CONSTRUCTABILITY PRACTICE AND PROJECT DELIVERY PROCESSES IN THE NIGERIAN CONSTRUCTION INDUSTRY

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Abstract

As projects are getting complex by the day and for the fact that project failures – project abandonment, collapsed structures are constant discourse in the Nigerian news media, the need for constructability becomes very crucial in order to achieve project success. This study is aimed at investigating and analyzing the implementation of constructability in project delivery process in the Nigerian construction industry using Rivers State, Nigeria as a case study. Data was collected through questionnaire and interview approach. Results of data analyzed revealed that although a high percentage of the sampled population are familiar with the term “constructability”, nearly all do 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 virtually 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 the carrying out of 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 revealed an agreement of opinion between different respondent groups in the sampled population. Engineers, project managers and other industry practitioners are enjoined to adopt these principles in their planning, design and construction activities in order to improve the overall project performance and achieve best practices in the industry.

Key words: constructability, construction, project management, procurement, project delivery.

Introduction

Constructability has been defined by CII (1987) as the optimum use of construction knowledge and experience in the planning, design, procurement and field operations to achieve overall project objectives. It is obvious from the definition that the application of constructability principles during the project life cycle is very important in order to reduce or prevent errors, delays, disputes and cost overruns. To enhance constructability therefore, the most suitable project procurement method should be adopted. In many developed countries, much research effort has been directed at improving constructability through the integrated effort of owners, designers and constructors (Bakti *et al*, 2003).

However, the performance of the industry with regards to cost, quality and time of project delivery has not been impressive (Akpan, 2009). Among the Nigerian construction industry, 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.

The performance of engineering projects in the Nigerian construction industry is far below international standards according to various reports from the Nigerian news media. 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 and most of the roads and other public infrastructure built with taxpayers funds fail to provide value for money due to quality related issues which oftentimes necessitated the setting of probes to investigate the causes. Schedule and cost overruns for many public or private projects have been of great concern to industry and practitioners alike. All these have varied negative impacts on the socio-economic development of the nation.

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 according to Bakti *et al.* (2003). 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 United States of America (USA), United Kingdom (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 on projects in principle and practice, in order to mitigate the aforementioned challenges and improve projects performance in the Nigerian construction industry. In summary the objectives of the study are stated as follows:

- To investigate the level of awareness and knowledge of constructability concepts and principles among the construction professionals with a view to understanding the problem bedeviling the construction industry in Nigeria.
- To identify and rank conditions that constrains constructability of projects in the opinion of Nigerian professionals.

The answer to the above objectives would be approached using hypothesis testing as given:

- There is no agreement between the opinion of different respondent groups on constructability principles and degree of importance.
- There is no strong agreement between the opinions of different respondent groups on conditions constraining constructability.

Review of related literature

A project is a temporary endeavour undertaken to create a unique product, service or result according to PMBOK - Project Management Body of Knowledge (2008). Temporary means that every product has a definite beginning and an 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 buildings have been developed, but each individual facility is unique - different owner, different design, different location, different contractors, etc. Project has been defined by many authors including Kerzner (1995) who asserted it to be a series of activities and tasks that have a specific objective to be completed within certain specification, defined start and end dates with funding limit. 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. Even within this definition 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 to include the fact that the production process takes place at the site where the product (project) is to be implemented, engineering construction design must be produced, the projects are considerable in size and at fixed location, project production involves many specialist professionals and wide range of mixed craftsmen and finally contract options 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.

The above explanation is necessary because this study is focused on engineering construction projects. The 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. Clients 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 over the years. 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 advantages and disadvantages and some methods are better suited for certain kind of projects. It is a well recognized fact according to Wong *et* *al.* (2005) that constructability could be improved upon by adopting certain procurement methods as inappropriate procurement systems could have negative effects on constructability. They went on to state that as a function of project management, procurement systems have wide-ranging effects on a variety of project parameters and that these parameters can in turn affect constructability. Hence, by selecting the right contractual relationship of the involved parties and the degree of their involvement, constructability can be improved upon. The common project delivery methods in use today are:-

Design-Bid-Build (DBB)

Berman (1999) who has written extensively on the procurement delivery system has stated that the design-bid-build (DBB) 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 DBB 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 bidding cost. According to Amade (2012), most government contracts are done using this method and it is the most commonly used method applied in building construction in Nigeria. From the legal point of view, Berman (1999) posits that even though the DBB method promotes the construction of a quality project, 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.

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's risk from the client and to reduce the delivery schedule by overlapping the design and construction phases 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 as contractors would usually favour designs to be as 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 could be incurred in case of late design changes. Apart from these, the seemingly apparent advantage of using D&B is not realised in all cases. He further stated that 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 to construction.

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. 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 this problem according to Berman (1999), the design consultants engaged by the clients could be substituted 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 to engage a construction manager to perform tasks such as assisting with the development of accurate construction cost estimates that are within the client's budget, scheduling, technology issues, reviewing the architect's plans for constructability, obtaining and negotiating bids, and coordination of all aspects of the work. The construction manager acts as the client's agent and in theory is supposed to have greater knowledge regarding the cost and availability of labour 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 (Akpan and Chizea, 2002).

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, it often finances, maintains, operates or leases the space back to the owner. Whether a project is turnkey or design-build, it has significant implications regarding the liability of the contractor. This method is mostly used to execute 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.

Constructability and Buildability

The concept of "constructability" in the US or "buildability" in the UK emerged in the 1970s 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 outcome requires that the knowledge and experience of both parties be applied to project planning and design processes (Bakti and Trigunarsyah, 2003).

The concept of buildability originated in the United Kingdom and is 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 expertise in the design process. Zolfagharian *et al.*(2012) stated that this concept integrates knowledge and experience of the design professionals thereby eliminating rework in construction. 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 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).

In summary the concept of buildability 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's life cycle is important in order to reduce or prevent error, delays, disputes and cost overruns (Wong *et al.*, 2007).

Constructability concepts and principles

In the US, the Construction Industry Institute (CII) carried out studies and developed fourteen constructability concepts applicable to the project stages of conceptual and planning, design engineering, procurement and site operation. According to Griffith and Sidewell (1995), the American Society of Civil Engineers (ASCE) suggested six principles of constructability to include evaluating the various design configurations to optimize owner requirements, knowing the various project systems and their interface requirement with other project components, understanding trade skills and practices, construction methods, materials, labor and sub-contract resources and plant and equipment, appreciation of local climatic conditions, evaluating site conditions both above and below ground and realizing their possible implications upon construction and finally determining availability of space and access routes on site. O'connor *et al.*(1987) went on to examine how constructability may be improved during design development stage and their findings seem to support the earlier principles. 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 later added three new principles to the previous fourteen principles of constructability improvement. The first two – project team responsible for constructability are identified early on and the second, advanced information technologies are applied throughout the project for improvement at the conceptual planning phase while the third principle - 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 which simply means that the design, standards, specification and everything pertaining to project implementation be kept straight and simple. 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, an appraisal system called Buildable Design Appraisal System was developed (Zolfagharian *et al*., 2012). These three principles of constructability in these appraisal systems are standardization, simplicity and single integrated element.

Constructability implementation in project delivery process

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 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 labor usage in construction and therefore higher site labour productivity.

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. The results showed high acceptance of 22 out of the 23 concepts. These engineers accepted the constructability concepts from the theoretical point of view but generally they did not apply these concepts in their practices. Studies 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. Ardit *et al.* (2002) stated that constructability of design is a subjective scale that depends basically on a number of interdependent projects and related factors. The research effort examined design professional's effort to pursue constructability using mailed questionnaire to top US firms. The results showed that the maximum benefits of constructability reviews measured by their ability to influence cost were obtained in the design phase. It was also found out that 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 shows 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 on one of the Indonesian construction companies that 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. the project performance variables measured were operation and cost, quality and safety, benefit of constructability and constructability lessons learned. The 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. In Nigeria, Mbamali *et al.* (2004) in their research work interviewed building industry professionals - architects, engineers, quantity surveyors etc. to assess randomly selected buildings for their content of buildability features. The results showed a high level of 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.

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 aimed at providing architects with information that can be used to improve performance and achieve high quality overall project performance in Nigerian construction industry. The result shows 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 the Nigerian construction industry.

In his own work, Trigunarsyah (2006) examined the role of clients. Clients have the 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. The research was carried out by means of case studies of some notable projects in Indonesia. The results shows 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.

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 attributed to several sources. He stated that some problems emanate from projects with demanding construction methodologies engaging complex and innovative technologies and techniques and that deficiency in constructability considerations may be traced back to the tight timeframe for designing and tendering such that designers and bidders 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 tunneling which entail temporary works and lots of coordination and overcoming of site constraints, poor constructability is likely to result.

To aggravate the problems, there may be no clear-cut formula of deciding how constructible 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.

In response to the 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 coordinating the delivery process, revisiting works done, training on site production techniques and cross-discipline communication, etc. From the procurement perspectives, partnering in Design & Build was considered a better option in alleviating buildability problems.

Research methodology

The research is focused on constructability practice in engineering and construction sectors of the Nigerian economy. Rivers State with Port Harcourt as capital was used as the case study area. A judgmental sampling technique was used and a total of 30 engineering and construction firms consisting of both public and private engineering construction sectors and 50 professionals including engineers, architects, project managers, quantity surveyors, builders, etc. were sampled for the study. Information on the study area, tools, methods, and techniques adopted for data collection and analysis were presented. The models used for the analysis and rationale for their selections were also presented and it is believed that the findings contained herein would give a reliable representation of what obtains in the industry.

These professionals are engaged in planning, design, management and execution of projects and therefore formed the nucleus of the respondents for the study in their various organizations. The professionals in these organizations provided the data required for the study as representatives of the study population. Three hundred (300) companies surveyed fall within this target group and the sample size with confidence level of 95% (based on Kish (1995)) is given as 23. This gives a very good representation of the population.

The questionnaire was designed as multi-choice and open-ended 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 questionnaires were delivered by hand to the respective organizations' head/branch/site offices. Some were sent by e-mail. Even though the sample size as calculated is 23, a figure higher than this was used for more reliability of the result with one hundred (100) questionnaires being sent out and fifty (50) of them returned which represents 50 % response rate. It is important to note the quality of respondents, more than 85% highly literate and over 10years experience in their respective professions. Various methods for data analysis employed include the percentage analysis, mean rating analysis, Spearman rank correlation analysis. Percentage analysis was 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 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 in the industry. Mean rating analysis was used to analyze the response from the structured part of the questionnaire that 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: Constructability Principles and Degree of Importance, Conditions Constraining Constructability.

Data for 42 out of 50 respondents that had complete responses were used for these analyses. The analysis was done in accordance with the Multi-attribute Utility approach of Chang and Ive (2002). The total number of respondents (TR) rating each parameter was used to calculate the percentage 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 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)

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. Since there may be many pairings for the purpose of analysis in order to draw meaningful conclusion, we decided to concentrate on respondent groups of "Consultant versus Contractor" and "Consultant versus Owner".

Data Analysis and presentation

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.

Table 1: Position held by respondents in engineering & construction industry

Respondents	Project Manager	Design Lead / Engineer	Construction Supervisor	Others(Architects, Q/S etc)	Total
Total number	11 (22%)	21 (42%)	8 (16%)	10 (20%)	50

Table 2: Qualification of these professionals in engineering & construction industry

Qualification	BSc//HND	MSc	PhD	Total
Number of Reponses	34 (68%)	15 (30%)	1 (2%)	50

Table 3: Experience of these professionals in engineering & construction industry

Years of Experience	1-5 years	6-10 years	10-15 years	16-20 years	20+ years	Total
Total number	16(32%)	11(22%)	9(18%)	7(14%)	7(14%)	50

Table 4: Type of Organisations

Type of Organisation	Consultants	Contractor	Owner	Total
Total number	23	13	6	42

Table 5: Constructability awareness

No of respondents who have heard of “constructability”	No of respondents who have not heard of “constructability”	Total
42	8	50

Table 6: Level of Constructability awareness

Level of awareness	Very High	High	Average	Low	Nil	Total
No. of respondents	6(12%)	26(52%)	9(18%)	4(8%)	5(10%)	50

Based on the literature review, these principles were derived and the questionnaire was developed along this line to assess the awareness and knowledge of constructability and principles among construction professionals in the selected area.

Table 7: Constructability Principles

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

Table 8: Constructability Principles and Degree of importance ranking

Factors	Very Important %	Important %	Moderately important %	Little Important %	Not Important %	TR	MR	Rank
A1	87.5	12.5	0	0.0	0	40	4.87	1
A2	83.3	16.7	0	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	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	0.0	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 9: Conditions constraining constructability

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

Table 10: Conditions constraining constructability and their ranking

Code	Very High %	High %	Average %	Low %	None %	TR	MR	Rank
B1	70.0	17.5	5.00	7.5	0.0	40	4.50	1
B2	70.0	17.5	7.50	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

Table 11: 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	

Table 11 shows the results of Spearman coefficient and significant level calculation for the variable – Constructability principles and degree of importance. For consultant versus contractor pairing, Spearman coefficient R = 0.694 and p = 0.001 while for consultant versus 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 accepted.

Table 12: 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	

Table 12 shows the results of Spearman coefficient and significant level for the variable – Conditions constraining constructability. For consultant versus contractor pairing, Spearman coefficient R = 0.830 and p = 0.001 while for consultant versus owner pairing, Spearman coefficient R = 0.067 and p = 0.835. It can be inferred that for the pair of consultant versus contractor, a strong correlation exists and the result is statistically significant. Therefore the second null hypothesis H_{o2} is rejected and the alternative accepted. However, for the pair of consultant versus owner, only a weak correlation exists and result is not statistically significant.

Discussion of results

The percentages of respondents are Design Lead Engineers (42%), Project Managers (22%) and Construction Supervisors (16%) and others (20%). 68% of those respondents have B.Sc. qualification, 30% have M.Sc. and 2% with Ph.D. 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 6 shows 52% high, 12% with Very High and 18% with 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.

It can also be observed from Table 8 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 (ranked1); Development of a project plan (ranked 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 (Akpan and Igwe, 2001). Constructability and other performance indices obtained in this study could be a confirmation of this notion. On the contrary, most private and turnkey projects especially for big organizations e.g. 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* (*ranked 3*), *Design for safe construction (ranked 4)* and *Provide Detail and Clear information (ranked 5); Understanding Client's corporate objectives (ranked 6) Selection of major construction methods (ranked 7), Encourage standardization and repetition (ranked 8); Design for simple assembly (ranked 9)* and *Early involvement of construction personnel (ranked 10).* These results agree with the findings of Lam *et al* (2005) and Trigunarsyah (2006).

Table 10 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 (DBB) where in most cases, limited time is allowed for design before tender/construction, hence a lot of errors and defects. This is perhaps some are of the opinion 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 (ranked 2); Non standardized designs (ranked 3); Budget limitation (ranked 4); Lack of construction experience (ranked 5); Tight timeframe for designing and tendering (ranked 6). Non participation of discipline design teams during preliminary design stage (ranked 7); Adversarial relationship between designer and contractor (ranked 8); Contractors lack of knowledge of design philosophy (ranked 9); Resistance of owner to formal constructability program (ranked10).* Formal constructability implementation requires finance; but the benefits outweigh the costs. This is supported by Jergeas and Van der Put (2001).

In DBB, the architect or engineer completes the design before input by other professionals. No major changes can be made at this stage even if the project is considered not buildable because it would amount to starting it all over. In the Oil industry, however, this problem is eliminated by the multidiscipline approach of many engineering design companies in the oil industry. The first null hypothesis H_{01} tested by Spearman Rank correlation showed that for consultant versus contractor pairing, R = 0.694 and p= 0.001 while for contractor versus owner pairing, R = 0.600 and p = 0.005. Therefore the null hypothesis H_{01} is rejected and the alternative is accepted. The second hypothesis tested showed that for consultant versus contractor R = 0.830 and p= 0.001; while for contractor versus owner R = 0.067 and p = 0.835. Therefore the null hypothesis is accepted while the alternative is rejected.

From the above analyses, it follows that 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. There is also a strong positive correlation among the respondent group of consultant versus 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 versus owner, only a weak correlation exists in their opinions.

Conclusions

On the basis of the findings discussed above, the study concludes as follows:
Results of data analysis revealed that although a high percentage of the sampled population are familiar with the term "constructability", nearly all do not have corporate constructability implementation manual nor apply formal constructability implementation programs and techniques as obtained in more developed countries and this may be applicable to the other parts of Nigeria. Constructability implementation is therefore neither systematic nor comprehensive in nearly all the firms surveyed. It is one thing to be aware of the process, it is yet another to fully utilize the process for the intended purpose. This result is in line with the findings of Nima *et al.* (2001) of similar studies in Malaysia. Having identified these principles and the response from the industry practitioners, attempts were made in terms of severity so that efforts could then be targeted from those at the top and coming down in curtailing their effects on project performance. This forms the second objective of the study.

In view of the findings of this study, it is recommended that formal constructability methodology should 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 be encouraged to play more active roles in the enforcement 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.

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