# ANALYSIS OF CONSTRUCTABILITY PRACTICE IN PROJECT DELIVERY PROCESS IN THE NIGERIAN ENGINEERING/CONSTRUCTION INDUSTRY

BY

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## APPROVAL PAGE

This research thesis has been certified to have met the requirements for the award of Master of Business Administration (MBA) degree in Project Management by the Department of Project Management Technology, School of Management Technology, Federal University of Technology, Owerri

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## DEDICATION

This thesis is dedicated to my wife, Ogechukwu Ekweozor and my sister, Nonyelum Ndimele for all their support.

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Chike Ekweozor

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## ABSTRACT

This study is aimed to investigate and analyze the implementation of constructability in project delivery process in the Nigerian engineering / construction industry using Rivers state as case study area.Data was collected through questionnaire and interview approach. Analysis of data was carried out with the use of SPSS V16.Results of data analysis revealed that although a high percentage of the sampled population are familiar with the term “constructability”,nearly alldo not have corporate constructability implementation manual nor apply formal constructability implementation programs and techniques as obtained in more developed countries. Constructability implementation is therefore neither systematic nor comprehensive in nearly all the firms surveyed. The universal principles of constructability were accepted by the professionals and rated in the order of importance. The most critical was identified as: carry out thorough investigation of site and development of a project plan. Conditions that constrain constructability in the opinion of the professionals were also identified and rated in the order of impact. Spearman rank correlation analysis shows agreement of opinion between different respondent groups in the sampled population. Engineers, project managers and other industry practitioners are enjoined to adopt these principles and findings in their planning, design and construction activities in order to improve overall project performance and achieve best practices in the industry.

**Keywords:** Constructability, buildability, project management, engineering, construction, procurement, hypothesis, tools, ranking, correlation.

# CHAPTER 1

# INTRODUCTION

## 1.1 BACKGROUND OF STUDY

Constructability has been defined as the optimum use of construction knowledge and experience in planning, design, procurement and field operations to achieve overall project objectives. Application of constructability principles during the project life cycle is important in order to reduce or prevent errors, delays, disputes and cost overruns. The concept of “constructability” in the US or “buildability” in the UK emerged in the 1970’s in an effort to stop the declining cost-effectiveness and quality of the construction industry (Wong et al, 2006).It was born out of the realization that designers and contractors see the same project from different perspectives, and that optimizing the project requires that the knowledge and experience of both parties be applied to project planning and design processes (Bakti et al, 2003).

Construction project delivery is achieved through different procurement systems. Among these are the traditional Design-Bid-Build (DBB), Design and Build (D&B), Develop and Construct (D & C) and Management Contracting. It is common knowledge that different procurement systems have varied influence on the project’s constructability performance. The procurement system employed in a project has considerable impacts on the project outcomes such as time, cost, quality, complexity etc. To enhance constructability therefore, the most suitable procurement approach for a project should be selected. In many developed countries, much research effort have been directed at improving constructability through the integrated effort of owners, designers and constructors.

The Nigerian infrastructure sector has experienced massive growth over the past few years with a steady rise in construction expenditure in the country, primarily due to the growing oil revenues. The impact of the construction industry on the economy is a known reality. It is a key indicator and driver of economic activity and wealth creation.

However, the performance of the industry with regards to cost, quality and time of project delivery has not been impressive. Among the local companies especially, cases of project delays, abandonment, cost overrun and failures can be attributed to a large extent, to lack of adequate knowledge and non-implementation of constructability principles in the project delivery process.

With the increased competitiveness in the construction industry, the high technical complexity of today's project and the ever increasing demands for faster and lower cost delivery of finished facilities, the application of formal and informal constructability programs is imperative for any firm that is concerned about survival and quality of its services . The Nigerian construction industry practitioners should take advantage of advances already made in the general improvement of construction performance in more advanced countries, adapt and apply as appropriate, in order to compete favorably in the prevailing global market challenges.

## 1.2 STATEMENT OF PROBLEM

The performance of engineering projects in the Nigerian Construction industry in is far below international standards. Examples abound of failed and abandoned projects which are scattered all over the country. Buildings collapse on regular basis in different parts of the country. Most of the roads and other public infrastructure built with taxpayers funds fail to provide value for money due to quality issues. Schedule and cost overruns for many public or private projects have been of greatconcern to industry practitioners. All these have varied negative impacts on the socio-economic development of the nation.

There are factors which are capable of causing project failure if not addressed early in the project delivery process, some of which include:

• Design errors, in either material selection or dimensions.

• Ambiguous specifications.

• Project features that will be difficult or exceedingly costly to construct as designed.

• Project features that exceed the capability of industry to properly build.

Engineering/construction professionals need adequate knowledge and deployment of the right tools to deal with these issues.

Constructability or buildability is a project quality improvement technique that if implemented throughout the project delivery process, mitigates these challenges. Constructability implementation ensures that design professionals consider how a builder will implement the design, which otherwise could lead to scheduling problems, delays, disputes and cost implications during the construction process.

The state of the Nigerian construction industry does not suggest good constructability practice. Hence the need to investigate and analyze the extent of constructability input by industry professionals, in order to make deductions and recommendations that would improve performance.

In the US, UK and other developed countries, formal and informal application of the principles of constructability is part and parcel of the project delivery process. Research and continuous improvement in this area has been on-going for the past three decades.

This research therefore brings to the fore the importance of carrying out constructability of projects in principle and practice, in order to mitigate the aforementioned challenges and improve projects performance in the Nigerian construction industry.

## 1.3 AIMS AND OBJECTIVES OF STUDY

This study is aimed to investigate and analyze the implementation of constructability in project delivery process in the Nigerian construction industry. The objectives are as follows:

- To investigate the level of awareness and knowledge of constructability concepts and principles among the engineering/construction professionals.
- To identify constructability tools and programs deployed by professionals and determine the extent of their use in project delivery process.
- To identify and rank conditions that constrain constructability of projects in the opinion of Nigerian professionals
- To make deductions and recommendations that would improve performance of engineering projects in Nigeria

## 1.4 RESEARCH QUESTIONS

In this study, answers will be sought for the following questions:

1. What is the level of awareness and knowledge of constructability concepts and principles among industry practitioners –designers, constructors, project managers etc., and what can be done to improve if inadequate.
2. What constructability tools/programs are developed and applied by practitioners in the Nigerian construction industry and to what extent.
3. What conditions constrain constructability of a projectin the opinion of Nigerian professionals and to what degree.

4. What can be done to close the gaps identified and so improve the general performance of engineering projects in the industry.

## 1.5 RESEARCH HYPOTHESIS

1. There is no agreement between the opinion of different respondent groups on “constructability principles and degree of importance”.
2. There is no agreement between the opinion of different respondent groups on “conditions constraining constructability”.

## 1.6 SIGNIFICANCE OF STUDY

The application of project quality improvement techniques, one of which is constructability is of paramount importance for the overall improvement and optimisation of engineering projects.

The world today is divided into the under-developed, developing and developed societies; the difference being in the quality and standard of life obtainable. The construction industry in developed nations is highly advanced due to the right application of modern technology and techniques as well as innovations in construction methods and management.

In the US, UK and other developed countries, formal and informal application of the principles of constructability is part and parcel of the project delivery process. Research and continuous improvement in this area has been on going for the past three decades.

Nigeria and most other developing nations are still lagging behind in this regard considering that there is little research effort on the area. The world is a global village and there is world-wide competitive markets for the production, distribution and consumption of goods and services. For both the local and multinational firms, the challenge of increased competitiveness in the construction industry demands improvements in the capabilities of construction companies combining the quality of material and construction works with economic and schedule aspects. Also, the high technical complexity of today's project and the ever increasing demands for faster and lower cost delivery of finished facilities, make constructability input indispensable(Fischer and Tatum, 1997).

It is therefore of utmost significance that a study of this nature be carried out in order to create more awareness among industry practitioners on the importance of constructability input in the project delivery process. It is expected that more research work would be directed to this area among the academia which would provide more information for industry regulatory agencies, professional bodies, designers, constructors, project managers etc. This would lead to better appreciation of the importance of constructability input in the project delivery process and general improvement in the performance of the Nigerian construction industry.

## 1.7 SCOPE AND LIMITATION OF STUDY

This study covers the area of definitions, concepts and principles of constructability and buildability as a project management technique. It focuses on construction industry professionals – engineers, architects, builders, project managers etc, as well as design and construction firms in the engineering/ building as well as the oil and gas industry.

Due to the limitation of available time and resources, the study covered mainly Rivers state of Nigeria. However, the researcher has made efforts to reduce the effect of these limitations in order to achieve the objective of the study.

## 1.8 ORGANISATION OF STUDY

This study is made up of five chapters. Chapter one contains the introduction which includes background information, statement of the problem, aims and objectives as well as research questions. In chapter two, a comprehensive review of relevant literature is covered. Chapter three is dedicated to detailed analysis and discussion of tools and techniques used for data collection. Chapter four contains the data presentation, analysis and discussion of results. Chapter 5 concludes the study with a summary of findings and recommendations.

## CHAPTER 2

## LITERATURE REVIEW

### 2.1 INTRODUCTION

In this section, the views of other researchers as published in textbooks, journal articles, seminar papers, etc on constructability/ buildability concepts, principles and practices is presented. Preceding this is introduction of foundational concepts and terms such as Projects and its characteristics.

### 2.2 PROJECTS

According to PMBOK - Project Management Body of Knowledge (2004), a project is a temporary endeavour undertaken to create a unique product, service or result. Temporary means that every product has a definite beginning and a definite end. The end is reached when the project objective has been achieved or otherwise terminated. A project creates unique deliverables. Uniqueness is an important factor of project deliverables. For example, many thousands of office building have been developed, but each individual facility is unique - different owner, different design, different location, different contractors, and so on. Project has been defined by many authors among which is Kerzener (1995), which defined project as any series of activities and tasks that

a. Have a specific objective to be completed within certain specifications.
b. Have defined start and end dates
c. Have funding limits
d. Consumes resources.

Akpan and Chizea (2002) posits that the term project connotes any unique activity, situation, process, task, program, scheme or any human endeavour in which human time and other resources are utilized to satisfy a definable and definite one-off (single or multiple) objective. The realization of the set of objective generally signals the completion of this unique activity.

However, Pinto and Slevin (1988) noted that developing a definition of what exactly a project is, is often difficult because any definition must be general enough to include examples of the wide variety of organizational activities which managers consider to be project functions.

They stated that the definition should also be narrow enough to include only those specific activities which researchers and practitioners can meaningfully describe as project oriented. Two of the many definitions of projects that have been offered are as follows:

a. A project is an organization of people dedicated to specific purpose or objective. This is a general definition and tend to highlight project chararcteristics as involving the following: large, expensive, unique, high risk undertaking which have to be completed by a certain date, for a certain amount of money, within some level of performance and having well defined objective and sufficient resources to carry out all required tasks.
b. A project is a combination of human and non-human resources pulled together in a temporary organization to achieve a specified purpose.

## 2.3 ENGINEERING CONSTRUCTION PROJECTS

Engineering construction projects have certain features that distinguish it from the non-engineering construction projects. Obiegbu (1987) identified some essential features of an engineering construction project as follows:

i. Production takes place at the site where the product (project) is to be consumed.
ii. Engineering construction design must be produced.
iii. The projects are considerable in size and of fixed location.
iv. Projects operations are mainly construction activities which takes considerable time.
v. Project production involves many specialist professionals and wide range of mixed craftsman
vi. Contracts option usually form the major method/ approach of project execution

From the above, engineering construction projects can be defined as a system or structure formed through an assemblage or combination of various materials and components on site. By this definition, any project having the primary objective of forming, erecting or construction of various materials on site is an engineering construction project. Examples of engineering construction projects are as follows: buildings, highways, oil and gas facilities, industrial development, general infrastructure, etc. It follows that any project whose primary objective is not to form, erect or construct a system/structure could be described as non-engineering construction project. Examples of non-engineering construction projects are as follows: Agriculture, research/development, supply service, manufacturing etc.

This study is focused on engineering construction projects.

## 2.4 PROJECT LIFE CYCLE

A project has a well defined beginning and an end. According to Ntamere (1995), Project life cycle are the phases of a project development. Factors such as environmental, technical, cost etc determine the nature and duration of the various phases of project.

The definition of project life cycle phases are as follows: Conceptual phase, Planning, Execution and Termination.

Conceptualization: this is the initial phase when the necessity of the project is established, preliminary goals and alternatives specified.

Planning: Establishment of more formalized set of plans to accomplish the initially developed goals. The planning activities include scheduling, budgeting and allocation of specific tasks and resources.

Execution: this deals with the actual work of the project. Materials and resources are procured, project is produced and performance capabilities are verified.

Termination: upon completion, transfer of project to client, reassignment of project team personnel.

## 2.5 PROJECT MANAGEMENT AND IT'S CHARACTERISTICS

The need to plan, coordinate and control the complex and diverse activities of modern industrial and commercial enterprises gave rise to the evolvement of project management.PMBOK (2004) states that Project management is the application of knowledge, skills, tools and techniques to project activities to meet project requirements. Project management is accomplished through the application and integration of the project management processes of initiating, planning, executing, monitoring and controlling and closing. The project manager is the person responsible for accomplishing the project objectives.Managing a project includes:

- Identifying requirements
- Establishing clear and achievable objectives

- Balancing the competing demand for quality, scope, time and cost
- Adapting the specifications, plans and approach to the different concerns and expectations of various stakeholders.
- In managing competing project requirements, the triple constraints of project scope, time and cost. Project quality is affected by balancing the three factors.

Akpan and Chizea (2002) defined project management as follows: Project management is essentially the efficient utilization of available human and material resources under time and cost constraint for the satisfactory realization of the pre-determined project objective.

In summary, economic pressure of the industrialized world, competition between rivalry contractors and greater regards for value and well being of the people who constitute the project stakeholders have all led to the development of new techniques for managing projects such as project management technique.

## 2.6 PROJECT DELIVERY (PROCUREMENT) SYSTEMS

Delivery of an engineering/ construction project, requires a coordination of the efforts of the owner, designers (engineers/architects), and contractor in an accepted and acceptable contract form. Owners and other participants in the construction process have diverse needs in the project construction process. To accommodate these differing needs, various options for building a structure have evolved. These various options are referred to as project delivery methods. Methods range from the basic (design-award-build) to the more complex (fast-track and turnkey construction). Each method has its own benefits and disadvantages and some methods are better suited for certain kinds of projects.

There are various definitions of procurement systems as reported by some authors such as: Wong et al (2005), "*the amalgam of activities undertaken by a client to obtain a building".* Franks (1998),the *"organisational structure adopted by the client for the implementation and at times eventual operation of a project".* Masterman (2002)

They in simple terms are dealing with the management and structuring of project activities as well as defining the functional and contractual relationships among project team members.

The procurement system employed in a project has considerable and multi-faceted impacts on the project outcomes. These impacts include cost, time, quality, complexity, client's involvement, communication with clients, management of risks and flexibility for changes etc. (Chan and Yung, 2000). As one of the functions of project management system, procurement system also provides a means for project management by manipulating the contents of contracts governing each activity performed by the project participants. To enhance constructability, the most suitable procurement approach for a project should be selected.

It is well recognised that constructability could be improved by adopting procurement methods where construction expertises are sought during the design stage. Conversely, inappropriate procurement systems could have negative effects on constructability. Wong et al (2005), stated that as a function of project management, procurement systems have wide-ranging effects on a variety of project parameters. These parameters in turn affect constructability. Hence, by managing the contractual relationship of the involved parties and the timing of their involvement for efficient construction operations, constructability can be improved. The common project delivery methods in use today are highlighted below.

**Design-Bid-Build**

The design-bid-build method is the most common construction delivery method. This process begins with an owner selecting the Engineers/architects to prepare construction documents. Under the traditional Design-Bid-Build procurement method, the Architect or Engineer designs everything whereas contractors have no involvement in the pre-contract stage. In most cases, the architect will release these construction documents publicly, or to a select group of general contractors, who will then place a bid on the project which reflects what they believe to be the cost of construction. This bid is inclusive of a multitude of subcontractor bids for each specific trade. The general contractor's fee is generally built into the bid cost. Most government contracts are bid competitively using this method.

From the legal point of view, Berman (1999) posits that although the DBB method promotes the construction of a quality project, because of the inherent tension between the design professional and the contractor, this method is often criticized because of the extended time involved in designing and constructing the project as well as the somewhat adversarial nature of the relationship between the architect and the contractor. The two look over each other's shoulder and are all too ready to finger-point if something goes wrong. Because of this situation and others, many variations of this construction method have developed.

**Design and Build (D&B)**

D&B allows commencement of construction before completion of designs. By using this method, constructability could be enhanced because of the involvement of construction experts in the design stage. Clients could also enjoy single point responsibility of the D&B contractors. .

The design-builder is usually the general contractor, but in many cases it is also the design professional (architect or engineer). This system is used to minimize the project risk for an owner and to reduce the delivery schedule by overlapping the design phase and construction phase of a project. Where the design-builder is the contractor, the design professionals are typically retained directly by the contractor.

In his analysis of this method, Berman (1999) suggested that in using D&B, clients should be aware of its shortcomings. Naturally, contractors would usually favour designs to be as constructable (or simple) as possible. As a result, control by clients over the contractors and the quality of the built products may be lost. Moreover, additional costs would be incurred in case of late design changes. Apart from these, the seemingly apparent advantage of using D&B is not realised all the time. The design-build form of construction fosters teamwork between the designer and contractor early in the project and facilitates early budgeting, programming, and financing. It also promotes review of the design as it proceeds for constructability and cost of construction. Well suited for fast-track construction and modern project management techniques, design-build projects are often more cost-effective and less susceptible to delays in the work than traditional projects.Perhaps the greatest advantage for the owner is that the owner only has to look to one party for the design and the construction. If a problem arises, design-build avoids the customary finger pointing that results when the architect and the contractor attempt to blame each other for a problem.

**Develop and Construct (D&C)** The D&C method shifts the design responsibility as well as clients' controls to the contractors at a later stage than using D&B. It allows larger clients' influence and control on the designs. But this method may attract higher tender prices because contractors may worry about the liabilities transferred to them by the client's design team. Another disadvantage is the discontinuity of designs because of different design teams being involved in the development of designs. To alleviate the problem, the design consultants engaged by the clients could be novated to the contractor under a novation arrangement.

**Management Contracting**

To avoid some of the problems inherent in the traditional design-award-build project, it is common for workers to engage a construction manager to perform tasks such as assisting with the development of accurate construction cost estimates that are within the owner's budget, scheduling, technology issues, reviewing the architect's plans for constructability, obtaining and negotiating bids, and coordination of aspects of the work. The construction manager acts as the owner's agent and in theory is supposed to have greater knowledge regarding the cost and availability of labor and materials and estimating the cost and time for completion of construction tasks. Because of the nature of the duties usually assigned to the construction manager, the role of construction manager is most often filled by a contractor, although architects also act as construction managers. **Construction Manager as Constructor**

Under this delivery method, a construction manager is hired prior to the completion of the design phase to act as a project coordinator and general contractor. Unlike the DBB method, a construction manager is hired during the design phase, which allows the construction manager to work directly with the architect and circumvent any potential design issues before completion of the construction documents. After documents are completed, the construction manager accepts bids for the various divisions of work from subcontractors or general contractors.

**Engineering Procurement and Construction (EPC)**

In the design-build method, the owner contracts with a single entity to provide both the design and construction of the building, systems, or equipment. The term is often used interchangeably with turnkey and EPC (engineer, procure, and construct) which is similar to design-build; however, with turnkey construction, in addition to designing and constructing, the same entity often finances, maintains, operates or leases the space back to the owner. Whether a project is turnkey or design-build can have significant implications regarding the liability of the contractor.

This method is mostly used to excecute very large and complex projects such as industrial plants, refineries, power stations etc, and is also used for major projects in the Oil & Gas industry.

## 2.7 CONSTSTRUCTABILITY AND BUILDABILITY

### 2.7.1 DEFINITION

The concept of "constructability" in the US or "buildability" in the UK emerged in the 1970's in an effort to stop the declining cost-effectiveness and quality of the construction industry (Wong et al, 2006).It was born out of the realization that designers and contractors see the same project from different perspectives, and that optimizing the project requires that the knowledge and experience of both parties be applied to project planning and design processes (Bakti et al, 2003).

The concept of buildability originated in the United Kingdom and was defined as the extent to which the design of a building facilitates ease of construction, subject to overall requirements for the completed building (CIRIA, 1983). Buildability stresses on integration of design and construction to achieve the project goal by enriching the knowledge of designers in construction operations and involving construction expertises in the design process.

Construction Industry Institute (CII) in the United States proposed a similar concept to buildability and labeled it as constructability. Constructability was defined as the optimum use of construction knowledge and experience in planning, design, procurement and field operations to achieve overall project objectives (CII, 1987).

In Australia, the term of constructability and buildability are used interchangeably and the concept has been re-defined as the extent to which decisions made during the whole building procurement process, in response to factors influencing the project and other project goals, ultimately facilitates the ease of construction and the quality of the

completed project (Mc George et al, 1992) or alternatively the integration of construction knowledge in the project delivery process and balancing the various project and environmental constraints to achieve project goals and building performance at an optimal level (CII Australia, 1992).

The above definitions have pointed out that constructability can be improved by optimally incorporating practical construction knowledge throughout the whole building development process. Since a project owner usually has a variety of project objectives, it is by no means possible to maximise the achievement of all objectives, including constructability. Instead, a balance has to be struck among the objectives in order that the overall project goals are achieved

Wong et al (2007) conducted recent study aimed at identifying the common approaches for improving constructability and evaluating their effectiveness of implementation. Results showed that buildability is mainly concerned with design, quality of built product, ease of construction, as well as efficient and economic construction. Constructability emphasizes integration of construction knowledge and experience at various project stages, optimization of different project requirements to achieve overall goals and ease of construction. Therefore, “constructability” embraces the concept of “buildability”.

Put in another way, the concept of buildability mainly deals with design deliverables, whereas constructability which is more comprehensive is concerned with the management system in the building development process to enhance construction performance. Application of constructability principles during the project life cycle is important in order to reduce or prevent error, delays, disputes and cost overruns.

### 2.7.2 CONSTRUCTABILITY CONCEPTS AND PRINCIPLES

In the US, the Construction Industry Institute (CII) carried out studies and developed fourteen (14) constructability concepts applicable to the project stages of conceptual & planning, design engineering, procurement and site operation. According to Griffith and Sidewell (1995), the American society of Engineers (ASCE) suggested six principles of constructability which are as follows;

a. Evaluating various design configurations to optimize owner requirements.
b. Knowing the various project systems and their interface requirement with other project components.
c. Understanding trade skills and practices, construction methods, materials labour and sub-contract resources and plant and equipment..

d. Appreciation of local climatic conditions.
e. Evaluating site conditions both above and below ground and realizing their possible implications upon construction.
f. Determining availability of space and access routes on site

Following the initial studies O'connor et al (1987) examined how constructability may be improved during design development stage. The resulting report entitled "Constructability Improvement During engineering and Procurement" described how construction knowledge and experience may be most effectively used during the engineering and procurement phases of projects. Result of the study identified seven constructability principles as follows;

a. Constructability is enhanced when design and procurement schedules are construction –driven.
b. Constructability is enhanced when design are configured to enable efficient construction.
c. Constructability is enhanced when design elements are standardized and repetition is taken advantage of
d. Constructability is enhanced when pre-assembly work is scoped in advance and module/pre-assembly designs are prepared to facilitate fabrication, transport and installation.
e. Constructability is enhanced when design promotes accessibility of manpower, material and installation
f. Constructability is enhanced when design facilitates construction under adverse weather conditions when they exist.

g. Constructability is enhanced when the owner, designer, and constructor personnel review specification in details. It also serves to simplify the field construction process.

O'Connor and Davis (1988) in further research identified the constructability improvement that can be made during field operation. One principle was identified, which is constructability is enhanced when innovative construction methods are utilized.

As pointed out by O'connor and Miller (1994), CII added three new principles to the previous fourteen principles of constructability improvement. Two are for improvement at the conceptual planning phase while one principle is for improvement at the design and procurement phase

The two principles for the conceptual planning phase are

a. Project team responsible for constructability are identified early on

b. Advanced information technologies are applied throughout project

The new principle for design and procurement phase is - Design and construction sequencing should facilitate system turn-over and start-up.

Boyce (1991) in his study on principles for improving constructability introduced what is called The Ten commandments of KISS Design:

a. Keep it straight and simple

b. Keep its structures simple

c. Keep its specifications simple

d. Keep it shop standard

e. Keep its standards simple

f. Keep it the same size

g. Keep it square and squatty

h. Keep it support sacred

i. Keep it schedule sacred

j. Keep it site suitable

In the UK where the concept of “Buildability” originated, the Construction Research Information Association (CIRIA) provided seven guidelines for buildability which was later expanded to sixteen(16) design principles for practical buildability (CIRIA 1983).

a. The thoroughness of design and investigation
b. Planning for site production requirements
c. Planning for practical sequence of operations and early enclosure
d. Planning for simplicity of assembly and logical trade sequences
e. Detailing for maximum repitition and standardization
f. Detailing for achieving tolerances
g. Specify robust and suitable materials

Further research commissioned by CIRIA reported by Adams (1989) developed the above seven principles into sixteen more definite concepts stated as design principles. Each design principle is defined as and described with the aid of practical design examples.

A total of fifty practical design examples have been documented.

The sixteen design principles are as follows;

a. Investigate thoroughly

b. Consider access at the design stage

c. Consider storage at the design stage

d. Design for minimum time below ground

e. Design for early enclosure

f. Use suitable materials

g. Design for the skill available

h. Design for simple assembly

i. Plan for maximum repetition and/standardization

j. Maximise the use of plant

k. Allow for sensible tolerances

l. Allow for practical sequence of operations

m. Avoid return visit by trades

n. Plan to avoid change to work by subsequent operations

o. Design for safe construction

p. Communicate clearly.

In Australia, in 1993, the construction Industry Institute, Australia (CIIA), through collaboration with CII in the United States developed their own constructability principle files which represent the best in current constructability practice (CIIA, 1993). It consists of 12 principles of constructability, implementation advise on how to establish constructability program, and database of examples from constructability savings. It is aimed at encouraging a project team to apply them when appropriate to their projects. The constructability principles developed by CIIA are;

a. Constructability must be made an integral part of the project plan
b. Project planning must actively involve construction knowledge and experience
c. The experience, skills composition of the project team must be appropriate for the project

d. Project team gains an understanding of the clients corporate and project objectives
e. The technology of the design solution must be matched with skill and resources available
f. External factors can affect the cost and /or program of the project
g. The overall program of the project must be realistic and construction sensitive, and have the commitment of the project team
h. The project must consider construction methodology
i. Accessibility is considered in the design and consruction stages of the project
j. Construction efficiency is considered in specification development
k. The use of innovative techniques during construction will enhance constructability
l. The project team undertakes post-contruction analysis

The Building and construction authority in Singapore has equally developed a Code of Practice on Buildable Design. The focus of their constructability improvement principles is towards minimizing the labour usage during construction. As a result, appraisal system called Buildable Design Appraisal System (BDAS 2000) was developed. There are three principles of constructability in this appraisal system which are standardization, simplicity and single integrated element.

### 2.7.3 CONSTRUCTABILITY PROGRAMS

Interview data conducted by CII (CII 2008) revealed eight general approaches to constructability currently used in the construction industry. Each approach depends on the variety, type and size of projects in which an organization participates. The project delivery method plays an important part. The various approaches to constructability are presented below;

Construction Management Historical Practice: Constructability input is often obtained by in-house personnel. Very little documentation for constructability is provided including within contract documents. This approach lacks any method of estimating the value of constructability efforts.

Constructability Contract documents- As in the previous approach, constructability is considered to be an integral part of construction management activities. However, contract clauses and brief constructability procedures are implemented as part of an informal means of obtaining construction knowledge during the detailed design phase. Some organizations use constructability plan review checklists in order to draw attention to design materials frequently overlooked

Constructability Services: Constructability input is considered to be a service provided along with preconstruction services. This approach usually associates constructability with value engineering. The service usually reviews the cost of design alternatives

Constructability Design Review: Reviews of project design and specifications are performed at set percentages of design completion using formal design checklists. The reviews typically check designs for accuracy, completion,, cost effectiveness, and compatibility with project constraints.

Specialized Formal Constructability Programs: This involves the following - obtain constructability input during conceptual planning and preliminary design, establish a philosophy for projects, outline constructability procedures, and track progress of constructability efforts.

Standard Constructability Guidelines: Organisations that often use formal constructability programs usually incorporates constructability philosophy proven during various projects into corporate constructability manual and training program. As the corporate level program evolves, the philosophy becomes widely accepted and tracking of constructability savings becomes less necessary.

Comprehensive Tracking: Similar to standard Constructability guidelines approach with two additions. First a paper or computer database is created with the purpose of communicating lessons –learned from project to project. This enables project participants to view construction alternatives and their associated costs and relate it to their own projects, the second feature is a database established to record and track constructability savings including cost and schedule, in order to justify future use of constructability programs. This approach usually requires a constructability database manager

It is noteworthy to state that the approach to a corporate level constructability program depends on organization type while the project-level program is the same whether the participant is the owner, designer, or contractor of the project.

### 2.7.4 CONSTRUCTABILITY IMPLEMENTATION IN PROJECT DELIVERY PROCESS

The various approaches to constructability implementation in the global construction industry as given by different authors is highlighted below:

In Nigeria, Mbamali et al (2004) in his research work interviewed Building industry professionals architects, engineers, quantity surveyors etc to assess randomly selected buildings for their content of buildability features. Result showed a high awareness (3.39 - 3.35 points on a scale of 0-4) and application of standardization and simplicity principles as most important principles to adopt.

Nima et al (2001) carried out a similar work in Malaysia where Industry wide questionnaire were administered. Respondents were engineers working with owners, consultants, contractors and sub-contractors and construction management firms. Results showed high acceptance of 22 concepts out of 23. These engineers accepted the constructability concepts from the theoretical point of view but generally they did not apply these concepts in their practices. Study also showed that Malaysian engineers show a wide understanding of the majority of the concepts. However, they did not link those concepts under the umbrella of constructability.

According to Uhlik and Lores (1998), prior research has found a lack of constructability efforts among participants in the construction industry especially general contractors. However, from data obtained in the US, results show that contractors applied constructability concepts and participated during the earliest phase of the projects more often than is thought. The findings also showed that constructability practices differed depending on the characteristics of the organization, the type of work performed and the type of contractual arrangement.

Constructability is an approach that links the design and construction processes which can lead to significant savings in both cost and time required for construction project. Improving constructability is the responsibility of all project stakeholders: owners, designers and contractors.

In his own work, Trigunarsyah (2006) examined the role of owners. Owners have the more authority in enforcing implementation therefore their role in constructability improvement is most important. The paper describes how construction project owners integrate construction knowledge and experience in planning and design in existing practice. Research was carried out by means of case studies of some notable projects in Indonesia. Results show that project owners in Indonesia do have some understanding of the importance of constructability. The selection of project delivery method determined the type of constructability input for the respective projects.

Arditi et al (2002) stated that Constructability of design is a subjective scale that depends basically on a number of interdependent project related factors. The research effort examined design professional's effort to pursue constructability using mailed questionnaire to top US firms. Results showed that the maximum benefits of constructability reviews measured by their ability to influence cost, are obtained in the design phase

.- Most design professionals are aware of constructability as a quality indicator of their finished product.

- About half of the designers indicated they have a documented formal corporate policy to conduct constructability reviews in their organization.
- Evidence that designers are abandoning the traditional physical small scale models in favour of computer-generated 3D models. Only 1/3 of the designers still use physical models as constructability tool.
- Peer reviews and feedback systems are the most prevalent tools used to achieve high constructability

Also, Bakti and Trigunarsyah (2003) carried out a case study at one of the Indonesian construction companies who applies the design and build type of contract for industrial plant projects such as cement and mineral, petrochemical, power plant, oil and gas projects etc. Project performance variables measured were operation and cost, quality and safety, benefit of constructability and constructability lessons learned. Results show that constructability implementation can increase and improve project performance. Early involvement of construction knowledge and experience, constructability resource personnel and standardization of design are most influencing factors of constructability for increasing project performance.

### 2.7.5 IMPROVING BUILDABILITY/CONSTRUCTABILITY OF PROJECTS

Highlights of efforts being made to improve constructability are discussed in the following research works:

Lam et al (2005), through a questionnaire survey, identified the significant factors affecting buildability and constructability and classified them into those related to the design process and design outcome. To enhance buildability and constructability of any project requires efforts in (i) carrying out thorough site and ground investigation prior to design, (ii) coordinating design documents, components and working sequences as well as (iii) designing for standardization, repetition, safety and ease of construction.

Oyedele and Tham (2005) performed a study in Nigeria aimed at providing architects with information that can be used to improve performance and achieve high quality overall project performance in Nigerian construction industry. Results showed that the architects need to focus on management skills and ability, buildability, design quality, project communication, project integration and client focus. These results would encourage architects to perform better within their full responsibilities in the building delivery process and deliver high-quality project within Nigerian construction industry.

In Singapore, Poh and Chen (1998) carried out a study to examine relationship between site productivity construction costs and the “buildable score” of a building design appraisal system recently developed by the Singapore Construction industry. The buildable score for a building is a numerical figure computed by taking into account the level of standardization, simplicity and extent of integrated elements used in the design of building. Result of study supports the proposition that a design with a higher buildable score will result in more efficient labour usage in construction and therefore higher site labour productivity.

### 2.7.6 CONSTRAINTS TO EFFECTIVE CONSTRUCTABILITY IMPLEMENTATION

In the project delivery process, there are many constraints to effective constructability implementation starting from the planning phase to the actual construction phase for a typical engineering project.

According to Wong et al (2005), the common constructability problems are mainly attributable to several sources. Some problems come from projects with demanding construction methodologies engaging complex and innovative technologies and techniques. Deficiency in constructability considerations may be traced back to the tight timeframe for designing and tendering such that designers and tenderers do not have enough time for preparing designs and pricing respectively. In addition, if detailed planning prior to construction is not in order, whenever underground works is involved, e.g. substructures and railway tunnelling which entail temporary works and lots of coordination and overcoming of site constraints, poor constructability is likely to result.

To aggravate the problems, there is no clear-cut formula deciding how constructable the building should be. In reality, different projects have different constructability requirements with different site conditions and structures. The requirements for constructability can range from 0% to 100% from projects to projects. For example, to build a 2-storey standard house with proven methods of construction, contractors need not worry too much about constructability problems. Rather, when it comes to constructing a bridge or a basement, a variety of factors including the choices of foundation, support and piling should be thoroughly considered.

The weight of constructability in a project depends on the client's preferences and who the beneficiaries are. It is always a balance between time, cost, quality and the goals that client specified.

Alinaitwe et al (2007), in their paper, posit that poor productivity of construction workers is one of the causes of cost and time overruns in construction projects. The paper reports on a survey made on project managers of building projects in Uganda where an increase in productivity is being sought. It reports that ten most significant problems affecting labour productivity were identified as

- incompetent supervisors
- lack of skill from the workers
- rework, lack of tools/equipment
- poor construction methods
- poor communication
- inaccurate drawings
- stoppage because of work being rejected by consultants

- political insecurity
- tools/equipment breakdown
- and harsh weather conditions

In response to a recent report of the Construction Industry Review Committee for improving buildability in Hong Kong, a research project was commissioned to develop a buildable design appraisal system for use in the city. In their paper, Wong et al (2006), after series of interviews with experienced industry practitioners in Hong Kong (including expatriates) was conducted and analysis made, came up with the following findings: Buildability problems emerged because of the lack of clear project briefing and insufficient considerations of buildability at the design stage. Mitigation measures at the design stage include co-ordinating the delivery process, revisiting works done, training on site production techniques and cross-discipline communication, etc. From the procurement perspectives, Partnering in Design & Build is a better option in alleviating buildability problems.

### 2.7.7 BENEFITS OF CONSTRUCTABILITY INPUT IN THE PROJECT DELIVERY PROCESS

The benefit of constructability input in the project delivery process is numerous as highlighted by many researchers. Total Quality management (TQM) and Value engineering have two principal objectives:

- customer satisfaction and
- continuous improvement

Russel et al (1994) in his paper, attempts to conceptually describe how constructability is related to both. The goals of TQM and constructability are similar if not the same. Similarity show that Constructability is one aspect necessary to achieve quality in a constructed facility. A constructability program can enhance customer satisfaction by facilitating teamwork among owner, designer, and constructor representatives as early as the planning phase of a project. By so doing, it provides more resources including construction knowledge and experience for planning and designing a quality project that maximizes construction productivity. Constructability is a means of continuous improvement in several respects. Maintaining a lessons-learned database, allows communication of positive and negative activities and experiences from one project to future projects. Also construction personnel may be more aware of innovations in equipment or construction techniques that may play a key role in improving designs.

The primary objective of value engineering is to reduce the total life-cycle cost of a facility, whereas constructability focuses upon optimization of the entire construction process. In most cases of industry implementation, value engineering is normally performed during the design phase of the facility delivery process. An effective formal constructability program ideally begins during the conceptual planning phase and continues through construction.

In summary, Total Quality management, value engineering and constructability are not mutually exclusive. Instead, value engineering and constructability are complementary work processes that may be used as key elements in achieving total quality.

Pheng and Abe (2000) is of the view that Productivity and quality are two interrelated issues of utmost importance in the construction industry. In this regard, the buildability concept and ISO 9000 quality management systems are used to help raise productivity and quality standards in construction. The paper argues by means of a case study that buildability principles can be integrated within ISO 9000 QMS to achieve overall improvement in productivity and quality standards of given project.

Mbachu and Nkado (2004) performed a descriptive survey method sample of principal partners in South Africa of consulting and contracting firms. Premised on the opinion of key stakeholders providing insight on how to minimize construction costs and deliver greater value to clients, the paper submits that the global construction industry is plagued with cost overruns in project delivery. This development has brought about loss of client's confidence in consultants, added investment risks, and disinvestment in the construction industry.

Furthermore, architects, consulting engineers, cost consultants, construction project managers, contractors, and client could effectively contribute to reducing construction costs through the

- provision of comprehensive construction information (architects),
- providing accurate and comprehensive details and specifications as and when needed by contractors (consulting engineers),
- ensuring realistic cost estimates through proper cost studies (cost consultants),
- efficient scope and time management (construction project managers),
- minimizing poor quality workmanship and improving productivity (contractors),
- and allowing sufficient time for proper project development appraisal, design and documentation before tender invitations and or project implementations (clients).

According to AACE No 30R-03 (2009), the purpose of constructability reviews is to identify the following

- Design errors, in either material selection or dimensions

- Ambigous specifications
- Project features that will be difficult or exceedingly costly to construct as designed
- Project features that exceed the capability of industry to properly build
- Project features that are difficult to interprete and will be hard to accurately bid.
- Constructability reviews add value to the project and development process through the following methods:

1. Strategies by which to implement improved constructability include:

- Use of improved construction systems
- Simplify the design or combine elements
- Standardize the design and repeat elements
- Improve information availability and clarity
- Improve construction sequence
- Improve the use of equipment and tools
- Improve constructor-designer communication

1 Cost savings derive from:

- Fewer delays
- Reduced direct construction effort
- Shortened duration of activities
- Less work at higher elevations
- Less material required
- Decreased likelihood of labour conflicts

2 One must initially invest to earn the cost savings from better constructability

- More effort for design and procurement
- More communication among builder, designer and vendors

1. Improve constructability and reduce costs by

- Mitigating the effects of adverse site conditions
- Implementing better design, building, or process technologies
- Offering assembly-line conditions
- Accelerating the schedule by decoupling sequential workforce activities
- Reducing the number of workers and costlier skills

2. Better constructability methods can include:

- Pre-fabrication, Economies and quality via manufacturing process.
- Pre-asssembly. Join components into sub-unit at remote, better-controlled location
- Modularization. Assembly operations create the largest unit logistically possible; contains all components of final state.

Organisations that are new to implementing constructability can draw from the successful experience of the US Army corps of engineers (USACE) who in the early 80's instituted a program of conducting formal constructability review on all projects before they are released for bids. Experience in USACE showed that virtually every review catches some factor that if it were left unchanged would have necessitated a potentially costly construction change order during the project. Benefits of constructability review as follows:

Reduced cost

Shorter schedules

Improved quality

Enhanced safety

Better control of risks

Fewer change orders

Fewer claims

For this recommended practice, method by which to implement constructability might involve changes to:

- Field supervision and operational planning
- Location of direct effort from workshop to shop
- Equipment and tool application
- Design effort and material selection
- Communication between designer and builder

“Constructability can mean better projects – lower costs, better productivity, earlier project completions and earlier start –ups.” Owners designers and builders who belong to the Construction Industry Institute (CII) believe this statement and their message is “Be sure that construction considerations are incorporated into every phase of a project – feasibility studies, conceptual planning, design, procurement as well as construction” (CII Publication SD -83-1992).

# CHAPTER 3

# RESEARCH METHODOLOGY

## 3.1 INTRODUCTION

This research is focused on constructability practice in engineering and construction sectors of the Nigerian economy. Rivers state with Port Harcourt as capital, is the case study area. A variety and number of engineering and construction organizations and professionals were required for the study. A total of 30 engineering and construction firms and 50 professionals were sampled for the study.

In this chapter, information on the study area, the tools, methods, and techniques adopted for data collection and analysis are presented. The models used for the analysis and rationale for their selection are also presented. The researcher believes that the findings contained herein would give a reliable representation of what obtains in the industry.

## 3.2 THE STUDY AREA

Rivers State, one of Nigeria's 36 States was created from the then Eastern Region of Nigeria by Decree No. 19 of 1967. Before then, the territory was referred to as Oil Rivers Protectorate, a name derived from its central role in the oil trades of the last two centuries. First, the trade in palm oil and then, crude oil. The state is the heart of the hydro-carbon industry, responsible for a huge chunk of the nation's foreign exchange earnings. It is accountable for over 48% of crude oil produced on-shore in the country and 100% of the liquefied natural gas that Nigeria is currently exporting to several countries of the world.

The State is bounded on the South by the Atlantic Ocean, on the North by Anambra, Imo and Abia States,the East by Akwa Ibom State and the West by Bayelsa and Delta States. Rivers state is one of the wealthiest states in Nigeria in terms of gross domestic product and foreign exchange revenue from the oil industry, crude oil being its main export earner.

Port Harcourt is the capital city of Rivers State. The city plays host to the Rivers State University of Science and Technology; there is also a University of Port Harcourt, which is Located in Obio/Akpor which was carved out of Port Harcourt Local Government Area for ease of administration. Rivers state has two refineries, a petro-chemical plant, fertilizer plant and a liquified natural gas plant. The city is a major industrial center as it has a large number of multinational firms as well as other industrial concerns, particularly business related to the petroleum industry. It is the chief oil-refining city in Nigeria.

Port Harcourt is one of the fastest growing metropolitan cities in Africa. Most of the companies sampled have their headquarters in Port Harcourt.

## 3.3 POPULATION OF THE STUDY

The study population is as follows:

Public and private Engineering and construction sectors such as consultants, construction firms, parastatals. Professionals are as follows: engineers, architects, project managers, quantity surveyors, Builders, etc. Project owners were also among the population.

These professionals are engaged in planning, design, management and execution of projects and therefore form the nucleus of the respondents for the study in their various organizations.

## 3.4 RESEARCH DESIGN

A cross section of descriptive analysis on selected organizations was adopted in the research design. The professionals in these organizations provided the data required for the study as representatives of the study population

## 3.5 SAMPLING PROCEDURE AND SAMPLE SIZE

The study population is defined to include engineering design and construction companies practicing in Rivers State. About 300 companies fall within this target group. The sample size from the population was determined using a statistical principle for this type of investigation to reflect a confidence level of 95%.The sample size was determined using the following equations(Kish, 1995):

$$n_o = (p * q) / V^2$$

$$n = n_o / (1 + n_o/N)$$

where:

$n_o$ = sample size from an infinite population

p = proportion of the characteristics being measured in the target population

q = complement of p i.e. 1- q

V = maximum standard error allowed

N = population size

n= sample size

To maximize the sample size n, the value of both p and q are set to 0.5; the target population N is 300; maximum standard error is set at 10% or 0.1.

Substituting the values into the equation above, the minimum sample size calculated is 23.

A total of 30 engineering and construction firms and 50 professionals were sampled for the study. Therefore, this can be regarded as being very good and highly representative of the population.

## 3.6 TYPES OF DATA AND METHODS OF COLLECTION

The basic types of data collected for the study are primary and secondary data.

Secondary data are already published information relevant to the subject matter. These are sourced mainly from textbooks, journals, workshop and seminar papers, professional handbooks and operating manuals of the different organizations sampled. The secondary data establishes the theoretical foundation of the study and shape standards for acceptance through literature evidences.

The primary data were generated by the researcher through structured questionnaire administered on the respondents/professionals in the various organizations used for the study.

The questionnaire was designed as multi-choiced and open ended pattern in order to give respondent the flexibility to express their views and as such provide alternative set of answers which best represents the actual situation in their respective organizations.

The data generated was further substantiated by observations and oral interviews in some cases (See Appendix)

The questionnaires were sent by hand delivery to the respective organizations head/branch offices, site office. Some were sent by e-mail. A total of One Hundred (100) questionnaires were sent out. 50 of them were returned which represents 50 % response rate as shown in Table 3.0.

Table 3.0 SAMPLE SIZE SHOWING NUMBER OF QUESTIONNAIRES DISTRIBUTED AND PERCENTAGE RESPONSE

| S\N | Respondents | Total distributed | Total retrieved | Percentage response |
|---|---|---|---|---|
| 1 | Engineering and construction professionals | 100 | 50 | 50 |
| | | | | |

It is important to note the quality of respondents, which have more than 85% being highly literate and over 10years experience in their respective professions.

The researcher faced some challenges in administration of questionnaires because most of the respondents were very busy, and have little or no time to spend on filling questionnaires. However, with persistence, a number of them responded.

## 3.7 METHODS OF DATA ANALYSIS

The main tools employed in the analysis of the primary data collected for the study are:

Percentage analysis

Mean Rating analysis

Spearman rank correlation analysis

### 3.7.1 PERCENTAGE ANALYSIS

This analysis is used to establish the percentage response to the tested parameters especially those arranged in a non-structured pattern. Spreadsheets were used for this purpose. This tests the percentage response to the parameter under consideration and is represented by the equation

$P = O/N \times 100\%$

Where P (%) = percentage response

O = observed response

N = sample size of respondents

For the purpose of this study, a response is considered significant if P ≥ 60% and insignificant if P < 60%

This test was applied in determining the percentage of respondents' qualification and experience in the industry. It was also applied in determining the level of awareness of constructability among the professionals as well tools used in various organizations in the industry.

### 3.7.2 MEAN RATINGANALYSIS

Analysis of the responses for structured part of the questionnaire was carried out using the multi-attribute analytical technique with a view to establishing a mean rating point for each group of respondents. SPSS V16 was used for the analysis of the following variables under investigation:

(i) Constructability Principles and Degree of Importance

(ii) Conditions Constraining Constructability

Data for 42 out of 50 respondents had complete responses and were used for these analyses.The analysis was done in accordance with the Multi-attribute Utility approach of Chang and Ive (2002) as cited by Mbachu and Nkado (2004). The total number of respondents (TR) rating each parameter was used to calculate the percentage number of respondents associating a particular rating point to each parameter.

The Mean Rating for each parameter is given by the following expression:

$$MR_j = \sum_{k=1}^{5} \left(R_{pjk} \text{ x} \%R_{jk}\right)$$

(Where: $MR_j$ = Mean Rating for parameter *j*; $R_{pjk}$ = Rating point *k* ranging from 1 – 5; $\%R_{jk}$ = Percentage response to rating point k; for parameter *j*)

This is used to assess and rank the respective parameters based on their order of significance.

Table 3.1: Rating point of Responses

| Options | Rating Point | Interpretation |
|---|---|---|
| Very Important (VI) | 5 | Has very high impact (A) |
| Important (I) | 4 | Has high impact (B) |
| Moderately Important (MI) | 3 | Has fair impact (C) |
| Little Important (LI) | 2 | Has poor impact (D) |
| Not Important (NI) | 1 | Has no impact (E) |

### 3.7.3 SPEARMAN RANK CORRELATION

Correlation coefficient is the actual measure of the amount of relationship or correlation that exists between two given variables. Spearman's coefficient of rank correlation was used to indicate whether agreement or disagreement exists among each pair of respondent groups surveyed. SPSS V16 was used for this analysis.Respondent groups tested are as follows:

(1) Consultant versus Contractor

(2) Consultant versus Owner

The expression for Spearman rank correlation coefficient according to Nworuh (2001) is as follows:

$$r_s = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n(n^2 - 1)}$$

Where: $d_i$ is the difference between the assigned ranks.

For this purpose, two statistical hypotheses were formulated as follows:

**NULL HYPOTHESIS ($H_{01}$):**

There is no agreement between the opinion of different respondent groups on "constructability principles and degree of importance".

**ALTERNATIVE HYPOTHESIS ($H_{02}$):**

There is agreement between the opinion of different respondent groups on "constructability principles and degree of importance".

**NULL HYPOTHESIS ($H_{01}$):**

There is no agreement between the opinion of different respondent groups on "Conditions constraining constructability".

**ALTERNATIVE HYPOTHESIS ($H_{02}$):**

There is agreement between the opinion of different respondent groups on "conditions constraining constructability".

CHAPTER 4

DATA PRESENTATION AND ANALYSIS

## 4.1 INTRODUCTION

The primary data used for this research are presented in the Tables below. The data are based on responses extracted from the research questionnaire. The questionnaire has been structured in a manner that would allow for weighting and ranking of responses for the purpose of quantification and empirical analysis.

**SUMMARY OF DATA COLLECTED FROM ENGINEERING AND CONSTRUCTION INDUSTRY PROFESSIONALS FOR CONSTRUCTABILITY ANALYSIS**

TABLE 4.1: POSITION HELD BY RESPONDENTS IN ENGINEERING & CONSTRUCTION INDUSTRY

| Respondents | Project Manager | Design Lead / Engineer | Construction Supervisior | Others (Architects, Q/S etc) | TOTAL |
|---|---|---|---|---|---|
| Total number | 11 | 21 | 8 | 10 | 50 |

TABLE 4.2: QUALIFICATION OF RESPONDENTS IN ENGINEERING & CONSTRUCTION INDUSTRY PROFESSIONALS

| Qualification | BSC/HND | MSC | PHD | TOTAL |
|---|---|---|---|---|
| Number of Reponse | 34 | 15 | 1 | 50 |

TABLE 4.3: EXPERIENCE OF ENGINEERING & CONSTRUCTION INDUSTRY PROFESSIONALS

| Years of Experience | 1-5 YEARS | 6-10 YEARS | 10-15 YEARS | 16-20 YEARS | 20+ YEARS | TOTAL |
|---|---|---|---|---|---|---|
| Total number | 16 | 11 | 9 | 7 | 7 | 50 |

TABLE 4.4: TYPE OF ORGANISATIONS

| Type of Organisation | CONSULTANTS | CONTRACTOR | OWNER | TOTAL |
|---|---|---|---|---|
| Total number | 23 | 13 | 6 | 42 |

TABLE 4.5: CONSTRUCTABILITY AWARENESS TABLE-1

| No of respondents who have heard of “constructability” | No of respondents who have not heard of “constructability” | TOTAL |
|---|---|---|
| 42 | 8 | 50 |

TABLE 4.6: CONSTRUCTABILITY AWARENESS TABLE-2

| LEVEL OF AWARENESS | VERY HIGH | HIGH | AVERAGE | LOW | NIL | TOTAL |
|---|---|---|---|---|---|---|
| NO OF RESPONDENTS | 6 | 26 | 9 | 4 | 5 | 50 |

Table 4.7 CONSTRUCTABILITY TECHNIQUES USED BY RESPONDENTS

| VARIABLE | FREQUENCY OF RESPONSE | | | | |
|---|---|---|---|---|---|
| **Constructability Techniques/Tools** | **Yes** | | **No** | | Total |
| | Frequency | % | Frequency | % | |
| Corporate implementation manual | 3 | 7.1 | 39 | 92.9 | 42 |
| Contract Incentive Clause | 15 | 35.7 | 27 | 64.3 | 42 |
| Formal Implementation Process | 3 | 7.1 | 39 | 92.9 | 42 |
| Corporate lessons learned log/file | 10 | 23.8 | 32 | 76.2 | 42 |
| Constructability resources | 9 | 21.4 | 33 | 78.6 | 42 |
| Graphical computer based tools CAD | 39 | 92.9 | 3 | 7.1 | 42 |
| PDMS models | 4 | 9.5 | 38 | 90.5 | 42 |
| Non graphical computer models | 13 | 31.0 | 29 | 69.0 | 42 |
| Small scale physical models | 8 | 19.0 | 34 | 81.0 | 42 |
| Brainstorming | 38 | 90.5 | 4 | 9.5 | 42 |
| Peer Review | 28 | 66.7 | 14 | 33.3 | 42 |

4.2 DATA ANALYSIS

4.2.1 PERCENTAGE ANALYSIS

Percentage analysis was used to assess parameters such as respondents' position in organisation, qualification, experience level, constructability awareness, constructability techniques and tools utilization, etc.

- Position
- Qualification
- Experience
- Type of organisation
- Constructability awareness
- Constructability techniques used

Analysis results are presented in form of bar charts, pie-charts and tables. These are shown in Figures 4.2.1- 4.2.5.

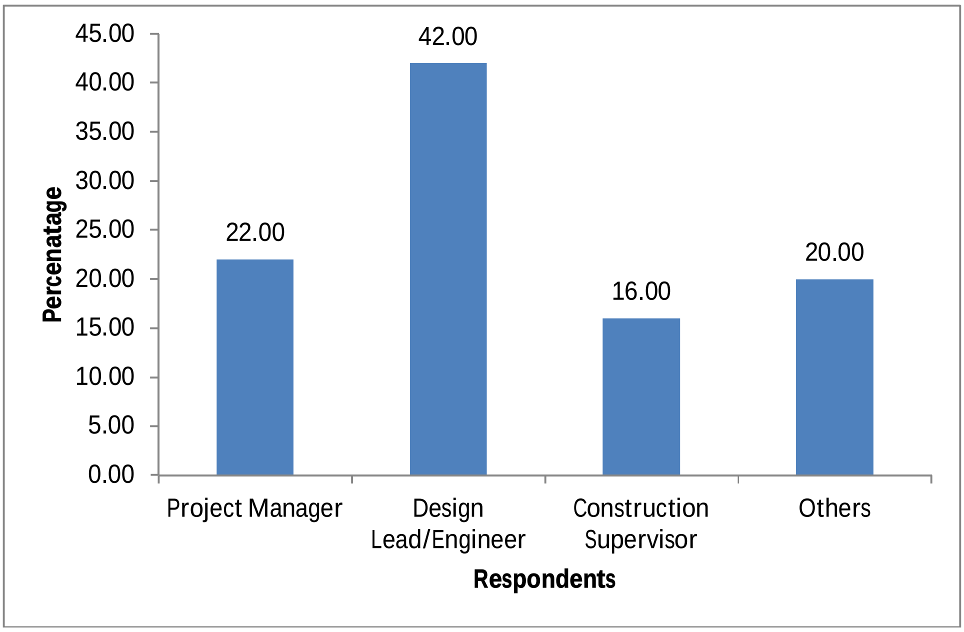


Figure 4.2.1: Respondents Position in Organisation

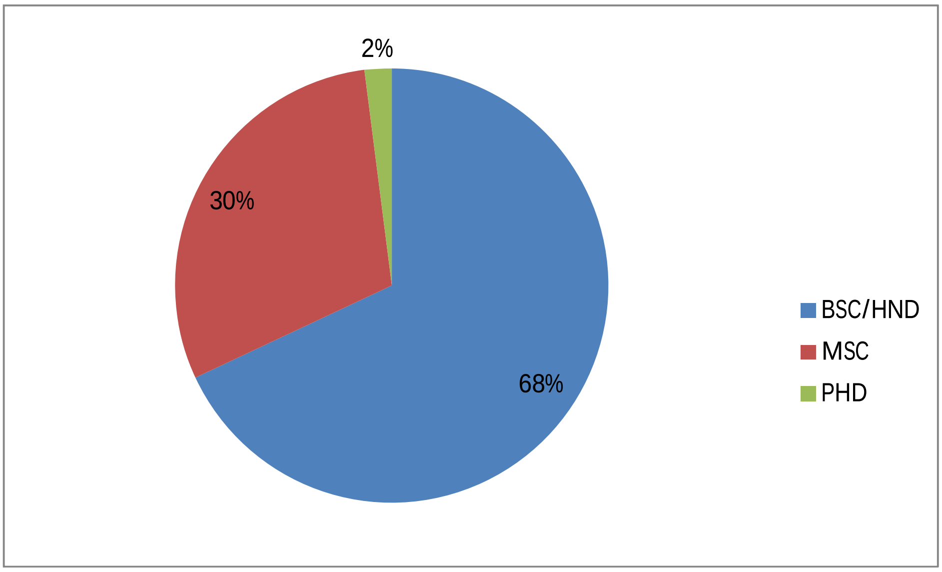


Figure 4.2.2 Respondents Level of Qualification

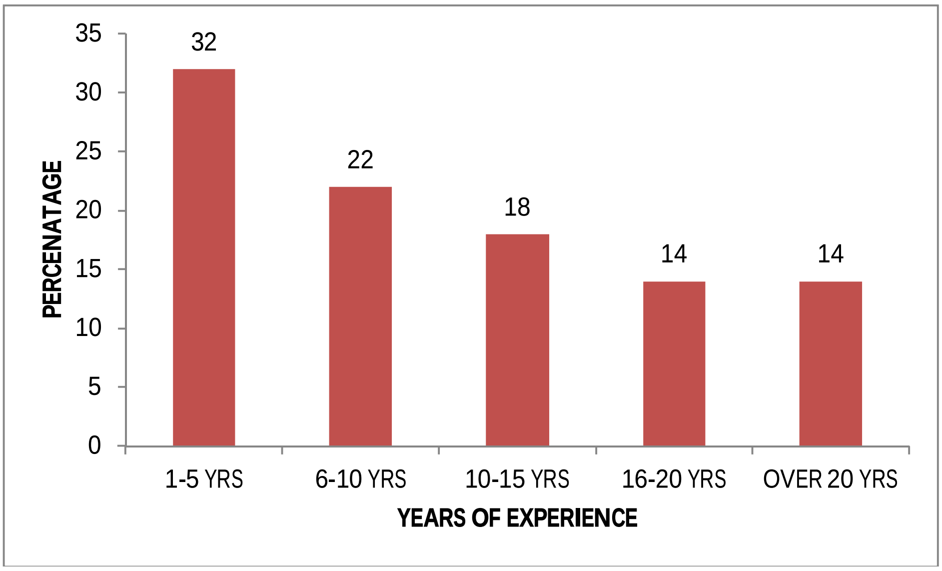


Figure 4.2.3: Respondents Experience Level

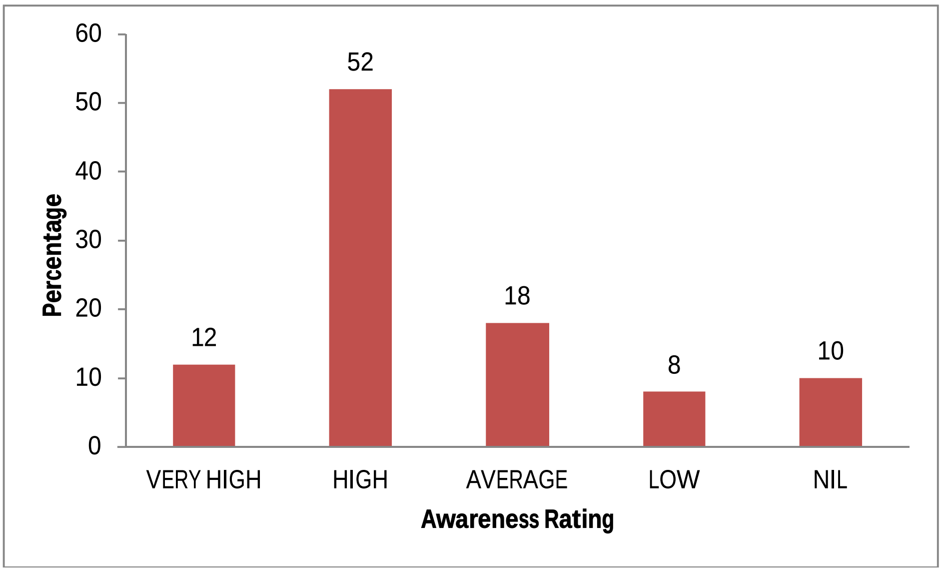


Figure 4.2.4: Respondents Level of Awareness

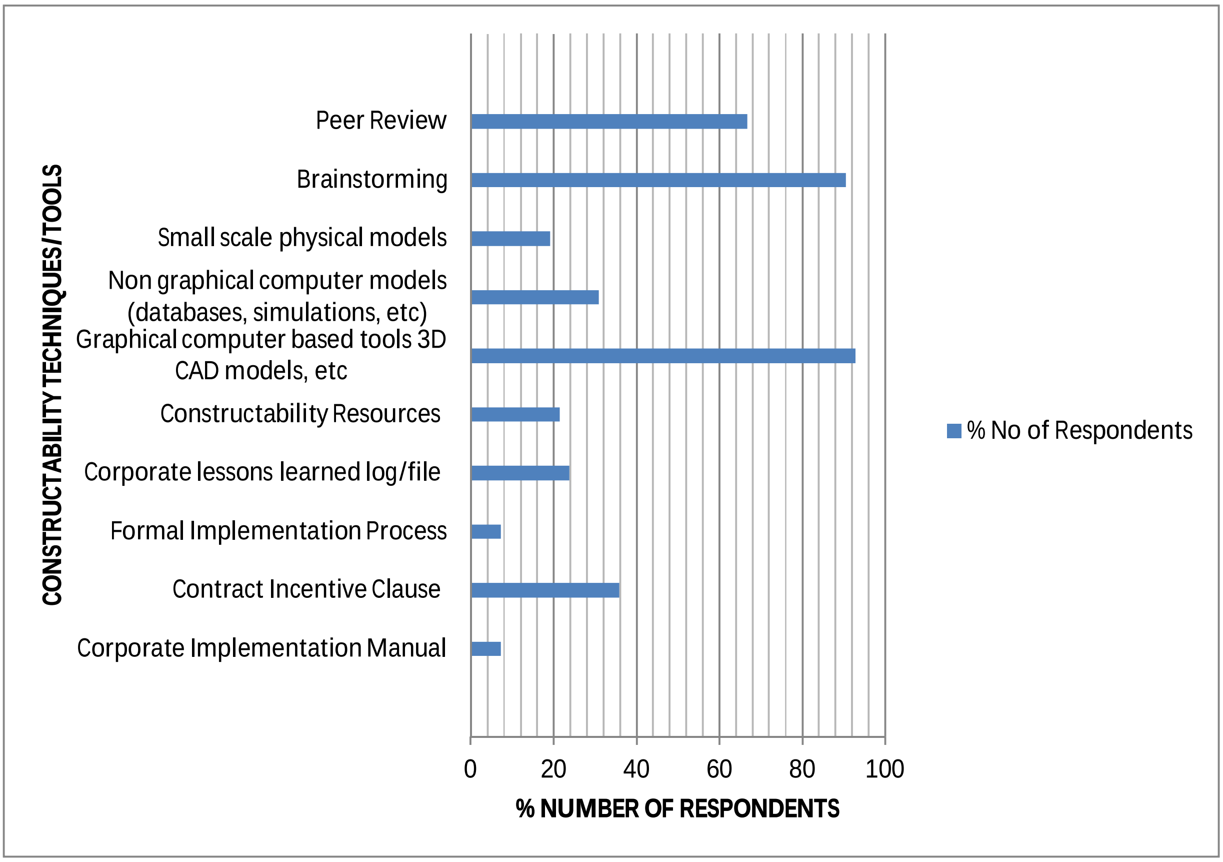


Figure 4.2.5: Respondents Use of Constructability Techniques/tools

### 4.2.2 MEAN RATING ANALYSIS

This analysis was used to establish the degree of importance of respective variables and parameters under broad areas of constructability concerns. SPSS V16 was utilized.

Variables were tested in order of relative significance and impact and ranked accordingly.

The variables were tested under the following broad areas of concern:

(1) Constructability principles and degree of importance

(2) Conditions constraining constructability

Analysis results are shown in Tables 4.11 – 4.12

TABLE 4.11: CONSTRUCTABILITY PRINCIPLES AND DEGREE OF IMPORTANCE RANKING

| **Key** | **Constructability Principles** |
|---|---|
| A1 | Carry out thorough investigation of site |
| A2 | Development of project Plan |
| A3 | Selection of major construction methods |
| A4 | Early involvement of construction personnel |
| A5 | Understanding clients corporate and project objectives |
| A6 | Construction driven schedule |
| A7 | Design for simple assembly |
| A8 | Encourage standardization/repetition |
| A9 | Design for preassembly and/or modularization |
| A10 | Employ visualization tools such as 3D CAD/PDMS to avoid physical interferences |
| A11 | Allow for practical sequence of construction |
| A12 | Consider storage requirement at the jobsite |
| A13 | Design for safe construction |
| A14 | Design for skills available |
| A15 | Use suitable materials |
| A16 | Maximize use of plant |
| A17 | Provide Detail and clear information |
| A18 | Allow for sensible tolerances |
| A19 | Avoid return visits by trades |
| A20 | Consider adverse effects of weather in selecting materials for construction |

| Factors | Very Important | Important | Moderately important | Little Important | Not Important | TR | MR | Rank |
|---|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | | | |
| A1 | 87.5 | 12.5 | 0 | 0 | 0 | 40 | 4.87 | 1 |
| A2 | 83.3 | 16.7 | 0 | 0 | 0 | 42 | 4.83 | 2 |
| A15 | 85.7 | 9.5 | 0 | 4.8 | 0 | 42 | 4.76 | 3 |
| A13 | 83.3 | 11.9 | 0 | 4.8 | 0 | 42 | 4.74 | 4 |
| A17 | 76.2 | 19.0 | 2.4 | 2.4 | 0 | 42 | 4.69 | 5 |
| A5 | 68.3 | 14.6 | 12.2 | 2.4 | 2.4 | 41 | 4.44 | 6 |
| A3 | 47.6 | 45.2 | 7.1 | 0 | 0 | 42 | 4.4 | 7 |
| A8 | 56.1 | 29.3 | 12.2 | 2.4 | 0 | 41 | 4.39 | 8 |
| A7 | 56.1 | 29.3 | 9.8 | 2.4 | 2.4 | 41 | 4.34 | 9 |
| A4 | 50.0 | 35.7 | 11.9 | 0 | 2.4 | 42 | 4.31 | 10 |
| A20 | 54.8 | 28.6 | 11.9 | 2.4 | 2.4 | 42 | 4.31 | 11 |
| A11 | 51.2 | 29.3 | 14.6 | 4.9 | 0 | 41 | 4.27 | 12 |
| A16 | 42.9 | 42.9 | 9.5 | 2.4 | 2.4 | 42 | 4.21 | 13 |
| A14 | 43.9 | 41.5 | 7.3 | 4.9 | 2.4 | 41 | 4.2 | 14 |
| A6 | 42.1 | 42.1 | 7.9 | 5.3 | 2.6 | 38 | 4.16 | 15 |
| A18 | 36.6 | 43.9 | 17.1 | 2.4 | 0 | 41 | 4.15 | 16 |
| A10 | 42.9 | 33.3 | 19.0 | 2.4 | 2.4 | 42 | 4.12 | 17 |
| A12 | 40.0 | 35.0 | 17.5 | 5.0 | 2.5 | 40 | 4.05 | 18 |
| A9 | 26.8 | 41.5 | 19.5 | 12.2 | 0 | 41 | 3.83 | 19 |
| A19 | 18.4 | 31.6 | 39.5 | 10.5 | 0 | 38 | 3.58 | 20 |

TABLE 4.12: CONDITIONS CONSTRAINING CONSTRUCTABILITY RANKING

| Keys | Constraining Constructability Factors |
|---|---|
| B1 | Faulty, ambiguous or defective working drawings |
| B2 | Incomplete or ambiguous specifications |
| B3 | Non- standardized designs |
| B4 | Adversarial relationships between designer and contractor |
| B5 | Resistance of owner to formal constructability program |
| B6 | Budget limitations |
| B7 | Lack of construction experience and technologies on the part of designers |
| B8 | Contractors lack of knowledge of design philosophy |
| B9 | Limitation of lump-sum competitive contracting |
| B10 | Tight timeframe for designing and tendering |
| B11 | Non participation of all discipline design teams during preliminary design stage of project. |
| B12 | Separation of design and construction processes in traditional contractual procedure |

| Code | Very High | High | Average | Low | None | TR | MR | Rank |
|---|---|---|---|---|---|---|---|---|
| | % | % | % | % | % | | | |
| B1 | 70.0 | 17.5 | 5.0 | 7.5 | 0.0 | 40 | 4.50 | 1 |
| B2 | 70.0 | 17.5 | 7.5 | 2.5 | 2.5 | 40 | 4.50 | 2 |
| B3 | 53.8 | 23.1 | 17.9 | 2.6 | 2.6 | 39 | 4.23 | 3 |
| B6 | 42.5 | 27.5 | 25.0 | 5.0 | 0.0 | 40 | 4.08 | 4 |
| B7 | 46.2 | 25.6 | 10.3 | 15.4 | 2.6 | 39 | 3.97 | 5 |
| B10 | 22.9 | 40.0 | 37.1 | 0.0 | 0.0 | 35 | 3.86 | 6 |
| B11 | 38.5 | 17.9 | 28.2 | 15.4 | 0.0 | 39 | 3.79 | 7 |
| B4 | 20.5 | 43.6 | 25.6 | 10.3 | 0.0 | 39 | 3.74 | 8 |
| B8 | 28.2 | 38.5 | 12.8 | 17.9 | 2.6 | 39 | 3.72 | 9 |
| B5 | 22.5 | 27.5 | 35.0 | 10.0 | 5.0 | 40 | 3.53 | 10 |
| B9 | 16.7 | 19.4 | 50.0 | 11.1 | 2.8 | 36 | 3.36 | 11 |
| B12 | 16.2 | 24.3 | 40.5 | 13.5 | 5.4 | 37 | 3.32 | 12 |

### 4.2.3 SPEARMAN RANK CORRELATION ANALYSIS

Spearman's coefficient of rank correlation was used to indicate whether agreement or disagreement exists among each pair of respondent groups. Respondent groups tested are as follows:

- Consultant versus Contractor
- Consultant versus Owner

Analysis results are shown in Tables 4.21 – 4.22

Table4.21shows the results of SPSS analysis of Spearman coefficient and significant level calculation for the variable – Constructability principles and degree of importance. For consultant vs contractor pairing, Spearman coefficient R = 0.694 and p = 0.001; while for consultant vs owner pairing, Spearman coefficient R = 0.600 and p = 0.005. It can be inferred that there is a good agreement between the respondent groups and by implication a consensus of opinion.

Therefore the first Null Hypothesis $H_{o1}$ is rejected and the alternative $H_{o2}$accepted.

TABLE 4.21: CONSTRUCTABILITY PRINCIPLES –SPEARMAN RANK CORRELATION

| Code | All | | Consultant | | Contractor | | Owner | |
|---|---|---|---|---|---|---|---|---|
| | MR | Rank | MR | Rank | MR | Rank | MR | Rank |
| A1 | 4.87 | 1 | 4.86 | 2 | 4.85 | 1 | 5.00 | 1 |
| A2 | 4.83 | 2 | 4.87 | 1 | 4.69 | 4 | 5.00 | 3 |
| A15 | 4.76 | 3 | 4.83 | 3 | 4.77 | 2 | 4.50 | 9 |
| A13 | 4.74 | 4 | 4.70 | 5 | 4.69 | 3 | 5.00 | 2 |
| A17 | 4.69 | 5 | 4.74 | 4 | 4.62 | 5 | 4.67 | 7 |
| A5 | 4.44 | 6 | 4.48 | 8 | 4.23 | 10 | 4.80 | 6 |
| A3 | 4.40 | 7 | 4.35 | 11 | 4.38 | 7 | 4.67 | 8 |
| A8 | 4.39 | 8 | 4.45 | 9 | 4.38 | 6 | 4.17 | 15 |
| A7 | 4.34 | 9 | 4.50 | 6 | 4.00 | 15 | 4.50 | 10 |
| A20 | 4.31 | 11 | 4.35 | 12 | 4.23 | 8 | 4.33 | 12 |
| A4 | 4.31 | 10 | 4.30 | 14 | 4.08 | 13 | 4.83 | 5 |
| A11 | 4.27 | 12 | 4.50 | 7 | 3.77 | 17 | 4.50 | 11 |
| A16 | 4.21 | 13 | 4.35 | 10 | 4.08 | 12 | 4.00 | 17 |
| A14 | 4.20 | 14 | 4.00 | 18 | 4.23 | 9 | 4.83 | 4 |
| A6 | 4.16 | 15 | 4.29 | 15 | 4.08 | 14 | 3.75 | 20 |
| A18 | 4.15 | 16 | 4.23 | 16 | 4.15 | 11 | 3.83 | 18 |
| A10 | 4.12 | 17 | 4.35 | 13 | 3.62 | 19 | 4.33 | 14 |
| A12 | 4.05 | 18 | 4.05 | 17 | 3.92 | 16 | 4.33 | 13 |
| A9 | 3.83 | 19 | 3.82 | 19 | 3.69 | 18 | 4.17 | 16 |
| A19 | 3.58 | 20 | 3.55 | 20 | 3.50 | 20 | 3.83 | 19 |
| Maximum Responses | 42 | | 23 | | 13 | | 6 | |

**Spearman´s rank correlation coefficient, R**
Consultant vs. Contractor: r=0.694, p=0.001
Consultant vs. Owner: r=0.600, p=0.005

Table4.22 shows the results of SPSS analysis of Spearman coefficient and significant level calculation for the variable – Conditions constraining constructability. For consultant vs contractor pairing, Spearman coefficient R = 0.830 and p = 0.001; while for consultant vs owner pairing, Spearman coefficient R = 0.067 and p = 0.835. It can be inferred that for the pair of consultant vs contractor, a strong correlation exists and the result is statistically significant .Therefore the second Null Hypothesis $H_{o1}$ is rejected and the alternative $H_{o2}$accepted. However, for the pair of consultant vs owner, only a weak correlation exists and result is not statistically significant.

TABLE 4.22: CONDITIONS CONSTRAINING CONSTRUCTABILITY–SPEARMAN RANK CORRELATION

| Code | All | | Consultant | | Contractor | | Owner | |
|---|---|---|---|---|---|---|---|---|
| | MR | Rank | MR | Rank | MR | Rank | MR | Rank |
| B1 | 4.50 | 1 | 4.74 | 1 | 4.75 | 1 | 2.80 | 11 |
| B2 | 4.50 | 2 | 4.61 | 2 | 4.67 | 2 | 3.60 | 2 |
| B3 | 4.23 | 3 | 4.23 | 3 | 4.50 | 3 | 3.60 | 3 |
| B6 | 4.08 | 4 | 4.13 | 4 | 4.17 | 4 | 3.60 | 4 |
| B7 | 3.97 | 5 | 4.05 | 5 | 4.08 | 5 | 3.40 | 6 |
| B10 | 3.86 | 6 | 4.00 | 7 | 3.75 | 8 | 3.50 | 5 |
| B11 | 3.79 | 7 | 3.73 | 10 | 3.83 | 7 | 4.00 | 1 |
| B4 | 3.74 | 8 | 4.05 | 6 | 3.50 | 10 | 3.00 | 9 |
| B8 | 3.72 | 9 | 3.83 | 8 | 3.91 | 6 | 2.80 | 12 |
| B5 | 3.53 | 10 | 3.78 | 9 | 3.25 | 11 | 3.00 | 10 |
| B9 | 3.36 | 11 | 3.25 | 12 | 3.64 | 9 | 3.20 | 8 |
| B12 | 3.32 | 12 | 3.38 | 11 | 3.18 | 12 | 3.40 | 7 |
| Maximum Responses | 42 | | 23 | | 12 | | 5 | |

**Spearman´s rank correlation coefficient, R**

Consultant vs. Contractor: r=0.830, p=0.001

Consultant vs. Owner: r=0.067, p=0.835

## 4.3 DISCUSSION OF RESULTS

### 4.3.1 CONSTRUCTABILITY AWARENESS PARAMETERS

Results of the percentage analysis shown in Figures 4.2.1 – 4.2.6 indicate the following:

The highest percentage of respondents are Design Leads & Engineers (42%), Project Managers (22%) and Construction Supervisors (16%), others (20%).

68% of total respondents have B.Sc. qualification, while 30% have M.Sc. and 2% have PHD.

Experience level indicates 32% for 1-5 yrs, 22% for 6-10yrs, 18% for 10-15yrs, 14% for 16-20yrs and 14% for over 20 years.

This shows that the respondents are mostly professionals with high level of training and experience.

Among the respondents, a total of 84% have heard of constructability, while 16% have not heard.

On the level of awareness in respective organizations, Table 4.2.4 shows 52% high, 12% Very High and 18% Average.

This implies that on the average there is generally a high level of awareness of constructability concepts and principles among the various professionals surveyed.

Whether this amounts to an equally high level of constructability input and performance is another issue.

On the use of constructability tools/ techniques and the various approaches of constructability implementation by organisations sampled, the following summary was obtained as shown in Table 4.7 and bar chart(Figure 4.2.5):

Most used tools are: *Graphical computer based tools CAD (92.9%), Brainstorming (90.5%), Peer review (66.7%).* For the last two, in most organizations, this is carried out in form of project review meetings, inter-discipline reviews etc.

It is noteworthy that most respondents indicated absence of corporate implementation manual and formalized approach to constructability implementation in form of scheduled constructability reviews for scheduled milestones. Percentage score for this stands at 7.1% - YES and 92.9% -NO.

Only a few EPC and multinationals especially in the oil and gas industry occasionally adopt this approach. Even at that, this is usually client-driven.

### 4.3.2 CONSTRUCTABILITY PRINCIPLES AND DEGREE OF IMPORTANCE RANKING

It can be observed from Table 4.11 that all known constructability principles listed were accepted by respondents as being significant going by the values of Mean Rating (MR) obtained for each.

The ranking of principles according to the degree of importance is as follows:

*Carry out thorough investigation of site (rank=1); Development of a project plan(rank = 2)*. This implies the general understanding that the constructability input of an engineering construction project must begin at the project planning stage, and this is critical for overall project performance. The poor performance and frequent failure of many government projects in Nigeria can be attributed to many factors. Besides, political reasons, a major reason for failure of projects is that most government projects are known to be poorly planned or lack planning at all, before execution. Constructability and other performance indices obtained in this study could be a confirmation of this notion. In the contrary, most private and turnkey projects especially for big organizations eg. oil and gas companies are generally more successful because of good planning and conceptualization before execution.

Other principles rated high by respondents are as follows: *Use suitable materials* (*rank = 3*), *Design for safe construction (rank = 4)* and *Provide Detail and Clear information (rank 5); Understanding Client's corporate objectives (rank =6) Selection of major construction methods (rank =7),Encourage standardization and repetition(rank = 8); Design for simple assembly (rank =9) Early involvement of construction personnel(rank = 10).*

These results agree with other research findings in other parts of the world as cited in literature survey such as Lam et al (2005) and Trigunarsyah (2006).

### 4.3.3 CONDITIONS CONSTRAINING CONSTRUCTABILITY RANKING

Table 4.12 shows a list of 12 conditions capable of constraining constructability of a project. By the Mean Rating analysis results, the most significant condition is

*Faulty, ambiguous or defective drawings* which is ranked first. One project delivery method prone to this is the traditional Design-bid build where in most cases, limited time is allowed for design before tender/construction, hence a lot of errors and defects. This is perhaps why some are of the opinion that that the DBB is not good for constructability (Berman et al (1999)). Future study could be aimed at investigating this opinion as it concerns the Nigerian construction industry.

Other factors of high significance are as follows:

*Incomplete or ambiguous specifications(rank = 2); Non standardized designs(rank = 3); Budget limitation(rank = 4); Lack of construction experience (rank =5);Tight timeframe for designing and tendering (rank =6).Non participation of discipline design* *teams during preliminary design stage (rank =7); Adversarial relationship between designer and contractor (rank = 8); Contractors lack of knowledge of design philosophy (rank = 9); Resistance of owner to formal constructability program (rank =10)*

Formal constructability implementation requires finance; but the benefits outweigh the costs. This is supported by research work of Jergeas and Van der Put (2001). Sometimes it requires special software eg. PDMS or 3D CAD in order to manage interface with different disciplines. Also formal constructability reviews need to be scheduled at respective milestones. In some case, a constructability expert is hired.

In DBB, the architect or engineer completes the design before input by other concerned disciples. No major changes can be made at this stage even if project is considered not very buildable because it would amount to starting all over. In the Oil industry, however, this problem is eliminated by the multidiscipline approach of many engineering design companies in the oil industry.

### 4.3.4 RESULTS OF STATISTICAL HYPOTHESIS

Results of the statistical analysis by SPSS V16 is tabulated in Tables 4.2.1 and 4.2.2.

The first null hypothesis $H_{01}$ tested by Spearman Rank correlation showed that for consultant vs contractor pairing, R = 0.694, p= 0.001; while for contractor vs owner pairing, R = 0.600, p= 0.005. Therefore the null hypothesis $H_{01}$ is rejected and the alternative is accepted.

The second hypothesis tested showed that for consultant vs contractor pairing, R = 0.830, p= 0.001; while for contractor vs owner pairing, R = 0.067, p = 0.835. Therefore the null hypothesis is accepted while the alternative is rejected.

The result of the statistical analysis is summarized as follows:

i. There is a positive correlation among the respondent groups in their opinion on Constructability principles and degree of importance. This implies there is consensus of opinion and by implication levels of understanding among the respondent groups.

ii There is a strong positive correlation among the respondent group of consultant vs contractor in their opinion on “Conditions constraining constructability”. This implies there is consensus of opinion and by implication levels of understanding among the two respondent groups. However for the consultant vs owner pairing, only a weak correlation exists in their opinions.

# CHAPTER 5

# CONCLUSIONS AND RECOMMENDATIONS

## 5.1 INTRODUCTION

This study is aimed to investigate and analyze the implementation of constructability in project delivery process in the Nigerian construction industry and make deductions that could improve overall project performance.

## 5.2 CONCLUSION

On the basis of the findings discussed above, the study concludes as follows:

The level of awareness of constructability concepts and principles among industry professionals is high. The general principle of constructability is accepted by professionals and the fact that its application in project delivery is beneficial and can lead to improvement in project performance.

Ranking of constructability principles show the degree of importance of respective principles in the opinion of the professionals. The highest ranking principles are: *Carry out thorough investigation of site (rank=1) and Development of a project plan(rank = 2)*. The lowest ranking principles are: *Design for preassembly and/or modularization (rank =19)* and *Avoid return visit by trades (rank = 20)*

However, the level of knowledge and application of formal constructability programs/tools by sampled population is very low as shown in Table 4.7 e.g. *Formal Implementation Process (7.1%).*This includes scheduled constructability reviews for pre-determined milestones. Other formal techniques also scored low such as *Corporate implementation manual (7.1%), Constructability resources (21.4%).*

The most common constructability techniques/tools used by the sampled population in the order of percentage frequency scores are: *Graphical computer* *based toolsCAD (92.9%),Brainstorming (90.5%),Peer review (66.7%)*. These tools are standard practice by most firms and are informal in nature. Application of such informal tools alone cannot make the desired impact for improved project performance.

Constructability implementation is therefore neither systematic nor comprehensive in majority of the firms surveyed as input is mostly informal and mainly at the design phase. This may account to a large extent for the low performance of projects in Nigeria, without prejudice to other political or technical reasons.

Only few of the sampled population understand the formal implementation procedures/tools and actually adopt formalized procedures and programs of implementation.

The conditions that could constrain constructability which are prevalent in the Nigerian engineering /construction industry were identified and ranked according to their respective levels of impact.

The most significant condition is *Faulty, ambiguous or defective drawings (rank =1.*

Other factors of high significance are as follows:

*Incomplete or ambiguous specifications(rank = 2); Non standardized designs(rank = 3);*

The condition of *Seperation of design and construction processes in traditional contractual procedure (rank =12)* is not considered to be of much impact in constraining constructability.

## 5.3 RECOMMENDATIONS OF STUDY

In view of the findings of this study, it is recommended that more awareness and knowledge of formal constructability implementation processes be created by professional bodies and researchers through workshops, training and research publications. Improvement of project performance is better achieved by diligent application of formal and informal constructability techniques and tools. Better use of the formal constructability tools should to be encouraged among industry practitioners.

Also formal constructability methodology could be inserted in contract clauses to ensure compliance in the project delivery process. Project owners need to be informed and educated on the benefits of constructability input in the project delivery process and how to play more active roles by request and enforcement of implementation of formal constructability processes in their projects.

Conditions that constrain constructability have been identified and rated in the order of impact.

Engineers, project managers and other industry practitioners are enjoined to adopt theses principles and findings in their planning, design and construction activities in order to improve overall project performance and achieve best practices in the industry.

## 5.4 RECOMMENDATIONS FOR FURTHER STUDY

This research has shown that constructability concepts and principles are known and accepted by engineering/construction industry practitioners in Nigeria, though not fully implemented in the project delivery process.

Detailed study of constructability performance in different project delivery methods was not covered in this study. It is therefore recommended that further study be conducted on comparative study of constructability performance between the various procurement methods available.

## BIBLIOGRAPHY


Adams S. (1989) Practical Buildability. Butterworths, London.

Akpan E.O.Pand Chizea F. E.(2002) "Project Management: Theory and Practice", *Owerri,FUTO Press Limited.*

ASCE (1991) "Constructability and constructability programs: White paper"; *Journal of Engineering management* Vol 117 issue 1, pp 67 – 89.

AACE International Recommended Practice No 30R-03 Implementing Project Constructability (2009)

Alinaitwe H. M, Mwakali J. A., Hansson B (2007) "Factors Affecting the productivity of Building Craftsmen – Studies of Uganda", *Journal of Civil Engineering and Mnagement,* Vol XIII, No 3, pp. 169-176

Arditi D., Elhassan A., Toklu Y. (2002) "Constructability Analysis in the Design Firm". *Journal of Construction Engineering and Management*Vol 128: 2(117)

Aibinu A. A., Odeyinka H. A. (2006) "Construction Delays and their Causative factors in Nigeria." *Journal of Construction Engineering and Management,* Vol 132, No 7, pp. 667-677.

Assaf A. S., Al-Hejji S. (2006) "Causes of Delay in Large Construction Projects."*International Journal of Project Management,* 24 pp. 349 - 357.

Bakti E. S., Trigunarsyah B.(2003) "Constructability Implimentation at Corporate Level" *The nineth East Asia-Pacific Conference on Structural engineering and construction (EASEC9)* 19-18 Dec 2003, Bali Indonesia, pp. 88-93.

Berman H. W (1999) of Bodman LLP – "Understanding project Delivery methods", *FindLaw publication.*

Burati, J.L., Matthews, M.F., and Kalidindi, S.N. (1992). "Quality management organizations and techniques," *Journal of Construction Engineering and Management,* ASCE 118(1), pp. 112-128.

Bower, D. ed. (2003) "Management of procurement."*Thomas Telford Publications, London.*

Boyce W. J. (1991) "Design for Constructability", *35th Annual meeting of the 1991Transactions of the American association of cost Engineers*, Seatle, W.A, USA, p b.1.1-b.1.7.

Chan A.P.C. and Yung E.H.K. (2000) “Procurement selection model for Hong Kong.” *Monograph published by the Dept. of Building and Real Estate,* The Hong Kong Polytechnic University.

Chang C. and Ive G. (2002) “Rethinking the multiattribute utility approach based on procurement route selection technique.”*Construction management & Economics*, 20 (3), 275-284.

CII Products online (2008) “Benefits and costs of constructability: Four case studies.”*Construction Industry Institute*

Code of Practice on Buildable Design (2005) Building and Construction Authority Singapore

Constructability Concepts File (1987). *The Construction industry Institute. Publication* 3-3 University of Texas, Austin, Texas.

Constructability Implementation Guide (1993). *The construction Industry Institute. Publication* 34-1. University of Texas, Austin, Texas.

Construction Industry Research and Information Association (CIRIA) (1983) Buildability: An Assessment. CIRIA, London. P. 26

Constructability and constructability programs: White paper (1991); *Journal of construction and Engineering management*, Issue 110.1061/(ASCE)0733-9364(1991)117:1(67)

Construction Industry Institute Australia (1992). Constructability Principles File. Adelaide,*Construction Industry Institute*, Australia. 2nd Ed.

Fischer, M., and Tatum, C. B. (1997). ‘‘Characteristics of Design-relevant Constructability Knowledge.’’ *J. Constr. Eng. Manage.,* 123(3), 253–260.

Franks J. (1998) “Building procurement system, a client’s guide.”*Addison Wesley Longman Limited and the Charted Institute of Building.*2nd Edition.

Griffith A. Sidewell A. C. (1997) “Development of Constructability concepts, principles and practices.”*Engineering construction and Architectural Management* Vol 4 Issue (4) pp. 295-310

Hardesty Joseph L. (2005) “Selecting the Right Construction Project Delivery System”, *Construction Update – Article id 54*, newsletter id 13, category id 3

Jergeas G, Van der Put J. (2001) “Benefits of Constructability on Construction Projects”, *Journal of Construction Engineering and management*, Vol 127, Issue 4,pp 281-290

Kerzner, H. (1995) “Project Management: A Systems Approach to Planning, Scheduling and Controlling”: *Van Nostrand Reinhold*, New York

Kish, L. (1995). “Methods for Design Effects”, *Journal of official Statistics*, Vol. 11, pp.55-77.

Lam P. T I, Wong F. W. H. Chan A. P. C. (2005) “Contribution of Designers to Improving Buildability and Constructability”; *Journal of Design Studies* Vol 27, Issue 4 pp 457-479

Le-Hoai L., Dai Lee Y., Yong Lee J. (2008) “Delay and Cost Overruns in Vietnam Large Construction projects: A comparison with other Selected Countries.”*KSCE journal of Civil* Engineering 12 (6): 367-377

Lock, D. (1996) Project management (6th ed) *Wiley Publishers,* New York

Masterman J.W.E. (2002) Introduction to Building Procurement Systems.*Spon Press*, London; New York.

Mbamali I. Aiyetan O. A., Kehinde J. O.(2004): “Building Design for Buildability: an investigation of current practice in Nigeria”,*Journal of Building and Environment*, Vol 40, Issue 9 pp. 1267-1274

Mbachu J. I. C., Nkado R. N. (2004) “Reducing Building Construction Costs: The Views of Consultants and contractors”. *The International Construction Research conference of the Royal Institution of Chartered Surveyors*, Leeds Metropolitan University.ISBN 1-842-19193-3

McGeorge D., Chen S.E. and Ostwald M.J. (1992),“The development of a conceptual model of buildability which identifies user satisfaction as a major objective.”*CIB Conference*, Rotterdam.

Meredith, C and Mentel P. (1995) “Engineering –based Project management”, *PMI Journal* Upper Derby

Nima M. A.; Abdul-kadir M. R; Jaafar M. S. Algbulami R. G. (2001) “Constructability implementation: A survey in the Malaysian construction industry”. *Construction management and economics*, Vol 19, Number 8, pp 819-829 (11).

Ntamere C. C. (1995) Project Management. *Alphabet Nigeria Publishers*, Owerri, Nigeria.

Nworuh G. E. (2001) Fundamentals of Applied Quantitative Techniques for Management Decisions. Bon Associates – HRDC Owerri, Nigeria.

Obiegbu, M. E. 1987 “The future of Nigerian Construction Industry”; *Building Journal of the ABQSS,* IMT Enugu, Vol 6 pp.83-94.

O’Connor T. J, Miller S. J, (1994) “Barriers to Constructability Implementation”. *Journal of Perf. Constr. Fac*. Vol 8, issue 2pp 110-128

O’Connor, J. T., and Davis, V. S. 1988. ‘‘Constructability improvement during field operations.’’ *J. Constr. Eng. Manage.,* 114(4), 548–564.

O'Connor, J.T., Rusch, S.E., and Schulz, M.J. (1987). "Constructability concepts for engineering and procurement," *Journal of Construction Engineering and Management*,ASCE, 113(2), 235-247.

Oyedele L. O., Tham K. W. (2007) “Client’s assessment of architects performance in building process delivery: Evidence from Nigeria.” *Building and Environment* Vol 42, Issue 5, pp 2090-2099

Oladapo M. A. (2002). “Procurement Systems and Project Organisation Model for Low Cost Housing”, International Congress Washington DC USA, April 19-26, 2002

Oyedele L., Tham K. W (2006) “Client’s assessment of architect’s performance in building delivery process: Evidence from Nigeria.” *Journal of Building and Environment* Vol 42, Issue 5, 2090-2099

Pinto, J.K. and Slevin, D. P. (1988) “Project Success: Definitions and Measurement Techniques”, *Project management Journal* (1) 67-75

PMBOK 2004 Project Management Body of Knowledge

Pheng L. S., Abeyegoonasekera B.(2000) “Integrating Buildablity in ISO 9000 quality management systems: case study of a condominium project.” *Journal of Building and Environment* Vol 36, Issue 3 299-311

Poh P. S. H., Chen J. (1998) “The Singapore Buildable Design appraisal System: a preliminary review of the relationship between buildability, site productivity and cost.”*Journal of construction management and Economics*, Vo 16, Issue 6, pp. 681-692.

Russell, J. S., Swiggum, K. E., Shapiro, J. M., and Alaydrus, A. F.(1994). ‘‘Constructability related to TQM, value engineering, andcost/benefits.’’*Journal of Performance of Constructed Facilities,* Vol 7, pp. 27-45.

Trigunarsyah B. (2006), “Case Studies on implementation of Constructability Improvement by Construction Project Owners in Indonesia.” *Cooperative Research Centre (CRC) for Construction Innovation.*

Wong F. W. H., Lam P. T. L., Chan E. H W. (2005) “Optimising Procurment approaches to address constructability problems.”*Conference Proceedings, The QueenslandUniversity of Technology Research Week International Conference*, Brisbane Australia, 4-8 July 2005ISBN 1-74107-101-1

Wong F. W. H. Lam P. T I, Chan E. H. W., Shen L. Y (2007) “A study of measures to improve constructability”; *International Journal of Quality and Reliability Management* Vol 24 Issue 6, pp. 586-601.

Wong F. W. H. Lam P. T I, Chan E. H. W., Wong F. K. W  (2006) “Factors Affecting Buildability of Building Designs”, *Canadian Journal of Civil Engineering* 33 (7) 795-806

Wong, Franky W.H.,De Saram, D. Darshi,Lam, Patrick T.I.,Chan, Daniel W.M. (2006) “A compendium of buildability issues from the viewpoints of construction practitioners”, *Architectural Science Review* Vol 49, No 1, pp.81-90.

Wright, P. E., (1994) Constructability Guide. Obrien-Kreitzberg Assoc Inc.

Uhlik F. T., Lores G. V. (1998) “Assessment of Constructability Practices among General Contractors”; *Journal of Architectural Engineering* Vol 4, Issue 3, pp. 113-123.

**APPENDIX 1: SAMPLE OF QUESTIONNAIRE**

Dear Respondent,

This questionnaire is designed for the primary purpose of conducting research on the above stated topic in partial fulfillment of the requirements for the award of postgraduate degree in Project Management. The research is aimed among others at investigating the level of awareness and practice of constructability principles, as well as it's performance and ease of application in project delivery process in the Nigerian engineering/construction industry.
You are please requested to answer as appropriate. All information given shall be treated with strict confidence.

Thank you for your understanding.

## QUESTIONNAIRE

Please tick/indicate in the box as appropriate.

**SECTION I**

1. Name:

| |
|---|
| |

2. Sex:

| | |
|---|---|
| Male | |
| Female | |

3. Nationality:

| | |
|---|---|
| Nigerian | |
| Non-Nigerian | |

4. Company:

| |
|---|
| |

5. What best describes your position in the company?

| Proprietor | Project Director | Project Manager | Construction supervisor | Design Lead | Client representative | Others(specify) |
|---|---|---|---|---|---|---|
| | | | | | | |

6. What best describes your educational qualification?

| HND/B.Sc. | M.Sc./MBA | PHD | Others (specify) |
|---|---|---|---|
| | | | |

7. How long have you been in the construction industry?

| 1-5 years | 6-10 years | 10-15 years | 16- 20 years | Over 20years |
|---|---|---|---|---|
| | | | | |

8. State number of years that you have put into design practice?

| Nil | 1-5 years | 6-10 years | 10-15 years | 16- 20 years | Over 20 yrs |
|---|---|---|---|---|---|
| | | | | | |

9. What is your specialization?

| Architect | Civil/Structural Engineer | Mechanical Engineer | Electrical Engineer | Quantity Surveyor | Project Manager | Others (specify) |
|---|---|---|---|---|---|---|
| | | | | | | |

10. What is the type of your organization or company?

| Owner | Consultant | Contractor | Others (specify) |
|---|---|---|---|
| | | | |

11. What type of services are offered by your organization.

| **Type of Services** | **Yes** | **No** |
|---|---|---|
| Multi-discipline Engineering | | |
| Civil/structural | | |
| Mechanical/Electrical | | |
| Quantity Surveying | | |
| Project Management | | |
| Architectural | | |
| Construction | | |
| Others (Specify) | | |

12. What type of project delivery system is typical to your organization?

| **PROCUREMENT SYSTEM** | |
|---|---|
| **Design – Bid – Build (DBB)**<br>Owner selects consultant who completes design before contractor bids. | |
| **Design & Build (D & B)**<br>Design and construction is contracted to a single entity. | |

| | |
|---|---|
| **Management Contracting (MC)**<br>Construction manager is hired during design phase to co-ordinate issues and receive contractor bids | |
| **Develop & Construct (D&C)**<br>Similar to D&B but design responsibility is shifted to contractor at later stage | |
| **EPC Contracting**<br>Engineering, Procurement and Construction responsibility; typical to heavy oil/gas, power projects, etc. | |
| Others (specify) | |

13. What type of work is your organization typically involved in? (tick all that apply)

| Building | Engineering (highways, heavy etc) | Industrial (power plants, refineries) | Oil & Gas (flowstation, platforms, etc) | Others (specify) |
|---|---|---|---|---|
| | | | | |

14. Please tick the number of projects above 50,000,000 Naira which your firm has done in the past 5years.

| 1-3 | 4-6 | 7-9 | 10-12 | 13-15 | 16-18 | Others |
|---|---|---|---|---|---|---|
| | | | | | | |

15. What value best describes your organization's average annual turnover on projects in the last 5 years (Naira)?

| Below 10 million | 10-50 million | 50-100 million | 100-200 million | Above 200 million |
|---|---|---|---|---|
| | | | | |

**SECTION II**

7. "Constructability" (or "buildability") has been defined as the extent to which the design of the structure facilitates ease of construction, subject to overall requirements of the completed structure.

Have you heard this term before?

| Yes | No |
|---|---|
| | |

*If your answer is "No", do not attempt to answer the remaining questions. Please return the questionnaire to the researcher.*

7. Please tick the constructability principles you are familiar with and the degree of importance.

| **Constructability Principles** | **Very Important** | **Importan t** | **Moderatel y Important** | **Little Important** | Not Important |
|---|---|---|---|---|---|
| *I. PLANNING & CONCEPTUAL PHASE* | | | | | |
| **Carry out thorough investigation of the site** | | | | | |
| **Development of project plan** Constructability made an integral part of project plan | | | | | |
| **Selection of major construction methods** | | | | | |
| **Early involvement of construction personnel** (or knowledge & experiences) | | | | | |
| **Understanding client's corporate and project objectives** | | | | | |
| **Construction driven schedule** Overall project schedules are construction sensitive | | | | | |
| *II. DESIGN PHASE* | | | | | |
| **Design for simple assembly** Effort is made to produce the simplest possible design details | | | | | |
| **Encourage standardization/repetition** Effort is made to maximize standardization/repetition of elements | | | | | |
| **Design for pre-assembly and/or modularization** Pre-assembly/module designs are prepared to facilitate fabrication,transport and installation | | | | | |
| **Employ visualization tools such as 3D CAD/PDMS to avoid physical interferences** | | | | | |
| **Allow for practical sequence of construction** | | | | | |
| **Consider storage requirement at the jobsite** | | | | | |
| **Design for safe construction** The impacts of design on safety of workers, public, property etc during construction is considered | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| **Design for skills available**<br>Technology of design solution must match the skill and resources available | | | | | |
| **Use suitable materials** | | | | | |
| **Maximize the use of plant** | | | | | |
| **Provide detail and clear information**<br>The accuracy and completeness of design information is checked. | | | | | |
| **Allow for sensible tolerances** | | | | | |
| **Avoid return visits by trades** | | | | | |
| **Consider adverse effects of weather in selecting materials or construction**<br>The impact of weather is considered for every design solution | | | | | |
| *III. FIELD OPERATIONS PHASE* | | | | | |
| **Innovative construction techniques** | | | | | |

3 What is the level of awareness of constructability concepts in your organization?

| Very High | High | Average | Low | Nil |
|---|---|---|---|---|
| | | | | |

4. Do you have a documented corporate philosophy for dealing with constructability issues in your organization?

| Yes | No |
|---|---|
| | |

5. Do you adopt formal constructability programs for project execution in your organization?

| Yes | No |
|---|---|
| | |

6. What constructability techniques are in use by your organization? (tick all that apply)

| Constructability Technique | Yes | No |
|---|---|---|
| *POLICY/PROCESS BASED TOOLS* | | |
| **Corporate implementation manual**<br>Containing Corporate commitment, philosophy and procedures related to constructability | | |
| **Contract Incentive Clause**<br>Specify types of process to improve constructability | | |
| *MODELLING TOOLS* | | |
| **Formal Implementation Process**<br>Scheduled contructability reviews for pre-determined milestones | | |
| **Corporate lessons learned log/file**<br>Reference for future projects | | |
| **Constructability resources**<br>Involvement of construction personnel in planning/design or provision of constructability services by constructor or construction management firm | | |
| *TECHNOLOGY BASED TOOLS* | | |
| **Graphical computer based tools** (3D CAD models, CAD animation) | | |
| PDMS models | | |
| **Non graphical computer models** (databases, simulations, artificial intelligence) | | |
| *OTHER TOOLS* | | |
| Small scale physical models | | |
| Brainstorming | | |
| Peer Review | | |
| Others (specify) | | |
| | | |
| | | |

7. At what stage of the project delivery process do you perform constructability analysis? (tick all that apply)

| | |
|---|---|
| During the conceptual planning stage | |
| During the preliminary design stage | |
| During the detailed design stage | |
| After finishing the design | |
| During the construction phase | |

## SECTION III

1. Rate the following factors with respect to their effect on constructability.

| **Factors affecting constructability** | **Very High** | **High** | **Average** | **Low** | **None** |
|---|---|---|---|---|---|
| Project delivery system (design-bid-build, design & build, contract management, etc) | | | | | |
| Project complexity (construction methods and technologies) | | | | | |
| Project size | | | | | |
| Design standards and codes | | | | | |
| Project location (local, national, international) | | | | | |
| Project type ( building, engineering, industrial) | | | | | |
| Client type (public, private) | | | | | |
| Design practices and philosophy | | | | | |
| Others (specify) | | | | | |
| | | | | | |

2. Rate the following conditions with respect to constraining constructability

| **Factors constraining constructability** | **Very High** | **High** | **Average** | **Low** | **None** |
|---|---|---|---|---|---|
| Faulty, ambiguous or defective working drawings | | | | | |
| Incomplete or ambiguous specifications | | | | | |
| Non- standardized designs | | | | | |
| Adversarial relationships between designer and contractor | | | | | |
| Resistance of owner to formal constructability program | | | | | |
| Budget limitations | | | | | |
| Lack of construction experience and technologies | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| on the part of designers | | | | | |
| Contractors lack of knowledge of design philosophy | | | | | |
| Limitation of lump-sum competitive contracting | | | | | |
| Tight timeframe for designing and tendering | | | | | |
| Non participation of all discipline design teams during preliminary design stage of project. | | | | | |
| Separation of design and construction processes in traditional contractual procedure | | | | | |
| Others (specify) | | | | | |
| | | | | | |

3. Rate the following project delivery systems with regards to constructability performance

| **Procurement system** | **Very High** | **High** | **Average** | **Low** | **None** |
|---|---|---|---|---|---|
| Design – Bid – Build (DBB) | | | | | |
| Design & Build (D&B) | | | | | |
| Management Contracting (MC) | | | | | |
| Develop & Construct (D&C) | | | | | |
| Engineering, procurement and construction (EPC) | | | | | |
| | | | | | |

4. Rate the following project delivery systems with regards to ease of application of formal constructability programs.

| **Procurement system** | **Very High** | **High** | **Average** | **Low** | **None** |
|---|---|---|---|---|---|
| Design – Bid – Build (DBB) | | | | | |
| Design & Build (D&B) | | | | | |
| Management Contracting (MC) | | | | | |
| Develop & Construct (D&C) | | | | | |
| Engineering, procurement and construction (EPC) | | | | | |
| | | | | | |

Thanks.
*Researcher*