BUILDABILITY PROBLEMS IN CONSTRUCTION PROJECTS IN NIGERIA; CAUSES AND IMPACTS

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Abstract

Adoption of buildability concepts has contributed to improved project delivery processes in the U. K, US and other countries. However, in Nigeria, the neglect of this concept shown by the preference accorded the traditional separation of design and construction has created fertile grounds for occurrence of buildability problems with its attendant effects. Determination of the causes of these problems in construction projects and their impact were the goals of this research. The study was conducted with questionnaire administered on sixty project managers of on-going building projects in Lagos, Nigeria. The respondents were required to evaluate causes of buildability problems in construction projects on a five- point likert scale and acted as a panel for analytical hierarchical process (AHP) for assessing impact of identified causes on the construction process. Findings revealed that the prominent causes of buildability problems were insufficient data and project drawing information, poor specification and choice of materials and inadequate project scope definition. Ranking of the AHP vectors revealed that impact of buildability problems on project delivery were mainly felt as 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. These findings corroborated the culpability of the gulf between design and construction as the main cause of buildability problems and increased cost to clients.

Keywords: Buildability, causes of buildability problems indices (CBPI), analytical hierarchical process (AHP)

Introduction

The concept of constructability/buidability evolved in the late 1970s for integrating design/engineering, construction and operating knowledge for the purpose of increasing cost efficiency, quality of projects and optimum project objectives in the construction industry (Nawi, *et al*, 2009, Trigunarsyar, 2004). Nations and local construction industries that embraced these concepts have either infused them into their procurement processes or evolved novel procurement options reflecting and delivering benefits of the new knowledge. For example, in two decades of its evolution, constructability concepts have been highly developed and applied in the USA, UK and Australia (Nawi, *et al*,2009). Studies have also demonstrated that improved constructability has resulted in significant savings in both cost and time required for completing construction projects in these countries (Russel et al, 1992, Jergeas and Vender Put, 2001)

Furthermore, the construction industry in the USA in its improving process was reported to be gradually showing preference for integrated project delivery options as championed by constructability concepts. There were also surveyed indicators that the USA construction industry was responding to the benefits of integration. (Arditi, 2002)

However, in developing countries like Nigeria, often referred to as an emerging economy, the procurement process for construction products is still predominantly traditional, with the hallmark of separation of design and construction and almost absolute non-participation of the construction team in the pre-contract stages of project evolvement. More than 60% of construction projects are still delivered through the traditional procurement mode (Ojo, 2010).

The non-participation of construction experts at the design/pre-contract stage of projects is not only because of predominance of the traditional procurement route. But it is more because of deep seated adversarial relationships among key participants in the project delivery process. It is more a case of professionals at the pre-contract stage protecting their traditional roles and displaying unearned versatility often shown in their being both the designer and the constructors thus counting other roles/participants as irrelevant in the project chain.

The separation of design from construction in traditional procurement option is indeed a fertile ground for occurrence of buildability problems. The predominance of this procurement option in Nigeria predisposes ample grounds for the occurrence of buildability problems. This background is the impetus for this research. The focus is to determine how buildability issues impact the construction process.

Impact of Buildability Problems on Project Delivery

The impact of buildability problem on clients is usually enormous, those with little project management experience are usually at a loss on how these issues should be handled and they can be says issues like this are usually vexing and time consuming to resolve. Particularly, in the face of the time pressure clients usually face by prospective occupants of new facilities, clients sometimes end up bearing these costs.

Furthermore, serious buildability problems could impact a project enomously costwise and even become a social problem due to future repairs, inconveniences and other perils, including safety (Rimer, 1976). Occurrence of buildability problems in a construction project at the point of implementation is a fertile ground for occurrence of a myriad of negative issues, some of which include delay, rework, errors, time and cost overruns, litigations, building collapse and in the extreme case, outright abandonment.

Li and Taylor (2011) defined two kinds of extra work that undiscovered rework (which may be induced by unbuildable design) may cause. One is work that was not in the initial project scope but has to be completed to support those parts of the project that are related to the part being reworked. The other type is the work that was in the initial project scope and was initially installed correctly but needs to be reworked because it is closely related to a separate item being reworked.

To further underscore the impact of a design/construction altercation induced by buildability issues, Li and Taylor (2011) considered an example of an engineer who designed a highway project and made an error in sizing storm sewer pipes passing under the highway. This error was not identified at the design stage. During construction the wrong size pipes were installed underneath the pavement and the pipe sizing error was not discovered until after the placement of the pavement. In order to correct the pipe sizing error, the pavement above the pipe must be demolished (work that was completed correctly but required rework due to rework in adjacent systems) and the excavation must be shored (work that was not required as part of the original project scope). The summary is that in complex projects where activities are closely related to each other, the longer it takes to find a mistake, the more additional work can be created in the process of correcting the mistake and the more the total project performance can be degraded.

Research Methodology

The study was conducted with primary data obtained through a sample survey conducted with questionnaire and interviews. The questionnaire was structured according to the objectives of the study. The first section was designed to identify causes of buildability problems in the construction industry. The causes of buildability were categorized into three main headings, namely; causes at the inception stage, design stage and at construction stage. These categories have combined thirty sub categories. These causes of buildability problems were presented to sixty project managers on construction sites in Lagos, Nigeria. The project managers were asked to rank these causes of buildability problems on a Likert scale of 1-5. On this scale, 1, 2, 3, 4 and 5 represented very low, low, average, high and very high occurrence respectively. The preference of the project managers were used to calculate causes of buildability problems indices (CBPI). For the CBPI, the total weight value for each criterion was obtained by summing the product of the number of responses for each rating to a criterion and the respective weight of the value is expressed as

TWV = ¢ z P λ í ....(1)

Where TWV is the total weight value, Pi is the number of respondents rating criterion I and Vi is the weight attached to criterion i. the CBPI for each criterion was derived by dividing TWV by the total number of respondents.

CBPI = ü zñz / _ …………………………………………............. (2)

The second objective of this study was to determine the impact that buildability problems had on the construction process. The analytical hierarchical process (AHP) was adopted to analyze these impact because of its strength in eliciting accurate qualitative data.

The AHP approach involves decomposing a complex problem into a multi-level heirachical structure of characteristics and criteria, these criteria are simply such as those used in a Likert ranking types of variables. The process of data collection for the AHP involves pair-wise judgments/evaluation of the criteria by the judging panel (Project managers in this case). Some of the advantages of the AHP includes:

- AHP can accommodate subjective and objective data very well (Islam, 2005). AHP compares two decision elements (criteria/alternative) at a time. In this way the decision maker becomes more focused and consequently the accuracy and reliability of the results are improved. As Chan and Lynn (1991) wrote: The use of the AHP for multi-criteria rating is superior to other multiple attribute scoring models or to ad hoc weighing because it has the advantage of forcing the decision marker to focus exclusively on two objects at a time and the way they relate to each other, which is a simpler and more manageable process than comparing five, twelve objects simultaneously.

The AHP measuring scale

AHP uses pair-wise comparison of alternatives or variables (Saaty, 1990). This requires the decision marker to express their opinion about the value of a single pair-wise comparison at a time using what Saaty (2001) called a fundamental scale (Table 1). The fundamental scale is a one-to-one mapping between the set of discrete linguistic choices available to the decision maker and a discrete set of numbers which quantify the linguistic choices (Oladapo 2011).

In comparing criterion A to criterion B, a decision maker may determine from the scale in table 1 that A is of “very strong” importance than B and accordingly assign a relative importance value of 8 to A. This measures that the value of the relative importance of B to A is $^1/_8$. The quantified judgments on pairs of criteria c in cj (pair wise comparisons) are presented by an n x n matrix.

A = $(ay), i, j =$ 1, 2, 3 ….h ---------------------------------- (3)

The entries ay are defined by the following entry rules.

Rule 1, if ay = a, then $a\mu = {}^I/_a$, a ≠ 0

Rule 2, If Ci is judged to be of equal relative importance to Cj, then ay = $a\mu$ = 1, ay = 1 for all i

Thus the matrix A has the form:

$$A = \begin{pmatrix} 1a_{12} \ldots\ldots\ldots\ldots (a_{in}) \ldots\ldots\ldots \\ 1/a_{12}\ 1 \ldots\ldots\ldots (a_{2n}) \ldots\ldots \\ 1/a_{in} \quad 1/a_{2n} \ldots\ldots\ldots\ 1 \end{pmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4)}$$

Where ay is the relative importance of criterion i to criterion j, having recorded the quantified judgments of comparisons on pairs (Ci, Cj) as numerical entries ay in the matrix A.

Table 1: AHP Fundamental Scale

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally
2	Weak	Between equal and moderate
3	Moderate importance	One activity slightly farvoured above other
4	Moderate plus	Between moderate and strong
5	Strong importance	Strongly favour one activity above other
6	Strong plus	Between strong and very strong
7	Very strong or demonstrated importance	Very strongly favoured one activity above other/dominance is demonstrated
8	Very, very strong	Between very strong and extreme
9	Extreme importance	Highest affirmation favouring one activity above the other

Source Saaty (2001)

To find the weight of each criterion included in the ranking analysis, the eigenvector corresponding to the maximum eigenvalue is determined from matrix analyses. The principal eigenvector is computed and normalized to give the vector of weight.

Data Analysis and Discussion of Findings

Causes of buidability problem

Thirty causes of buildability problems under three main categories were presented to project managers in this survey for assessment. The overall result is presented in Table 2. Among the causes of buildability problems, insufficient data and drawing information was ranked as the most important causes of buildability problems on the construction sites surveyed. The study established that its causes of buildability problems indices (CPBI) was 3.30, poor specification and choice of materials ranked next in importance to this with CPBI of 3.26. Other prominent causes of buildability problems were inadequate project scope definition and briefing, inaccurate drawing scale, design and detailing, lack of builders' /contractors' input in design and budget based on incomplete data and fragmented decision making. These all have CPBI of 3.20, 3.10, 3.10 and 3.10 respectively. The average CBPI for the three categories of buildability problems were 2.67, 2.68 and 2.32 for the inception stage, design stage and construction stage respectively. This result established that design and inception stages were the major sources of buildability problems and were thus ranked higher than the construction stage.

Furthermore, the prominent type of buildability problems in each category was considered. Under the inception stage category, inadequate project briefing and scoping ranked highest, (CPBI = 3.1) and poor estimating, functionality, viability and defect analysis (CPBI = 2.9). Other important sources of waste in this category in the order of importance of CPBI were unavailability of functionality and maintainability statistics and data, economic constraints, lack of pre-design meeting, lack of construction experience by the clients and resistance of clients to buildability programmes. In the design stage category, insufficient data and drawing information was ranked the most important type of buildability problem; next in importance to this was poor specification and choice of materials and inaccurate drawing scale, design and detailing respectively.

Finally, in the construction stage category, the order of importance was poor construction methodology, communication breakdown, incompetent and lack of skilled and technical personnel and poor workmanship and control system respectively.

Table 2. Causes of buildability problems

Category	Causes of buildability problems	TWV	CBPI	Overall rank	Rank in class
Inception	Inadequate project briefing and poor scoping	134	3.2	3	1
	Budget based on incomplete data and fragmented decision making	130	3.1	6	2
Mean CPBI = 2.67	Poor estimating, functionality, viability and defect analysis	122	2.9	11	3
	Lack of pre-design meeting	112	2.7	15	6
	Unavailability of functionality and maintainability statistics and data	118	2.8	13	4
	Economic constraints	113	2.7	14	5
	Lack of construction experience by the clients	100	2.4	20	7
	Resistance of client to buildability program	96	2.3	21	8
	Lack of financial incentive for design	80	1.9	29	
Design stage	Insufficient data and drawing information	137	3.3	1	1
	Poor specification and choice of materials	135	3.2	2	2
	Inaccurate drawing scale, design and detailing	132	3.1	4	3
Mean CPBI= 2.68	Lack of builder's input into design	130	3.1	5	3
	Fragmented design process	126	3.0	9	5
	Lack of design quality management	125	3.0	10	6
	Under design and over design	119	2.8	12	7
	Omission and discrepancies in the drawing	104	2.4	18	8
	Lack of design rationalization	99	2.4	19	9
	Poor tolerance accommodation	85	2.0	26	10
	Choice of poor construction methods	83	2.0	27	11
	Misinterpretation of clients needs and requirements	78	1.9	28	
Construction stage	Poor construction methodology	126	3.0	7	1
	Communication breakdown	124	3.0	8	2
	Incompetent and lack of skilled and technical personnel	110	2.6	16	3
Mean CPBI= 2.32	Poor workmanship and control system	100	2.4	17	4
	Poor information and control system	91	2.2	22	5
	Omission and divergence	87	2.1	23	7
	Lack of adequate qualification of contractor	85	2.0	24	8
	Adversarial working relationship/environmental	83	2.0	25	9
	Poor monitoring of work progress	74	1.8	30	10

Impact of buildability problem on construction projects

In order to study the types of impact buildability problems have on construction projects in the study area; three categories of factors were considered; client requirement factors, building life cycle and maintenance factors and sustainability factors. These categories were populated with sixteen sub-factors on which the AHP was conducted to determine their relative weights in the global pool of these factors (See Table 3).

Table 3: Impact of buildability problems on construction process.

Main Category	Buidability problems impact factors
Client requirement	Inability to give client value for money.
	Difficulty in constructing the design and working drawing to details.
	Inconsistency in construction.
	Lack of efficiency, idleness and wastage of construction resources.
	Quality control and management laxity.
Buildability lifecycle and maintenance	Poor serviceability, functionality and structural instability as a result of reconstruction.
	Excessive cost and probable abandoning of project.
	Delay due to uncertainty in design and interpretation.
	Excessive variation and disorganization.
	Impossible cost control and management failure.
Sustainability	Possible building collapse, component failure and high risk in usage.
	Dimensional inaccuracies and high defect rate.
	Unpredictable life cycle and deterioration pattern of component and subsystem.
	Unsustainable building components
	Constant trouble shooting
	Poor building construction form.

To conduct the AHP for client requirement factors for example, the five factors here were presented to the panel of judges (project managers) to conduct a pair-wise comparison of all the factors against one another based on the scale of evaluation in Table 1. The judgment of the project managers were used to generate a 5 x 5 matrix according to equation (2). Further matrix analysis including transposition and normalization were conducted to reduce the matrix to vectors which are the relative ranking of criteria. The process is shown below;

Table 4: Pair-wise comparison/ judgement matrix on client requirement factors (buildability problems impact factors).

Factors	Inability to give clients value for their money	Difficulties in constructing the design from the working drawing	Inconsistency in construction	Lack of efficiency, idleness and wastage of construction resources	Quality control and management
Inability to give clients value for their money	1	2.19	2.15	1.17	2.02
Difficulties in constructing the design from the working drawing	0.46	1	2.18	3.00	1.47
Inconsistency in construction	0.47	0.51	1	2.22	2.19
Lack of efficiency, idleness and wastage of construction resources	0.49	0.46	0.33	1	2.34
Quality control and management laxity	0.68	0.45	0.46	0.43	1

Table 5:Inconsistency matrix on client requirement factors.

Factors	Inability to give clients value for their money	Difficulties in constructing the design from the working drawing	Inconsistency in construction	Lack of efficiency, idleness and wastage of construction resources	Quality control and management
Inability to give clients value for their money	0.48	0.48	0.42	0.29	0.29
Difficulties in constructing the design from the working drawing	0.22	0.22	0.43	0.45	0.21
Inconsistency in construction	0.22	0.11	0.19	0.33	0.31
Lack of efficiency, idleness and wastage of construction resources	0.23	0.09	0.06	0.15	0.33
Quality control and management laxity	0.32	0.09	0.09	0.06	0.14

Table 6 :Priority vectors (normalized Eigen vector) on client requirement factors.

Factors	Priority vectors (normalized Eigen vectors)	Rank
Inability to give clients value for their money	0.392	1
Difficulties in constructing the design and working drawing	0.306	2
Inconsistency in construction	0.232	3
Lack of efficiency, idleness and wastage of construction resources	0.172	4
Quality control and management	0.140	5

The maximum principal Eigen vector = 5.55
Consistency index (CI) = 0.138

Consistency ratio (CR) = 12%, this is more than 10% required, but it is border line acceptable (Kniaz, 2013) thus establishing that the judgment of the respondents was consistent and acceptable.

Usually, after constructing the pair-wise judgment matrices, the consistency ratio (CR) is calculated for each matrix to ascertain the consistency of the judgment. The CR is calculated using the following equations:

CI = (N-n)/(n-1) ………………………….. (3),

N is the maximum principal Eigen vector n is the size of matrix.

CR = CI/RI, ………………………………....................................... (4).

RI = Random consistency index as determined in table of random consistency index (Table 8), as developed by Saaty (2003).

Table 7: Random consistency index

Matrix &Size	1	2	3	4	5	6	7	8	9	10	11
RI	0.0	0.0	0.58	0.9	1.2	1.24	1.32	1.41	1.45	1.49	1.51

When the AHP process was repeated for all categories of factors, the table containing their normalized Eigen vectors is shown below

Table 8: Priority vector (Normalized Eigenvector) for all factors

Main category	Factor	Priority vector	Rank in class	Rank in global class
Client requirement	Inability to give client value for money	0.392	1	1
	Difficulty in constructing the design and working drawing to details	0.306	2	4
	Inconsistency in construction	0.232	3	6
	In-efficiency, idleness and wastage of construction resources	0.172	4	9
	Quality control and management laxity	0.140	5	11
Buidability lifecycle and	Poor serviceability, functionality and structural instability as a	0.36	1	2

maintenance	result of reconstruction			
	Excessive cost and probable abandonment of project	0.28	2	5
	Delay due to uncertainty in design and interpretation	0.17	3	10
	Excessive variation and disorganization	0.11	4	12
	Impossible cost control and management failure	0.08	5	14
Sustainability	Possible building collapse, component failure and high risk in usage	0.32	1	3
	Dimensional inaccuracies and high defect rate	0.19	2	7
	Unpredictable life cycle and deterioration pattern of component and subsystem	0.18	3	8
	Unsustainable building components	0.14	4	11
	Constant trouble shooting	0.09	5	13
	Poor building construction form	0.07	6	15

Impact of buildability factors on construction process

The sixteen factors used to determine the impact of buildability problems on construction process under three major headings were assessed using the AHP; the eigenvectors were their eventual relative ratings. The values of these eigenvectors and their rankings are contained in Table 8. This table contains the overall ranking and ratings within the three categories of factors. Inability to give clients value for their money ranked the highest with priority vector (PV) of 0.392. Poor serviceability, functionality and structural instability as a result of reconstruction ranked next in importance to this with PV of 0.360.

Other prominent factors that determined the impact of buildability problems on construction process were possible collapse, component failure and high risk in building usage, difficulties in constructing the design and working drawing, excessive costs and probable abandoning of project and inconsistency in construction. They have priority vectors of 0.320, 0.306, 0.280 and 0.232 respectively. In addition, the prominent factors that determined the effect of buildability problem on construction process in each category were also established. In the client requirement category, inability to give clients the value for their money ranked highest. Next in importance was difficulties in constructing the design from the working drawing and inconsistency in construction. They have PV of 0.392, 0.306 and 0.232 respectively. Also in the building life cycle and maintenance category, the ranking of the factors that determined the effect of buildability problems in order of importance was poor serviceability, functionality and structural instability as a result of reconstruction, excessive costs and probable abandoning of project and delay due to uncertainties in design and interpretation, they have PV of 0.360, 0.280 and 0.170 respectively.

In the sustainability category, the list of factors that determined the effect of buildability problems on construction process in descending order include: possible building collapse, component failure and high risk in building usage, dimensional inaccuracy and high defects rate, unpredictable life cycle and deterioration pattern of component and subsystem and unsustainable building respectively, having PV of 0.320, 0.190, 0.180 and 0.140 respectively.

Conclusion

From this survey, the project managers in charge of the construction sites in the study area ranked the following factors through the AHP process as having the most impact on the construction process from the occurrence of buildability problems. The five factors in order of importance are; inability to give client value for money, poor serviceability and functionality, component failure and risk in usage, difficulty in constructing the design and excessive cost and probable abandonment of project.

Although the respondents were all project managers and project based, they have ranked client-related impacts higher than project-related, for example giving clients value for money, poor serviceability and component failure higher than difficulty in construction, dimensional inaccuracies and constant trouble shooting. This position supports the notion that although the whole construction industry suffers from occurrence of buildability problems, eventually the client pays for it and the economy bleeds for it. The client does not get value for money, what he pays is actually the worth of one and a half or two of the one property that he gets, totally not due to his or her fault.

Poor serviceability and component failure are related issues and they usually arise from the forced compromise emanating from poor buildability management process. In the example earlier discussed by Li and Taylor (2011) on a highway construction, the cost of correcting the pipe sizing was prohibitive, and the project team resolved to use the wrong pipes in place. It is obvious that the life of that roadway will be bedeviled by serviceability and functionality problems. Difficulty of constructing an unbuildable design comprises of the decision processes and limitation of finding solution and the extended activities of pulling down and rebuilding the structure. All these are accompanied by extra and unplanned costs.

Furthermore, these findings have implication for the Nigerian economy at large. The Nigerian government has been touted as the biggest customer of the nation's construction industry (Dantata, 2008), thereby being the biggest client and thus the recipient of these aforementioned impacts with its ripple cost and inefficiency on the economy. The Nigerian government in its three tiers of federal, states and local arms have combined organs of more than three thousand semi-autonomous organizations. The budgetary practice of all these bodies is to subdivide annual budgets into recurrent and capital budgets. Usually, the bulk of the capital budget goes into construction-related activities of all sorts. Sometimes the capital budget could be 30% of the whole, running into billions of dollars. If the impact of the buildability problems earlier discussed is factored into this 30%, it could translate into heavy wastage. The budget issue raised here presupposes the need for government to develop policies aimed at improving project delivery processes that will encourage integration of design and construction experts from the commencement of a project until the end. This was the case in the UK, thus giving birth to Lathan Report of 1994 and Egan report of 1998 and the accompanying innovation and efficiency of the UK construction industry.

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