**Journal of Construction Project Management and Innovation Vol. 4 (1): 734-754, 2014**
**ISSN 2223-7852**


# EVALUATION OF THE BARRIERS TO THE USE OF APPROPRIATE CONSTRUCTABILITY PRACTICES ON CONSTRUCTION PROJECTS

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## ABSTRACT

Within the Nigerian and Sub-Saharan African construction industries generally there has been a lack of research profiling the constructability practices of contractors and possible barriers to the use of appropriate methods. The aim of this study was to assess constructability practices of contractors in construction projects in this context. The objectives were to identify current constructability practices, and to examine the barriers typically affecting constructability practices. Convenience sampling was used to select 19 contractors in Lagos state, Nigeria, who were interviewed using a structured interview protocol. The data collected was analysed using descriptive statistics. Results indicated that constructability practices common to contractors include checking M & E drawings for clashes and errors; site-layout planning; and preparation of schedule/construction programmes. In-situ constructions, crane/lifting equipment, formwork technologies and external scaffolding systems were used during site operations. Barriers affecting constructability practices stem from contractors' internal conditions, external factors, and project-related factors including design, lack of knowledge in construction methods, and project size and complexity. The findings have important implications for policy and practice. We recommend public laws making it mandatory for projects to implement constructability reviews and analyses. We also recommend that practice-experienced constructors be employed on projects, and that professional bodies train and educate members on constructability principles and practice for the better management of projects.

**Keywords:** Assessment, Constructability practice, Contractors, Design, Knowledge, Nigeria

## 2. INTRODUCTION

Constructability and buildability are two important concepts that emerged in the construction industry in the late 1970's. According to Trigunarsyah (2004a) the idea of constructability emerged in USA, while the concept of buildability evolved in the UK construction industry. Constructability has been defined as a project management technique that involves the optimum integration of construction knowledge and experience in planning, engineering, procurement and field operations in the building process. It also entails balancing various projects and environmental constraints in achieving the overall objectives (The Institution of Professional Engineers New Zealand, [IPENZ], 2008). Buildability has been defined as the extent to which the design of the building facilitates the ease of construction, subject to the overall requirements for the completed building. These two terms are used interchangeably in construction management literature and are documented in various studies (Arditi, Elhassan and Toklu, 2002; Trigunarsyah, 2004a; IPENZ, 2008; Othman, 2011) among others. In particular, IPENZ (2008) emphasized that when a construction project becomes complex, the issues of constructability become very important. It is thus important for project participants to consider constructability early in the life of the project, in order to prevent litigation, claims, change orders and disputes, as well as client dissatisfaction with the delivery system.

Constructability principles are integrated into projects to prevent the above problems from occurring. Also, different construction management literatures (Arditi, Elhassan & Toklu, 2002; Motsa, Oladapo & Othman, 2008) have documented further benefits of constructability in terms of developing better relationships between clients and contractors, building a good reputation, providing professional satisfaction and doing efficient design. Some of these benefits could also be harnessed in construction projects in Nigeria if constructability principles and practices were to be integrated into our construction system. Fortunately, construction professionals are gradually becoming aware of the concepts of constructability and buildability in their construction practice. Several construction projects undertaken by small and medium sized contractors have used some level of constructability practice. A recent study in Nigeria (Adekunle, 2012) also revealed that construction professionals are aware of constructability concepts in their practices but do not have a documented corporate philosophy for dealing with constructability issues in their organizations. These results suggest a low level of constructability implementation in projects, which is a cause for concern.

The present study has therefore been undertaken to investigate small and medium sized contractors' constructability practices within construction projects in Nigeria. The study first determined the current constructability practices being used by the contractors, and then examined the barriers affecting constructability practices within the contractors' projects.

This study is significant in that it provides (1) current literature on constructability practice, (2) an insight into contractors' practice of constructability and (3) it reveals the factors affecting constructability practices in Nigeria.

## 2. CONSTRUCTABILITY CONCEPTS AND GUIDELINES

Constructability is viewed as the optimum use of construction knowledge and experience (Construction Industry Institute [CII] 1986 and CII 1992; 1996), construction resources (O'Connor & Tucker, 1986) and specific technology based on construction knowledge (Yu & Skibniewski 1998) in the project delivery process in order to maintain the overall project objectives and building performance at an optimal level. Constructability emphasizes the integration of construction knowledge and experience at various project stages. It refers to the optimization of different project requirements to achieve the overall goals of the project, and to make construction easier.

Early research work in the UK focused more on design rationalization, whereas the focus in the USA and Australia was on the development of management systems and subsystems which enabled construction knowledge to be brought further forward in the project delivery process (Cheetham & Lewis, 2001). In Singapore the focus was on both design rationalization and construction practice and processes. In the United States, the Construction Industry Institute (1987) developed fourteen (14) constructability concepts which were later modified to seventeen (17) (Russell et al., 1992). These modifications are to help improve constructability. In Australia, Trigunarsyah (2004a) noted that the CIIA developed twelve (12) principles of constructability based on the CII constructability concepts, which were tailored to the needs of the Australian construction industry. The Constructability Appraisal System (CAS) was also developed by the BCA in Singapore as a performance based system with flexible characteristics. Its objective was to bring about the wider use of labour-saving construction methods and technologies that would help to reduce the demand for manpower on site. The CAS is based on the construction methods adopted by the various competing contractors, determined by their individual construction knowledge, constructors' conditions or project characteristics.

While Gibson et al. (1996) note that this project approach varies widely between contractors, Uhlik and Lores (1998) argue that general contractors show a significant lack of formal constructability efforts in their work. Furthermore, it has been widely reported in the construction management literature that construction methods/practices (or constructability practices) adopted by contractors can affect the efficiency and effectiveness of construction/production processes, particularly labour productivity, project costs, schedule performance and safety (CII 1986; Gibson et al. 1996; Yu and Skibniewski 1998; Low 2001; Jergeas & Van der Put 2001; Cheetham and Lewis 2001; Trigunarsyah 2004; Pocock et al. 2006; Liu & Low 2007; Saghatforoush et al. 2009; and BCA 2011).

The foregoing discussions on constructability are relevant to the present study as the constructability practices of contractors and the factors affecting their constructability practices in construction projects in Nigeria are investigated. This study draws on construction methods/practices, issues of construction/production processes, labour productivity and schedule performance.

### *2.1 Constructability Practice in Construction Projects*

Lam et al. (2007) note that good constructability should facilitate efficient, economical and safe building processes. Table 1 presents the summary of a comprehensive literature review of constructability practices/concepts that are considered by scholars to enable effective and efficient construction processes. The objective of the review is to acquire in-depth knowledge of the constructability practices/concepts available in the literature. Scholars identified nine main constructability practices/concepts while the tenth concept, labour/skills, has specific applications to all practices. These identified practices are grouped into two, namely, construction management and site technology. Further sub-division of the nine construction methods and site practices identified, produced 41 attributes of constructability practice, which formed the basis of the criteria for the assessment of constructability regarding the contractors in this study.

**Table 1. Summary of Constructability Practices/ Concepts identified in Literature**

| Constructability Practices/Concepts | Studies on constructability in various countries | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jergeas and Put (1986) | CII (1987) | CII Australia (1996) | Uhlik and Lores (1998) | Yu and Skibniewski (1999) | Cheetham and Lewis (2001) | Trigunarsyah (2004a and b) | Pockock et al. (2006) | Liu and Low (2007) | Lam et al. (2007) | Saghatforoush et al. (2009) | Singapore BCA (2011) | Present study in Nigeria |
| Construction Analysis | | | | | | ✓ | ✓ | ✓ | | | | ✓ | ✓ |
| Analyzing site layout and temporary facilities | ✓ | ✓ | | | | ✓ | ✓ | | | | ✓ | | ✓ |
| Planning the sequence of field tasks, scheduling, estimating and organizing | | ✓ | | ✓ | | ✓ | ✓ | | ✓ | | ✓ | | ✓ |
| Monitoring and control | | | | | | | | | | | | ✓ | ✓ |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Innovation/New ideas, methods, materials and equipment | ✓ | ✓ | ✓ | | | | | ✓ | ✓ | | | | ✓ |
| Modularization/Prefabrication | ✓ | ✓ | | | | ✓ | | | | | | ✓ | ✓ |
| Traditional in-situ methods of construction | | | | | | | | | | ✓ | | | ✓ |
| Formwork Technologies, plant and equipment | | ✓ | ✓ | | ✓ | ✓ | | | | | | ✓ | ✓ |
| Labour skills | | | | | | | | | | | | | ✓ |
| External access systems | ✓ | ✓ | | | | | ✓ | | | | | ✓ | ✓ |

Key: ✓ - Relevant literature citing particular constructability practices/concepts

(Source: Literature Study)

### *2.2 Barriers Affecting Contractors' Constructability Practices on Projects*

According to Lam et al. (2007), it is hard to realize improvements to constructability practices without clearly defining the factors affecting constructability. Yu and Skibniewski (1999) determine that certain external and internal conditions, as well as project characteristics, affect the constructability practices used by a constructor on a considered project. Tatum (1987) notes that a contractor would need to consider the level of skills available in the local industry before bringing in new ideas/innovation. Barriers identified by Pocock et al. (2006), Trigunarsyah (2004a and b), Uhlik and Lores (1998), Yu and Skibniewski (1999), Tatum (1987) and Jergeas and Put (1986), are summarized in Table 2.

**Table 2. Barriers affecting Constructability Practices identified in Literature**

| |
|---|
| **External Factors** |
| Design |
| Lack of open communication between designers & constructors |
| Skilled labour shortage |
| Contractors are usually not involved until the designs have been completed |
| Professional designers & constructors are engaged with separate contracts |
| Highly competitive construction market |
| Material supply shortage |
| Building Codes do not require constructability |
| Competitive equipment rental market |
| **Contractors Internal Conditions** |
| No knowledge of the latest construction methods & techniques |
| Inadequate construction experience |
| Lack of resources |
| Lack of project management ability/qualified personnel |
| Low availability of skilled labour |
| Time required to adequately train staff in the use of computer systems that seem to change frequently & lack user friendliness |
| Equipment adequacy |
| High material inventory |
| Low work backlog |
| **Project Characteristics** |
| Size and complexity of the project |
| High project quality requirement |
| Congestion around construction sites especially those around operating Facilities |
| Method used in project procurement |
| Project duration is strictly constrained |

(Sources: Pocock et al., 2006; Trigunarsyah, 2004a and b; Uhlik and Lores, 1998; Yu and Skibniewski, 1999; Tatum, 1987; and Jergeas and Put, 1986)

Uhlik and Lores (1998) established that the method of project procurement, contract type, designers' knowledge and attitude have an impact on the constructability practices used on most projects. This study ascertains that constructability concepts are implemented more frequently in construction management and design-and-build procurement methods more than in traditional methods.

Uhlik and Lores (1998) further identified some common barriers affecting constructability as designers' lacking construction experience and knowledge of construction technologies; the use of lump-sum competitive contracting; and the adversarial attitude between designers and contractors (which includes the reluctance of designers to include contractors in the constructability review for fear of ruining their reputation). These barriers are relevant to the present study as this research explores all barriers affecting contractors' use of appropriate constructability practices on construction projects in Nigeria.

## 3. RESEARCH METHODS

The research was undertaken during the period of February to July 2012. A literature review was undertaken to ascertain the main issues relating to constructability concepts and guidelines, constructability practice on construction projects, as well as barriers affecting contractors' constructability practices. The study took place in Lagos State, Nigeria. The population of the study consisted of small and medium sized contractors that have on-going construction projects. The study used an exploratory multi-case study research design that utilized semi-structured interview protocols to collect information from respondents. The research instrument was designed with the constructability concepts identified by the BCA (2011) on Buildability. They separate the need for buildable design upstream from construction methods/technologies (or constructability) adopted by the contractors downstream.

The development of the research instrument drew on previous research by Jergeas and Put (1986), CII (1987), Uhlik and Lores (1998), Cheetham and Lewis (2001), Trigunarsyah (2004a and b), Pocock et al. (2006), Liu and Low (2007) and Saghatforoush et al. (2009). To ensure that each respondent had the same understanding of constructability, definitions of constructability were provided. For each of the constructability attributes, respondents were asked to select their responses based on a 3-point Likert Scale where 1= not used, 2 = partially used, 3 = fully used, for contractors' constructability practices. For measuring the barriers affecting constructability practice responses were based on a 3-point Likert Scale of 1 = no influence, 2 = partial influence and 3 = high influence.

Convenience sampling was used in selecting the participants for the study. The criteria for selection of the contractors were that they must be (1) listed in the Nigerian Institute of Building (NIOB) Business Directory, (2) be based in Lagos State Nigeria and (3) must have on-going construction projects. Contractors that fitted these categories were all contacted either by telephone or at their business addresses in order to determine who would be willing to participate in the study.

In all, 19 contractors agreed to participate. Personal interviews were undertaken to collect empirical data from the respondents. The information from these contractors was used for the data analysis. Descriptive statistical tools such as tables, mean item scores (MIS), percentages and rankings were used in analyzing the data collected and in making decisions about the constructability practices of small and medium sized contractors in Nigeria.

$$MIS = \frac{3M_3 + 2M_2 + 1M_1}{3 \times (M_3 + M_2 + M_1)}$$

Where M3, M2 and M1 are frequencies of the rating responses given to each constructability variable.

## 4. RESULTS AND DISCUSSION

### *4.1 Characteristics of Participants*

The characteristics of the contractors who participated in the study are presented in Table 3. Four types of organizations were represented: 37% of the respondents were general contractors, 32% were building contractors, 26% were civil engineering contractors, while the remaining 5% were developers. Since the majority of respondents were general contractors they must have been exposed to different construction projects for which constructability principles must have been used. Also, for the area of operation of respondents, 53% of these respondents operated nationally across several states, 37% operated across different regions of the country in the northern, eastern, western and southern political regions, while the remaining 5% operated both locally and internationally (i.e. beyond Nigeria's borders).

**Table 3. Characteristics of respondents that participated in the study**

| Respondent characteristics | Frequency | Percentage (%) |
|---|---|---|
| **Types of organizations** | | |
| Building contractors | 6 | 32 |
| Civil Engineering contractors | 5 | 26 |
| General contractors | 7 | 37 |
| Developer | 1 | 5 |
| Total | 19 | 100 |
| **Company's areas of operation** | | |
| Local | 1 | 5 |
| Regional | 7 | 37 |

| | | |
|---|---|---|
| National | 10 | 53 |
| International | 1 | 5 |
| Total | 19 | 100 |
| | | |
| **Designation of respondents** | | |
| Director | 7 | 37 |
| Project Manager | 4 | 21 |
| Engineer | 1 | 5 |
| Builder | 7 | 37 |
| Total | 19 | 100 |
| | | |
| **Respondents' experience in the construction industry** | | |
| Less than 5yrs | 2 | 10 |
| 6-10yrs | 3 | 16 |
| 11-15yrs | 3 | 16 |
| 16-20yrs | 5 | 26 |
| Above 20yrs | 6 | 32 |
| Total | 19 | 10 |

Further results presented in Table 3 regarding the designation of respondents show that 37% of the respondents were Directors and another 37% were Builders in their various organizations, 21% of the respondents were Project Managers while 5% of the respondents were Engineers. Since most respondents were either Directors or Builders, it suggests that they must have been involved in different construction projects from which lessons were learnt and experience was gained. Such projects can be used to provide relevant information for this study.

In addition, the results in Table 3 regarding the experience of respondents in the construction industry indicate that 32% of the respondents had over 20 years of experience in the industry, 26% had between 16-20 years experience, 16% had 6-10 years, 6% had 11-15 years experience, while the remaining 10% of the respondents had less than 5 years of experience. Since most respondents had over 15 years experience in the construction industry, they must have been fully exposed to different construction experiences and knowledge, and could therefore provide valuable information for this study. It also emerged that the average turnover of the companies interviewed was ₦ 79,643,176 ($497,770). The projects in which they had been involved included residential, educational, commercial and institutional work, and varying in size from simple one floor to five floor high projects.

### *4.2 Constructability Practices of Small and Medium Sized Contractors*

Contractors who participated in this study were asked to indicate their level of implementation of constructability principles in recently completed construction projects. Their responses to the utilization of these principles are presented in Table 4.

Results in Table 4 indicate that, in terms of implementing mechanical and electrical (M & E) design checks on projects, checking for clashes in M & E service drawings ranks highest (MIS=0.85) while production of M & E coordination drawings is ranked second (MIS=0.79). These results suggest that most contractors check for clashes on M & E drawings more often than they produce M & E coordination drawings.

**Table 4. Constructability principles implemented on construction projects**

| Constructability principles Implemented on projects | Level of Constructability Practice MIS | Group Ranking | Top Eight important areas of constructability practice |
|---|---|---|---|
| **Construction Analysis** | | | |
| Check for clashes in Mech. & Eng. (M&E) services drawings | 0.85 | 1 | |
| Produce M&E co-ordination drawings, architectural shop drawings & concrete body plan for construction purposes | 0.79 | 2 | |
| **Site Analysis** | | | |
| Allow working space for labour, materials and plant on site | 0.90 | 1 | 8 |
| Ensure less environmental nuisance (traffic, noise, dust, public safety etc.) | 0.82 | 2 | |
| Allow less wet trades on site | 0.61 | 3 | |
| **Planning** | | | |
| Prepare schedule/construction program | 0.94 | 1 | 1 |
| Prepare estimates and budgets | 0.90 | 2 | |
| Logical sequence of field tasks | 0.88 | 3 | |
| Resource analysis and scheduling | 0.85 | 4 | |
| Establish production targets – time, cost & quality | 0.85 | 4 | |
| Prepare organization structure | 0.82 | 6 | |
| Allow construction traffic early on permanent structure after erection | 0.76 | 7 | |
| Simulate construction schedules & resource planning | 0.67 | 8 | |
| **Monitoring & Controlling** | | | |
| Implement measures to improve productivity & performance | 0.85 | 1 | |
| Adopt a trade productivity monitoring system | 0.77 | 2 | |
| Benchmark outputs & project performance to leaders in the field | 0.73 | 3 | |
| Conduct monthly work study sessions to improve work processes on site | 0.67 | 4 | |
| Conduct work studies on site processes if productivity levels deviate | 0.55 | 5 | |
| **Innovation** | | | |
| Use of cranes/lifting equipment | 0.61 | 1 | |
| Use of hydraulic stationary concrete placing boom | 0.58 | 2 | |
| Use of self compacting concrete | 0.55 | 3 | |
| Use of ceiling inserts/cast-in brackets to support M&E fittings | 0.55 | 3 | |

| | | | |
|---|---|---|---|
| Strut free basement construction | 0.50 | 5 | |
| Use of prefab plant/piping modules | 0.45 | 6 | |
| Use of scissor lift/boom lift in lieu of traditional scaffold for AMEP works | 0.39 | 7 | |
| **Modularization/Prefabrication** | | | |
| Use of spray painting | 0.50 | 1 | |
| Precast concrete lintels | 0.48 | 2 | |
| Precast concrete slabs | 0.42 | 3 | |
| Precast concrete beams | 0.42 | 3 | |
| Precast concrete columns/walls | 0.39 | 5 | |
| No screed on RC floors (to immediately receive tiles, carpets etc.) | 0.39 | 5 | |
| No plaster on RC walls (ditto) | 0.39 | 5 | |
| Use of flexible pipes for domestic water systems | 0.64 | | |
| **In-situ Construction** | | | |
| Cast in-situ concrete column | 0.94 | 1 | 1 |
| Cast in situ concrete walls | 0.94 | 1 | 1 |
| Block wall construction with plastering | 0.94 | 1 | 1 |
| Cast in-situ concrete slabs | 0.91 | 4 | 5 |
| Cast in-situ concrete beams | 0.91 | 4 | 5 |
| Cast in-situ concrete lintels | 0.91 | 4 | 5 |
| **Formwork Technologies** | | | |
| Conventional/traditional timber/metal formwork – with metal props | 0.88 | 1 | |
| Ditto with Bamboo/timber props | 0.73 | 2 | |
| Equipment lifted panel form system | 0.55 | 3 | |
| No formwork (stay-in-place precast concrete form system) | 0.48 | 4 | |
| **External Access Systems** | | | |
| Traditional external scaffold – independent or putlog – constructed with metal poles & connectors | 0.85 | 1 | |
| Ditto with Bamboo/timber poles | 0.64 | 2 | |
| No external scaffold | 0.52 | 3 | |
| Self-climbing perimeter scaffold | 0.48 | 4 | |
| Crane-lifted perimeter scaffold/fly cage | 0.39 | 5 | |

These checks can help identify design problems and obstacles before field operations are carried out on the project. Also, for site–layout, planning which allows for working space for labour, materials and plant on site (MIS=0.90) ranks first, ensuring less environmental nuisance (MIS=0.82) ranks second, while allowing less wet trades on site (MIS=0.61) ranks third. These results also indicate that most contractors provide working spaces for labour, materials and the plant on site. This in itself enhances constructability of field operations where ample working spaces are available to aid manoeuvrability on site for prefabrication, formwork utilization and the use of scaffolding systems.

Of the eight factors used in rating the level of constructability practice in the conceptual planning of the project, the preparation of schedule/construction programmes (MIS=0.94) ranks first, the preparation of estimates and budgets (MIS=0.90) ranks second, logical sequencing of field tasks (MIS=0.88) ranks third while simulation of construction schedules and resource planning (MIS=0.67) ranks eighth. These results suggest that most contractors are more used to the preparation of schedule/construction programmes in their implementation of constructability principles in their projects than other planning operations. This could possibly be because of the importance attached to schedule/construction programmes in project execution. Most projects will not be constructible if schedule/construction programmes are not well prepared ahead of the field operations.

With respect to the five factors that are used in rating the level of constructability practice in project monitoring and control, implementing measures to improve productivity and performance (MIS=0.85) ranks first, adoption of a trade productivity monitoring system (MIS=0.77) ranks second, benchmarking outputs and project performance for leaders in the field (MIS=0.73) ranks third, while conducting work studies on site processes if productivity levels deviate (MIS=0.55) ranks fifth.

In terms of innovation in constructability practice, of the seven factors used in rating the contractors constructability practice, the use of crane/lifting equipment (MIS=0.61) ranks first, the use of a hydraulic stationary concrete placing boom (MIS=0.58) ranks second, the use of self compacting concrete (MIS=0.55) ranks third while the use of a scissor lift/beam lift in lieu of a scaffolding system (MIS=0.39), ranks seventh. These results suggest that most contractors in their constructability practice use crane/lifting equipment for their construction activities. This is a good innovation to aid mechanization of their lifting operations, since depending on manual labour for lifting operations is slow and reduces productivity on construction sites.

With respect to constructability practices in modularization/prefabrication techniques of site operations, the use of flexible PVC pipes for domestic water systems (MIS=0.64) ranks first, the use of spray painting (MIS=0.50) ranks second while the use of precast concrete columns/walls, no screeding on reinforced floors to immediately receive tiles, no plastering on reinforced concrete walls to receive finishing (MIS=0.39), all rank sixth. These results suggest that most contractors who participated in this study made more frequent use of flexible PVC pipes for domestic water supply, than of the other listed techniques. Site operations can be enhanced if such modularization units are employed rather than galvanized piping systems that may require time, labour and money to implement.

In terms of in-situ constructions, cast in-situ columns, concrete walls and block wall construction with plastering (MIS=0.94) all rank first, while cast in-situ concrete slabs, concrete beams and concrete lintels (MIS=0.91) all rank fourth.

These results suggest that most of the contractors use cast in-situ columns, concrete walls and block wall construction with plastering more than other in-situ construction methods. In-situ construction of vertical elements (columns, walls and block walls) can increase the speed of construction in field operations and also enhance monolithic connections with the rest of the structural frame in a building.

Regarding contractors' constructability practices in the use of formwork technologies on site operations, conventional/traditional timber/metal formwork with metal props (MIS=0.88) ranks first, use of bamboo/timber props (MIS=0.73) ranks second while the use of no formwork or stay in place precast concrete form system (MIS=0.48), ranks fourth. These results also indicate that most contractors that participated in this study utilize traditional timber/metal formwork for site operations more than other types of formwork technologies in use on site operations. Formwork is an important technology for most in-situ and prefabricated construction in reinforced and pre-stressed concrete. In Nigeria, most construction operations utilize concrete technology and hence most contractors would prefer timber/metal formwork, as both are durable, re-usable and therefore economical.

Lastly, in respect of external access systems used in site operations, the use of a traditional external scaffold system (MIS=0.85) ranks first, the use of bamboo/timber props (MIS=0.64) ranks second, while the use of a crane lifted perimeter scaffold/fly cage (MIS=0.39) ranks fifth. These results indicate that contractors use traditional external scaffolding systems for their site operations. Construction workers easily understand the technology of this external scaffold system, and its use in site operations enhances productivity. By contrast, prefabricated modular metal pipe systems may be expensive and beyond the reach of small and medium sized Nigerian contractors.

Summarizing the findings on contractors' constructability practices, it can be seen that most contractors check for clashes on their M & E drawings to minimize site operation problems; undertake site-layout planning by providing working spaces for materials, labour and plant on site to ensure maneuverability; prepare schedule/construction programmes to enhance constructability of site operations; and also implement certain measures to improve productivity and performance. Also, most contractors enhance constructability in their projects by using (1) crane/lifting equipment in their site operations to entrench mechanization in site operations, (2) PVC pipes for domestic water supply systems that integrate modularization in site operations, (3) in-situ construction in form of cast in-situ columns and walls to enhance monolithic connections, (4) formwork technologies in the form of traditional timber/metal formwork and (5) external access systems like traditional scaffolding systems.

Further results from Table 4 also indicate that the top eight constructability practice enhancement areas of most contractors in Nigeria are cast in-situ concrete columns, concrete walls, block wall construction with plastering, preparation of schedule/construction programmes (MIS=0.94), cast in-situ concrete slabs, beams and lintels (MIS=0.91), and allowing working space for labour, material and plant (MIS=0.90). These top eight constructability practice enhancement areas are from in-situ constructions, conceptual planning and site layout planning. These are areas of constructability practice that contractors can draw on to improve future construction practices in Nigeria.

### *4.3 Barriers to Contractors' Constructability Practice on Construction Projects*

The various barriers affecting contactors' constructability practices on the construction projects studied are summarized in Table 2 and Figures 1 to 3. Figure 1 shows that with respect to external factors affecting contractors' constructability practices, design (MIS=0.94) ranks first, lack of open communication between designers and constructors (MIS=0.91) ranks second, while a competitive equipment rental market (MIS=0.67) ranks ninth.

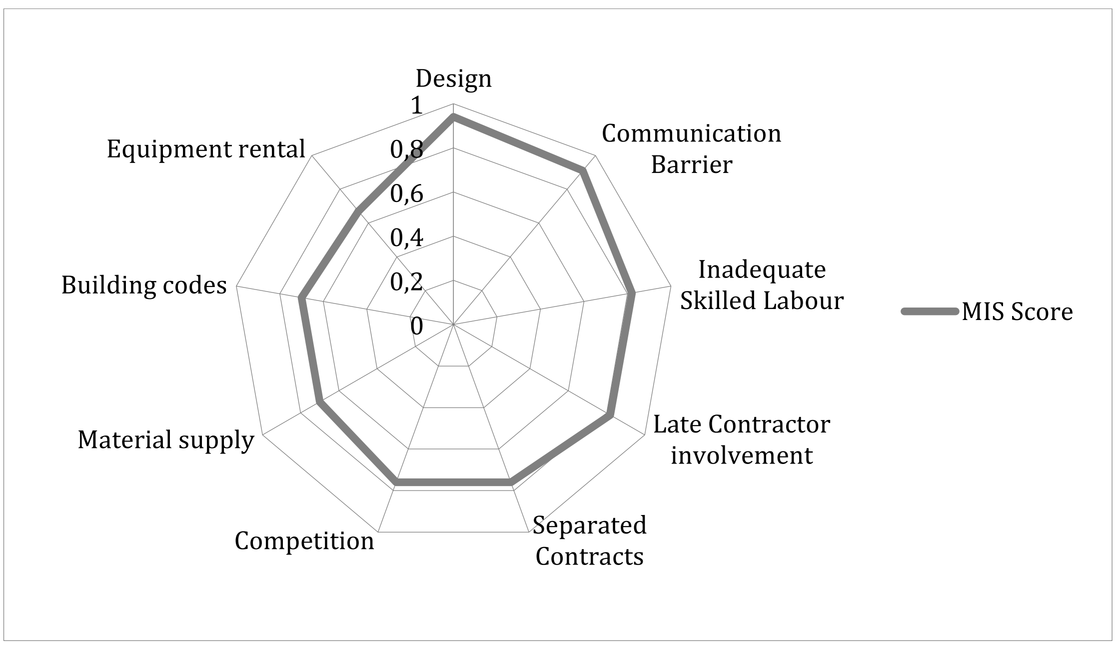


**Figure 1. Influence of External Factors on Constructability**

In terms of barriers stemming from internal factors, lack of knowledge of the latest construction methods and techniques (MIS=0.97) ranks first, inadequate construction experience (MIS=0.94) ranks second, while time required to train staff in computer literacy (MIS=0.76) ranks sixth. These results also indicate that the most important barrier to constructability practice is a contractors' lack of the latest knowledge of construction methods and techniques. This finding is valid because if contractors do not update their knowledge of construction methods and techniques it will be difficult to bring new ideas and innovations into constructability practice.

In addition, regarding barriers to constructability practice that emanate from project related factors (see Figure 3), size and complexity of the project (MIS=0.97) rank first, high project quality requirements and congestion around construction sites (MIS=0.88) both rank second, while strictly constrained project duration ranks fifth. These results demonstrate that project size and complexity are the most severe barriers to constructability practice. If the project is very large and of a complex nature, it may require more detailed constructability reviews, conceptual planning and programming to tackle and prepare for the construction problems that may arise ahead of site operations. It may also require an experienced constructor to integrate construction knowledge and experience on the project.

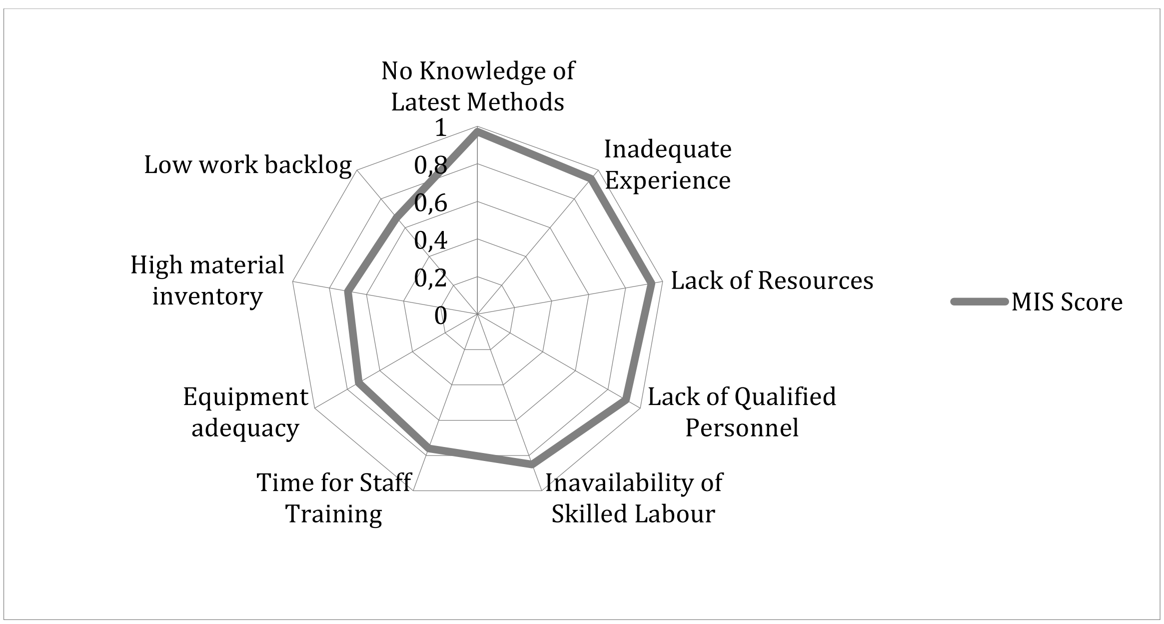

**Figure 2. Influence of Internal Conditions on Constructability**

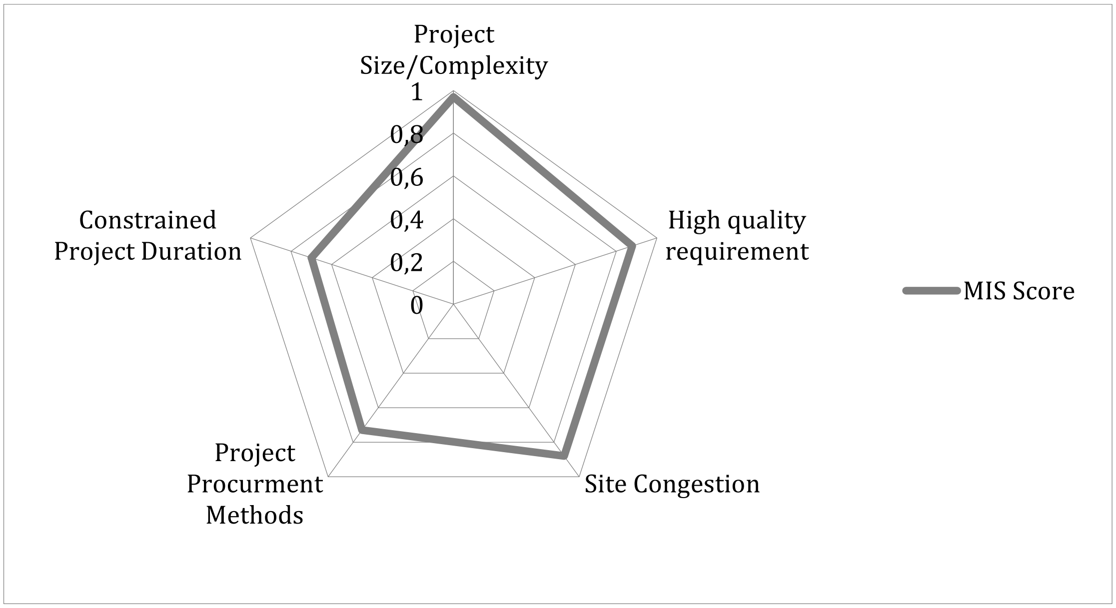


**Figure 3. Influence of Project Characteristics on Constructability**

### *4.4 Discussion of Findings*

The data suggests that the most severe barriers to improved constructability practices include a design that may be faulty or with incomplete specifications; lack of the latest knowledge on construction methods and techniques; and project size and complexity that may require extensive constructability reviews, planning and programming to tackle. Furthermore, results presented in Figure 1 to 3 indicate the top ten severe barriers to contractors' constructability practice as lack of knowledge on latest construction methods and techniques, size and complexity of the project, design, inadequate construction experience, lack of resources, lack of project management ability/qualified personnel, lack of open communication between designers and constructors, high project quality requirement, congestion around construction sites (especially those around operating facilities) and low availability of skilled labour. Most of these barriers to constructability practice stem more from contractors' internal factors than from external and project related factors. These findings are similar to those of earlier scholars such as Pocock et al. (2006), Trigunarsyah (2004a), Uhlik and Lores (1998), Yu and Skibnieski (1999), Tatum (1987) and Jergeas and Put (1986).

Based on our sample, it would appear that small and medium sized construction firms in Nigeria lean towards the use of more conventional than contemporary constructability practices, especially in the area of site technology, formwork technology and scaffold technology. Where they do conform to global construction practices is in the area of construction management. Furthermore, respondents affirmed that the construction methods used by the small and medium sized building contractors in Nigeria do not conform to global best practice. A respondent observed that contractors do not use best practice because the National Building Code in Nigeria is "unabled" (powerless) and not a legal document, and that a National Building Code that specifies the construction methods/practices to be adopted by contractors should be developed in Nigeria.

The results of this study demonstrate that design is the most important barrier to a contractors' constructability practice. If designs are faulty, or ambiguous working drawings are provided for use on projects, it makes the project very un-constructible. This finding is in agreement with Arditi, Elhassan and Toklu (2002) who identified faulty working drawings and incomplete specifications as factors constraining constructability practices in design firms in the United States of America. This finding also supports Motsa, Oladapo and Othman (2008), whose study in KwaZulu Natal Province of South Africa found that the most significant factor hindering the implementation of constructability in design was the designer's lack of knowledge.

## 5. IMPLICATIONS OF THE STUDY FOR POLICY, THEORY AND PRACTICE

The study is aligned to previous research (see Yu and Skibniewski, 1999; and Tatum, 1987) and provides further evidence that the barriers militating against constructability practices stem mainly from contractors' internal conditions, and from external and project related factors. This is shown schematically in Figure 4.

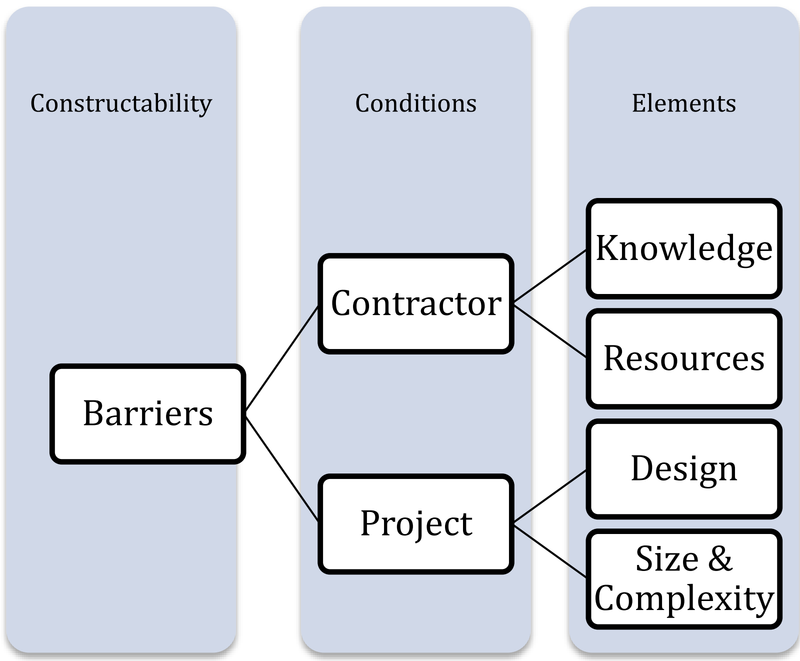


**Figure 4. Elements of Barriers to the use of suitable constructability practices on site**

It can be inferred from the results of this study that the more knowledgeable a contracting firm is, and the lower the size and complexity of the project (which are issues related to design — see Radosavljevic and Bennett, 2012), the more contractors will make use of good constructability practices. Implications of these findings for policy makers in government and practitioners is in the enactment of a public law (where such a law is not yet in existence) for all government construction projects of any value to undergo constructability reviews and analysis. The findings of this study also provide evidence to support the constructability theory that in-situ constructions, conceptual planning, and site layout planning all enhance constructability practice; and that experienced constructors should be employed for constructability reviews and analyses on construction projects in Nigeria and in other developing countries.

## 6. CONCLUSIONS

Based on the findings of this study it can be concluded that constructability practices of contractors have been enhanced by integrating a host of factors including in-situ constructions, conceptual planning and site-layout planning into their various construction projects.

The study recommends that contractors should pioneer and arrange for constructability reviews and analyses once awarded a tender. They should also work towards acquiring the necessary skills and equipment that will bring about appropriate construction methods that are aligned with global best practices. Professional bodies should train and educate their members on constructability principles to ensure better management of future projects. To maintain effective constructability practice on projects, contractors need to attend seminars, conferences and training programmes to improve their knowledge of construction methods and techniques. Finally, there should be codes that specify the construction methods/practices that should be adopted by contractors on construction projects.

This study is limited by its small sample size. Further research with larger samples is needed to validate the findings of the study. Furthermore, a further study to rank the construction practice/methods/systems that are commonly adopted in building construction, and whether there is any relationship between the levels of constructability practiced on site and project performance is recommended.

## 7. REFERENCES

Arditi, D., Elhassan, A and Toklu, Y.C (2002). Constructability Analysis in the Design Firm, *Journal of Construction Engineering and Management,* 128(2), 117-126.

Building and Construction Authority, (BCA) (2011). *Code of Practice on Buildability*, Singapore: BCA.

Cheetham, D., and Lewis, J. (2001). Productivity, buildability and constructability: is work study the missing link? *In*: *Proceedings of 17th Annual ARCOM Conference,* Akintoye, (Ed.), 5-7 September, University of Salford, (1), pp 271-80.

Construction Industry Institute (CII) (1986). *Constructability: A Primer*, Austin, Texas: CII.

Construction Industry Institute (CII) (1987). *Constructability concept file*, Austin, Texas: CII.

Construction Industry Institute Australia (CII Australia) (1992). *Constructability principles File*, Adelaide: CII Australia.

Construction Industry Institute Australia (CII Australia) (1996). *The Development of Constructability Principles for the Australian Construction Industry*, Adelaide: CII Australia.

Gibson, G. E., McGinnis, C. I., Flanigan, W. S., and Wood, J. E. (1996). Constructability in public sector, *Journal of Construction Engineering and Management*, 122(3), 274-280.

Jergeas, G., and Van der Put, J. (2001). Benefits of constructability on construction projects, *Journal of Construction Engineering and Management*, 127(4), 281-290.

Institution of Professional Engineers New Zealand Incorporated, (IPENZ) (2008). Constructability Practice Note 13. [Online]. Available at <http://www.ipenz.org.nz/ipenz/forms/pdfs/PIN13_Constructability.pdf.

Lam, P. T. I., Chan, A. P. C., Wong, F. K. W., and Wong, F. W. H. (2007). Constructability rankings of construction systems based on the Analytical Hierarchy Process, *Journal of Architectural Engineering*, 13(1), 36-43.

Liu, J. Y and Low, S. P. (2007). Enhancing buildability in China's construction industry using Singapore's buildable design appraisal system, *Journal of Technology Management in China*, 2(3), 264-278.

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

Motsa, N., Oladapo, A.A and Othman, A.A.E. (2008). The Benefits of Using Constructability during the Design Process, Proceedings of the 5th Post Graduate Conference in Construction Industry Development, Bloemfontein, South Africa,16-18 March 2008, pp. 157-167. [Online]. Available at <http://www.cib2007.com/papers.html. (accessed on 2nd September, 2013).

O'Connor, J. T., and Tucker, R. L. (1986). Industrial project constructability improvement, *Journal of Construction Engineering and Management*, 127(4), 281-290.

Othman, A. A. E. (2011). Constructability for reducing construction waste and improving building, *Built Environment Journal*, *8*(2), 31-54.

Pocock, J. B., Kuennen, S. T., Gambatese, J., and Rauschkolb, J. (2006). Constructability state of practice report, *Journal of Construction Engineering and Management*, 132(4), 373-383.

Radosavljevic, M. and Bennett, J. (2012) *Construction management strategies: A theory of construction management*, United Kingdom: Wiley-Blackwell.

Russell, J., Radtke, M., and Gugel, J. (1992). *Project-level model and approaches to implement constructability*, Austin, Texas: CII-Doc. 82.

Saghatforoush, E., Hasim, S., Jaafar, M., and Abdul Kadir, M. (2009). Constructability implementation among Malaysian building contractors, *European Journal of Scientific Research*, 29(4) 518-532.

Tatum, C. B. (1987). Improving constructability during conceptual planning, *Journal of Construction Engineering and Management*, 113(2), 196-206.

Trigunarsyah, B. (2004a). A review of current practice in constructability improvement: case studies on construction projects in Indonesia, *Construction Management and Economics*, 22*,* 567-580.

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

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

Yu, W., and Skibniewski, M. J. (1999). Quantitative constructability analysis with a neuro-fuzzy knowledge-based multi-criterion decision support system, *Automation in Construction*, 8, 553-565.