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CREATING SUSTAINABLE CONSTRUCTION: BUILDING INFORMATICS MODELLING AND LEAN CONSTRUCTION APPROACH

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ABSTRACT

Sustainability concept has been a driving force in construction process because it has become a priority in the industry. This research explores a means to the desired good results by introducing the integration of Lean construction and Building information modeling in the construction industry. It was observed that most companies implemented the use of BIM tools in their design process but yet do not realize that a greater level of efficiency can be attained by the integration of the duo. This research sought to find answers to the areas of construction that Lean and BIM can be applied. Their workability, barriers to their implementation and the success factors for their effective implementation. Random sampling technique was used in sample sizing, 150 samples of questionnaire was used in data collation and processed with SPSS software. It was discovered among the number of construction companies surveyed that there is major focus on various challenges of delay and ineffective works during the course of their construction process. As a result of the research, a model was created to aid the easy implementation of lean construction using a BIM tool without playing blind to the truth that lean construction requires a conscious change of way of thinking and order of operations within a company.

Keywords: *Construction, Sustainability, BIM, Lean, Diffusion, Integration*

1. INTRODUCTION

Sustainable construction has been acknowledged as one of the drivers of economic transformation, however the study of sustainable construction practice has not prospered as due to lack of proper exposure to cutting edge practice (.Afjalur. Rahman 2013).The introduction of cutting edge practices has lead to complexity in the delivery of project using sustainable construction practice. The complexity include, repeated design recapitulations, advanced models, analyses, additional site precautions, and the use of new and unfamiliar materials, which are typically more complicated considering traditional projects Christine Pasquire and Jose Salvatierra-Garrido (2011). The paradigm shift in the consideration of cost and value is accelerating the rate of has made adoption of lean construction an important issue. This Lean approach to projects brings with it some key concepts, among the most important of which are value, flow and pull (Ballard and Gregory Howell 2004). Building Information Modelling (BIM) on the other end facilitates complex processes and analysis that were previously too arduous or expensive to perform, using software. Galvanizing BIM and Lean concept together can generate a formidable application that could be useful in creating attributes that could help produce a sustainable construction practice. Sustainable design seeks to alleviate the deleterious impact of greenhouse emission through the use of environmentally sensitive design and construction practices. Producing buildings that are environmentally responsible, profitable and healthy to live and work still remains the goal of sustainable design. It aims at improving energy efficiency and performance of the building. In order to assess building performance in the design and preconstruction phases accurately, access to a comprehensive set of knowledge with respect to building's form, materials, context, and technical systems are required.

2. REVIEW OF RELATED LITERATURES

Building Information Modelling and Lean construction are driving fundamental change in architecture, engineering and construction. They have been individually explored in the construction and engineering industry leading to a notable amount of positive impact on each's path. Lean construction and BIM are not dependent upon one another (i.e. that lean construction practices can be adopted without BIM, and BIM can be adopted without lean construction), and this has been illustrated by the numerous cases of separate adoption of each in design and construction companies within the past decade. However, (Eckblad et al. 2007), proposed that neither can fully achieve its potential for improvement of the results of construction projects unless they are integrated, as they are in the Integrated Project Delivery (IPD) approach. In the words of the American Institute of Architects document on IPD, 'Lean construction focuses on reduction of waste, increase of value to the customer, and continuous improvement.' The question still remains "How does Building Information Modelling contribute to the Lean goal?"

2.1 Sustainable Construction

Sustainability in construction remains a longing of clients and contractors and is gradually becoming the major defining factor for value. Sustainability focuses on physical environmental issues, recognizes that social and economic factors are fundamentally important and relate to the design and construction of buildings as proposed by Cork October (2011). Therefore, Sustainable development is a development that delivers environmental, economic and social services to all residents of a community, without threatening the viability of the natural, built, economic and social systems upon which the delivery of these systems depend. WCED (1987). A sustainable building satisfies the following criteria; green, ecological, sustainable, energy efficient and environmental friendly. Sustainable construction aims at reducing waste, as it has been ascertained by Kier Group that 13% of waste are new unused material and a huge 60% results from skipped material in packaging.
Sustainable construction has emerged as a guiding paradigm to create a new kind of built environment: "one that meets the needs of humans in the present without limiting the ability of future generalizations to meet their own needs" (Ofori, 2001).

The implementation or the attainment of sustainable construction has been researched on by Henry O. (2011) in Sustainable or Green Construction in Lagos, Nigeria: Principles, Attributes and Framework. The areas that should be taken into cognizance as it regards sustainable construction were harvested as follows: Energy Efficiency, Integrated Design, Indoor Air Quality, Thermal Comfort and Visual comfort, Site Suitability, Acoustic Comfort, Spatial Comfort and Building Integrity. Sustainable construction cannot be exhausted without the introduction of waste management or eradication. Lean therefore finds its place in reduction of waste towards sustainable construction and Building information Modelling in the digital representation of construction processes and Building information Modelling gives a resourceful forecast as it regards the end product on the construction. This research therefore ascertains the workability of Lean construction and Building Information Modelling for sustainable construction.

2.2 Reoccurring Waste And Their Impact In Construction

According to Love (1996), there are many wasteful activities during design and construction process. Majority of these, consume time and effort without adding values to the client.
Waste can include mistake, working out of sequence, redundant activity and movement, delayed or premature inputs and products or services that do not meet customer needs (construction industry board, 1998).
According to the production philosophy, waste should be understood as any inefficiency that results in the use of equipment, materials, labor, or capital in larger quantities than those considered necessary in the production of a building (Formoso et al, 1999). Waste includes both the incidence of materials losses and the execution of unnecessary work that generates additional costs but does not add value to the product (Koskela, 1992). Alarcon (1993), Ishiwata (1997) Koskelal (1992), and Serpell et al (1995) stated that waste in construction and manufacturing include delay times, quality costs, lack of safety, rework, unnecessary transportation trips, long distance, improper choice of management, methods or equipment and poor constructability.
For the purpose of this research the various reoccurring waste streams that cause inefficiencies in production process are:

i. Overproduction
ii. Waiting (Idling)

iii. Inventory
iv. Transport
v. Motion
vi. Corrections
vii. Over processing

i. Overproduction: This involves building or producing more than what is needed or producing too early which could lead to one or more of the order waste. This can be seen in reports and presentation containing more information than needed, or produced too frequently such as unused drawing details, unused fabricated assembly because they were brought in too early often resulting in scrap. A clear scenario is when casting is being done and at the conclusion of the casting it is discovered that the concrete mix was more than needed. Most times the amount left is usually a small portion but when this occurs almost every time casting is done, the total sum of waste on casting alone will definitely result a huge amount of wasted material
ii. Waiting (Idling): The delay or idle time before a person is able to start the next activity. This could be waiting for approval, waiting for the security to open the gate before work can start, and failure of a team members to show up, meeting not starting on time, missed or shifting deadlines, waiting on instruction plans or resources to do assignments. This is caused by late decision making, inadequate coordination, no shows or late attendees at meetings, broken processes in systems and delay created by drawing released in large barges instead of in timely smaller chunks. This results in waste of time.
iii. Inventory: This involves carrying stock that is more than what is needed. The work stacked up too far in advance of when needed or in big batches waiting for use. This may trigger other waste such as unnecessary transport or defect from mishandling or contamination. This usually happens due to cheap cost of procuring materials in bulk without considering the long term cost of storage of excess materials and the waste that could occur if not properly stored.
iv. Transport: The moving material from one place to another. This waste can be seen in the excessive manual routing of documents, multiple moves of stock piles and clearing documents out of passive travel or out of areas of work. This be could be caused by lack of process flow, poor site layout, lack of planning by foreman and supervisors, and early deliveries adding to the congestion of the site.
v. Motion: The extra body movements and searches that does not necessarily add extra value to the job. This can be seen by the excessive searching for information, walking from meeting to meeting, and multiple trips up and down the ladder to get tools or parts, and poor work layout resulting in ergonomic injuries and safety issues. This could be due to inefficient folder structures, poor design processes, lack of standard work method, poor work area organization and no preplanning.

2.3 Theoretical Background

Combining Lean concept and BIM in order to create sustainable construction practice requires innovativeness, therefore literature review in this study addressed underpinning theoretical framework and prevous studies that addressed application of BIM and Lean concept in bulding. Innovativeness in the application of lean and BIM concept in this context , the study approached this from the perspective of the three phases of innovation adoption. For instance, Rogers (2003) listed phases of innovation application to include awareness, interest, evaluation, trial and adoption/application. Similarly, there are other theories applied in this study which guided the philosophy behind the integration of Lean and BIM as applied in this research. Some of the theories include Rogers Everett (1962) theory of innovation and creativity diffusion (DOI) which underlined the concept behind integration of Lean and BIM in this study. Similarly, Tornatzky and Fleischer (1960) organization, technology and environment theory(OTE) was used in censoring the construction organization perspective in developing an inclusive model that integrate construction technology to form an organization that create sustainable construction environment among others.

Furthermore, acceptability is an important phase of innovation opinion based model was developed which is all inclusive model since user of an innovation could provide direction as regards the level of innovation to be incorporated into an application.,therefore technology acceptance theory (TAT);and theory of acceptance and use of technology(UTATUT) Trans et al., (2011)

2.4 Applicability of Previous Studies

A study was carried out on implementing lean construction and its implementation by Sherif Mostafa and Soltan (2013) the study considered the limitations to its implementations in the South Australia. In concluding the research work, a frame work with detailed four implementation phases was proposed to overcome the limitations of lean implementation.

Also, Emmitt (2011) conducted a research on Technical University in Denmark, in attempt to answer the question why lean design management has not been tackled with the same enthusiasm as lean construction in the article lean design management, architectural engineering and design management. The study was conducted in Technical University in Denmark with journals as the major source of analysis resulting in the publishing of four articles addressing the lean application in design management.
In another related study. Glenn and Gregory (2003)studied distinction between lean construction and project management. A model of lean project management was presented with strong characteristics that galvanized lean and traditional approaches, this lead to evolution of four tools or interventions.

Similarly, Geir and Nils (2003) elaborates on lean thinking in design management, discussing how lean concepts can be understood and how this can affect the design process. The research was done based on case studies of two hospital projects, flexibility in the design process and design in relation to lean principles were discussed. The study indicates the importance of integrated nature of the design process. Finally, Lauri, Bob, Bhargav (2010), Rafael Sacks (2008)investigated the drivers of construction: lean construction, building information modelling and sustainability in the article titled Lean construction, building information modeling, the study discovered that the combination of the three parameters or techniques appeared tasking but possible and effective. To this end the study researched into the following questions that ultimately dovetailed into pertinent objectives on account of gaps observed in the literatures reviewed: what is the extent of lean construction and BIM implementation in indigenous construction companies?;what are the areas in which lean construction and bim application in construction?; is the integration of BIM and lean construction in design achievable?; what are the critical success factors of the integration of lean construction and BIM for sustainable construction?; and is any hinderance or barrier to lean construction, building information modelling and sustainability?.

3.1 Opinion Based Model For Building Information Modelling And Lean Construction Based Integration For Sustainable Building Construction Method

3.2 Research Methodology

The use of multi-choice questionnaires was employed to collect data from the sample population. The questionnaire was designed to meet the stated research objectives. Closed ended questions were used to record workers perception on the workability of the integration of lean construction and Building Information Modelling for sustainable construction. The distributed questionnaire was designed in Likert scale 1 to 5, the respondent were requested to express their opinion in the degree tabulated on the questionnaires. A scale 1 to 5 was adopted, with 1 representing “strongly disagree (SD)” 2 – being disagree (D) 3 – being neither agree nor disagree (N), 5- being strongly agree (SA).

Agreement index of the respondents was generated using the relation

$$R.A.I = \frac{5S.A + 4A + 3S.D + 2D + 1N}{5(S.A + A + S.D + D + N)}$$

4. RESULT ANALYSIS AND DISCUSSION

4.1 Model Development

Combination of stepwise multiple regression methods and factor analysis was used for data reduction. The response from respondents was loaded (SPSS) software, the factors were subjected to factor rotation so as to ensure emergence of stable criteria which would be used in modeling and represent relationship among the twenty five variables regarded as ability parameters. The resultant factors were then subjected to stepwise multiple regression analysis to establish pattern of relationships among them for model development.

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4.2 Factor Extraction

Percentage of total variance obtained from each of the independent variables (the twenty-five (25) variables (sub factors affecting quality) were examined). Each variable was standardized to have variance of 1, while total variance was given by the sum of each variable which totaled twenty-five (25). This study adopted Eigen value greater than 1, this toes line of submission in which Chan and Tam (2009) submitted that in Eigen value approach, only variable with Eigen value greater than one (1) should be included in the model formation. Similarly, in scree plot approach, there is differential relationship pattern among variables; there is always a distinct demarcation between large variables on steep slope and gradual trailing off scores of the rest variables. This usually occurs at the variable, where K is the true number of variables Chan and Tam (2009). However, in this study regression coefficient approach was used.

4.3 Factor Rotation

Factors rotation is used to identify the relationship of individual variables to the set of common factor synthesized; oblim rotation approach was adopted to achieve this feat. On the other hand, Rostom and Amer (2006), used variance rotation methods, and were able to discover each Variable with a single factor. The new set of eleven (11) factors that emerged after rotation is presented in this study(Amusan, Ayo (2017).

4.4 Method Of Data Presentation And Analysis

The method of data presentation was done through effective data analysis using SPSS 16.0. The data was then presented in the frequency distribution tables, and charts.

4.5 Extent Of Lean Construction And Bim Implementation In Indigenous Construction Companies

Questionaires were collected from respondents and analyzed for the extent of implementation of lean in cconstruction companies as contained in Fig 1.1, it shows that 68% don't know about lean, 16% know about lean but don't implement lean, 8% implement lean construction in their construction processes and the remaining 8% did not respond to the questionnaire.

4.6 AREAS FOR LEAN CONSTRUCTION AND BIM APPLICATION IN CONSTRUCTION

This table shows the areas for Lean construction and BIM application in construction projects in the sampled questionnaire.

Table 1 Areas of Lean and BIM application in construction projects

Areas of Application	R.A.I	RANK
Design Stage	0.882	3
Pre-construction	0.931	1
Construction stage	0.914	2
Maintenance	0.757	4

Source: field survey (2016)

The table above indicates some areas of lean construction and BIM application in construction. Lean construction and BIM has greatest application and has highest Relative agreement Index (R.A.I) of 0.931, Construction stage has relative agreement index of 0.914 while Design stage and maintenance has R.A.I of 0.882.

4.7 Integration Of Bim And Lean Construction In Design

This table shows the benefits of the integration of lean construction and BIM in design of a project.

.4.8 Lean And Bim In Construction Process

This table shows the benefits of the integration of lean construction and BIM in the construction process

Table 2a. Integration Of Lean And BIM In Construction Process

Lean and BIM in Construction process	R.A.I	RANK
Improves safety and environmental issues	0.834	3
Improves time, cost and quality	0.845	2
Helps to identify constraint within construction	0.824	4
Focuses on value than cost	0.860	1
Optimizes resource delivery schedules	0.785	5
Aids reduction in on-site transportation	0.832	4
Results in standardization of work practices	0.748	6

Source: field survey (2016)

Table 2 shows the application of the integration of lean construction and BIM in the construction stage results in focus on cost than value as it ranks the first with R.A.I of 0.860. The second on the ranking is that it improves time, cost and quality (0.845) and then it improves safety and environmental issues (0.834). It was also agreed that it helps to identify constraint within construction, ranking fourth with R.A.I of 0.824. It also follows that other

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benefits are it optimizes resource delivery schedules (0.785) and it results in standardization with the lowest rank (0.748).

4.9. Principles Of Building Information Modelling

This table shows the relative agreement index of the principles of Building Information Modelling in construction.

Table 2b.Principles of BIM

Principles of BIM	R.A.I	RANK
a) Rapid generation of multiple design alternatives.	0.817	3
b)Visualization of form (for aesthetic and functional evaluation).	0.824	2
c).Use of model data for predictive analysis of building performance.	0.772	8
d).Maintenance of information and design model integrity.	0.882	1
e).Automated generation of drawings and documents	0.665	9
f).Collaboration in design and construction	0.778	6
g).Rapid generation and evaluation of construction plan alternatives.	0.776	7
h).Online/electronic object-based communication	0.804	4
h).Direct information transfer to support computer-controlled fabrication	0.794	5

Source: field survey (2016)

Table 4.10 assesses the respondent's agreement to the principles of Building Information Modelling as it has been practically applied in their various companies and Maintenance of information and design model integrity ranked the highest with the R.A.I as 0.882. Visualization of form (for aesthetic and functional evaluation) (0.824) ranked second and Rapid generation of multiple design alternatives (0.817) ranking third. The principles that ranked fourth, fifth and sixth respectively as already shown in the table are Online/electronic object-based communication (0.804), Direct information transfer to support computer-controlled fabrication (0.794) and Collaboration in design and construction (0.778). Rapid generation and evaluation of construction plan alternatives ranked seventh with R.A.I of 0.776, use of model data for predictive analysis of building performance with R.A.I of 0.772 rank eighth and the lowest ranking the ninth which is automated generation of drawings and documents has a relative agreement index of 0.665.

4.10 Barriers To Lean Construction, Building Information Modelling And Sustainability

This table shows the barriers to lean construction, Building Information Modelling and Sustainability in the project process.

Table 3 Barriers to Lean, BIM and Sustainable construction

Barriers to Lean construction, Building Information Modelling and Sustainability	R.A.I	RANK
Lack of management commitment	0.815	5
Long implementation period	0.843	2
Lack of proper training	0.589	11
Lack of adequate skills and knowledge	0.832	3
Lack of application of the fundamental techniques	0.632	10
Gaps in standards and approaches	0.826	4
Fragmented nature of industry	0.856	1
Cultural barriers	0.772	7
Lack of implementation understanding & concepts	0.826	4
Resistance to change	0.813	6
Government bureaucracy and instability	0.718	9
Long lists of supply chain and lack of trust	0.720	8

Source: field survey (2016)

Table 3 shows the barriers to the application of lean construction and BIM in building construction. The fragmented nature of the industry ranked first with R.A.I of 0.856 followed by long implementation period (0.843) and then lack of adequate skills and knowledge (0.832).Gaps in standards and approaches (0.826) is also a barrier to the implementation of lean. Other barriers are lack of management commitment (0.815), resistance to change (0.813), cultural barriers (0.772), long lists of supply chain and lack of trust (0.720) and government bureaucracy and instability (0.718). With the lowest rankings of tenth and eleventh respectively the barriers of the application of lean construction and BIM in building construction are as follows lack of application of the fundamental techniques (0.632) and lack of proper training (0.589).

4.10 The Critical Success Factors Of The Integration Of Lean Construction And Bim For Sustainable Construction.

This table shows the critical success factors of the integration of lean construction and Building Information Modelling for sustainable construction

Table 4 Critical Success Factor In The Implementation Of Lean And BIM

	R.A.I	RANK
Management commitment	0.845	1
Good working environment	0.819	4
Customer focus and integration	0.774	7
System and process change management	0.727	10
Regular training of workforce	0.843	2
Effective planning	0.806	5
Integration of team and end to end supply chain	0.757	8
Adoption of a continuous improvement culture	0.804	6
Benchmarking of suppliers against each other	0.738	9
Communication and coordination between parties	0.834	3

Source: field survey (2016)

Table 4 addresses the critical success factors to the application of lean and BIM in construction with management commitment as the highest rank with R.A.I of 0.845 followed by regular training of workforce (0.843) and then communication and coordination between parties (0.834), good working environment (0.819), effective planning (0.806) and adoption of a continuous improvement culture (0.804). With proper customer focus and integration (0.774), integration of team and end to end supply chain (0.757) and benchmarking of suppliers against each other (0.738) the integration of both BIM and Lean construction can be applied. According to the relative agreement index the least ranked success factor is the system and project change management (0.727).

4.11 Opinion Based Model For Building Information Modelling And Lean Construction Based Integration For Sustainable Building Construction Method.

AREAS OF APPLICATION OF LEAN CONSTRUCTION

c) Lean concept has its prominent application in the manufacturing sector where production can be done under a very controlled environment. In recent times, it has also been discovered that Lean can also have its place in construction. This research assesses the applicability of lean in the design stage, construction stage, post construction stage and maintenance stage. Mohamed Marzouk (2011) in application of lean principles to design processes in construction consultancy firms stated that, simulation modelling and Lean principles have both been applied in the construction industry to improve work processes. The outcomes from their implementation are outstanding and have motivated construction researchers to seek means by which other aspects of construction production could benefit from this development. Most indigenous construction companies in Lagos State, Nigeria currently seem to the oblivious to the concept of lean construction, therefore this project focuses on the introduction of the workability of the duo into the construction industry in Lagos

d) **BUILDING INFORMATION MODELLING**

The glossary of the BIM Handbook (Eastman et al. 2008) defines BIM as “a verb or adjective phrase to describe tools, processes and technologies that are facilitated by digital, machine-readable documentation about a building, its performance, its planning, its construction and later its operation.” The result of BIM activity is a ‘Building information model’.

The individual areas of Lean Construction and BIM have been researched extensively in recent years. Object modeling implies the use of software objects, which group data and the methods to manipulate them, to represent real-world concepts (Galle 1995). The concepts may be physical, such as parts of a building, or abstract, such as a cost estimate or a structural analysis result (Turk et al. 1994).

> ’Building Information Modelling (BIM) is core to Autodesk’s sustainable design approach. BIM is an integrated workflow built on coordinated, reliable information

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about a project from design through construction and into operations.
Autodesk BIM software makes sustainable design practices easier, more efficient, and less costly by enabling architects, engineers, builders, and owners to:
• Easily create coordinated, digital design information and documentation
• Use that information to accurately visualize, simulate and analyze project performance, appearance, and cost
• Reliably deliver the project faster, more economically, and with reduced environmental impact through the project lifecycle from design through operation
With BIM, the information required for sustainable design, analysis, code compliance, and certification becomes available as a by-product of the standard design process, making the sustainable design process inherently more efficient and cost-effective.
Further, analytical capabilities not possible in traditional, drawing-based methods are easily accessed through BIM.'(Autodesk 2011)

Building information Modelling has its various applications that aid the construction process. A number of them have been implemented or been put in use over time and as proven to work effectively in driving construction towards sustainability. The BIM applications are numerous and more applications are invented and upgraded per day. There are various functionality that BIM technology provides for compiling, editing, evaluating and reporting information about building projects.

The table below shows the various application of BIM to various Stages of construction as written by Brown in BIM- Implication for Government

Table 2.2: The application of BIM to various Stages of Construction (Brown, 2008)

Design	**Construction**	**Operation/ Facility management**	**Decommissioning**
Ensure the right facility is designed Evaluate the design from many perspectives Evaluate the design against building codes and sustainability before construction	More productive crews, as there are fewer changes to design once construction has started, the ability to track work in real time, faster flow of resources and site management Enables demonstration of the construction process, including access and egress, traffic flows, site materials, machinery, etc. Better tracking of cost control and cash flow- particularly for large projects	Keep track of built asset Manage the facility proactively Such a model can be handed from one contractor to another, thus enhancing facilities management Capability to schedule maintenance and review maintenance history	Identify elements which can be recycled or those which require particular care (e.g. Hazardous materials) Know the composition of structure prior to demolition

BIM has been widely penetrating into the construction industry, getting its stand as predicted as the future of BIM. It aids the speed of work, enhances communication amongst project

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stakeholders and guarantees increase in value and accuracy of project especially at the planning stage.

Factor rotation analysis was conducted on twenty-five (25) factors; the factors were reduced to a sizeable number. The co-efficient of the factor was used to select resultant factors that could be used as benchmarked parameters. Correlation co-efficient and Eigen-value were used in selecting the best factor. After rotation, variables with coefficient greater than 0.96 were preliminarily selected, the factors were later sized and selection parameters benchmarked to coefficient value 0.97 to Eigen value of 1.00. Extracted values were scheduled in Table 4.11. Table 4.11 presents the extracted coefficients of the factors; this action reduced the factors from 25 to 11 factors, with strong Regression coefficients and Eigen values.

Factors F13, F1, F7, F11, F4, F10, F9, F6 and F12 emerged as favorable factors that constitutes benchmarked parameters. Factor 7 was tagged with one variable; F11 with 1 variable, F4 (1-variable); F9 (1-variable); F12 (1-variable); F13 (2-variables); F1 (2-variables); f10 (2-variables) and F6 with two (2) variables. This forms the nucleus of benchmarked quality parameters in Table 4.12.
In Table 5, quality parameters were benchmarked into three (3) quality dichotomies, namely: zero defect, medium quality and high quality. Zero defects occur when there is near-zero defect situations. The benchmarked quotient for this status is 1.00. Medium quality is the second dichotomy; medium is benchmarked to occur at 80% quality. Three (3) factors were tagged coded as Zero defect factors, these factors when observed would guaranteed zero defect(Amusan , Joshua, Oloke 2013; Tunji-Olayeni; Lawal and Amusan 2013).

Table 6 Extraction Factor Coefficient

Parameters	Factors	Factors	Factors
Direct information transfer to support computer-controlled fabrication	F13(0.998)		
Rapid generation and evaluation of construction plan alternatives.	F13(0.998)		
Use of model data for predictive analysis of building performance.	F1(0.998)		
Automated generation of drawings and documents	F7(1)	F11(0.998)	
Online/electronic object-based communication	F4(0.998)	F10(0.998)	
Rapid generation of multiple design alternatives.	F1(0.998)	F6(1)	F9(0.998)
Visualization of form (for aesthetic and functional evaluation).	F6(0.998)	F10(1)	F12(0.999)

Source: field survey (2016)

Table 7 Benchmarked Quality Parameters

Zero Defect	1F7 + 01F6 + 1F10
90% High Quality	0.999F12
80% Medium Quality	0.998F13 + 0.998F13 + 0.998F1 + 0.998F11 + 0.998F4 + 0.998F10 + 0.998F1 + 0.998F9 + 0.998F6

From the model, the points of strength are F7(1), the integration of automated generation drawing and documents and creating flow along the value chain F6(1), the integration of rapid generation of multiple design alternatives and mapping the value stream process to achieve the predefined value and F10(1), the integration of visualization of form and reducing batch sizes. These points are the maximum point of strength given to the fact that their Eigen value equals one.

The next most applicable would be F12 (0.999) which is the integration of rapid generation of multiple design alternatives and visualization of forms.

In the third place of application will be F13 (0.998) which is the integration of direct information transfer to support computer-controlled fabrication and visualization of form for aesthetic and functional evaluation, F13 (0.998) the integration of Rapid generation and evaluation of construction plan alternatives and visualization of form, F1(0.998), the integration of Use of model data for predictive analysis of building performance and increasing the efficiency of value adding activities, associated to the improvement of production technology and production skills. F11 (0.998) represents the integration of increasing flexibility and automated generation of drawings and documents. F4(0.998) represents the integration of Online/electronic object-based communication and improving in a comprehensive and integrated way, balancing actions oriented to implement lean production principles and design, control and production systems. F10 (0.998) is the integration of Online/electronic object-based communication and reducing batch sizes. F1(0.998) is the integration of Rapid generation of multiple design alternatives and increasing the efficiency of value adding activities, associated to the improvement of production technology and production skills. F9 (0.998) represents Rapid generation of multiple design alternatives and reduce cycle times and the final factor F6 (0.998) which is the integration of Visualization of form and mapping the value stream process to achieve the predefined value.

5. RESEARCH CONTRIBUTIONS:

Arising from the research questions earlier articulated at the introductory part of this study.The study has achieved the following feats: the extent of lean construction and BIM implementation in indigenous construction companies has been documented; the areas in which lean construction and BIM application could be applied in construction has been articulated while applicability of the integration of BIM and lean construction in design and construction has been demonstrated. Similarly, critical success factors of the integration of lean construction and BIM for sustainable construction has been outlined in this work likewise hindrances or barriers to lean construction, building information modeling and sustainability has been duly documented for implementation. Above all, an integrated BIM and Lean model for sustainable construction has been developed and presented.

5.1 Area of Further Research

Lean construction is becoming a trend likewise building informatics, in furtherance of this work the Lean and BIM concept under the framework of the theories can be applied to the life cycle process of a project taking it through all the stages. This may be possible on account of gaps identified in the literatures reviewed.

6. CONCLUSION

A total of 100 respondents were selected to answer the questionnaires. Ninety three questionnaires were collected back. From ninety three respondents we were able to get information concerning the integration of lean construction and Building information modelling in the construction industry.

From the results of analysis in the study, integration of the Lean construction process and Building Information model is more prominent within the pre-construction stage and it can also be substantially infused within the design, construction and maintenance stage. It was discovered among the number of construction companies surveyed that there is major focus on various challenges of delay and ineffective works during the course of their construction process. As a result of the research, a model was created to aid the easy implementation of lean construction using a BIM tool without playing blind to the truth that lean construction requires a conscious change of way of thinking and order of operations within a company.

Following the principles of lean and BIM harvested from the field survey it is therefore concluded that F7(1), the integration of automated generation drawing and documents, creating flow along the value chain F6(1), the integration of rapid generation of multiple design alternatives, mapping the value stream process to achieve the predefined value. Also, F10(1), that is, the integration of visualization of form and reducing batch sizes will produce maximum result as these are the strong points given to support the validation of the integrated model developed.

REFERENCES

[1] Afjalur, R., Vicente.A, G., & Robert , A. (2013). Exploring the synergies between BIM and Lean construction to deliver highly integrated suzstainable projects. 1-12.

[2] Christine Pasquire and Jose Salvatierra-Garrido (2011). *Introducing the Concept of First and Last Value to Aid Lean Design:* Learning from Social Housing Projects in Chile. pp 2-3

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[3] Ballard, G., & Howell, G. A. (2003). Lean project management. *Building research and Information*, 1-15.
[4] Rogers Everett (1962) Diffusion Of Innovations Third Edition Everett M. Rogers(3rd Edition, The Free Press A Division of Macmillan Publishing Co., Inc.
[5] Rogers (2003) Diffusion of Innovations (5th ed.). New York: Free Press
[6] Tornatzky and Fleischer (1960) Tornatzky, L. and Fleischer, M. (1990) The Process of Technology Innovation, Lexington, MA, Lexington Books
[7] Tran, Q., Huang, D., Liu, B. and Ekram, H.M. (2011) A Construction Enterprise's Readiness Level in Implementing EProcurement: A System Engineering Assessment Model, Systems Engineering Procedia, 2, p.131-141. doi: https://doi.org/10.1016/j.sepro.2011.10.016
[8] Mostafa, J. D. and Sultan A. (2013). A framework for lean manufacturing. *Production & Manufacturing Research*, 44-64.
[9] Emmitt, S. (2011). Lean Design Management. *Architectural Engineering and Design Management*, 67-69.
[10] Chan, A.P and Tam C.M (2009) *Factors Affecting Quality of Building Projects in Hong-Kong*. International Journal of Quality Reliability Management 17(4), 43-441.
[11] Lauri Koskela, Bob Owen, Bhargav Dave (2010). *Lean construction, Building Information Modelling and sustainability*. Pp 1-5
[12] Rustom, R.N and Amer, M.I. (2006) *Modelling the Factors Affecting Quality in Building Construction Projects in Gaza Strip*. Journal of Construction Research. 7(2), 33-67.
[13] Lekan M Amusan, Charles Ayo (2017) Multi-Parameter Optimization Of Cost Entropy For Reinforced Concrete Office Building Projects Using Ant Colony Optimization. Journal of Engineering And Applied Sciences.12(9). 2260-2275.
[14] Amusan Lekan Murtala, Joshua Opeyemi, Oloke Olayinka (2013). Performance of Build-Operate-Transfer Projects: Risks' Cost Implications from Professionals and Concessionaires Perspective. European International Journal of Science and Technology 2 (3), 239-250
[15] Tunji-Olayeni, P.F; Lawal O.P and Amusan L.M (2013). Developing Infrastructure in Nigeria: Why is the Cost so High?. Mediterranean Journal of Social Sciences. 3 (12), 257-263.