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BIM Maturity Level of Architectural firm BIM Operators in Lagos State Nigeria.

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Abstract
The four levels of project collaboration also known as BIM Maturity Levels has increasingly become the criteria for assessing the BIM compliance of firms and project teams. The study provides an insight into the four BIM Maturity Levels and seeks to identify the BIM Maturity Level of Architectural Firms in Lagos State, Nigeria. A non-experimental research design approach was adopted for the study which involved the collection of quantitative data from 140 Architectural Firms in Lagos State. The collected data was analyzed using descriptive statistics and findings were presented in form of tables and charts to illustrate the level of BIM Maturity of Architectural firm BIM Operators in Lagos State. Chi-Square Test of association was also used to confirm the relationship between the four BIM Maturity Levels and Firm's Information Technology (IT) Infrastructure and the level of relationship that exists between them. The findings revealed that 14.3% of the sampled firms have the IT Infrastructure requirements of BIM Maturity Level 3 which is the highest BIM level where the full collaborative benefits of the BIM tool can be optimized. Of the 14.3%, only 3.6% are BIM Level 3 compliant in their project documentation processes. The remaining 10.7% have the IT Infrastructure requirements but are not BIM level 3 compliant with their project documentation processes. The study also revealed that 62.1% of the sampled firms have the IT Infrastructure requirements of BIM Maturity Level 2 which is a partial collaborative platform for BIM. Of the 62.1%, only 22.1% are BIM Level 2 compliant in their project documentation processes. The remaining 40% have the IT Infrastructure requirements but are not BIM level 2 compliant with their project documentation processes. The chi square test of association conducted between the relationships of the BIM Maturity levels and IT Infrastructure revealed that BIM Maturity level 3 has a significantly large relationship with Firm's IT Infrastructure with the omega coefficient (ω) of 0.533 which is above the 0.5 benchmark for a large relationship determinant. This means that a full BIM collaborative benefit will not be experienced by BIM Operators without a dependable and functional IT Infrastructure setup. Similarly, a large relationship was confirmed between BIM Level 2 and Firm's IT Infrastructure with the omega coefficient (ω) of 0.498. Medium relationship was confirmed between BIM Level 1 and Firm's IT Infrastructure with omega coefficient (ω) of 0.355. A non-significant chi-square test revealed shows no relationship was confirmed between BIM Level 0 and IT Infrastructure. In conclusion, the study revealed that majority of the sampled architectural firms are actively operating on BIM Level 1 and BIM Level 0 which are BIM Levels that would not enable the optimization of the inherent benefits of the BIM Tool and processes by Architectural firms.

Keywords: Architectural Firms, BIM, Collaboration, IT Infrastructure, Maturity Level, Technology

1.0 INTRODUCTION

Building Information Modelling (BIM) is the very foundation of the recent digital transformations in the Architecture, Engineering and Construction (AEC) Industry. [15] defined BIM as the generation and management of digital representations of physical and functional characteristics of buildings through its ability to create intelligent and multi-dimensional building models. [2] defined BIM as the detailed digital process of replicating building environment with the primary aim of providing a collaborative platform for managing Building Information throughout the lifecycle of a facility. [10] defined BIM as an integrated and structured digital database that consist of 3D parametric objects which allows for interoperability. For the purpose of this study, BIM is defined as the sustainable and integrated collaborative process that bring together project stakeholders through its digital information storage and editing systems to facilitate a seamless design documentation, construction and building facility management for shared benefits of improved accuracy, productivity, communication, decision making, waste reduction and efficiency of time, energy, water and material resources. BIM is the overall process of creating three-dimensional database in the form of model of information as it relates to the planning, design, construction and operations of any built asset. The ability to incorporate series of building information inside the BIM model is achievable through specific components called BIM objects which has editable geometry and unique data parameters to accommodate design changes at any stage of the building development lifecycle [13]. Numerous benefits of BIM have been registered by AEC professionals over the years till date. [4] and [1] noted that BIM have the capacity to transform, facilitate and enhance project performance by decreasing inefficiencies, improving and increasing collaboration among project team and external stakeholders. BIM facilitates design visualization, fast creation of alternative designs, assessment of model reliability and building performance forecasting [16]. According to [12], BIM helps to facilitate quantity take off, cost estimation process, improve the accuracy of cost estimation and removal of unbudgeted variations.

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[14] established that BIM helps architects resolve potential construction issues ahead right from the design stage through its ability to detect clashes in the building model during the design stage. [9] also noted BIM's advantage of facilitating design review, cost and time savings in design and construction, effective integration of contractor inputs and supplier material specification at the design stage thus leading to an improvement in project constructability. [18] also established that BIM helps to facilitate the identification of conflicting interdisciplinary building component, systems and installations. [17] also noted that BIM allows for an intelligent and conservative use of resources and optimization of workflows which ultimately leads to increased productivity and profitability. He also explained that BIM's advantage in construction is seen in the easy monitoring, cost and time efficiency of the construction process through constructible BIM model which can be prototyped virtually to try out various building solutions in advance before the actual construction commences. The various stages of any built asset from planning, design, construction all through to the operation phase has registered various BIM deployment benefits. Maximum experience of the BIM potential benefits on any project is however dependent on the level at which BIM is deployed on the project. This is a function of the BIM Maturity Levels of the various BIM Operators and stakeholders involved in a project.

2.0 BIM MATURITY LEVEL

BIM Maturity Level is a terminology used to define the degree of collaboration and information sharing between different stakeholders on any project. [19] defines BIM Maturity as the quality, repeatability and the degree of excellence in delivering a BIM Model. [5] developed the UK BIM Maturity Model which till date has remained a relevant component of BIM Implementation Strategy in the UK and adopted in other part of the world. The four levels of shared collaboration identified in the Maturity Model are BIM Level 0, BIM Level 1, BIM Level 2 and BIM Level 3 respectively as shown in figure 1 below.

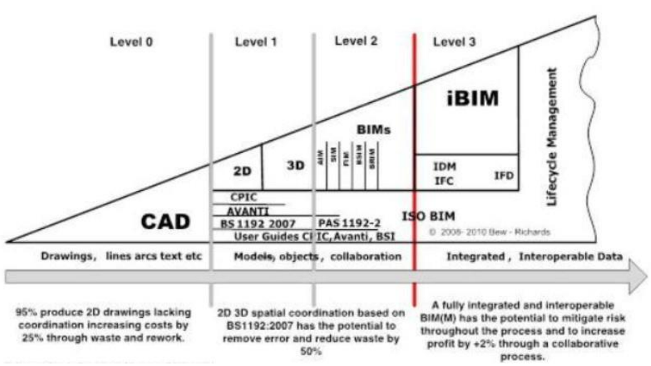

Figure 1: The UK BIM Maturity Model.
Source: (Bew & Richards, 2008)

BIM Level 0 represents a lack of BIM expertise. Drawing data are essentially created using the 2D CAD software. It is otherwise regarded as a digital drawing board level. [8] explained BIM Level 0 as the use of unmanaged CAD where building information is exchanged only via paper or PDF files containing very basic asset information. There is no collaboration at BIM Level 0. At BIM Level 1, 2D and 3D information is created and exchanged [17]. The 3D data could either be created using a CAD model or a BIM tool. The 2D data for regulatory planning submission and construction is however generated in CAD. Little BIM Expertise is applicable at BIM Level 1 and it offers little or no BIM collaborative benefit. It is otherwise referred to as a lonely BIM. At BIM Level 2, both 2D and 3D data are generated and managed within a 3D environment but on separate discipline 3D Models. Partial collaboration is achieved through a super-imposition of the different discipline model for coordination and clash detection [20]. A federated model is the assemblage of the distinct models from different disciplines such as the architects, structural engineers, mechanical and electrical engineer to create a single complete model for design coordination. At BIM Level 2, a single source of data from where all disciplines work is still lacking [17]. At BIM Level 3, full collaboration in planning, design, construction and operational life cycle of a built asset is achieved [22]. Both 2D and 3D data for all disciplines are generated and managed within a single source collaborative 3D Common Data Environment (CDE). 4D, 5D, 6D and 7D data are also generated. Figure 2 below shows the difference between the traditional information sharing model and the Common Data Environment (CDE) Information Sharing.

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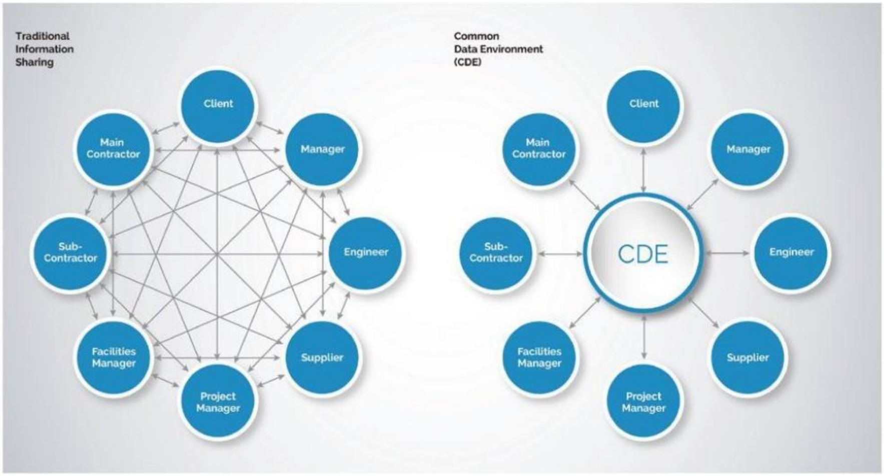

Figure 2: Traditional Information Sharing vs Common Data Environment (CDE).
Source: Thurairajah & Goucher, 2013

2.1 BIM Maturity Level and Information Technology (IT) Infrastructure

[18] stated the three components of BIM Maturity to include technology, process and policy as shown in figure 3 below. He further explained the composition of technology to comprise of software, hardware, equipment and network systems/servers required to improve efficiency, productivity and profit in the AEC Industries. All these compositions are what is summarized as IT Infrastructure in this paper. [11] also confirmed the relevance of the totality of the technology components towards BIM Maturity amongst AEC Firms. The study by [11] revealed that most firms in Indonesia have invested in the software and hardware of BIM but are still lacking in the investment of network systems and server. This in turn affected the BIM Maturity of most Indonesian AEC firms as the study revealed.

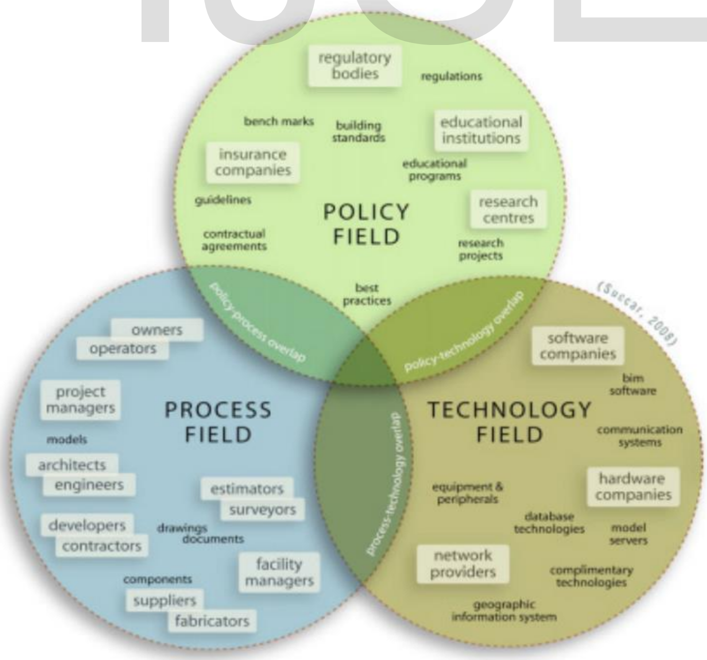

Figure 3: Three BIM Maturity Components (Source: Succar, 2009)

[21] identified 8 BIM Maturity Factors at Macro Level as seen in table 1 below.

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Table 1: Components of BIM Maturity at Macro Level (Succar and Kassem, 2015)

	Macro Level BIM Maturity Factors	Description
1	Objectives and Milestones (OM)	Policy Objectives defining progressive targets for BIM implementation at market/country level
2	Champions and drivers (CD)	Key individuals or organizations promoting the value of BIM at market/country level
3	Regulatory Framework (RF)	The normative, regulatory and legal systems supporting the delivery of BIM projects within a market/country
4	Noteworthy publications (NP)	Availability of relevant BIM documents addressing the implementation
5	Learning and education (LE)	Availability of BIM training and skills development opportunities within academia and market generally
6	Measurements and benchmarks (MB)	Metrics and scales to assess BIM capabilities at market/country level
7	Standardized parts and deliverables (SD)	Availability of standardized BIM components and use within the market
8	Technology and Infrastructure (TI)	Hardware and software systems to support information exchange within the market

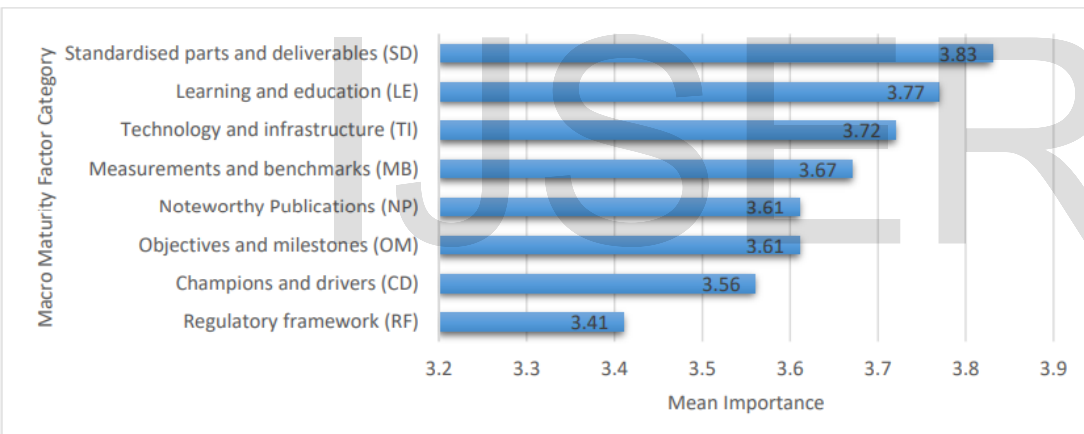

Figure 4: Ranking of Macro Level BIM Maturity Factors for designers in Italy. Source (Troiani et al., 2020)

A study by [23] ranked the 8 BIM Maturity Factors using the mean score derived for designers in Italy. As shown in Figure 4 above, Technology and Infrastructure (TI) was ranked 3rd with a mean score of 3.72. Prior studies in other countries therefore shows that Technology and Infrastructure otherwise identified as IT Infrastructure in this study is a component of BIM Maturity. This study will seek to confirm this within the context of Architectural Firms in Lagos State Nigeria. IT Infrastructure for the purpose of this study within the context of BIM is defined as the system of hardware, software, network resources, servers and services that is required for the delivery of BIM project lifecycle process. The aim of this study is to establish the BIM Maturity Level of Architectural Firm BIM Operators in Lagos State, Nigeria.

To achieve the research aim, the following objectives were derived:

- To examine the four BIM Maturity Level Categories
- To identify the relationship between BIM Maturity Levels and Sampled Firm's IT Infrastructure
- To identify the BIM Maturity Level of Architectural Firm BIM Operators in Lagos State.

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Four research hypothesis statements were also developed as listed below

Hypothesis 1

H1o: There is no relationship between BIM Maturity Level 0 and Firm's IT Infrastructure

$H1_1$: There is relationship between BIM Maturity Level 0 and Firm's IT Infrastructure

Hypothesis 2

H2o: There is no relationship between BIM Maturity Level 1 and Firm's IT Infrastructure

$H2_1$: There is relationship between BIM Maturity Level 1 and Firm's IT Infrastructure

Hypothesis 3

H3o: There is no relationship between BIM Maturity Level 2 and Firm's IT Infrastructure

$H3_1$: There is relationship between BIM Maturity Level 2 and Firm's IT Infrastructure

Hypothesis 4

H4o: There is no relationship between BIM Maturity Level 3 and Firm's IT Infrastructure

$H4_1$: There is relationship between BIM Maturity Level 1 and Firm's IT Infrastructure

3.0 RESEARCH METHOD, ANALYSIS AND DISCUSSION OF FINDINGS

The research method for the study was divided into two parts. The first part comprised of literature review of related journals, articles and conference proceedings to provide background information on the concept of BIM and BIM Maturity Levels. The literature review also guided the development of the research instrument adopted. Field survey was conducted with the use of a structured questionnaire administered on field respondents. The sample frame is made up of registered architectural firms in Lagos State, Nigeria. The Unit of Analysis is the BIM Manager or selected BIM Operator in the selected architectural firm. [3] noted that a total of 1470 architectural firms have been registered to deliver architectural professional services in Nigeria till date. Lagos State has the highest number with a total of 459 architectural firms. A sample size of 160 was gotten using the Cochran sample size formular developed by the Creative Research Systems [7]. Table 2 below shows the response rate of respondents in the study. Out of the 160 distributed questionnaire 140 representing 87.5% of the distributed questionnaire was returned duly filled. The remaining 20 representing 12.5% of the distributed questionnaire were not returned.

Table 2: Analysis of Questionnaire Distribution

QUESTIONNAIRE	NUMBER	PERCENTAGE
Distributed	160	100
Retrieved Questionnaire	140	87.5
Unreturned Questionnaire	20	12.5

Feedback from the questionnaire were assessed on a five-point Likert scale where 1= strongly disagree, 2 = disagree, 3= undecided, 4 = agree and 5= strongly agree. The gathered data was analyzed using descriptive statistics and the chi square test of association inferential statistical method. Results were presented in form of tables, charts and textual discussion of research findings.

3.1 Data Analysis

The pie chart in figure 5 below shows the distribution of architectural firm respondents based on the year each firm started the deployment of BIM tool and process on projects. It can be seen that firms that started BIM deployment within the past 6 to 11 years topped the list with 60% representation. Just 4.3% of the sampled firms began BIM deployment within the past 12 to 17 years ago. A total of 64.3% of the sampled firms was identified to have commenced BIM deployment tools and processes for the past 17 years till date. The remaining 35.7% also commenced BIM deployment within the past 5 years till date.

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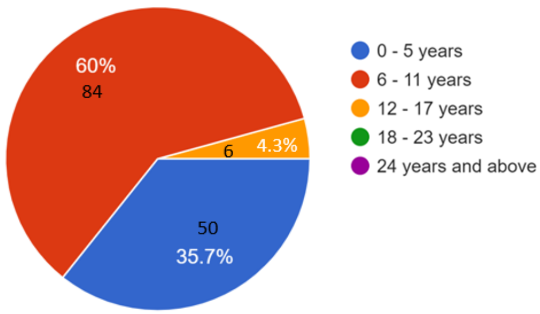

Figure 5: Year of Firm's BIM Deployment. Source: (Field Survey, 2022)

Table 3: Frequency Distribution Table for BIM Maturity Level of Sampled Firms. Source: Field Survey, 2022

S/N	BIM Maturity Levels	Categories	Frequency	Percentage	Cumulative Percent
1	BIM Maturity Level 0	Greatly Applicable	129	92.14	92.14
		Applicable	3	2.14	94.29
		Undecided	3	2.14	96.43
		Rarely Applicable	1	0.71	97.14
		Not Applicable	4	2.86	100.00
2	BIM Maturity Level 1	Greatly Applicable	124	88.57	88.57
		Applicable	12	8.57	97.14
		Undecided	2	1.43	98.57
		Rarely Applicable	0	0.00	98.57
		Not Applicable	2	1.43	100.00
3	BIM Maturity Level 2	Greatly Applicable	31	22.14	22.14
		Applicable	56	40.00	62.14
		Undecided	28	20.00	82.14
		Rarely Applicable	17	12.14	94.29
		Not Applicable	8	5.71	100.00
4	BIM Maturity Level 3	Greatly Applicable	5	3.57	3.57
		Applicable	15	10.71	14.29
		Undecided	16	11.43	25.71
		Rarely Applicable	72	51.43	77.14
		Not Applicable	32	22.86	100.00

The bar chart as shown in Figure 6 below shows the BIM Maturity Level Distribution of the sampled firms. The study revealed that just 3.57% of the sampled firms have the BIM Level 3 IT Infrastructure requirement and are indeed operating on BIM Level 3 which is the highest level with full collaboration benefit. Additional 10.71% indicated the availability of BIM Level 3 IT Infrastructure requirement but are not operating on the BIM level yet. The study revealed that BIM Level 2 which offers a partial collaboration benefit has 22.14% of the sampled firms with the IT Infrastructure requirement and actively operating on it. Additional 40% of the sampled firms indicated the availability of BIM Level 2 IT Infrastructure requirement but are not operating on the BIM level yet. Study revealed that 88.57% have the BIM Level IT Infrastructure being deployed. Table 3 above shows the frequency distribution of the BIM Maturity Level by the sampled firms.

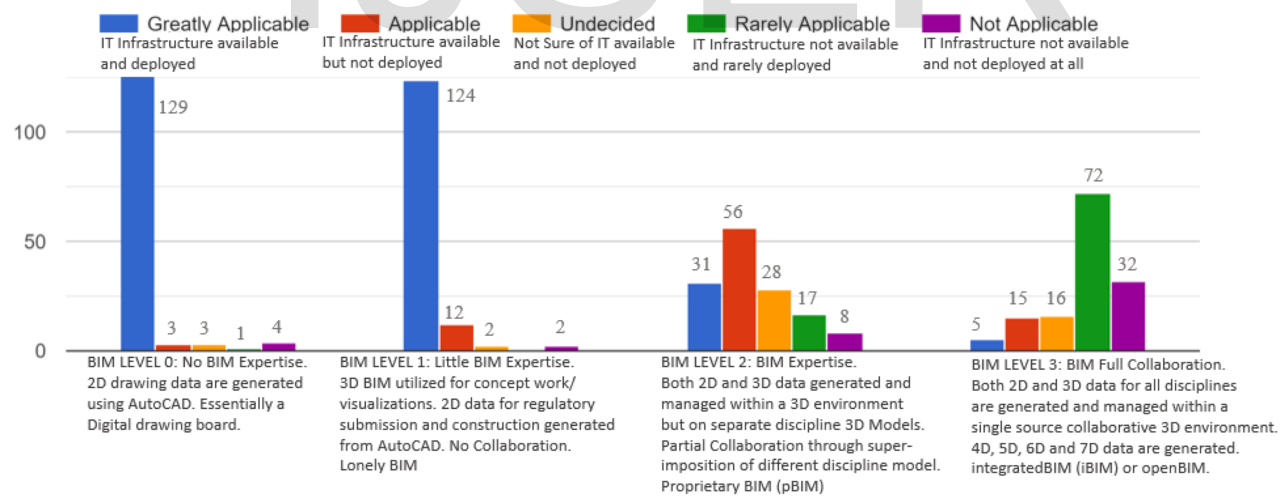

Figure 6: Bar Chart showing BIM Maturity Level of sampled firms. Source: Field Survey, 2022

3.2 Chi Square Test of Association

The study examined the relationship between Firm's IT Infrastructure and the BIM Maturity Levels using Chi-Square test of association inferential statistical method. The level to which they are related will also be confirmed.

3.2.1 Relationship between BIM Maturity Level 0 and Firm's IT Infrastructure.

From the literature review conducted, it was established that BIM Level 0 is a level of no BIM expertise where 2D drawing

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data generated using AutoCAD. It essentially represents a digital drawing board. It can be inferred from the above that the level of Firm's IT Infrastructure will have little or nothing to impact on BIM Maturity Level 0 which offers no BIM Optimization prospect. This study seeks to confirm this through chi-square test of association statistical method. Table 4 below shows the result of the cross tabulation conducted between BIM Maturity Level 0 and Firm's IT Infrastructure while Table 5 shows the chi-square test result.

Table 4: BIM Level 0 and Firm's IT Infrastructure.
Source: Field Survey 2022

BIM Maturity Lvl 0 * Firm's IT Infrastructure Crosstabulation

			Firm's IT Infrastructure				Total
			Poor	Average	Good	Excellent	
BIM Maturity Lvl 0	Not Applicable	Count	0	1	3	0	4
		Expected Count	.2	2.2	1.5	.2	4.0
		Residual	-.2	-1.2	1.5	-.2	
		Std. Residual	-.4	-.8	1.2	-.4	
	Rarely Applicable	Count	0	0	1	0	1
		Expected Count	.0	.5	.4	.0	1.0
		Residual	.0	-.5	.6	.0	
		Std. Residual	-.2	-.7	1.0	-.2	
	Undecided	Count	0	1	1	1	3
		Expected Count	.1	1.6	1.1	.1	3.0
		Residual	-.1	-.6	-.1	.9	
		Std. Residual	-.4	-.5	-.1	2.4	
	Applicable	Count	0	0	3	0	3
		Expected Count	.1	1.6	1.1	.1	3.0
		Residual	-.1	-1.6	1.9	-.1	
		Std. Residual	-.4	-1.3	1.8	-.4	
	Greatly Applicable	Count	6	74	44	5	129
		Expected Count	5.5	70.0	47.9	5.5	129.0

Table 5: Chi-Square Test for BIM Maturity Level 0 and Firm's IT Infrastructure.
Source: Field Survey, 2022

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	16.212[a]	12	.182
Likelihood Ratio	14.141	12	.292
Linear-by-Linear Association	4.474	1	.034
N of Valid Cases	140		

a. 16 cells (80.0%) have expected count less than 5. The minimum expected count is .04.

The Pearson chi square test indicates that there is no relationship between BIM Maturity Level 0 and Firm's IT Infrastructure with p value significantly greater than 0.05. The result of the Chi Square presents Pearson's [χ^2 (12) = 16.212, p = .182]. The Likelihood Ratio (LR) chi-square test result also has p-value greater than 0.05. Likelihood chi-square result [LR χ^2 (12) = 14.141, p = .292]. The Null hypotheses 1 statement for this study is therefore valid and accepted. The symmetric measure result as presented in table 6 below also shows that the degree of relationship is non-significant.

Table 6: Symmetric Measures (Phi and Cramer's V).
Source: Field Work, 2022

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.340	.182
	Cramer's V	.196	.182
N of Valid Cases		140	

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3.2.2 Relationship between BIM Maturity Level 1 and IT Infrastructure.

From the literature review conducted, it was established that BIM Level 1 is a level of little BIM expertise with no collaboration benefits accomplished. It is essentially regarded as lonely BIM. It can be inferred from the above that the level of Firm's IT Infrastructure will have little or nothing to impact on BIM Maturity Level 1 which offers little BIM Optimization prospect. This study seeks to confirm this through chi-square test of association statistical method. Table 7 below shows the result of the cross tabulation conducted between BIM Maturity Level 1 and Firm's IT Infrastructure while Table 8 shows the chi-square test result.

Table 7: BIM Maturity Level 1 and Firm's IT Infrastructure Cross Tabulation.
Source: Field Survey, 2022

BIM Maturity Lvl 1 * Firm's IT Infrastructure Crosstabulation

			Firm's IT Infrastructure				
			Poor	Average	Good	Excellent	Total
BIM Maturity Lvl 1	Not Applicable	Count	0	1	1	0	2
		Expected Count	.1	1.1	.7	.1	2.0
		Residual	.0	.0	.3	.0	
		Std. Residual	-.3	.0	.3	-.3	
	Undecided	Count	0	1	1	0	2
		Expected Count	.1	1.1	.7	.1	2.0
		Residual	.0	.0	.3	.0	
		Std. Residual	-.3	.0	.3	-.3	
	Applicable	Count	0	1	11	0	12
		Expected Count	.5	6.5	4.5	.5	12.0
		Residual	-.5	-5.5	6.5	-.5	
		Std. Residual	-.7	-2.2	3.1	-.7	
	Greatly Applicable	Count	6	73	39	6	124
		Expected Count	5.3	67.3	46.1	5.3	124.0
		Residual	.7	5.7	-7.1	.7	
		Std. Residual	.3	.7	-1.0	.3	
Total		Count	6	76	52	6	140
		Expected Count	6.0	76.0	52.0	6.0	140.0

Table 8: Chi- Square Test for BIM Maturity Level 1 and Firm's IT Infrastructure.
Source: Field Survey 2022

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	17.574[a]	9	.040
Likelihood Ratio	18.765	9	.027
Linear-by-Linear Association	2.494	1	.114
N of Valid Cases	140		

a. 11 cells (68.8%) have expected count less than 5. The minimum expected count is .09.

The Pearson chi square test indicates that there is relationship between BIM Maturity Level 1 and Firm's IT Infrastructure with p value slightly less than 0.05. The result of the Chi Square presents [Pearson's χ^2 (9) = 17.574, $p < 0.05$]. The Likelihood Ratio (LR) chi-square test result also has p-value less than 0.05. Likelihood chi-square result [LR χ^2 (9) = 18.765, $p < 0.05$] also shows a relationship between BIM Maturity Level 1 and Firm's IT Infrastructure. Where relationship is established between 2 variables, [6] proposed the use of the omega coefficient (ω), to determine the degree of association or relationship between the 2 variables. In the case of higher dimensional tables like this study where #rows >2 and #columns >2, then φ' ≠ ω. but φ = ω. where φ is the Phi value and φ' is the Cramer's V value. The symmetric measure table 9 below shows the Phi and Cramer's V value for this study.

Table 9: Symmetric Measures (Phi and Cramer's V).
Source: Field Survey, 2022

		Value	Approx. Sig.
Nominal by Nominal	Phi	.354	.040
	Cramer's V	.205	.040
N of Valid Cases		140	

Cramer's V can be converted into omega (ω) using the following formula:

$$\omega = \varphi' \sqrt{\min(\#r, \#c) - 1}$$

#r stands for number of row and #c stands for number of column

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For this study, $\omega = .205\sqrt{4-1} = .355$.

The benchmark parameter by [6] to judge the degree of relationship between 2 variables proposed that the relationship between 2 variables is small when the omega value (ω) is .1 and medium if the omega value .3. Omega value with .5 figure shows that a large relationship exists between the 2 variables. For the relationship test between BIM Level 1 and Firm's IT Infrastructure, the Omega value of .355 shows that a medium relationship exists between the 2 variables. The Null hypotheses 2 ($H2_0$) statement for this study is therefore rejected. The alternative hypotheses 2 ($H2_1$) statement is valid and accepted with a medium relationship confirmed.

3.2.3 Relationship between BIM Maturity Level 2 and Firm's IT Infrastructure.

From the literature review conducted, it was established that BIM Level 2 is a level with partial collaboration benefits where 2D and 3D data are generated and managed within a 3D environment but on separate discipline 3D models. This study seeks to confirm the degree of relationship between BIM Level 2 and Firm's IT Infrastructure. Table 10 below shows the result of the cross tabulation between BIM Maturity Level 2 and Firm's IT Infrastructure while Table 11 below shows the chi-square test result.

Table 10: BIM Maturity Level 2 and Firm's IT Infrastructure Cross Tabulation.
Source: Field Survey, 2022

BIM Maturity Lvl 2 * Firm's IT Infrastructure Crosstabulation

			Firm's IT Infrastructure				
			Poor	Average	Good	Excellent	Total
BIM Maturity Lvl 2	Not Applicable	Count	4	16	10	2	32
		Expected Count	1.4	17.4	11.9	1.4	32.0
		Residual	2.6	-1.4	-1.9	.6	
		Std. Residual	2.2	-.3	-.5	.5	
	Rarely Applicable	Count	2	47	22	1	72
		Expected Count	3.1	39.1	26.7	3.1	72.0
		Residual	-1.1	7.9	-4.7	-2.1	
		Std. Residual	-.6	1.3	-.9	-1.2	
	Undecided	Count	0	8	8	0	16
		Expected Count	.7	8.7	5.9	.7	16.0
		Residual	-.7	-.7	2.1	-.7	
		Std. Residual	-.8	-.2	.8	-.8	
	Applicable	Count	0	4	10	1	15
		Expected Count	.6	8.1	5.6	.6	15.0
		Residual	-.6	-4.1	4.4	.4	
		Std. Residual	-.8	-1.5	1.9	.4	
	Greatly Applicable	Count	0	1	2	2	5
		Expected Count	.2	2.7	1.9	.2	5.0
		Residual	-.2	-1.7	.1	1.8	
		Std. Residual	-.5	-1.0	.1	3.9	
Total		Count	6	76	52	6	140
		Expected Count	6.0	76.0	52.0	6.0	140.0

Table 11: Chi- Square Test for BIM Maturity Level 2 and Firm's IT Infrastructure.
Source: Field Study, 2022

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	34.765[a]	12	.001
Likelihood Ratio	26.310	12	.010
Linear-by-Linear Association	12.775	1	.000
N of Valid Cases	140		

a. 12 cells (60.0%) have expected count less than 5. The minimum expected count is .21.

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The Pearson chi square test indicates that there is relationship between BIM Maturity Level 2 and Firm's IT Infrastructure with p value significantly less than 0.05. The result of the Chi Square presents [Pearson's χ^2 (12) = 34.765, $p < 0.05$]. The Likelihood Ratio (LR) chi-square test result also has p-value less than 0.05. Likelihood chi-square result [LR χ^2 (12) = 26.310, $p < 0.05$] also shows a relationship between BIM Maturity Level 2 and Firm's IT Infrastructure. The symmetric measure table 12 below shows the Phi and Cramer's V value for this study.

Table 12: Symmetric Measures (Phi and Cramer's V). Source: Field Study, 2022

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.498	.001
	Cramer's V	.288	.001
N of Valid Cases		140	

Cramer's V converted into omega (ω) using the following formula:

$\omega=\varphi'\sqrt{\min(\#r,\#c)-1}$

#r stands for number of row and #c stands for number of column

For this study, $\omega = .288\sqrt{4-1} = .498$.

Comparing the omega (ω) value of .498 with the standard omega value benchmarks as postulated by [6] where a .5 value represents a large relationship, it can be concluded that there is a large relationship between BIM Maturity Level 2 and IT Infrastructure. The Null hypotheses 3 ($H3_0$) statement for this study is therefore rejected. The alternative hypotheses 3 ($H3_1$) statement is valid and accepted with a large relationship confirmed.

3.2.4 Relationship between BIM Maturity Level 3 and IT Infrastructure.

From the literature review conducted, it was established that BIM Level 3 is a level of full BIM process compliance with full collaboration benefits where 2D and 3D data for all disciplines are generated within a single source collaborative environment. It is also known as an integratedBIM (iBIM) or openBIM. This study seeks to confirm the degree of relationship between BIM Level 3 and Firm's IT Infrastructure. Table 13 above shows the result of the cross tabulation conducted between BIM Maturity Level 3 and Firm's IT Infrastructure while Table 14 shows the chi-square test result. The Pearson chi square test indicates that there is relationship between BIM Maturity Level 3 and Firm's IT Infrastructure with p value significantly less than 0.05. The result of the Chi Square presents [Pearson's χ^2 (12) = 39.717, $p < 0.05$]. The Likelihood Ratio (LR) chi-square test result also has p-value less than 0.05. Likelihood chi-square result [LR χ^2 (12) = 43.887, $p < 0.05$] also shows a relationship between BIM Maturity Level 3 and Firm's IT Infrastructure.

Table 13: BIM Maturity Level 3 and Firm's IT Infrastructure Cross Tabulation. Source: Field Survey, 2022

BIM Maturity Lvl 3 * Firm's IT Infrastructure Crosstabulation

			Firm's IT Infrastructure				
			Poor	Average	Good	Excellent	Total
BIM Maturity Lvl 3	Not Applicable	Count	0	1	7	0	8
		Expected Count	.3	4.3	3.0	.3	8.0
		Residual	-.3	-3.3	4.0	-.3	
		Std. Residual	-.6	-1.6	2.3	-.6	
	Rarely Applicable	Count	2	9	5	1	17
		Expected Count	.7	9.2	6.3	.7	17.0
		Residual	1.3	-.2	-1.3	.3	
		Std. Residual	1.5	.0	-.5	.3	
	Undecided	Count	2	25	1	0	28
		Expected Count	1.2	15.2	10.4	1.2	28.0
		Residual	.8	9.8	-9.4	-1.2	
		Std. Residual	.7	2.5	-2.9	-1.1	
	Applicable	Count	1	31	23	1	56
		Expected Count	2.4	30.4	20.8	2.4	56.0
		Residual	-1.4	.6	2.2	-1.4	
		Std. Residual	-.9	.1	.5	-.9	
	Greatly Applicable	Count	1	10	16	4	31
		Expected Count	1.3	16.8	11.5	1.3	31.0
		Residual	-.3	-6.8	4.5	2.7	
		Std. Residual	-.3	-1.7	1.3	2.3	
Total		Count	6	76	52	6	140
		Expected Count	6.0	76.0	52.0	6.0	140.0

Table 14: Chi- Square Test of association between BIM Maturity Level 3 and Firm's IT Infrastructure.

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	39.717[a]	12	.000
Likelihood Ratio	43.887	12	.000
Linear-by-Linear Association	3.368	1	.066
N of Valid Cases	140		

a. 12 cells (60.0%) have expected count less than 5. The minimum expected count is .34.

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The symmetric measure in table 15 below shows the Phi and Cramer's V value for the study from where the level of relationship between BIM Maturity Level 3 and IT Infrastructure is determined.

Table 15: Symmetric Measures (Phi and Cramer's V).
Source: Field Study, 2022

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.533	.000
	Cramer's V	.308	.000
N of Valid Cases		140	

Cramer's V converted into omega (ω) using the following formula:

$\omega = \varphi' \sqrt{\min(\#r, \#c) - 1}$

#r stands for number of row and #c stands for number of column

For this study, $\omega = .308\sqrt{4-1} = .533$.

Comparing the omega (ω) value of .533 with the standard omega value benchmarks as postulated by [6], it can be concluded that there is a significantly large relationship between BIM Maturity Level 3 and IT Infrastructure. The Null hypotheses 4 ($H4_0$) statement for this study is therefore rejected. The alternative hypotheses ($H4_1$) statement is valid and accepted with a large relationship confirmed.

3.2.5 Summary of Research Findings.

The study revealed that just 5 of the 140 sampled architectural firms amounting to 3.57% of the sampled firms have the IT Infrastructure for BIM Level 3 compliance and are indeed operating on BIM level 3. Additional 15 of the 140 sampled firms amounting to 10.71% of the sampled firms have the IT Infrastructure for BIM Level 3 compliance but are currently not deploying the BIM Level 3 IT Infrastructure capabilities. This shows that less than 5% of the sampled firms are actively on BIM Maturity Level 3 which is the highest maturity level for full optimization of the inherent BIM Deployment benefits. The study also shows that 31 of the 140 firms resulting to 22.14% of the sampled firms have the IT Infrastructure for BIM Level 2 compliance and are indeed operating on BIM level 2. Additional 56 of the 140 firms amounting to 40% of the firms have the IT Infrastructure to operate a BIM Level 2 process but are currently not deploying the BIM Level 2 IT Infrastructure capabilities. This shows that less than 25% of the sampled firms are actively on BIM Maturity Level 2 which offers partial BIM Collaborative benefit through super imposition of different discipline models. The study revealed that 124 of the 140 sampled firms resulting to 88.57% of the sampled firms are operating on BIM Maturity Level 1. This study shows that majority of the sampled architectural firms in Lagos State are on BIM Maturity Level 1 which offers little or no collaborative BIM benefit. The chi-square test conducted for this study also revealed that a strong relationship exists between firm's IT Infrastructure and BIM Maturity Level 2 and BIM Maturity Level 3 respectively thereby rejecting the null hypothesis statements 3 and 4 for this study.

4.0 CONCLUSION

The popularity of Building Information Modelling (BIM) tool and design process is fast gaining prominence amongst built environment professionals in Nigeria. Despite the numerous inherent benefits of BIM, the level of deployment and its process compliance by project team members will determine how well these benefits are maximized. It can be observed from this study that majority of the sampled architectural firms are actively operating on BIM Level 1 and BIM Level 0 which are BIM Levels that would not enable the optimization of the inherent benefits of the BIM Tool and processes. With a large relationship confirmed between Firm's IT Infrastructure and BIM Maturity Levels 2 and 3 respectively, it corroborated previous studies conducted by researchers in other countries who had categorized technology and infrastructure as one of the components of BIM Maturity. The study therefore recommends that Nigerian Architectural Firms invest more in IT Infrastructure setup that will be capable of supporting BIM Maturity Level 3 or at the minimum a BIM Maturity Level 2 for significant inherent benefits of BIM to be maximized by them.

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