BUILDING INFORMATION MODELLING CORE COMPETENCIES EXPECTED OF CONSTRUCTION MANAGEMENT GRADUATES: A NIGERIAN CONSTRUCTION INDUSTRY CASE STUDY

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Building Information Modelling (BIM) has been in existence since the 3rd industrial revolution phase. Most literature indicates its low usage in developing countries despite its great benefits. Moreover, the construction industry is still faced with getting knowledgeable professionals and graduates who understand the BIM model's integration and application. Thus, a need to employ construction management graduates (CMG) who possess substantial competencies in this regard. Therefore, this study investigates the expected BIM core competencies (EBCC) of CMG. 13 variables were obtained through review. Primary data was sourced through google form using a snowballing technique. 350 valid responses were obtained. Results found that all 13 variables were enormously significant: with RII values ranging from 0.88 to 0.93. ANOVA/KW reveal no notable difference between the perspectives of the three respondent groups. However; 7 EBCCs were ranked as the most important. This study will contribute to the body of BIM knowledge and innovative competencies expected of CMG.

Keywords: BIM; client; core competencies; Nigeria

INTRODUCTION

The technological advancement through the industrial revolution stages does not leave the construction industry behind. The rapid advancement of several technologies in the construction industry globally, including BIM, Augmented Reality, Robotics, Artificial Intelligence, Prefabricated or Modular Construction, 3D Scanning and Photogrammetry, Wireless Monitoring, 3D Printing, Cloud and Mobile Technology, Wearable Technology, and Machine Learning. These required more sophisticated competencies than the traditional methods of construction. Decades ago, construction professionals found it difficult to quickly upgrade themselves to technological advancements (Torres-Machí *et al.,* 2013). Similarly, quantity surveyors (QS) also did not find it easy to adapt to the revolving QS competencies in the construction industry (Yap *et al.,* 2021). Although the advancement is not limited to technology alone, it spans through "sustainability in construction", "social value in construction",

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"climate change agendas", and "global impacts on material management" (Farag *et al.,* 2016; Thuesen and Opoku 2018).

Nevertheless, the construction managers (CM) are under tremendous pressure as most of them struggle to align themselves with the evolving technology (Demirdoven and Arditi 2014). They need to quickly master the implementation and coordination of those software, applications, and models to remain relevant in the industry as innovation unfolds. The Architecture, Engineering and Construction (AEC) industries now experience a constant change in the mode of their activities, majorly due to the incorporation of new technologies; one of such is BIM (Toyin and Mewomo 2023). BIM is more than just a software program; it incorporates human activity, which substantially improves the building industry's processes (Demirdoven and Arditi, 2014).

BIM adoption in construction has notably improved building design, production, management, and operation and maintenance (O&M). BIM implementation gains more acceptance in the construction sector (Toyin and Mewomo, 2023). As a result, BIM knowledge is an essential skill expected of construction management graduates (Kolarić *et al.,* 2018). Construction management graduates (CMG) are employed in numerous organisations in the industry. These include construction and project management consultancy, building and civil engineering contracting, client (public and private) organisations, and developer organisations (Vaz-Serra and Mitcheltree, 2021).

However, CMG must be equipped with vital skills and competencies, including knowledge of recent software used in construction. These will enable them to operate effectively and proficiently with other professionals in the industry, subsequently giving them a range of career options (Dada and Jagboro, 2012). Moreover, the construction industry's distinctive structure, the innovative global transformation in construction and evolving regulatory requirements. Have forced the AEC employers to seek for CMGs who are academically sound and possess substantial competencies in construction-related software applications tools such as "BIM". In addition, "Intelligence, flexibility, adaptability, and the capacity to deal with uncertainty and rapid change" are all-important personal qualities that potential employers look for (Love *et al.,* 2001).

LITERATURE REVIEW

It is important to check if colleges/institutions reflect the evolving construction technology in their curricula. Mihara *et al.,* (2014) compared the curricula of UK and Japan Universities. The authors submit that most institutions have incorporated information technology studies such as BIM in their curricula. It implies that CMG from such institutions is expected to be familiar with the BIM process by default.

Competencies

GWA (2022) defines competency as the behavioural characteristics, abilities, skills, and knowledge necessary to deliver satisfactory results while on the job. Buvik and Rolfsen (2015) see competence as "the abilities, skills, and capabilities that a person has in a particular domain". Based on the above understanding, competency could be generally seen as the capability to utilise specific attributes of knowledge, skills, talent, or personal quality needed to achieve/deliver crucial tasks or jobs efficiently. According to Turner (2017), "the key competencies expected of project managers

encompass technical knowledge and behaviours, leadership capabilities and expertise in strategic and business management".

Torres-Machí *et al.,* (2013) researched in Spain focused on CMG students. The authors seek their point of view to know why the unemployment rate was high among young graduates of CM professionals. Lack of adequate communication (language barrier, due to the diverse nature of professionals in their industry), inadequate preliminary university program (lack of BIM knowledge), no eagerness to work, failure to explore other countries, inadequate master's degree to fulfil market demands, economic crisis, a surplus of universities awarding the similar graduate degree were seen as the primary reason. Nevertheless, researchers have documented extensive findings on the expected competencies of built professional graduates in the construction industry, but the available primary study focused on the Quantity Surveyor (QS). Dada and Jagboro (2012) researched Nigeria; their study result indicates the essential general skills are "computer literacy, building engineering, information technology, economics, measurement/quantification and knowledge of civil/heavy engineering works".

Wherein noted, the vital competencies for QS were: "cost planning and control, estimating, construction procurement system, contract documentation, contract administration and project management". Yap *et al.,* (2021) conducted a similar study in Malaysia. The authors also focused on QS's current and future expected competencies; their findings identified the most critical contemporary competencies as "cost planning, valuation of works, measurement/quantification, and contract documentation.". Moreover, the authors recalled that the expected future competencies required by expertise are: "communication and negotiation, ethics and professional conduct, and value management". Yogeshwaran *et al.,* (2018) conducted research focused on developing countries.

The authors submit that graduate QS competency in areas such as "cost planning," "strategic planning," "life cycle cost analysis," "sustainability," "building surveying," and "business management" is at accepted levels that exceed what the industry requires. Mitcheltree *et al.,* (2019) and Vaz-Serra and Mitcheltree (2021) researched in Australia, focusing on CMG competencies. It was concluded that more critical concern was placed on "interpersonal skills" and "competencies defined as traditionally fitting within core technical knowledge" within the Australian construction industry - however, the limited publication in this study context real low concentration to this study area. At the same time, non or few have investigated CMG's expected BIM core competencies in the construction industry. However, this study aims to add to the body of knowledge in this area and serve as the first empirical study in the Nigerian AEC industry. Therefore, this study intends to investigate the EBCC required of CMG by the employers (contractor/consultant and client) in the Nigerian construction industry. Table 1 shows the expected BIM core competencies required of CMG as identified from the published articles.

METHOD

This study adopts two distinct methods to source data. First method; secondary data were obtained through a thorough review of past published literature in the framework of this study. These yield 13 crucial Expected BIM Core Competencies (EBCC). Thus, identifying the 13 possible EBCCs is based mainly on competencies that have received ample consideration in studies conducted in different countries. Similar methods were adopted by (Chan *et al.,* 2018). The authors agreed it is "more

appropriate to use well-known factors for a research study, as that would allow respondents to respond easily".

Table 1: Expected BIM core competencies for CMG

Code	Competencies	References
EBCC1	Good communication	(Hodorog *et al.,* 2019; Kolarić *et al.,* 2018)
EBCC 2	Analytical and problem-solving skills	(Ku and Taiebat, 2011)
EBCC 3	Basic Modelling specification, validation, access management and control.	(Hodorog *et al.,* 2019; Kolarić *et al.,* 2018; Ku and Taiebat, 2011)
EBCC 4	ICT competence	(Hodorog *et al.,* 2019)
EBCC 5	Teamwork	(Raiola, 2016; Wang *et al.,* 2020)
EBCC 6	Basic understanding of the BIM process	(Raiola, 2016; Uhm *et al.,* 2017)
EBCC 7	Knowledge of the construction process	(Raiola, 2016; Bozoglu, 2016)
EBCC 8	Design coordination	(Mitcheltree *et al.,* 2019; Bozoglu, 2016)
EBCC 9	BIM coordination	(Wang *et al.,* 2020)
EBCC 10	Enthusiasm for learning new software	(Kolarić *et al.,* 2018)
EBCC 11	Experience using virtual design and construction (VDC)/Big room method	(Yakami *et al.,* 2017; Mitcheltree *et al.,* 2019)
EBCC 12	Quality and document management	(Ku and Taiebat, 2011)
EBCC 13	Technical Decision making	(Yakami *et al.,* 2017)

Second method; A web-based questionnaire survey was constructed to collect quantitative data. The questionnaire survey encompasses two main steps to assess the relevance and reliability of the questionnaire. Firstly, the questionnaire was reviewed by two real estate human resource managers (RE-HRM) and a contractor with over 10 years of practising experience in Lagos, confirming that unclear expressions were not contained in the survey and that suitable technical terms were used.

These professionals were assigned because; RE-HRMs are conversant with the essential required competencies and are responsible for interviewing /screening and employing potential employees; The contractors know the nature of the job and the possible competencies needed to carry out the job. The questionnaire covered the main expected BIM-related competencies required of CGM. Snowballing sampling technic was adopted to locate the relevant respondent, a similar approach adopted by Gledson *et al.,* (2016). Secondly, a pilot study with 20 respondents was first conducted to test the comprehensibility and design of the questionnaire before its wide distribution. The expected BIM core competencies were measured on a five-point Likert scale from 1 ("not significant") to 5 ("strongly significant"). One of the reliable methods used to validate quantitative questionnaire reliability is using Cronbach's alpha technics (Toyin and Mewomo, 2021b).

These technics determine the average relationship or internal regularity amongst factors/variables in a questionnaire. Using the IBM SPSS 27.0, the calculated α value for the 13 EBCC was 0.889. These indicated the measurement is reliable at a 5% significant level based on the five-point Likert scale. The collected data sample can be suitable for further descriptive and inferential analysis. As no further modification was made to the pilot study questionnaire, the responses of all 20 respondents involved were included in the primary survey. In this study, "section A requests demographic information of the respondents and section B requests expected BIM core competency (EBCC1-EBCC13), measured on a five-point Likert scale. The target population is CMG, contractor/consultant, and client (developer). The sample

frame involves representatives from the target population in the country's southwest region.

The students' viewpoints were obtained as they had reasonable experience with the employer's demands from their industrial training program experience. At the same time, the viewpoint of contractor/consultant and client was obtained since they deal directly with construction managers and know what is expected of them. Descriptive analysis: the mean Item Score (MIS) was used to rank the EBCS variables, while the relative importance index (RII) was used to rank the level of its significance. The variables were evaluated using the 5-point Likert scale to help determine the importance of each variable.

Inferential analysis: "Homogeneity of variances, one way ANOVA and Kruskal-Wallis (KW) tests are used to evaluate the perceived importance of the expected BIM core competencies between the different respondent groups of contractors/consultants, clients, and students". 'Secondary data obtained through a thorough literature review of related publications are then used as a guide for discussion and plotting of the findings (Yap *et al.,* 2021).

FINDINGS

Background Information

This section entails the respondent's background information categorised using gender, current role, and years of experience in construction. Table 2 shows detailed results in this regard. It reveals that 76% of the respondents had substantial working experience in construction. It could be concluded that the information gotten from them is reliable.

Table 2: Respondent background information

Demographic data	Respondents	Percentage %	Cumulative
Gender	245	70%	70%
Male	105	30%	100%
Female			
Current role			
Contractor/consultant	112	32%	32%
Client (Developer)	85	24.3%	56.3%
Student	153	43.7%	100%
Years of experience in the construction industry			
Less than 5 years	91	26%	26%
5-10 years	82	23.4%	49.4%
11-15 years	73	20.9%	70.3%
16-20 years	54	15.4%	85.7%
More than 20 years	50	14.3%	100%

Analysis of Results

Using the IBM SPSS 27.0 Statistical software, the Cronbach's alpha value of 0.893 for the 13 variables is superb, indicating that the five-point Likert scale measurement was reliable at the 5% significance level. The RII results reveal that all the (EBCS1-EBCS13) are statistically significant. Table 3 presents the mean scores and standard deviations of the significance ratings for each EBCS overall and as viewed by the

respondent types. Overall, the mean scores range from 4.42 to 4.67; Contractor/ consultant from 4.22 to 4.71; Client from 4.36 to 4.72 and student from 4.31 to 4.61. overall, the seven most essential competencies are: EBCS1, EBCC 5, EBCC6, EBCC4, EBCC7, EBCC8 and EBCC9 being good communication, Analytical and problem-solving skills, Teamwork, Basic understanding of BIM process, Knowledge of construction process, design coordination and BIM coordination with mean scores of 4.67, 4.62, 4.62, 4.61, 4.54, 4.54, and 4.54 respectively.

However, EBCC11: Experience using virtual design and construction (VDC)/Big room method; EBCC3: Basic Modelling specification, validation, access management, and control, with a mean score of 4.32 and 4.35, respectively, are ranked lowest. However, looking at the top-ranked variables, it could be deduced that the industry expects much from intending and current CMG. Good communication is essential in any labour-intensive organisation. Ranking it first shows that it's very crucial. Table 3 shows all the three respondent groups unanimously agreed on the criticality of the competencies. In the case of EBCC11 and EBCC3, ranking them as least important from the variable list doesn't mean they are not significantly important. The MIS is relatively strong.

Table 3: EBCC descriptive analysis for each group

Code	Contractor/ consultant N=112		Client (Developer) N=85		Graduate Student N=153		Overall N = 350	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
EBCS1	4.71	0.46	4.72	0.45	4.61	0.54	4.67	.559
EBCS2	4.46	0.67	4.52	0.55	4.53	0.60	4.51	.609
EBCS3	4.41	0.72	4.34	0.63	4.31	0.75	4.35	.710
EBCS4	4.55	0.72	4.68	0.54	4.61	0.57	4.61	.618
EBCS5	4.60	0.68	4.68	0.49	4.60	0.61	4.62	.607
EBCS6	4.60	0.59	4.69	0.56	4.59	0.73	4.62	.648
EBCS7	4.53	0.63	4.55	0.52	4.54	0.63	4.54	.603
EBCS8	4.47	0.71	4.65	0.57	4.52	0.63	4.54	.645
EBCS9	4.62	0.62	4.48	0.67	4.52	0.70	4.54	.666
EBCS10	4.48	0.70	4.51	0.63	4.49	0.67	4.49	.667
EBCS11	4.22	0.77	4.36	0.75	4.37	0.80	4.32	.780
EBCS12	4.39	0.79	4.42	0.66	4.46	0.69	4.43	.714
EBCS13	4.35	0.73	4.39	0.67	4.48	0.69	4.42	.700

From Table 4, the RII result ranges from 0.88 to 0.93. It could be concluded that the 13 variables, according to the viewpoint of the 350 respondents, are statistically strongly significant.

In this study, homogeneity of variance (HV) based on the mean (BM) was first conducted for the inferential statistics. Using SPSS 27.0, the significance level of 0.05 and confidence interval of 95.0 % were set. It was assumed that out of the 13 variables, EBCS4 and EBCS8 violated the rule of HV. Thereafter, one way ANOVA/KW statistical tests were conducted. The result shows that all the 13 variables accept the null hypothesis statement: 'The distribution of the EBCS1 to EBCS13 is the same across categories of 3 respondents' group. The decision was to retain the null hypothesis. These could be deduced from the result of Table 4. The significance level of all the variables is greater than 0.05. Fig. 1 and Fig. 2 justified the result of EBCC 4 and 8. Thus, no significant difference from the perspective of the respondents.

Table 4: Descriptive and inferential statistical test

Descriptive					HV		Hypothesis Test	
N = 350					Levene's Statistic:		ANOVA/KW	
Code	Mean	SD	RII	Rank	BM	Sig.	F	Sig.
EBCC1	4.67	.559	.93	1	2.235	.109	1.418	.244
EBCC2	4.51	.609	.90	8	.994	.371	.390	.678
EBCC3	4.35	.710	.87	12	3.091	.047	.614	.542
EBCC4	4.61	.618	.92	4	4.396	0.13*	1.054	.350
EBCC5	4.62	.607	.92	2	2.529	0.81	.592	.554
EBCC6	4.62	.648	.92	3	2.495	0.84	.735	.480
EBCC7	4.54	.603	.91	5	1.614	.201	.0.47	.954
EBCC8	4.54	.645	.91	6	4.755	.009**	2.159	.117
EBCC9	4.54	.666	.91	7	2.466	0.86	1.145	.319
EBCC10	4.49	.667	.90	9	.260	.771	.031	.970
EBCC11	4.32	.780	.86	13	1.065	.346	1.348	.261
EBCC12	4.43	.714	.89	10	1.375	.254	.327	.721
EBCC13	4.42	.700	.88	11	.002	.998	1.308	.272

RII values	Significance level
0.81≤RII≤1	Strongly significant
0.61≤RII≤0.8	Significant
0.41≤RII≤0.6	Neutral
0.21≤RII≤0.4	Less significant
0≤RII≤0.2	Not significant

a. The test statistic is adjusted for ties

b. Multiple comparisons are not performed because the overall test does not show significant difference across samples. (TS)= Test Statistic. Sig= Significance (P value).

Fig. 1 and Fig. 2 indicate the opinion of the respondents are likely the same across the three categories. Showing the Likert scale selection option falls from 3 to 5. Therefore, building back wiser from the traditional means of construction and design process, the CMG must possess the highlighted 13 minimum required competencies in the Nigerian AEC industry.

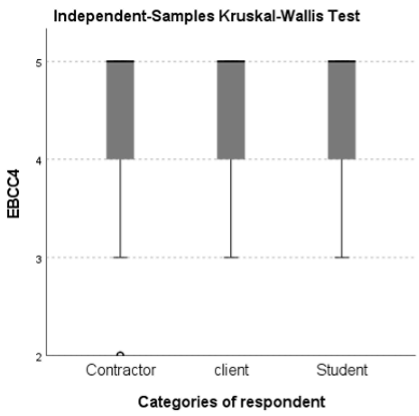

Figure 1: ANOVA/KW result (EBCC4)

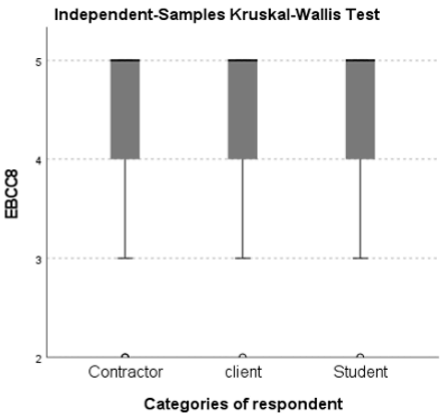

Figure 2: ANOVA/KW result (EBCC8)

CONCLUSIONS

This study investigated CMG's expected BIM core competencies in executing and managing their professional duties within the construction industry. The industry demands for BIM knowledgeable graduates are increasing rapidly and becoming more complex. For CMG to remain employable and relevant in the industry, they need to recognise and key into the required core competencies of the construction industry. This study obtained secondary data from the meta-analysis of the literature, which

identified 13 core BIM competencies. These were further subjected to targeted respondents to elicit primary data.

A structured questionnaire was used to solicit viewpoints from the three groups of respondent contractor/consultant, the client (developer) and CMG in the Southwest region of Nigeria. The data collected were analysed using both descriptive and inferential statistics. Overall, this research provides the answer to its study aims. It identified 13 core competencies and out of which seven were regarded as the most important: EBCS1, EBCC 5, EBCC6, EBCC4, EBCC7, EBCC8 and EBCC9, being good communication, Analytical and problem-solving skill, Teamwork, Basic understanding of BIM process, Knowledge of construction process, design coordination and BIM coordination.

The relative importance index reveals that all the 13 expected BIM core competencies are significantly important. At the same time, the inferential statistical analysis noted no notable difference between the respondents' perspectives. Based on these findings, it could be concluded that the Nigerian AEC industry expects CMG to acquire substantial construction innovative knowledge and personal competencies. These will enable them to quickly catch up with the advanced construction process during their undergraduate programme or internship. They must acclimate themselves to the evolving BIM-related software, programs, tools, and models and have good communication skills. These will enhance on-site productivity, information management, quality of work, and overall construction management. This study is only limited to the southwest region of Nigeria; therefore, it may not be generalised to the remaining five regions.

The only data gathering method, the use of questionnaires, may cause monomethod favouritism. Nevertheless, the adopted method for this survey is best suitable for efficiently collecting data from a large respondent sample size to enable easy statistical analysis computation. Nonetheless, the conclusions of this study are supported by data triangulation, which involves comparing them to earlier related research. Moreover, a questionnaire survey based on a Likert scale is a universal means of gathering data from a broad group of individuals. Different respondents may interpret each question differently. Regardless it is noted as one of the best widely utilised psychometric instruments for assessing self-reported views. More study is required using mixed method approaches to build a framework for measuring total construction management competency for future relevance.

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