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Evaluating the Features of Buildability and Maintainability of Architectural Designs in Jos Metropolis, Nigeria

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ABSTRACT
The construction industry is faced with challenges from design, construction and maintenance of a facility. The study investigates the characteristics of buildability and maintainability analysis of architectural designs with a view of promoting effective project delivery and maintenance. Relative Importance Index (RII) and ranking method were used to determine the most important factors or features of buildability and maintainability that improves and promotes efficient project delivery. The study reveal that the five (5) top buildability and maintainability factors are as follows: personnel skill, handling, details, dimensional/modular coordination and conversion. The study also identified lack of awareness of clients, unskilled professionals using foreign technology and adopting such technological advancement on current designs, lack of good law/enforcement on building practice in Nigeria, problem of monitoring and supervision by relevant government agency, compromising of building standards and the use of inferior materials in construction as some of the factors affecting the implementation of buildability and maintainability analysis in architectural designs. The study concludes that most approved building project designs in Jos metropolis contain one or more buildability and maintainability problems, thus, the research recommends an enlightenment campaign for key project stakeholders with respects to the adoption of buildability and maintainability principles and practices so as to take advantage of its benefits in improving project delivery.

Keywords: Architectural designs, Buildability, Construction, Maintainbility, Project Delivery

INTRODUCTION
The construction industry is faced with challenges from design, construction and maintenance of a facility. Buildability and maintainability evolved to solve these challenges which entail the process of minimising or removing waste and wasted efforts before construction activities commence on site. Traditional procurement paradigm is one of the construction methods that contributes to these challenges through the separation of design from construction. The separation of design from construction has been identified as a problem of barrier affecting the implementation of buildability practices in construction projects (Wong, Lam, Chan, & Shen, 2003; Bamisile, 2004). According to Aina (2015), the predominant procurement process in Nigeria is the traditional method with the hallmark of separating design from construction and non-participation of the construction team in the pre-constract stages of project evolvement. Most of the construction projects in Nigerian construction industry are still being executed through the traditional procurement method. The integration of construction into the design process provides benefits and solutions to achieving the design goals in a cost effective and timely manner (Abbas, 2014). The concept of buildability started in the late 1970s, it entails the integration of design, construction and operation of constructed facility for the purpose of increasing cost efficiency, quality of projects and meeting project objectives in the construction industry (Nawi, et al, 2009).

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The separation of design and construction leads to the problems of buildability. The poor buildability and maintainability analysis of designs has resulted in high cost of construction and difficulty in the maintenance of building projects. The separation of design from construction in traditional procurement is a fertile ground for occurrence of buildability problems (Aina, 2015). The purpose of buildability is to enhance efficiency in construction project delivery, reduce redundancies, wasted time and wasted efforts. This study is framed in the context of these issues. Thus, the study aims at evaluating the features of Buildability and Maintainability of architectural designs with the view to promoting effective building project delivery and maintenance. The aim was achieved by evaluating the buildability features of designs for building project, evaluating the maintainability features of building design, identifying the factors militating against the incorporation of buildability and maintainability features in building designs.

LITERATURE REVIEW

EFFECT OF BUILDABILITY AND MAINTAINABILITY PROBLEMS

Buildability affects various participants of the project as well as the progress of the project in numerous ways (O' Connor, 1985) in Amawu (2016). Serious buildability problems affect project cost and even become a social problem due to future repairs, inconveniences and other perils, including safety (Rimer, 1976) in (Aina, 2015). By using the buildability concept as a means to improve the construction industry, many ideas have been put forward by various researchers to remove the disadvantages of separating the design and construction process (CIRIA, 1983; CII, 1986; Tatum, 1987) in Oti (2013). According to Aina (2015), the occurrence of buildability problems during the implementation phase of a construction projects provides a fertile ground for negative issues to take place, some of which include delay, rework, errors, time and cost overruns, litigations, building collapse and in some cases total abandonment. The main indicators for project performance during the project implementation are quality, cost and probably schedule. Studies have been conducted in order to strive for better project quality performance through improving buildability. Francis, Chen, Mehrtens, Sidwell, and McGeorge (1999) found that good buildability leads to early completion of projects; Abass (2014) concluded that education and training on buildability are not provided to designer, lack of effective management response, the lessons-learned that arising from maintenance field is not documented, lack of buildability review for design, inadequate contractor resource, and inadequate designer technical knowledge are the most significant problems in buildability;

Jergeas and Van der Put (2001) showed that much savings could be achieved in project costs and costs of change orders through buildable designs. Aina (2015) concludes that the impact of buildability problems on project delivery are inability of clients to get value for money spent, poor serviceability, functionality and structural instability and high component failure and high risk in building usage. The results of good buildability projects are enormous, for example, the clients could have their building project completed within time and budget, without additional major costs to variation, minimum disruption, efficient operation on site, and aesthetically and functionally pleasant. The designers

could have less design problems on site during construction as well as when commissioning since their designs will have been evaluated base on the operational requirements on site. The objectives of buildability and maintainability analysis according to Obiegbu (2005) are reduction in the construction cost and increased productivity, reducing the production duration and avoiding abandonment, improving the project quality, reducing waste such as excessive cutting of components, reducing risks inherent in construction projects, making the construction process as easy and simple as possible, maximizing the use of site plants, discovering potential construction problems, assessing their implications and devising appropriate construction methods. The buildability and maintainability report of a Builder should include among others, the following; dimensional coordination; tolerance; discrepancies, omissions; errors; variety; conversion; handling; personal skills, details; spare parts, access for maintenance; guidelines for maintenance; buildability and maintainability factors and general comments/suggestions (Bamisele, 2004).

FACTORS THAT CAUSE BUILDABILITY PROBLEMS

Wong et al. (2006) in Abass (2014) listed the below main factors that causes the buildability problem due to designers

1. Lack of knowledge.
2. Experience in construction.
3. Designing without input or the involvement of contractors.
4. Projects with increasingly demanding coordination.
5. Requirements i.e sophisticated building services and building automation systems.
6. An ignorance of contractors' proposed changes, a lack of communication between the parties involved.
7. Time taken for a plan to be approved by the government.
8. The tight timeframe for designing and tendering has also resulted in designers and tenderers not having enough time to prepare careful designs and pricing, respectively.

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THE CRITERIA OF GOOD MAINTAINABILITY

Bamisile (2004) opined that for maintenance to be effective, a number of criteria must be observed by a builder during the buildability and maintainability analysis of the production information. These criteria include the following:

1. There must be a good access to those parts of the building requiring maintenance, especially the buildability services.
2. Such access must be safe to use for maintenance.
3. Dismantling, not breaking in, must be straight forward.
4. It must be easy to fix the new parts.
5. Reassembly, not rebuilding must be straight forward.

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6. Spare parts of essential requirements and replacement must be readily available.
7. Isolation of mechanical and electrical sub-systems must be possible.

These studies did not consider the features of these problem with respect to construction industry in Jos metropolis and this study covers only architectural designs for both buildability and maintainability analysis problems.

RESEARCH METHOD

The study was conducted with data that was obtained through a sample survey conducted with questionnaire and oral interviews. The questionnaire was structured according to the objectives of the study. The first section was designed to obtain information about the demography of the respondents. The rest part was structured in such a way that it enabled the study to capture the relevant information needed to identify or evaluate the buildability and maintainability features of designs for building projects, identify the factors militating against the incorporation of buildability and maintainability features in building designs. A total of fifty (50) questionnaires were administered among the selected population and thirty (30) were retrieved which were used for the final analysis. This was carried out by personal visits to the professionals, where oral interviews were also conducted. The following techniques were employed for data analysis; simple percentage method; relative Importance Index (RII). Simple percentage was used to analyse the first section of the questionnaire which comprise of the respondents' information. Importance Index (RII) was used to analyse section two of the questionnaire in which the response involve weight (Chekwa, 2015), they were analysed using ordinary ranking on a scale of 1-5. The numerical values assigned to the responses were VS-Very satisfactory as 5, S-Satisfactory as 4, AS- Averagely satisfactory as 3, US-Unsatisfactory as 2, NA- Not available as 1. It was thus evaluated through the expression:

$$RII = \frac{5n_1+4n_2+3n_3+2n_4+1n_5}{5N}$$

Where; N is the total number of respondents, $(n_1+n_2+n_3+n_4+n_5)$; n_1 is the number of respondents that marked 5, n_2 is the number of respondents that marked 4, n_3 is the number of respondents that marked 3, n_4 is the number of respondents that marked 2, n_5 is the number of respondents that marked 1.

The study area is Jos metropolise, Plateau State, Nigeria. Jos has become an important national administrative, commercial, and tourist centre. The "melting point" of race ethnicity and religion makes Jos one of the most cosmopolitan cities in Nigeria. There is massive infrastructural development embarked on by the state Government and a lot of building construction activities takes place because of their strategic location and growing population.

DISCUSSION OF RESULTS

Out of the fifty (50) copies of the questionnaires distributed, twenty (20) copies were not returned, which represents 40 % response rate and thirty (30) copies were returned back, which represents a response rate of 60%. This response rate is considered adequate as

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stated by Idrus and Newman (2002) in Amawu (2016) a response rate of 30 % is good enough in construction studies

Table 1: Demographic Information of Respondents

S/N	Item	Frequency	Percentage (%)
1	Profession		
	Architect	5	16.7
	Builder	11	36.7
	Quantity Surveyor	4	13.3
	Engineer	4	13.3
	Others	6	20
2	Academic Qualification		
	HND	5	16.7
	B.Sc./B.Tech	13	43.3
	M.Sc./M.Tech	10	33.3
	Ph.D.	0	0
	Others	2	6.7
3	Professional Qualification		
	Graduate Member		
	NIA	2	6.7
	NSE	3	10
	NIQS	2	6.7
	NIOB	7	23.3
	Others	4	13.3
	None	12	40
	Corporate Member		
	NIA	2	6.7
	NSE	1	3.3
	NIQS	2	6.7
	NIOB	5	16.7
	Others	1	3.3
	None	19	63.3
	Fellow Member		
	NIA	0	0
	NSE	0	0
	NIQS	0	0
	Others	1	3.3
	None	29	96.7
4	Years of Experience		
	1-10 years	19	63.3
	11-20 years	6	20
	21-30 years	2	6.7
	31 and above years	3	10

Table 1 shows the demographic information on respondents with regard to their profession, academic qualification, and professional qualification either as a graduate, corporate or fellow member and the years of experience. Builders are 11 of the respondents representing (36.7%), 5 were Architects representing (16.7%.), Quantity Surveyors and

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Engineers were 4 each representing (13.3%) each, while other professions were 6 representing (20%). Hence, it can be concluded that the highest respondents were Builders. The description of the respondents by academic qualification revealed that 5 of the respondents representing (16.7%) were HND holders, there were 13 B.Sc./B.Tech holders representing (43.3 %), 10 were M.Sc./M.Tech holders representing (33.3%), none has a Ph.D. representing (0%) of the respondents and 2 were of other qualifications representing (6.7%) of the respondents. This shows that majority were B.Sc. holders. Majority of the respondents are not member of their professional bodies. More than half of the respondents 19 (63.3 %) have working experience ranging from 1 – 10 years, 6 (20%) ranges from 11– 20 years, 2 (6.7%) ranges from 21 – 30 years and 3 (10%) have working experience ranging from 31 and above years. Majority have work experience ranging from 1-10 years which shows that the respondents are experienced in construction

Table 2. The assessment of project designs based on the buildability criteria/features is presented in the table below

S/N	Observation	Projects											
		1	2	3	4	5	6	7	8	9	10	Sum	Mean
1	Dimensional/Modular Coordination:	3	3	3	5	3	4	3	4	3	3	34	3.4
2	Tolerance:	2	3	3	2	2	3	3	3	4	3	28	2.8
3	Discrepancies:	3	3	5	3	3	4	5	5	5	5	41	4.1
4	Omissions:	3	5	4	4	3	4	3	4	5	3	38	3.8
5	Error:	3	2	5	3	2	5	3	5	5	3	36	3.6
6	Variety:	5	4	4	5	4	5	4	5	5	4	45	4.5
7	Conversion:	4	5	5	4	5	5	5	5	5	5	48	4.8
8	Handling:	3	3	3	3	3	3	3	3	3	3	30	3
9	Personnel Skill:	3	3	3	3	3	3	3	3	3	3	30	3
10	Details:	2	3	2	2	1	3	3	3	3	2	24	2.4

Table 2 shows the result of the buildability analysis carried out on ten (10) approved designs of building projects. Some factors (observation) were given an average score of 3 (averagely satisfactory) out of the rating scale of 1-5, because the researcher was not on site during the construction of the building. The factors include; handling and personnel skills. Details with a mean of (2.4) and tolerance with a mean of (2.8) indicates that all the designs has insufficient details and no much tolerance thereby, causing buildability problems. There are no much buildability problems with regard to conversion with a mean of (4.8), variety with a mean of (4.5) means there is no too much variety and discrepancies with a mean of (4.1) also means

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there is no much discrepancies. Omissions with a mean of (3.8) and errors with a mean of (3.6) need also be works upon so as to increase the level of buildability of building designs.

Table 3. The assessment of perception of professionals based on the buildability criteria is presented in the table below.

S/N	Buildability Factors	VS	S	AS	US	NA	Relative Importance index	Rank
1.	Personnel Skill	6	12	10	2	0	0.75	1
2.	Handling	7	10	10	3	0	0.74	2
3.	Details	5	15	5	4	1	0.73	3
4.	Dimensional/Modular Coordination	2	17	8	1	2	0.71	4
5.	Conversion	3	8	15	3	1	0.66	5
6.	Tolerance	0	12	15	2	1	0.65	6
7.	Variety	1	12	10	5	2	0.63	7
8.	Discrepancies	2	8	10	9	1	0.61	8
9.	Omission	1	7	11	10	1	0.58	9
10.	Errors	1	6	12	10	1	0.57	10

Table 3 shows that the five (5) top buildability factors are as follows: personnel skill was ranked first with a relative importance index of 0.75, followed closely by handling with a relative importance index of 0.74, details was ranked third with a relative importance index of 0.73, dimensional/modular coordination was ranked fourth with a relative importance index of 0.71 while conversion completed the top five with a relative importance index of 0.66.

Table 4. The assessment of project designs based on maintainability criteria is presented in the table below

S/N	Observation	Projects											
		1	2	3	4	5	6	7	8	9	10	Sum	Mean
1	Spare Parts:	4	4	5	4	5	5	5	5	5	5	47	4.7
2	Access For Maintenance:	1	1	1	1	1	1	1	1	1	1	10	1
3	Guidelines For Maintenance:	3	3	3	3	3	3	3	3	3	3	30	3

Table 4 shows the result of the maintainability analysis carried out on ten (10) approved designs of building projects. Guidelines for maintenance was given an average score of 3 (averagely satisfactory) out of the rating scale of 1-5, because the researcher was not on site during the construction of the building and at the time of completion. Access for maintenance with a mean of (1) indicates that all the ten (10) designs has no safe access for the maintenance of roof and plumbing services, therefore, there will be difficulties in carrying out maintenance.

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Table 5. The assessment of perception of professionals based on the maintainability criteria is presented in the table below

S/N	Maintainability Factors	VS	S	AS	US	NA	Relative Importance index	Rank
1	Access for maintenance	3	10	11	3	3	0.65	1
2	Spare parts	2	5	17	4	2	0.61	2
3	Guidelines for maintenance	2	8	7	8	5	0.56	3

Table 5 shows that the three (3) maintainability factors are as follows: Access for maintenance was ranked first with a relative importance index of 0.65, followed by Spare parts with a relative importance index of 0.61 and Guidelines for maintenance was ranked third with a relative importance index of 0.56.

Table 6: Description of the awareness of the Respondents about the concept of Buildabiliity and Maintainability

S/N	Variable	Frequency	Percentage (%)
5-Extremely		9	30
4-very Aware		18	60
3-Moderately Aware		3	10
2-Slightly Aware		0	0
1-Not at all aware		0	0

Table 6 shows that 9 (30%) of the respondents were extremely aware of the concept of buildability and maintainability, 18 (60%) of the respondents were very aware, 3 (10%) were moderately aware, none of the respondent was slightly aware and none of the respondent was not aware at all of the concept of buildability and maintainability. This shows that all the respondents were aware of the concept of buildability and maintainability.

Table 7: Description of the Respondents level of application of Buildability and Maintainability Concept

S/N	Variable	Frequency	Percentage (%)
5-Almost Always		10	33.34
4-Sometimes		16	53.33
3-Every once in a while		3	10
2-Rarely		0	0
1-Never		1	3.33

Table 7 shows that 10 (33.34%) of the respondents were almost always involved in the application of buildability and maintainability, 16 (53.33%) of the respondents were sometimes involved in application of buildability and maintainability, 3 (10%) were involved in the application of buildability and maintainability every once in a while involved in the application of buildability and maintainability, none (0%) of the respondents is rarely involved in the application of buildability and maintainability and 1 (3.33%) of the respondents had never been involved in its application. This showed that

large percent of the respondents have been involved in the application of buildability and maintainability.

FINDINGS/CONCLUSION

The study also revealed that the five (5) top buildability and maintainability factors are as follows: personnel skill, handling, details, dimensional/modular coordination and conversion. The following factors if not check carefully, makes building designs unbuildable. The three (3) maintainability factors are as follows: Access for maintenance, Spare parts and Guidelines for maintenance. Most designs have no safe access for the maintenance of roof and plumbing services, therefore, there will be difficulties in carrying out maintenance. The following were identified as the factors affecting the implementation of Buildability and Maintainability practice in Nigeria.

1. Lack of awareness of clients.
2. Unskilled professionals using foreign technology and adopting such technological advancement on current designs.
3. Lack of good law/enforcement on building practice in Nigeria.
4. Problem of monitoring and supervision by relevant government agency.
5. Compromising of building standards and the use of inferior materials in construction.
6. Cost overrun on projects.
7. Highly Fragmented nature of the building construction industry.
8. Lack of cooperation by professionals in the building construction industry.
9. Non approval of the National building code by the National assembly.
10. Lack of maintenance considerations at the design stage.
11. Involvement of non-professionals in the building construction industry.
12. Government policies.
13. Exclusion of Builders at the design stage of projects.
14. Lack of site investigations before design.

Based on the research findings, it can be concluded that most approved building project designs in Jos metropolis contain one or more buildability and maintainability problem. Therefore, if all building designs will undergo a buildability and maintainability analysis then most of the problems that arises during the construction of the building would have been avoided. The study recommends that clients should not be resisted to the buildability and maintainability programme. Sufficient fund must be budgeted for construction work and design must be of the standard one. Both designers and contractors should be aware of construction technology. The parties involved in the construction project should be aware of buildability and maintainability concepts. The communication skill among the parties involved must be effective. Also, those causes of buildability with high impact on the construction project must be understood by all the parties involved in the construction of the project. In this regard, to enhance buildability and maintainability practices, the need for buildability and maintainability analysis by the professional responsible for the management of the building production process in Plateau state and Nigeria at large is recommended on all building projects. Furthermore, the research recommends an

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enlightenment campaign for key project stakeholders with respects to the adoption of buildability and maintainability principles and practices to take advantage of its benefits.

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