Proficiency and Capacity Building of Human Capital in Architectural Firms in Nigeria

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ABSTRACT

Computer Aided Design (CAD) and Building Information Modelling (BIM) are essential design technologies for the production of services by architectural firms and architects. The study examines the availability/proficiency levels of CAD/BIM personnel in architectural firms in Nigeria; the existence of training programmes for these personnel; and the relationship between availability of personnel and existence of training programmes. The study adopted a cross-sectional survey and in-depth interviews, giving a good blend of quantitative and qualitative research methods. A response rate of 74.21% from the survey was achieved, with responses from 118 out of 159 firms sampled. The data were analyzed using descriptive statistics, cross-tabulations, content analysis and tests of associations. Reasonable levels of proficiency in the use of CAD, BIM, Renderers and the Internet were revealed. However, the study found no significant association between the availability of CAD/BIM proficient personnel and the existence of training programmes. Concerted efforts to improve existing training programmes and institutions should be championed by firms and professional bodies.

Keywords- Availability, BIM, CAD, Design, Personnel, Proficiency, Training, Technologies

1. BACKGROUND TO THE STUDY

The fact that in the mid 1950s, the United States Military precisely the Air force pioneered the development of the first graphic system called the SAGE (Semi Auto Ground Environment) cannot be overemphasized. The success of the system was enhanced by the military's partnership with the Lincoln laboratory of the Massachusetts Institute of Technology (MIT).

This institute was visibly at the fore front of studies in the areas of the earliest Computer Aided Design (CAD), Computer Aided Design and Drafting (CADD), Computer Aided Manufacturing (CAM) and other graphic solutions. Dr. Patrick Hanratty is popular for his pioneering research and discoveries in the field of Computer Aided Design and Manufacturing. Notable amongst his early creations is the PRONTO a numerical-control (NC) programming system.

Other notable personalities that contributed to the early development of CADD/CAM includes: Stromberk Carlson who created a system to interpret graphics from tape and output on screen display in 1959; Ivan Sutherland a researcher at MIT in 1960 developed the 'SKETCHPAD'; McDonnell introduced CADD the dimension of design and drafting to existing CAD solution in1965; also in1965 Lockheed introduced CAD/CAM for industrial operations; and David Prince wrote the first book on computer graphics in1971 [1] , [2].

CAD systems had been utilized in the 1970s in the design and manufacturing of Aircrafts in commercial quantities, however, the 1980s ushered in the introduction of the personal computer and PC CAD to architectural firms in the developed world. CAD made its first appearance in Architectural design in the roof works of Frei Otto for the Munich Olympic Stadium and Sports halls of 1972 [3]. Much later in the 1980s it spread to other developing countries. In 1982 the Autodesk Company was founded by sixteen people in the United States by the initiative of John Walker. The platform on which their first AutoCAD system was based is the MicroCAD earlier developed by Mike Riddle in1981.

Other companies that contributed to the development of desktop CAD applications include Unigraphics, Denebau Software, Dassault Systems, Visio, IBM, Bentley amongst others. In the 1990s graphic software companies created specialized solutions for particular industries providing capabilities for free form modelling, numerical control machining for surface and plastics manufacturing. Record sales were reached in 1994 with AutoCAD hitting the one million mark followed by CADkey with 180,000 copies sold and Micro Station with 155,000 mark. The advent of Microsoft's Windows 95 operating system characterized by its beautiful user-friendly interface paved the way for increased possibilities in CAD, CADD/CAM, Modelling and other graphic packages. The Internet technology (worldwide web) also became available creating the information super highway in cyberspace making information available at the click of a mouse [4], [2], and [3].

Dare-Abel [5] confirmed that architectural firms in Nigeria have accepted these technologies for operations since the early 1980s. Precisely 4.2% of the sample began operations with CAD systems during the period. Since then there has been incremental growth in the adoption

and developments in the practice of Architectural profession in Nigeria. There is therefore a need to study the context and the availability of the human capital that are required for successful adoption and deployment of the design technologies.

1.1 Computer Aided Design (2D and 3D CAD)

CAD initially offered opportunity for easier and faster design drafting for a wide range of professionals such as the architects, engineers, product designers, planners, surveyors graphic artists and a host of others. The real function as described by [6] was actually computer aided drafting. These CAD software provided platforms to work in 2 dimensions which for architects required a transitional medium such as a freehand sketch to be able to convey the design intent to digital format by the operator.

Most software developers identified this inadequacies and their response resulted in the birth of computer-aided design and drafting (CADD). CAD as used as a 2D tool is an aid for more efficient production of presentation drawings, working drawings, faster handling of repetitive tasks and detailing. This brought about a gradual end to the manual drafting and tracing era in architectural firms.

Emmit [6] and [7] both recognized certain advantages of CAD systems over manual drafting to include: Drawing clarity, precision and consistency in drawing style when multiple designers work on a drawing; elimination of repetition and the monotony in drafting is reduced and maybe even eliminated; increased speed of drawing production is increased in large scale works. Furthermore there are opportunities for ease of alterations and effecting changes; easy coordination and automatic drawing register; rapid access to previous projects and details; and drawing longevity in electronic formats and little storage space needed.

On the other hand the disadvantages identified include: high initial cost of hardware and software; high cost of maintenance, upgrades and training of staff; and health and safety implications. Other demerits comprise software compatibility problems, boredom and the possibility of a system crash.

1.2 Building Information Modelling (BIM) in Architectural Design and Practice

BIM with particular reference to [8] is a building design and documentation methodology which enables the user to create and manage information about a building project. The information about the building project is stored in a single database file or in multiple database files in which interrelationships are constantly well managed.

This ensures that the information is consistent and up to date. This also means that any Change in any part of the design is automatically reflected across the project. This concept explains what [9] termed bidirectional editing, the study also opines that Autodesk Revit, ArchiCAD, Bentley Architecture, VectorWorks ARCHITECT and Autodesk Architectural Desktop are good examples of BIM software. Available design technologies (software/applications) which are prevalent in the Architecture, Engineering and construction (AEC) industry in Nigeria are presented in Table 1.

BIM software that operate the unidirectional editing also exist in which case information is stored in separate document files but changes in one view does not automatically affect other views. The current trend for most BIM software is to adopt the bidirectional associative platform in view of the inherent advantages. Bachman [10] opines that BIM is more than a technology or tool as it has effect on over design culture, effective collaborative work and design process in architectural firms. Plate 3 shows an Autodesk Revit Architecture model rendered to reflect the desired environment.

BIM has been said to help architects explore early design concepts and forms thereby allowing them to accurately follow through the vision during design, documentation and construction. It is to be noted that most BIM packages are intuitive tools that work in predictive mode and are intelligent due to the high level programming that has been built in. All these attributes are useful in the production of sustainable design, clash detection, construction planning and component fabrication. Its effect on firms' productivity has been measured [8], [10] and [11].

Table 1: Major Design and Collaboration technologies and their Classification

	CAD	CAAD	BIM	CSCW Engines
1	AutoCAD	Architectural Desktop	Revit	Buzzsaw
2	ArchiCAD	ArchiCAD	ArchiCAD	Teamwork
3	SolidWorks	Bentley Architecture	Bentley Architecture	Delta Server technology
4	PowerCAD	PowerCAD	VectorWorks ARCHITECT	
5	TurboCAD	SketchUP	Graphisoft Constructor	
6	FormZ	FormZ	SolidWorks	
7	Inventor	3D home	Revit Structure	

Source: Author's Field Survey (2012)

2. STATEMENT OF THE PROBLEM

The issue of human capital development and capacity amongst architectural firms in Nigeria has not been sufficiently explained and understood with the evidence of empirical data. This calls for more inquiry into the availability, adequacy, and mode of training and retraining of architects that utilise CAD, BIM and other technologies in these firms. Generally firms request the services of already proficient CAD and BIM users and expect that they personally acquire new knowledge. It becomes pertinent to understand the basis and sustainability of this approach by architectural firms in the country.

3. OBJECTIVE

The main objective of this study is to examine the association between the availability of CAD/BIM proficient personnel and the existence of training programmes in architectural firms in Nigeria. To achieve this, the study sought to answer the following objectives:

1. Identify the availability and proficiency levels of the CAD/BIM personnel in the use of available design technologies.
2. Examine the existence of training programmes for CAD/BIM personnel in the Architectural firms.
3. Examine the association between the availability of CAD/BIM proficient personnel and the existence of training programmes in architectural firms in Nigeria.

Therefore the following hypothesis was formulated:

H_0 - There is no significant relationship between the availability of CAD/BIM proficient personnel in architectural firms in Nigeria and the existence of training programmes within the firms.

Ha - There is significant relationship between the availability of CAD/BIM proficient personnel in architectural firms in Nigeria and the existence of training programmes within the firms.

4. METHODOLOGY

4.1 The Research Design

A combination of quantitative and qualitative research method was adopted for this study. A Cross-sectional Survey was conducted and in-depth interviews were also conducted to complement the empirical data generated.

4.2 The Research Population

The study focuses on professional practice in architectural firms in Nigeria; therefore the study population is the total number of architectural firms in the country. However for purposes of legality, the total number of architectural firms that are licensed to operate in the country were adopted. This is because it may not be easy to determine the actual number of such firms that operate without the regulatory body's permission.

4.3 Sampling Frame

This study adopts the register of architectural firms entitled to practice in Nigeria 2010 as the sampling frame. This register is compiled and published annually by the Architects Registration Council of Nigeria (ARCON). It contains a list of 649 firms that were authorized to practice the profession.

4.4 The Sample

Multi-stage sampling which is a probability sampling method was adopted to enable an easy arrival at the final sample. The listed architectural firms were grouped geographically according to their locations into the six zones. The zones are north-west, north-east, north-central, south-west, south-east and south-south. The city-selection stage involved the choice of the city with the most number of firms, this information was extracted from the sampling frame and corroborated by precedents from previous studies. The final stage involved the selection of the calculated number of firms through random sampling by balloting. The six selected cities are Abuja, Kaduna, Maiduguri, Enugu, Lagos and Portharcourt. A sample of 159 architectural firms representing 24.5% of firms in the sample frame was calculated using a sample size calculator.

4.5 Data Collection

A structured questionnaire was developed along with an interview schedule as research instruments for the study. As a result of the field work a total of One hundred and eighteen (118) questionnaires out of (159) were returned duly completed. This indicates a response rate of 74.21%. Figure 4.1 presents the percentage distribution of the firms from the selected cities with Lagos contributing 44% of the sample and Maiduguri contributing 2% of the sample representing the least city contribution.

4.6 Method of Data Analysis

Data collected through the research instrument was analysed to test the hypothesis and provide study information. The following methods of analysis were employed: Descriptive statistics (univariate analysis) using mean, frequency, percentages and proportions. Bivariate analysis such as Cross tabulation and test of associations were also employed. Content and Thematic analysis was utilized for the qualitative data that were derived from the structured interviews. The various responses were analyzed between April and June 2012 using the statistical package for Social Scientists (SPSS Version 15).

5. DATA PRESENTATION

5.1 CAD Literate Personnel

Most of the architectural firms, about (51%) of the firms had between 1 and 5 persons that are CAD literate while a significant percentage (33.6%) possessed between 6 and 10 persons that are CAD literate in the firms' employment. Thirteen (13) firms which represent 11.2% had between 11 and 20 persons that are CAD literate in their employment.

The percentage of firms that employed between 21 and 50 persons who are CAD literate was 2.6% while only 1.8% of the architectural firms did not have any. The study further looked at the level of proficiency of these staff in the use of the design technologies, as presented in a subsequent subsection.

5.2 BIM Literate Personnel

BIM Technologies are multidimensional and bidirectional in nature. More and more CAD application names as standing on either side depending on the focus of the software. As earlier stated in Chapter 2, Revit, ArchiCAD, Bentley are some of the available BIM Technologies available. The result of the analysis shows that 51.7% of the firms had between 1 and 5 persons who are BIM literate in their organization. 21.2% of the firms had 6 and 10 persons who are BIM literate. The firms who do not have any BIM literate persons were 24.6% while only 2.5% of the sample had between 11 and 20 persons.

5.3 Staff Proficiency Levels AutoCAD

The deployment of the AutoCAD design technology recorded the proficiency levels in the architectural firms. A staff percentage of 9.3% do not use AutoCAD, while 0.8% have low average proficiency. Average proficiency level was recorded by 5.9% of the staff while most of the staff (56.8%) actually falls within those with above average proficiency.

No staff was grouped within the low proficiency level whereas staff with high (excellent) proficiency represented 27.1% of the sample. It can be deduced that more than 90% of the firms deploy AutoCAD technology and that most of the staff 89.8% fell within the average to high (excellent) proficiency levels. It follows that most staff in the industry were well advanced in the deployment of this technology. Staff proficiency levels for AutoCAD recorded a mean proficiency score of 3.82, SD = 1.36, as presented in table 2.

5.4 Staff Proficiency Levels Revit Architecture

Revit architecture in the past years has been enjoying acceptance and deployment as a Building Information modelling technology. The study also examined how proficient the staffs of the sampled architectural firms were, in the deployment of the software. The result of the analysis show that 33.3% of staff in firms do not use the software yet while 2.6% and 8.5% of the staff show low proficiency and below average proficiency respectively. Furthermore, 11.1% show average proficiency in the deployment of Revit (Architecture) while 30.8% of firms' staff representing the largest group show above average proficiency. Only 13.7% of the staff record high (excellent) proficiency in the deployment of Revit architecture. 55.6% of the staffs show proficiency levels that are between average to high (excellent) which also show that a sizeable number of firms staff have become confident and comfortable using the technology. Revit architecture in this study recorded mean proficiency score of 2.44 and SD = 1.94, as presented in table 2.

5.5 Staff Proficiency Levels – Renderers

The interview session with certain key personnel of some selected architectural firms yielded useful qualitative data that further explains certain areas that the questionnaire may not have richly explained. The study examined the use of software utilized for rendering 2D presentations and 3D models in the selected architectural firms. The data gathered from the interviews revealed that the following were generally used by majority of the firms; Studio Max, Artlantis, Kirketea, CorelDraw, Maya, picasa and Photo Paint.

The presentation of the result of the data analysis is seen in fig.1 below.

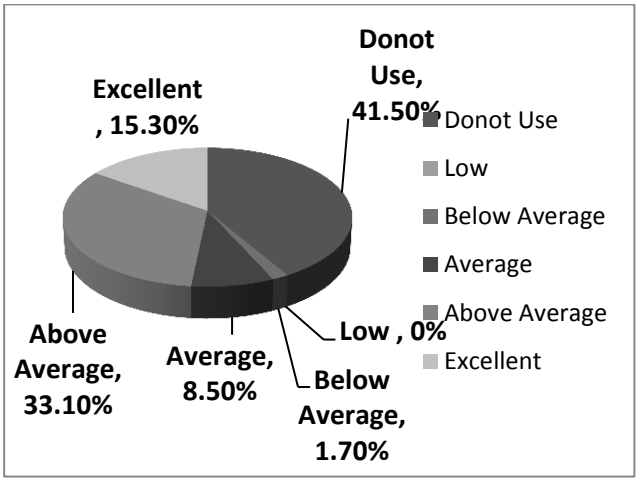

Fig. 1: Staff Proficiency Levels in the use of Renderers in Architectural Firms

Table 2: Staff Mean Proficiency Levels in the Available ICT Tools

Available ICTs/Software	Mean Score in proficiency	Rank
AutoCAD	3.82	1
Internet	2.99	2
Revit	2.44	3
ArchiCAD	2.39	4
Renderers	2.37	5
SketchUP	1.49	6
Buzzsaw	0.54	8

Source: Authors Field Survey (2012)

5.6 Existence of Staff Training Programmes

The study examined the existence of staff training programmes within the sampled architectural firms and found that sixty firms representing 50.8% of the sample

were involved in running training Programmes. Fifty five firms representing 46.6% of the sample were not involved in this scheme while three firms (2.5%) were yet to decide on the running training programmes. A significant percentage have existing programmes running, it is therefore hoped that more firms will consider this aspect of human capacity building which may in turn add value to their organizations. A graphical presentation is given in figure 2 below. Some of the principal architects interviewed on the availability of CAD and BIM proficient staff and the need for training programmes expressed different views on staff training but most agree on the fact that the young graduates have aptitude for CAD and BIM deployment. They also agree that within a short period, young graduate architects easily adjust to the demands of the firms but need to develop more realistic design decision making skills and diligence on the job. Most firms suggest that the skills on the various design technologies were acquired or inspired from their institutions of learning (schools of architecture).

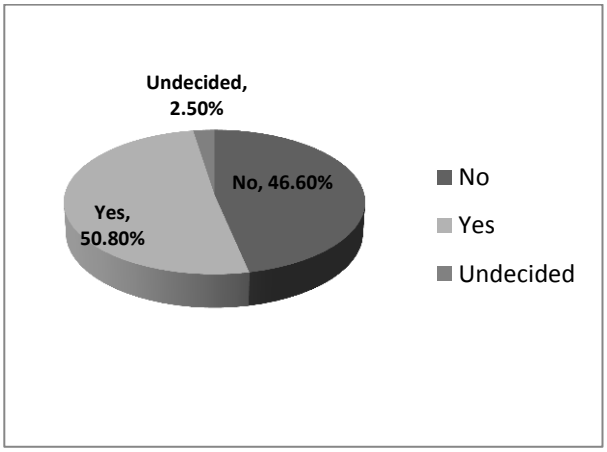

Fig. 2: Existence of Training Programmes in Architectural Firms

One of the principals made his opinion clear in the following statement:

> *"The young architects that are being employed in our firm have a reasonably good level of proficiency in CAD and BIM package, this I think is a commendable aspect on the part of the schools of architecture. Although the graduates themselves develop skills on their own for packages other than those taught in school, the essential foundation is in my opinion from the school. Our firm train these young ones on some of the peculiar design preferences that we hold dearly."*

Another architect had this to say with regards to the new architects employed in their firm:

> *"Within few weeks, the new architects catch up with our system and style of working (even the software we use). I think it is not that important to organize any formal training programme. We have not had any problems with our staff since the establishment of the firm."*

5.7 Training Methods Employed

The review of literature presented a number of approaches to the training of architects while on the job. The study adopted the methods presented and also expanded the options to accommodate certain popular methods within the Nigerian context. One-on-one, classroom format, lunch and learn were derived from [12]. Overseas training do-it-yourself and other forms of training were added to expand the options.

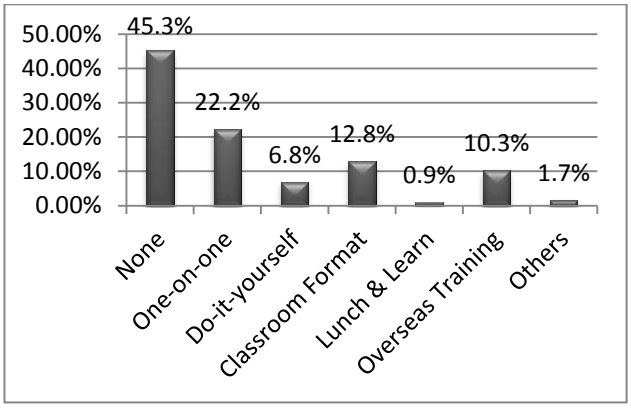

Fig. 3: Methods of Training Programmes in Architectural Firms

Source: Author's Field Survey (2013)

The analysis of the data on the various methods of training utilized by firms revealed, most firms (53 firms, 45.3% of sample) did not employ any form of training, since there was no training programme existing in the firms.

However, 26 firms (22.2%) used the one-on-one method, where more proficient architects in the firm train individual architects with lower proficiency, irrespective of their hierarchical placement within the firm. A graphical presentation is given in figure 3 above.

5.8 Availability of CAD/BIM Proficient Staff and the Existence of Training Programmes

The study examined the relationship between the availability of CAD/BIM proficient staff and the existence of training programmes. A chi square test of Association was conducted to find out the nature of relationships that exist between the two variables. The result of the cross tabulation sheet shows that 15 firms representing 15.3% of the sample do not have sufficient CAD/BIM proficient staff and also do not have any existing training programme. Another 15.3% of the sample do not have sufficient CAD/BIM proficient staff but have existing training programme in their organizations. 0.8% of firms that do not have sufficient CAD/BIM proficient staff were undecided about the existence of training programme in their organizations. On the other hand, 36 firms representing 30.5% of the sample had sufficient availability of CAD/BIM proficient staff but do not run an existing staff training programme, while 32.2% of the sample has sufficient availability of CAD/BIM proficient staff and also run existing staff training programme. Only

two firms representing 1.7% of the sample have sufficient availability of CAD/BIM proficient staff but were undecided on the existence of staff training programme.

However, four firms representing 3.4% of the sample were undecided on the availability of CAD/BIM proficient staff within, their organizations but confirm that the run staff training programmes. By implication, these firms could not admit either having sufficient or insufficient availability of CAD/BIM proficient staff. The chi square test of Association between availability of CAD/BIM proficient staff and existence of training programme based on the 118 cases presented show that the two variables are not associated. Availability of CAD/BIM proficient staff is not associated to the existence of training programmes within the firms. The results show chi square value of $X^2(6,118) = 5.11$, df = 6, P = 0.53 > 0.05. Therefore the null hypothesis is accepted. The study however confirmed that there is no association between availability of CAD/BIM proficient staff and the existence of training programme in Architectural firms in Nigeria.

6. DISCUSSION OF FINDINGS

Almost all the firms' architects were CAD literate with only 1.8% of the firms having personnel without CAD literacy. Most firms also had BIM literate staff as only 24.6% of firms did not have BIM literate personnel in their employment. The study showed the measure of proficiency levels of the staff in the deployment of the available software. The Mean proficiency scores for the studied software are: AutoCad - 3.82; ArchiCad - 2.39; Revit Architecture - 2.44; and SketchUp 1.49. Autodesk Buzzsaw which is a collaborative and cloud based application recorded low proficiency levels while renderers and other software recorded reasonable proficiency levels of the staff in their deployment. Chi square test of association revealed that there is no significant association between availability of CAD/BIM proficient staff and the existence of training programmes in the firms. The cross-tabulation results suggest that more CAD/BIM proficient staff are needed to improve service provided by the firms.

7. CONCLUSION

ICT deployment cannot be complete without the people that use, develop and evaluate it. People are important to ICT deployment as well as the infrastructure and environment of use [13]. Architectural firms in Nigeria are endowed with a number of graduate architects who are proficient at different levels in the deployment of various digital design technologies and web powered applications. An encouraging 73.4% of firms have BIM literate staff in their employment, this is a positive development. AutoCAD is the most widely deployed design technology within the firms and proficiency levels of the staff in this technology are higher than in the other available applications. This finding is consistent with that of [14], but there is observed growth in the deployment of other technologies and web powered applications. The study identified low level of development of web powered applications such as Autodesk Buzzsaw with mean proficiency score of 0.54 compared with 3.82 for AutoCAD.

The available training programmes still need to be better defined and structured for strategic gains for the firms and architectural practice in Nigeria at large. The study found that there is no Association between the availability of CAD/BIM proficient staff and the existence of staff training programmes in the firms. This makes it clear that training programmes do not determine the quality and availability of CAD/BIM proficient staff in the firms' employment. It follows that other factors might be responsible; the interview responses suggest that the schools of architecture have done much towards achieving the availability of CAD/BIM proficient staff. The study suggests a partnership between Architectural firms and schools of architecture to help improve on the training of graduates and also staff of firms. This may prove to be more cost efficient for the firms in the long term.

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