FACTORS INFLUENCING THE BUILDABILITY OF DESIGNS IN THE NIGERIAN CONSTRUCTION INDUSTRY

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Abstract

Hardly could projects be executed in Nigeria without alteration of design. This cannot be dissociated from designs which are not practically buildable or arising from changing taste of client. A study on factors influencing the buildability of designs in Nigerian construction industry was carried out to determine these factors and develop strategy to mitigate them. A total of one hundred (100) questionnaires were administered by the means of convenience and eighty six (86) was retrieved from a target population comprising; Architects, Builders, Engineers and Quantity Surveyors. The central tendency statistical tool was used for the analysis of data. The result of data analysis indicated that, clients briefing is an important factor for buildability of design. Among the influencing factors on buildability, complexity of the project followed by professional knowledge about construction ranks first and second and lastly cost economic value with no influence. On the current practice of buildability in Nigeria, the study revealed that Architects are mainly involved at the briefing stage to the award stages. While at the construction stage the Builder/Constructor features prominently at the various phases of construction. The study recommended the integration of Builder/Constructor at the early stage of building design.

Keywords: Buildability, Design, Professional, Construction, Project

1. INTRODUCTION

Today, design in construction industry can hardly be executed without alteration. This cannot be dissociated from designs which are not practically buildable. Designs require to be made by experienced architects and engineers or with the involvement of a builder/contractor at the early stages of design with the design team. Various authors have divergent views as to what buildability is. Gray (1983) posits that buildability is a method of analyzing to discover the potential construction problems within a particular project, to assess adequately the implication and to cover the risks involved. Mbamali et al. (2005) define the extent to which a building design facilitates the ease of construction as buildability: a British term, or constructability: an American term which is defined as the grouping of similar work components and the use of modular dimensions in design to reduce construction cost. Constructability is the optimum use of construction knowledge, experience in the conceptual planning and field operations, detail engineering and procurement to achieve project objectives (Nima et al., 2001). Buildability could be said to be identifying potentials that will render a design not buildable.

2. CONCEPT OF BUILDABILITY

The Construction Industry Research and Information Association (CIRIA) (1983) define buildability as the extent to which a building design facilitates ease of construction subject to the overall requirement of the completed building. This definition points out salient features of buildability, which indicate that there are a number of requirements to consider in a design before it could be said to be buildable.

The current practice of execution of project in Nigeria does not encourage the process of buildability. Constructors are not involved during the crucial stages of building conception. The practice in the conventional system can still enhance buildability by allowing an agreed period of delay at the inception of construction during, which the contractor could examine the drawings and put forward his comments in form of queries on the details. Olusola et al (2002) however opines that while this practice is acceptable, it still does not provide the complete solution required, since there must be a professional working on behalf of the client who should provide the construction details to minimize the unambiguous aspects of the construction projects.

Mbamali et al (2005) while expanding on the definition of CIRIA declare that buildability requirement is however one of the major factors necessitating the integration of construction experience into building design. Further, the principle entails bringing together the technical experience of a builder/constructor and the design experience of architects and engineers early enough at the design stage of a project. For ease of construction at every design stage the requirement for buildability is kept fresh in the mind. Upon integration into design the result is technical efficiency of the design with resultant effect on construction reflecting:

- (i) Good geometry/layout of the building – functional design,
- (ii) Design details – adequate consideration of the construction implications,
- (ii) Construction methods – the best technological methods of the construction processes culminating in minimization of waste, optimization of site labour and plant utilization.

2.1 Factors affecting Design Buildability

Several authors (Trigunarsyah, 2004 and Arditi et al., 2002) have discussed factors affecting design buildability. They are shortfalls that render the design practically not buildable or difficult to build. These include: tolerance; variety reduction; conversion; handling; repetition; dimensional coordination; personnel skills, and tools and equipment. These factors are discussed below:

2.1.1 Tolerance:

All components are likely to change slightly in relation to each other and it is important to be aware of the allowable deviations in the positions of components. Tolerance is affected by difference in behaviour and buildability of material components and sub-assemblies. The major factor to note during off-site fabrication is the provision of allowances for on-site fixing. In situations where the tolerance provided is not appropriate, two steps might be taken: re-fabrication or forging to allow for appropriateness. Arditi et al. (2002) suggest that faulty working drawings and incomplete specifications are the major constraints relative to constructability of designs, when dimensions are not accurate.

2.1.2 Variety Reduction:

Due to the high risk exposure of construction activities as a result of complexity the concept of unnecessary activities in the process of construction comes to focus. Personnel may have to learn many different assembly techniques or specialist personnel may have to be brought in. Tools, plants and equipment may lie idle for long. Designers are to ensure that buildings are dimensionally coordinated, preferably on the modular principle and that a system of preferred dimensions is used.

2.1.3 Conversion:

This is the process of standardization of materials either on-site or off-site into components and into sub-assemblies i.e. single integration in construction. The resultant effect of this factor is the achievement of variety reduction and it complements (facilitates) buildability.

2.1.4 Handling:

Handling of components is important in establishing “handling” precedence, last on, first off. Pre-cast concrete units are of different sizes and they must be loaded onto the delivery vehicle in the correct order from off-loading and transferring into the building.

2.1.5 Repetition:

The objectives of interest here are the achievement of organization processes necessary during the preparation and assembly stages and refinement of design solutions. Efficiency at work is attained when personnel understand properly the task they are to perform; tools, plant and equipment can be matched accurately to the work and interface thoroughly designed.

2.1.6 Dimensional Coordination:

When simplification of materials, components and sub-assemblies have been achieved, buildability would be enhanced if components and sub-assemblies are related to each other according to a set of geometrically and dimensionally coordination principles. Example is the supply of ceiling materials based on multiple of 100 mm; this will dictate the design geometry of the ceiling.

2.1.7 Skills:

The level of the skills of the constructor (his crew) and the designer affects greatly the ease at which a design is being constructed. Highly skilled personnel, those with advance constructional technology might not have it difficult to construct a design. It is apparent that this will reflect in the cost and duration of the project which should be as scheduled.

2.1.8 Tools, Plant and Equipment:

The availability of tools, plant and equipment increases productivity, and curbs the loss that would have accrued from employing large number of highly skilled but expensive tradesmen. Examples are the more powerful and versatile version of portable power tools e.g. hammer-action masonry drills, portable circular saw and range of specialized tools or of purpose-made adaptations to standard tools e.g. floated, troweller, surface grinders and circular cutters. These speed up and facilitate ease of production.

3. RESEARCH METHODOLOGY

Data for the study was obtained from a survey conducted in state capitals in Nigeria. There are 36 states in Nigeria and thus 36 state capitals were visited to collect data from firms, as construction activities are negligible in the rural areas of the country. A total of 100 questionnaires were administered and 86 were returned completed and were analysed, which equates to a 86% response rate. The sample consisted of Architects, Builders, Engineers, Project Managers, and Quantity Surveyors. A well structured questionnaire was used to obtain data from all parties involved. Projects which were completed newly were used as case study.

Table 1 indicates the characteristics of the respondents surveyed. 40.7% of the respondents were involved with the building sector. Builders, architects, and quantity surveyors predominated in terms of discipline. 46.5% of respondents had 11-15 years' experience, and a further 20.9% had 6-10years' experience. MSc / MTech level (34.8%) qualifications ranked marginally first in terms of qualifications followed by BSc / BTech (31.4%), and HND (19.8%). MNIOB (24.4%) predominated in terms of professional association.

31.4% of respondents had undertaken 6-10 projects, and 24.4% had undertaken 11-15 and also 16-20 projects. The professional's qualification, number of projects undertaken, years of experience, and the academic qualification of respondents suggest that data obtained from the respondents can deemed reliable. The mean score and frequency distribution were used for the analysis of the data for the study.

Table 1: Background information of respondents

Sector involved with	Frequency	Percentage (%)
Type of organisation		
Architect	22	25.6
Building	35	40.7
Civil	12	14.0
Quantity surveying	17	19.7
Total	86	100.0
Discipline of respondents		
Architect	21	24.4
Builder	33	38.4
Engineer	11	12.8
Quantity surveyor	16	18.6
Total	81	94.2
System	5	5.8
Years of experience		
⩽ 5yrs	15	17.4
6-10yrs	18	20.9
11-15yrs	40	46.5
16-20yrs	7	8.1
> 20yrs	6	7.0
Total	86	100
Academic qualification		
ND	6	7.0
HND	17	19.8
BSc / BTech	27	31.4
MSce / MTech	30	34.8
PhD	6	7.0
Total	86	100

Professional affiliation		
MNIQS	9	10.5
MNIOB	21	24.4
MNSE	8	9.3
MNIA	11	12.8
FNIQS	5	5.8
FNIA	5	5.8
Total	59	68.6
Number of projects undertaken		
1-5	12	14.0
6-10	27	31.4
11-15	21	24.4
16-20	21	24.4
> 20	5	5.8
Total	86	100.0

3.1 Data Presentation and Analysis

The mean years of experience was 14 and over 89% of them have over 6 years of experience indicating that they are knowledgeable in the field and that information supplied by them could be relied on (see Table 2).

Table 2: Years of experience

Years of experience	**No. of respondents**	**Percentage (%)**
1 – 5	11	13
6 – 10	18	21
11 – 15	24	28
16 – 20	17	20
21 – 25	6	9
26 – 30	7	8
31 – 35	2	1
Total	86	100

The most important buildability factor is the client's brief, with a weighted mean (Wt Mn) score of 0.229, while ease of construction with a Wt Mn score of 0.220 is ranked second. Cost is ranked least with a score of 0.158. The client's brief forms the basis of design and ease of construction indicates the level of buildability of the design. Cost of the project does not really affect design buildability (see Table 3).

Table 3: The Importance of Buildability Factors

Buildability factors	Ratings				Weighted frequency	Weighted Mean	Ranking
	4	3	2	1			
Clients brief	42	22	22	0	278	0.229	1
Functionality	39	22	25	0	249	0.205	3
Aesthetics	22	36	25	3	226	0.186	4
Ease of construction	39	25	14	8	267	0.220	2
Cost	14	14	39	19	45	0.158	5

The respondents' opinion on the factors that influence buildability of design, complexity of the project with Wt Mn score of 0.233 is most influential. It can, however be concluded that, designers are concerned more about the magnitude of the project in deciding the ease of construction. This is followed by the professional knowledge about construction incorporated at the design stage, which has a Wt Mn score of 0.214 (see Table 4).

Table 4: The Influence of Buildability Factors

Buildability factors	Rating					Weighted frequency	Weighted Mean	Ranking
	5	4	3	2	1			
Complexity of the project	5	8	20	0	0	382	0.23	1
Cost economic value	8	1	39	19	8	249	3	5
Project duration	6	4	8	14	6	318	0.15	4
Professional knowledge	2	3					2	
about construction	8	0	17	8	0	352	0.19	2
							4	
Materials available	4	1	8	6	3	342		3
	2	9					0.21	
							4	
	2	4					0.20	
	7	2					8	

Among factors influencing buildability of design, simplicity of design ranked first. When a design is simple it will be easy to construct. The technology and process will be easily selected and applied. Standardization and dimensional coordination ranked second among factors that makes a design easily buildable. This factor enables high speed of construction. The use of single integrated elements ranked least, and it has the same advantage as the second influencing factor (see Table 5).

Table 5: Ranking of the influence of factors on buildability of design

Factors	Rating			Weighted frequency	Weighted Mean	Ranking
	3	2	1			
Standardization and dimensional coordination	58	17	11	219	0.361	2
Simplicity	69	0	17	224	0.370	1
Use of single integrated elements	19	39	28	163	0.269	3

Relative to the approaches to buildability of design, incorporation of a constructor at the early stages of design has the highest ranking with a Wt Mn score of 0.304. This will eliminate the cost of training up engineers and architects extensively in construction technology thereby saddling them with too much responsibility, which is contrary to the second ranked factor of training architects and engineers in building construction methods and site operations (see Table 6).

Table 6: The approaches to buildability of designs

Approaches	Rating				Weighted frequency	Weighted Mean	Ranking
	4	3	2	1			
To train architects and engineers extensively in building construction methods and site operations.	36	39	11	0	283	0.294	2
Incorporate a constructor at the early stage of building design.	41	39	6	0	293	0.304	1
Use of the design and build system of contract	19	42	14	11	229	0.238	3
Making use of international standardization and dimensional coordination.	11	0	39	36	158	0.164	4

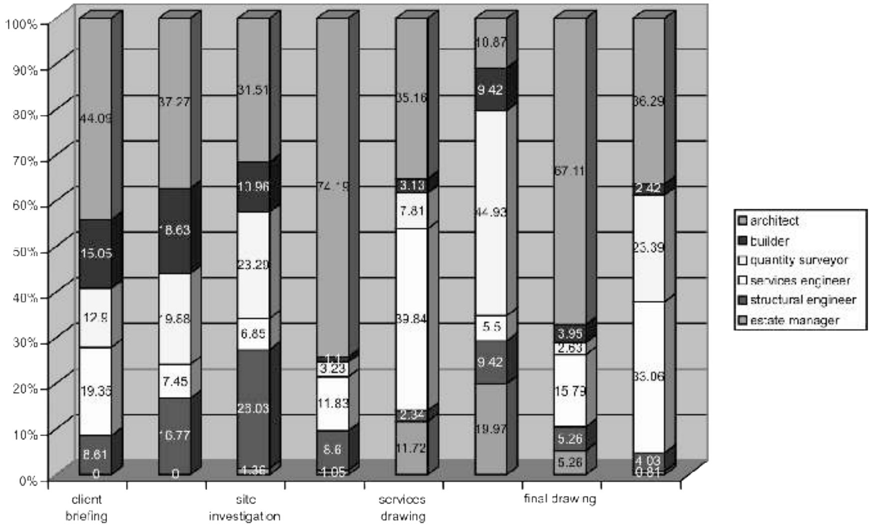

Fig.1: The involvement of professionals at various stages of design

Figure 1 reveals the current practice of buildability at various stages of design in Nigeria. It can be seen that the architect alone carries out the majority of the work involved at the preliminary stages of the project while the builder only has little input at this stage. Other professionals are seen to be involved in the various designs. This reveals to some extent reasons for building collapse in Nigeria as the experience of the constructor is not integrated at the early stages of a project (design stage).

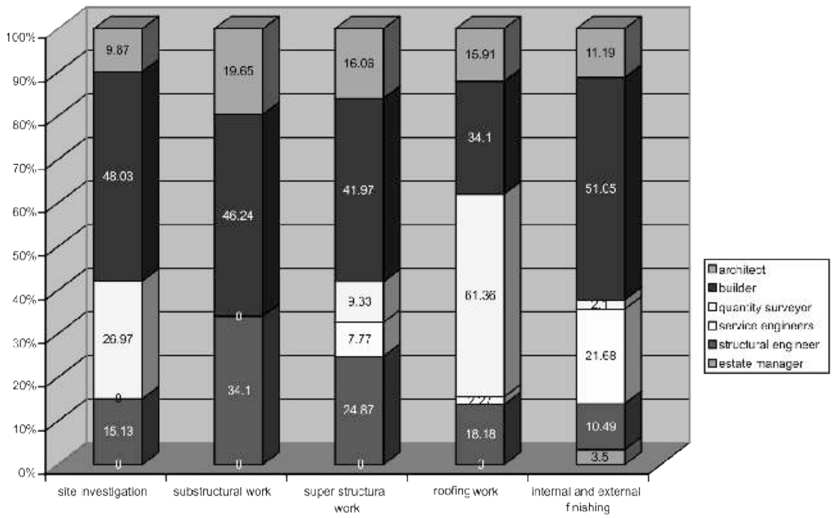

Fig.2: The extent of involvement of professionals at construction stage of building project

Figure 2 presents the involvement of professionals at the construction stage of a building project. It can be observed that the builder does most of the work at various stages of the project. His involvement at site investigation equals 48.01%, substructure level 46.25%, superstructure level 41.99%, at the finishing stage 31.14%. At the roofing stage, it could be argued that a mistake was made in filling out the information. Quantity surveyors involvement at work should be 2.27%, while the builder's involvement should be 61.35%. Contributions of other professionals at the stages of construction are minimal. The quantity surveyor is seen to be performing some functions at this stage, since he has to prepare interim valuation and give cost advice. The structural and services engineers are also involved at this stage but at a much less level of involvement, as they are to oversee the structural and services work of the constructor, while the architect supervises the construction.

3.2 Discussion

Fisher and O'Connor (1991) report that construction productivity improved by 24% when the design process was reviewed relative to constructability factors. This suggests that the ease of construction was enhanced reviewing designs with regards to constructability factors. The factor rated into the second place in terms of ranking regarding important factors of buildability in this study. This fact is buttressed by the study of Poh and Chen (1998) that established a positive correlation between productivity and buildability in Singapore, based on buildability score calculated by buildable design appraisal system (BDAS). Defective design has been revealed as one of the causes of late delivery of projects Andi and Minato (2004) and Al-Momani (2000). Designs that considered constructability reviews are likely to be more buildable, reduce re-work and lead to early completion.

Relative to influence of buildability factors, complexity of the project was rated by respondents as main factor that influence buildability of design. Chan (2007) says that designd that did not take account of buildability reviews at production stage adversely affects quality of the product. Low (2001) reports a positive relation between buildability and structural quality of products of a study undertaken. During the process of buildability review expert knowledge are brought to bear relative to simplifying complex design to enable buildability. The various methods for ease of construction are identified and documented. This study point, that simplicity of design is the outcome of the consideration of buildability review on design.

This study identified that the best approach to achieving buildable design is to incorporate a constructor at the early stages of building design. This corroborates the legal obligation relative to construction regulations to ensure that their designs are safe to build. This stems from observations that 60% of fatal accidents were traceable to decision and choices made before the project began (OGC, 2007).

Therefore, it can be deemed that buildability reviw afford ease of construction, eliminates re-work, and enhance eary completion of projects.

4. CONCLUSIONS

The professionals involved in the design of project are mainly the architect, structural and services engineer. It is established that the experience of a constructor is not brought into design early enough in the process of project execution. The research has shown that the factors that affect buildability of design are client's briefing, simplicity of design and the integration of a constructor at the early stages of design. It is recommended that constructors should be integrated at the early stages of design. Designers' should device a means of adequately capturing the intentions of clients relative to the type of facility to be built. Designs should be functional and ensuring correspondence of dimensions.

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