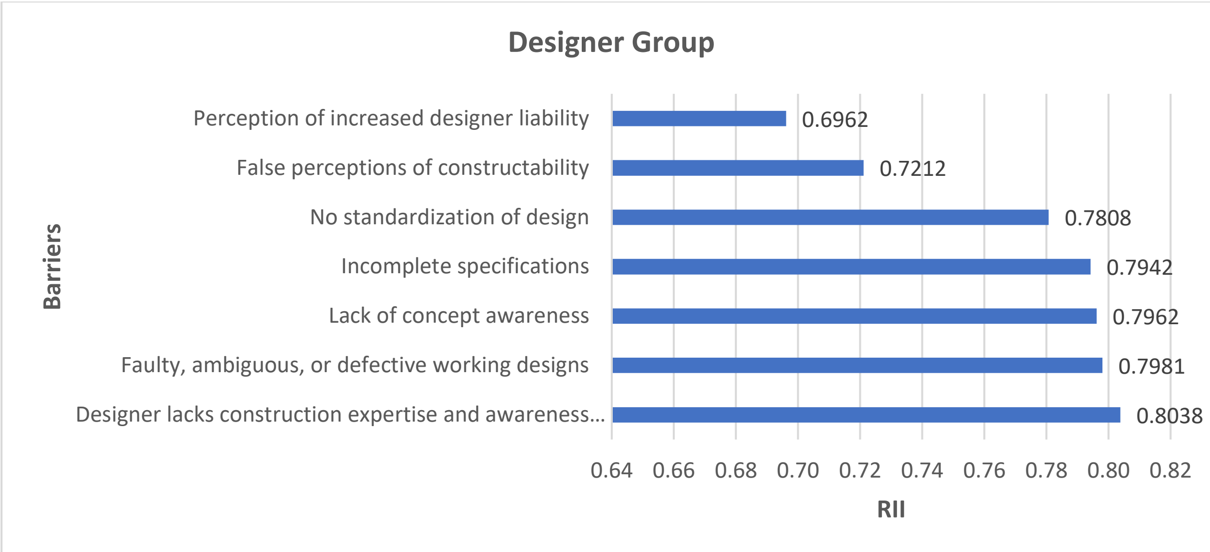

Figure 14: Relative Importance Index of Designer Group Barriers

4.3.4.5. Project Group

In this group the respondents ranked "Extreme project size and complexity" with RIF 0.8077 highly affecting factor while "Difficulty in proving the economics of constructability" with RIF 0.7173 is least affecting factor. The ranking of factors according to RIF is shown in Table.

Table 9: Results of Relative Importance Index of Project Group

S.No	Barrier	Group	RIF
1	Extreme project size and complexity	Project	0.8077
2	Strict time constraints/unrealistic schedule	Project	0.8000
3	Construction Sequence	Project	0.7808
4	Site and facility congestion	Project	0.7519
5	Adversarial stakeholders' relationships	Project	0.7404
6	Difficulty in proving the economics of constructability	Project	0.7173

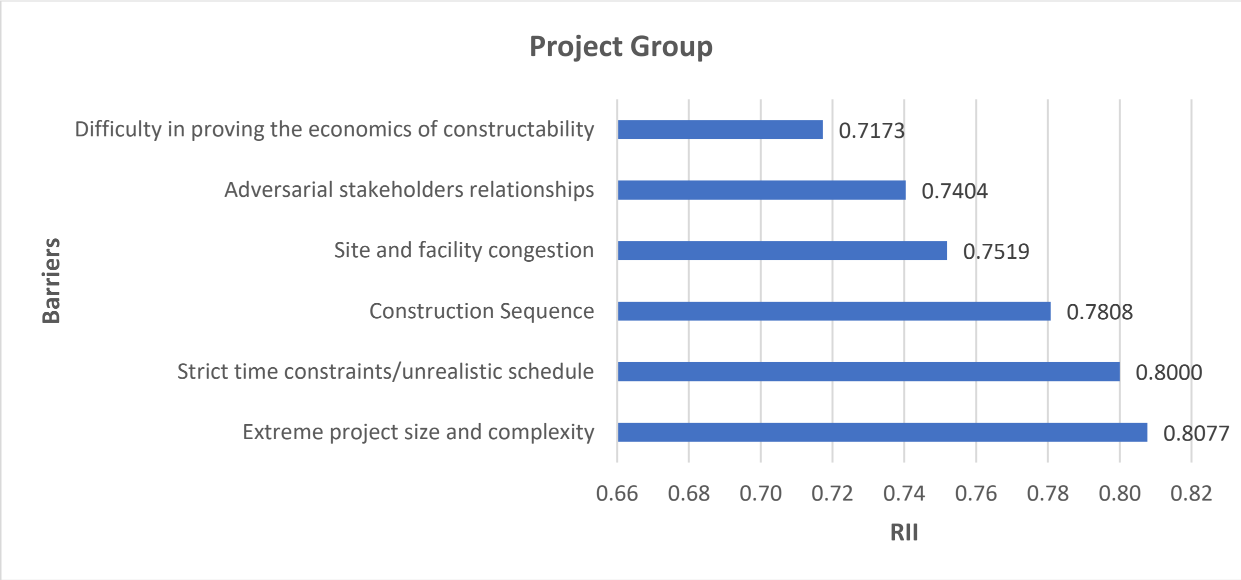

Figure 15: Relative Importance Index of Project Group Barriers

The interpretation of results in is mentioned in details in the next chapter.

Chapter - 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Constructability lays the foundation of effective design and execution of a project which results in cost savings as well completion of project without any delays in schedule. It involves in improving projects internal and external factors that enhances performance of a project. Constructability implementation is a great challenge to the practitioners since it requires putting all of the essential concepts identified into a workable package.

CI professionals considers constructability practices helps in cost reduction, enhances trust among stakeholders, reduces errors and disputes. Clashes between Civil and MEP components in design, can be resolved through proper clash detection before approving designs. Smooth and Cordial working relationships among contractor, consultant and the client can be achieved by implementing constructability practices.

A weighted list of barriers indicates that lack of communication among stakeholders which is contractor client consultant is the primary reason for the obstruction in the implementation of constructability practices in the construction industry. Followed by the lack of resources and available funds from owner or client also makes it difficult for the constructability team to perform efficiently and according to work breakdown structure .Another most significant hurdle or barrier in the implementation of constructability practices is the lack of designer construction expertise that results in faulty ambiguous drawings and specifications which leads to errors and disputes.

The unsurpassed and effective way of preventing obstructions in constructability implementation and to handle constructability problems is to involve experienced personnel or manager having expertise related to the project. Involving a experienced manager for quality control in early phases of project results in enhance project performance and project delivery process. Proper communication and data sharing and timely identifying, arranging and managing resources can be done by an experienced manager if involved in the early phases of the project.

5.2 Recommendations

This study has paved the way for the mathematical integration of the internal and external barriers involves in the constructability implementation and the development of framework which can create coordination among stakeholder's objective.

Further studies can focus on the systematic interconnection of constructability practices with risk analysis for a complete overview and managerial approach of the whole project lifecycle could be pursued through a methodology of progressive steps.

Development of constructability model in conjunction with already integrated processes focusing primarily on its interconnection with BIM so that clash detection can be achieved

References

(2017). Overview of the Economy, 2016-17.

Anderson, S. D., et al. (1995). Total constructability management: a process-oriented framework, Project Management Institute.

Arditi, D., et al. (2002). "Constructability analysis in the design firm." Journal of Construction Engineering and management **128**(2): 117-126.

Dillman, D. A. (2000). Procedures for conducting government-sponsored establishment surveys: Comparisons of the total design method (TDM), a traditional cost-compensation model, and tailored design. Proceedings of American Statistical Association, Second International Conference on Establishment Surveys.

Division, C. M. C. o. t. A. C. (1991). "Constructability and Constructability Programs: White Paper." Journal of Construction Engineering and management **117**(1): 67-89.

Dunston, P., et al. (2003). Benefit-cost model for highway department constructibility reviews. 82nd Annual Meeting of the Transportation Research Board (TRB).

Eastman, C., et al. (2011). BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors, John Wiley & Sons.

Eldin, N. N. (1999). "Impact of employee, management, and process issues on constructability implementation." Construction Management & Economics **17**(6): 711-720.

Elgohary, M., et al. (2003). "Constructability--from Qinshan to the ACR." Nuclear Plant Journal **21**(5): 31-35.

Farooqui, R. U. and S. M. Ahmed (2008). "Assessment of Pakistani Construction Industry - Current Performance and the Way Forward." Journal for the Advancement of Performance Information and Value **1**(1): 51-72.

Fisher, D. J. (2007). "An overview of constructability tools." Constructability concepts and practice: 82-101.

Fisher, D. J., et al. (2000). "Integrating constructability tools into constructability review process." Journal of Construction Engineering and management **126**(2): 89-96.

Force, U. o. T. a. A. C. I. I. C. T. and U. o. T. a. A. B. o. E. Research (1987). Guidelines for Implementing a Constructability Program, Institute, University of Texas at Austin.

Fox, S., et al. (2002). "Constructability rules: guidelines for successful application to bespoke buildings." Construction Management & Economics **20**(8): 689-696.

Gambatese, J. A., et al. (2007). Constructability concepts and practice, ASCE Publications.

Gambatese, J. A., et al. (2007). Constructability concepts and practice, American Society of Civil Engineers.

Gray, C. (1983). Buildability: The construction contribution, Chartered Institute of Building Ascot, UK.

Griffith, A. and A. C. Sidwell (1997). "Development of constructability concepts, principles and practices." Engineering, Construction and Architectural Management **4**(4): 295-310.

Hanlon, E. J. and V. E. Sanvido (1995). "Constructability information classification scheme." Journal of Construction Engineering and management **121**(4): 337-345.

Hardin, B. and D. McCool (2015). BIM and construction management: proven tools, methods, and workflows, John Wiley & Sons.

Hugo, F., et al. (1990). "Highway constructability guide."

Institute, U. o. T. a. A. C. I. (1986). Constructability: A Primer, Construction Industry Institute.

Jergeas, G. and J. V. d. Put (2001). "Benefits of constructability on construction projects." Journal of Construction Engineering and management **127**(4): 281-290.

John Thomas, O. C., et al. (1986). Constructability Improvement During Engineering and Procurement, [Construction Industry Institute, University of Texas at Austin [distributor]].

Kent, D. C. and B. Becerik-Gerber (2010). "Understanding construction industry experience and attitudes toward integrated project delivery." Journal of Construction Engineering and management **136**(8): 815-825.

Ku, K. and M. Taiebat (2011). "BIM experiences and expectations: the constructors' perspective." International Journal of Construction Education and Research **7**(3): 175-197.

Lam, P. (2002). "Buildability assessment: the Singapore approach." Journal of Building and Construction Management.

Liew, A. (2007). "Understanding data, information, knowledge and their inter-relationships." Journal of knowledge management practice **8**(2): 1-16.

Murray, M. (2003). Rethinking construction: the egan report (1998), Blackwell Science, Oxford, UK.

Nima, M. A., et al. (2002). "Constructability concepts in west port highway in Malaysia." Journal of Construction Engineering and management **128**(4): 348-356.

O'Connor, J. T. and S. J. Miller (1994). "Barriers to constructability implementation." Journal of Performance of Constructed Facilities **8**(2): 110-128.

Pheng Low, S. (2001). "Quantifying the relationships between buildability, structural quality and productivity in construction." Structural Survey **19**(2): 106-112.

Pocock, J. B., et al. (2006). "Constructability state of practice report." Journal of Construction Engineering and management **132**(4): 373-383.

Poh, P. S. and J. Chen (1998). "The Singapore buildable design appraisal system: a preliminary review of the relationship between buildability, site productivity and cost." Construction Management & Economics **16**(6): 681-692.

Pulaski, M. H. and M. J. Horman (2005). "Organizing constructability knowledge for design." Journal of Construction Engineering and management **131**(8): 911-919.

Radtke, M. W. and J. S. Russell (1993). "Project-level model process for implementing constructability." Journal of Construction Engineering and management **119**(4): 813-831.

Raviv, G., et al. (2012). Relationships between methods for constructability analysis during design and constructability failures in projects. Construction Research Congress 2012: Construction Challenges in a Flat World.

Russell, J. S., et al. (1992). Project-level model and approaches to implement constructability, Construction Industry Institute.

Russell, J. S., et al. (1994). "Comparative analysis of three constructability approaches." Journal of Construction Engineering and management **120**(1): 180-195.

Russell, J. S., et al. (1994). "Constructability related to TQM, value engineering, and cost/benefits." Journal of performance of constructed facilities **8**(1): 31-45.

Sacks, R., et al. (2010). "Interaction of lean and building information modeling in construction." Journal of Construction Engineering and management **136**(9): 968-980.

Sathyanarayanan, R. (2007). Constructability Review Process–A Summary of Literature. Constructability concepts and practice**:** 6-25.

Saunders, M., et al. (2009). "Research methods for business students. Essex." Financial Times/Prentice Hall.

Song, L., et al. (2009). "Early contractor involvement in design and its impact on construction schedule performance." Journal of Management in Engineering **25**(1): 12-20.

Tatum, C. and J. A. Vanegas (1986). Constructability improvement during conceptual planning, Construction Industry Institute, University of Texas at Austin [distributor]].

Tauriainen, M., et al. (2014). "The assessment of constructability: BIM cases." eWork and eBusiness in Architecture, Engineering and Construction: 55-61.

Touran, A. (1988). "Concrete formwork: constructability & difficulties." Civil Engineering Practice **3**(2): 81-88.

Trigunarsyah, B. (2004). "Constructability practices among construction contractors in Indonesia." Journal of Construction Engineering and management **130**(5): 656-669.

Uhlik, F. T. and G. V. Lores (1998). "Assessment of constructability practices among general contractors." Journal of Architectural Engineering **4**(3): 113-123.

Yang, H.-H., et al. (2013). Use of BIM for Construtability Analysis in Construction. Proceedings of the Thirteenth East Asia-Pacific Conference on Structural Engineering and Construction (EASEC-13), The Thirteenth East Asia-Pacific Conference on Structural Engineering and ….

Zhang, C., et al. (2016). "Quantitative assessment of building constructability using BIM and 4D simulation." Open journal of civil engineering **6**(03): 442.

Annexure-A

INVESTIGATING THE CHALLENGES FOR THE IMPLEMENTATION OF CONSTRUCTABILITY PRACTICES IN CONSTRUCTION INDUSTRY

Respected Sir/Madam,

This survey is being carried out as part of Masters' Research titled "INVESTIGATING THE CHALLENGES FOR THE IMPLEMENTATION OF CONSTRUCTABILITY PRACTICES IN CONSTRUCTION INDUSTRY ". The objective of this study is to identify barriers in the implementation of constructability practices in construction industry.

The main part of this research study relies on the questionnaire survey. Please be assured that the data will only be used for study purpose and no personal information will be disclosed at any forum/level. Please remember to click SUBMIT at the end. In case of any inquiry, please feel free to contact. Your contribution in this regard will be highly appreciated.

Thanking you in anticipation.

Regards,
Rao Umair Asghar
Post Graduate Student,
Dept. of Construction Engineering & Management,
School of Civil & Environmental Engineering (SCEE),
National University of Sciences & Technology (NUST),
Islamabad, Pakistan
Email: raoumairasghar@yahoo.com

*Required

1. **Email address** *

Section A: Personal Information

2. **Name** *

3. **Current Designation** *

4. **Please indicate your highest academic qualification** *
Mark only one oval.

- B.Tech
- BSc/B.Engg
- MSc/MEng/MTech/PG Dip
- PhD
- Other:

5. **Please indicate your years of professional experience** *
Mark only one oval.

- ( ) 0 to 5
- ( ) 6 to 10
- ( ) 11 to 15
- ( ) 16 to 20
- ( ) 21 and above
- ( ) Other: ____________________

6. **Please indicate your field of work (Please select all that may apply)** *
Tick all that apply.

- [ ] Architecture
- [ ] Infrastructure management
- [ ] Construction management
- [ ] Quantity surveying
- [ ] Site execution
- [ ] Monitoring & Evaluation
- [ ] Procurement
- [ ] Contract Management
- [ ] Other: ____________________

7. **Please indicate your country of work** *

____

8. **Please indicate your respective organization** *
Mark only one oval.

- ( ) Client
- ( ) Consultant
- ( ) Contractor
- ( ) Sub-Contractor
- ( ) Supplier
- ( ) Academician
- ( ) Other:

9. **Typical size of projects in PKR** *
Mark only one oval.

- ( ) Less than 10 million
- ( ) 10-100 Million
- ( ) 100-500 Million
- ( ) 500-1000 Million
- ( ) More than 1000 Million

Questionnaire Survey

Section 2 :

Please indicate to what extent following factors affect constructability implementation.
1- Very Low 2-Low 3-Neutral 4- Moderate 5- High

10. **Construct-ability has been defined as "The optimum use of construction knowledge and experience in planning, design, procurement and field operations to achieve overall project objectives" Are you familiar with this term?** *
Mark only one oval.

- Yes
- No

11. **Do you have a documentation that is related to practicing constructability by your organisation?** *
Mark only one oval.

- Yes
- No
- Maybe

12. **What are the techniques used in your company for constructability analysis or review?** *
Tick all that apply.

- [ ] Small Scale Models
- [ ] Computer Generated Models/Drawings
- [ ] Brainstorming
- [ ] Feedback or Lessons Learned
- [ ] Peer Review
- [ ] Other: ______

13. **Taking into account owner-related barriers, how much do you think the following factors affect the constructability implementation?** *
Mark only one oval per row.

	Very Low	Low	Neutral	Moderate	High
Reluctance for additional early project-stage Investments					
Owner Insistence in separating design and construction management operations	○	○	○	○	○
Lack of team-building and partnering abilities	○	○	○	○	○
Lack of resources	○	○	○	○	○
Dis-regard of constructability in selecting contractors and/or consultants					
Contracting difficulties in the constructability scope definition	○	○	○	○	○
limitations of lump-sum competitive contracting	○	○	○	○	○
Inappropriate contracting	○	○	○	○	○

14. **Taking into account general barriers, how much do you think the following factors affect the constructability implementation?** *
Mark only one oval per row.

	Very Low	Low	Neutral	Moderate	High
Stakeholder complacency regarding the efficiency of the project management procedures					
Lack of communication among designer ,contractor and consultant					
Disbelief in the potential utility of a constructability programme					
Lack of expert personnel					
Inappropriate project delivery method					
Lack of involvement of stakeholders in early phases of project					
False and ambigous information					
Failure to search out problems and opportunities					

15. **Taking into account designer-related barriers,how much do you think the following factors affect the constructability implementation?** *
Mark only one oval per row.

	Very Low	Low	Neutral	Moderate	High
False perceptions of constructabllity					
Lack of concept awareness					
Designer lacks construction expertise and awareness for construction technologies/softwares					
Incomplete specifications					
No standardization of design					
Faulty, ambiguous, or defective working designs					
Perception of increased designer liability					

16. **Taking into account contractor-related barriers , how much do you think the following factors affect the constructability implementation?** *
Mark only one oval per row.

	Very low	Low	Neutral	Moderate	High
Untimely knowledge feedback					
Untimely involvement in the early project-lifecycle phases					
Contractor outdated knowledge of construction methods and techniques					
Low availability of qualified and skilled labor					
Low work backlog.					
Inadequate contractor experience (work) causing error					

17. **Taking into account project-related barriers, how much do you think the following factors affect the constructability implementation?** *
Mark only one oval per row.

	Very Low	Low	Neutral	Moderate	High
Aversarial stakeholders relationships	◯	◯	◯	◯	◯
Extreme project size and complexity	◯	◯	◯	◯	◯
Construction Sequence	◯	◯	◯	◯	◯
Site and facility congestion	◯	◯	◯	◯	◯
strict time constraints/unrealistlc schedule	◯	◯	◯	◯	◯
Difficulty in proving the economics of constructability	◯	◯	◯	◯	◯

18. **What are the major benefits of implementing constructability?** *
Tick all that apply.

- [ ] Reduces project duration
- [ ] Reduces project cost
- [ ] Enhances partnering and trust among project team
- [ ] Increases owner satisfaction
- [ ] Reduction of errors
- [ ] Other: ____________________

19. **What problems in construction that you observe could be prevented by Improved constructability? (please type your answer here)** *

____
____
____
____
____

Powered by Google Forms