THE ROLE OF INFORMATION COMMUNICATION TECHNOLOGY ON SUSTAINABLE ARCHITECTURAL PRACTICE IN NIGERIA

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Abstract
Architectural practices are changing and changing very fast. The architect, the 'mother profession' of design professions was in charge of the project from the early days of conception to the very last day of execution and was accountable in case of failure. The role of the architect turned out to be directed on the general concept of structures and managing the relationship between the client and contractor, who builds the building. The relationship involves a chain of communication channels. The effectiveness of communication and performance of the architect is a factor of the technology employed in contemporary practice. The issues of design, sustainability of practice, awareness, and application of technology are crucial to the improvement of architectural practice. Current architectural practice demand effective communication of design information to clients or contractors. Therefore, this paper reviews the role of ICT on sustainable architectural practices Nigeria. The library research method was used in this study to gather secondary data from textbooks, articles and journals to develop a conceptual framework how green architectural practices can be used to mitigate climate change in order to sustain built environment in Nigeria. This paper reveals that ICT deployment in architectural firms has brought about organizational shift, improved building, increased productivity and better collaboration between designers and clients. The paper concludes by recommending that architect accept and deployed new ICT innovations in architectural firms for sustainable architectural practices considering the great benefits it brings to the profession.

Key words: *Information Communication Technology, Architect, Architectural firms, AutoCAD, Architectural Design*

Introduction

New technologies are changing the face of various professional practices worldwide. Architectural practices in particular are changing and changing very fast. Information and communication technology (ICT) in particular is influencing the way design and constructions are being carried out in contemporary architectural practice. According to Dare-Abel (2013), Architecture, Engineering and Construction (AEC) industry is notably one of the most crucial agents of national development. Qizhen *et al* (2002) suggest that there is a link between computers aided design and drafting (CADD) tools and productivity in the design and actualisation of AEC industry projects. Lock (2003), further concurs that the computer is essential for the handling of multiple data at high speed; prompt processing and presentation of management information; quick and easy incorporation of updates and Internet connectivity in a building project.

According to Murray (2011 cited in Wikipedia, 2016*)* information and communications technology (ICT) is an extended term for information technology (IT) which stresses the role of unified communications. It is the integration of telecommunications (telephone lines and wireless signals), computers as well as necessary enterprise software, middleware, storage, and audio-visual systems, which enable users to access, store, transmit, and manipulate information (Free Online Dictionary of Computing, FOLDOC, 2016 cited in Wikipedia, 2016). A major process in the architectural practice is heavy exchange of data and information between the architect and client, the architect and project participants on a daily basis. Architectural practices in Nigeria are gradually improving as well as profession. However, Dare-Abel (2013) noted that the challenge of the structure of practice, continuing education, training, revenue generation, design, and sustainability of practice, awareness, and application of technology are crucial to the improvement of architecture.

The issues of design, sustainability of practice, awareness, and application of technology are crucial to the improvement of architectural practice. Current architectural practice demand effective communication of design information to clients or contractors. Oyedele & Tham (2005 cited in Oladapo, 2006) suggests this singular factor as a key performance criterion. Li *et al*. (2000) in another study highlights how it has become a tactical necessity for consultants and other project participants to integrate their information systems with each other to improve the flow of information between them and enhance the effectiveness of decision-making. Various studies reveal the adoption and use of ICT facilitates this much-needed integration in the construction industry (Li *et al.,* 2000; Liston *et al*., 2000; Mohamed & Stewart, 2003). Therefore, this paper reviews the role of ICT deployment in architectural firms in Nigeria.

Research Methodology

The paper is a review. The library research method was used in this study to gather secondary data from textbooks, articles and journals to develop a review on the role of ICT deployment in architectural firms in Nigeria.

Architecture and the Architect

Architecture has been described as the 'mother profession' and is best known in the family of design professions. The architect was traditionally the master builder and the presence of architects, as has been documented, goes back to the third millennium before Christ; graphic conventions of architectural practice appeared even earlier (Kostof, 1977). The architect was in charge of the project from the early days of conception to the very last day of execution and was accountable in case of failure. The role of the architect turned out to be directed on the general concept of structures and managing the relationship between the client and contractor, who builds the building (Lewis, 1998).

According to Amole (2004) architecture can be defined as a discipline and profession with its own unique body of knowledge covering the social and physical sciences, the humanities and the fine and applied arts. It involves planning, designing, and construction of new buildings, and the maintenance of existing buildings and the associated environmental development with activities ranging from modification to conservation (Dare-Abel, 2013).

The British Standard Institution Glossary (1993) defines an architect as the person who designs buildings and super intends the execution of building works. The architects have been chosen in particular as they play a key role in the design process and have a wide responsibility of the design and building. The architects have traditionally specialized on several domain areas of knowledge. Such areas have been urban planning, project planning, office planning, public buildings, housing and during the recent years also information technology related issues, such as integrated design data management, 3Dvisualization and building information modeling (Penttila, 2006).

Scope of Architectural Services

The primary duty of architectural firms and licensed/chattered architects is to serve as prime consultants on building projects. Building projects cover the exterior/skin, structure, roof, services, furniture, fittings/fixtures, installations, infrastructure (power supply/generation, water supply/reticulation, and vehicular/pedestrian access routes), landscape, equipment and machinery.

The Nigerian Institute of Architects' conditions of engagement and consultancy services agreement (2000 cited in Dare-Abel, 2013) recognizes two categories of services provided by firms and architects. These include the Normal services and the Additional services. New construction works, maintenance (renovation, rehabilitation, restoration, refurbishing of existing buildings) and furnishing works all make up normal services.

Additional works include feasibility studies, preparation of development plans, site selection, site investigation, preparing measured drawings of existing buildings, development studies, special drawings and models, special meetings, redesigns, interior designs, landscape works, furniture and fittings, litigation and arbitration, supervision, additional design works, delayed works, and project management amongst others. It is pertinent to note that additional services may be required to augment normal services. In cases that established basis for remuneration is non-existent, the client and consultant discuss and agree on the fees payable at the onset (NIA, 2000). The list is not exhaustive, depending on the operating context and what is permitted by law.

Normal architectural services

The NIA and ARCON recognize three stages of normal architectural service or building project. The stages are generally termed stage 1, stage 2 and stage 3. Kirroff and Ostrowski (2001 cited in Dare-Abel, 2013) identified that most architectural firms concentrated on the design services which is however a very small portion of the entire building project process. Design services only make up parts of stages 1 and 2. The constituent services of the various stages are as outlined below.

Stage one: preliminary design stage

This stage consists of several activities such as obtaining brief from the client, site visits, analysis and appraisal, brief development, outline proposal, and sketch designs. Starting off has been observed to be a difficult part of any process as most things appear abstract. There is great dependence on the architect's imagination and ability to visualize the end product. Major decisions will be taken at this stage by both the client and architect.

Client's approvals are sought to be able to move ahead with the process. Other activities include, outline specifications, project report, estimated cost implications and outline work programme. These are crucial for new design/ construction works. Whereas for maintenance works, preparation of schedule of dilapidation, sketch proposal, repair and replacement schedule, and outline work programme are essential.

Stage two: production/working drawings, specifications and details

At this stage comprehensive working drawings and other contract documents which include schedule and details that provide information for the preparation bill of quantities and engineering/specialist designs are embarked upon. Construction details, Schedules (finishes, painting, doors and windows, materials) are also produced.

This stage is time consuming as all services rendered require a high accuracy and standard. The responsibility of the architect to coordinate and ensure proper integration of the contributions of other professionals in the design team is evident at this stage. Other activities include advising on the appropriate form of contract, prequalification of contractors, invitation to tender, issuance and collation of tender documents.

Stage three: obtaining tenders to completion

The major activities in this final stage are: obtaining full reports on tender; preparation and advising on contract and the appointment of the contractor; arranging for site possession; supervision, certification at the agreed project phases and monthly site meetings. This stage also involves preparation/distribution of the minutes of site meetings and progress reports; construction quality control; confirmation and certification for practical completion; commissioning and settling of final accounts.

The Royal institute of British architects (RIBA) operates a slightly different stage structure. However both structures basically have the same content, though the RIBA structure has eleven stages. The NIA stage one is similar in content to RIBA stages A, B and C. The NIA stage two is similar in content to RIBA stages D, E, F (F1 andF2) and G while NIA stage three corresponds with RIBA stages H, J, K, and L. (RIBA, 2009; NIA, 2000)

Antecedents of Architectural Practice in Nigeria

The inception of architectural practice in Nigeria is recorded to have been pioneered by the works of Maxwell Fry and Jane Drew who were commissioned to prepare master plans and building designs for the University College, Ibadan. The institution was established in 1948.

Prior to this time, the British introduced education, religion, trade/commerce, administration and colonial rule/government. As a result, some buildings were designed and prefabricated in Europe and thereafter shipped for assembly on site here in Nigeria. The next phase in the development of the practice of the profession witnessed a domination of foreign (British) architects. They established architectural firms to provide Professional services for the enormous physical developments embarked upon by the government and multi-national companies (Arayela, 2001 cited in Dare-Abel, 2013).

Notable Nigerian architects impacted the practice scene such that more young architects were produced. Most of the older architects were trained in foreign institutions, although some were trained both in the few colleges available within the country and abroad. The public works department (PWD) was the government's physical development agency during the post independence and early pre-independence period. This department (PWD) had an extensive training programme responsible for producing professionals, technical officers and artisans for the fields of engineering, architecture, building construction and other relevant fields.

This scheme produced the Late Arc. (Chief) M.O. Onafowokan graduated in 1938 as an engineer. Thereafter he proceeded to Glasgow University and qualified as the first Nigerian architect/planner in 1947. Onafowokan served the nation as a public officer for over three decades supervising most of the public buildings in Western Nigeria before setting up Onafowokan Cityscape group in 1969.

Daramola (2009) presented a chronological report of the development of architectural practice in Nigeria covering the period spanning 1861 to 2009. The study brilliantly identified four eras which are: the first era (1861-1930) colonial; the second era (1930-1947) later part of the colonial era; the third measuring the period within the late colonial/post independence (1947-1970); and lastly the period between 1970 and 2009. The study discussed the significant physical development, major contributors and the practice environment of the identified eras.

So much happened within the third era (1947-1970) as it was a crucial point in laying the foundation for architectural practice in the country. Many Nigerian architects were produced during this period and the rapid development of the premier universities provided opportunities for them to be engaged. However, British/expatriate owned firms initially dominated the scene. They included architectural firms as: Fry Drew and Partners, Watkins Gray Woodgate, Messrs Nickson and Boys, Ronald Ward and Associates, Design Group, James Cubitt and partners, Godwin and Hopwood amongst others.

Oluwole Olumuyiwa and Associates and Ekwueme and Associates were founded between 1958 and 1960, pioneering the establishment of indigenous architectural firms in the country. A handful of Nigerian architects had become senior public servants in government and directly involved in decision making. Shortly after the Independence, a few of the architects withdrew from the public service to set up their own firms. This move was necessitated by the opportunity created by the fact that the few available firms could not meet up with the demands of a rapidly growing nation and economy with the attendant developmental projects involved.

It is important to note that the Nigerian Institute of Architects (NIA) was birthed in 1960 by thirteen (13) members drawn from a group of Nigerian graduates of architecture from foreign universities and colleges. The founding members had as part of the vision an institute that would be responsible for creating and maintaining the standards of architectural practice and education. The formation of the education board and the practice and ethics committee give credence to the vision. From a membership of thirteen at inception there has been incremental growth to 2,362 fellows/full members by 2007. (Arayela, 2008; 2000)

Over the years, there has been a gradual growth of the profession and practice in the country. This was further enhanced by the formal structure of architectural practice as laid down by the Architects Registration Council of Nigeria (ARCON) established by decree No. 10 of 1969. ARCON's establishment gave a legal backing to the vision of the NIA and since 1969 there has been effective collaboration between the two bodies.

ARCON is the architecture regulatory body in Nigeria empowered to regulate both architectural education and practice. Practice is effectively regulated at individual professional level and also at organisational level (Firms, Public and private establishments). The register of Architects and architectural firms entitled to practice in the country is kept by this body on a yearly basis. It is noteworthy that NIA organizes the various professional examinations which include the Finals 1, Finals 2, and Professional Practice examinations (NIAPPE). All successful candidates in these examinations are presented for the various levels of registration by ARCON and the NIA. The successful NIAPPE candidates are licensed to practice and establish firms in accordance with the regulations by ARCON. The number of architectural firms also increased from a handful in the 1960s to 38 by 1975 and in 2007 to 546 firms. Table 1.0 shows a tabulated report of the number of registered architects at four different levels of registration, registered architectural firms and firms/membership ratios.

Antecedence of Computer and CAD, CAAD and Graphic Packages Development

According to Jack (2001) the seventeenth century birthed the production of the first kind of adding machine manufactured by French Tinkerers. Prior to this period stone counters and the abacus were used. In fact the abacus dates back to the Greek and Roman dispensations. In the Nineteenth century, an Englishman Charles Babbage designed a steam powered machine that could calculate square roots, cube roots and other exponential functions. This machine was described as the analytical engine which was based on punch cards and relays.

Several experiments took place across Europe and America in the 1930s and 1940s which culminated in the discovery of the Electronic Numerical Integrator and Computer (ENIAC) which was built in the University of Pennsylvania as was reported by Daniels and Kinney (1999). The first calculator was built by a German Professor and precisely in 1941 the 'Mark 1' was developed by Howard Hiken a Harvard University professor and his research team.

The first digital computer was developed in the 1940s and this was followed by the production of the commercial forms about a decade later for the use of organizations that could afford them at the time. Early computers were made up of bulky circuit components that performed operations via vacuum tubes unlike the modern computers that have micro-units called integrated Circuits (ICs). However modern day computers are still based on the same 'architecture' that was developed in 1945 and also work based on the same binary code in spite of the enormous transformation and development that has taken place in the last five decades (Daniels and Kinney, 1999; Jack, 2001; and Bozdoc, 2003).

After these pioneering feats, more specialized applications such as Space expedition calculations, bank deposits/financial transactions and bills were being handled by the existing computational machines. It is important to present the background of the development of the computer because it is the advent of this machine that brought about the development of all graphic packages and other associated developments as they exist today.

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 CAD, CADD/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. This earned him the appellation 'the Father of CADD/CAM'.

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 (Jack, 2001; and Bozdoc, 2003).

Mariam Bozdoc in her work CAD Chronology compiled between 1999 and 2003 gave a detailed time account of the development of CAD from the period before 1970to the year 2000. This unequivocally marked the period of deep technological exploits in information and communications technology world.

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 (Abubakar, 2006). 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 pioneered the development of desktop CAD applications include Unigraphics, Denebau Softwares, 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.

Mergers and acquisitions and alliances took place during this period positioning these companies for more challenging opportunities in the global context. A good example of this is the strategic alliance between Dassault Systems and IBM to produce a solution for the Product Development Management Market (PDM II).

Record sales were reached in 1994 with AutoCAD hitting the one million mark followed by CADkey with 180,000 copies sold and MicroStation 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 (Daniels and Kinney, 1999; Bozdoc, 2003; and Abubakar, 2006).

In 1998 the Autodesk Company introduced the Autodesk Architectural Desktop developed to be an integrated architectural solution initially based on the AutoCAD release 14 platform.

An attempt at 4D animation in CAD was initiated in the late 1990s by Maxon in their CAD solution named CINEMA 4D producing new possibilities in animation and rendering. The significance of CAD/CAM to the design and manufacturing industry culminated in 1999 with the signing of a 43 million dollar contract by UNIGRAPHICS with BOEING (the aerospace manufacturing giant) for CAD/CAM software.

The Real and the Virtual

In the design and visualisation contexts, the idea of an environment is crucial to the activities embarked upon. An object exists as an entity within an environment which may either be the real world or a virtual environment. The real world environment is easy to relate with since it consist of the existing physical landforms, flora, fauna, built environment and everything that is visible in the earth and locations outside the earth.

On the contrary, the virtual environment as earlier defined connotes an environment visible or existing in the human mind or on a computer screen. Virtual reality as described by Donath and Regenbretch (1999) is said to be a tool for architects, which is both intuitive and almost unrestricted exemplifying the creative abilities of the architect. It therefore appears to be a design asset for professionals and firms with goals and expectations of relevance in design and visualisation in the present dispensation.

The works of great philosophers such as Aristotle and Plato suggested the concept of parallel existences of both the Real and Virtual worlds. This is constantly being demonstrated between conception, design and the actualization of a building project.

Furthermore, virtual reality involves the interaction of 3dimensional objects or models with a digital environment acting as an autonomous part of the real world. It is however true that there are significant distinctions between the virtual environment and the real world. Virtual environments are spatial interfaces made possible by multidisciplinary efforts for over several years as seen in the historical account.
Oladapo (2006) suggests that productivity in the AEC industry is closely linked to the ability of professionals to manage and communicate project information and documents. The study stressed that the architect's ability to effectively communicate design information to contractors is a key performance criteria. Three areas of the impact of ICT on professional practice were identified by the study as: ease of practice tasks; facilitation of decision making and savings on operating costs.

ICT Applications in Architectural Firms
Grassi (2002 cited in Dare-Abel, 2013) identified that computer applications to design and drafting in Architecture have several advantages that ultimately affect the outcome of services provided. Such advantages include: drawing clarity; ease of making changes to drawings; drawing longevity; ease of managing drawing files; lower potential for errors; speed of plotting drawings and access to digital security. These benefits have been improved upon since that study with additional points being added to the list continually as a result of technological improvements.
Dehlin and Olofsson (2008) opined that the main purposes of ICT in the AEC industry include: the improvement of operational efficiency of the concerned organization; improvement of service or product quality; reduction in production time and increase in profit levels. These were the most vital identified by the researchers but other rather intangible purposes were identified. These include; sustainable competitive advantage; better project control and understanding; improved marketing and customer service.
Architectural firms may only be able to reap the full benefits of ICT when the understanding of technology products and applications deployed is rich and such firms are strategically positioned for change. Change in itself being either radical or incremental in nature. Radical change gives an idea of suddenness while incremental change connotes a step by step approach taken over a planned period. The ability of firms to decide with change type to engage at a given situation with accuracy may determine a successful outcome for the organisation. (Fasheun-Motesho, 2001; Collins, 1998).
Information technology (IT) is defined as the study, design, development, implementation, support or management of computer-based information systems, particularly software applications and computer hardware. Although IT covers a wide range of areas in computing and technology in general, Information and communications technology captures a lot more. ICT is an umbrella term that covers all advanced technologies in manipulating and communicating information. The inclusion of technologies such as telecommunications, mobile telecommunications, the camera, microphones, portable devices, software and hardware solutions, audio-visual devices and the internet in the definition of ICT expands its scope of coverage. Tongia *et al.* (2005) considers ICT to be built on four main areas which are communications, content, capacity building and computers. The study argues that ICT is much more than computers, internet and even telephony. It

also involves human independent systems, embedded ICT, distance education programs, e-commerce, e-governance and other intangible systems that are still being developed.
Tongia et al. (2005) also see ICT as both a means and an end for development since nearly about 34% of the results of development in the world are attributable to its systems.

Adoption and Deployment of ICT Applications in Architectural Firms
Penttilä (2006) identified three different periods of time where a hypothetical framework of changes within the architectural practice was created. The periods include Early 1980's (1980-85), Mid 1990's (1993-98) and Beginning of the 2000's (2000-05).
Early 1980's (1980-85) which were the last days of hand drawing (designs drawn on paper using pencil and ink) and the era before Computer Aided Designs (CAD). During these periods, communication was done in weekly face-to-face design meetings and with telephones (land lines and not mobile phones).
Mid 1990's (1993-98). This was the period of the expansion of architectural CAD and the era of appearing digital drawing. There was a shift from hand drawing to CAD-drawing during these periods. Also, paper prints of CAD drawings became prominent among the project teams and were distributed with traditional mail and couriers. After the invention of World Wide Web (www) in 1993, web-based communication started to expand, but it had not achieved very large volume yet in mid 1990's.
Beginning of the 2000's (2000-05). These periods brought about the rise of integrated and pervasive web supported digital design; two dimensional (2D) drawing became the main design method; three dimensional (3D) modeling was used in visualization; the advent of building information modeling (BIM) and the importance of communication. During this time, drawings were produced with enhanced CAD systems with extended drawing automation.
The introduction of these technologies to the organized workplace of architects suggests the process of adoption (Dare-Abel, 2013). Fasheun-Motesho (2001) qualifies adoption of IT applications for the business of architectural firms as use for core functions and activities such as design tasks, project supervision and administrative functions.
However Oyediran (2006) identified six stages of the adoption process of ICT as: awareness; learning the process; understanding and application of the process; familiarity and confidence; adaptation to other contexts; and lastly the creative application to new contexts. It is important to note that the key element of the process timing is missing in this definition even though the functional content of the context is captured.
The process of adoption requires concerted efforts on the part of decision makers (management staff) and the entire workforce of such firm. Time is taken to adjust to new systems and technologies which ultimately dictate new work processes and procedures. Professional firms in today's global context now have relative access to ICT applications to execute day-to-day tasks, services, and the organization of the workplace. Apart from industry specific applications, other software solutions cut across many organizations but in each profession there is a unique purpose to which these solutions are applied. This unique mode of application describes the idea of deployment. The term deployment means

to use something for a particular purpose, especially ideas, arguments, systems (Oladapo, 2006; Pinnington and Morris, 2002; Fasheun-Motesho, 2001).

There several areas where ICT is deployed in architectural firms. Some of the areas include administration, core architectural functions, computer aided design -CAAD and CAD, digital object library (DOL), design and virtual modeling, animations and simulations and 5D modeling.

Administration

The administration of architectural firms generate and utilize information from management and staff meetings, company's profile, clients' profiles, staff documents, memos, financial records (income and expenditure), business contacts, contract documents, training and seminars, reports, site meetings, e-mails, fax messages, design briefs, design information, and project/construction management data.

Technology applications such as word processing, desktop publishing, project management solutions, database management applications, data analysis tools, financial management solutions/spreadsheets and the Internet are heavily deployed for administrative purposes.

Core architectural functions

Communicating design intent seems to be at the centre of the services provided by architectural firms. Different media are engaged to convey design intent to colleagues (architects), clients, planners, consultants, developers, contractors and users. These media are drawings, models, specifications, reports and oral instructions. Design technologies as available today present opportunity for the integration of most of the above stated media (Dare-Abel, 2013).

The products of the core activities of design and presentation include: sketch design (design development drawings), presentation drawings, production drawings, working drawings, details, design development models, presentation models, schedules, and specifications (Emmitt, 2002; De Amicis et al, 2001). ICT applications have been deployed over the years in producing these service products. The software aspects of these applications (design technologies) as utilized by architectural firms are broadly grouped as 2D CAD, 3D CAD, CAAD, BIM and nD technologies.

Computer aided design

Computer aided design in the early development 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 Emmit (2002) 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). Ogunsote *et al* (2006) identified a number of CAD software commonly deployed as AutoCAD, Autodesk Architectural Desktop, Autodesk Revit Building, ArchiCAD, TurboCAD, Form-Z and 3D Home Architect. These CAD solutions also possess a level of rendering capabilities within their systems. However, other rendering software are available to complement the presentation visuals produced. Examples include 3D studio Viz, Accurender, CorelDraw, Corel Photopaint and a host of others. It is crucial to note as identified by Graphisoft (2006) that thousands of CAD software exist for divers uses for the broad range of designers the world over.

CAAD and CAD

Computer-Aided Architectural Design (CAAD) was developed and uniquely targeted to meet the needs and mindset of the architect. CAD cuts across a broad spectrum of designers while CAAD solutions are actually virtual building solutions in whose environments one can erect buildings in a similar manner to what obtains in the real world. This is made possible as a result of the building component (walls, floors, windows, doors, and roof) platform of the software. CAAD solutions are model-based software that assists the architect in designing, modelling, drafting and in some cases managing construction projects.

Digital Object Library (DOL)

The production of a detailed digital architectural model that is rich in design information requires the use of digital objects. Digital objects include 'micro-models' of building components, furniture, fixtures, flora, human figures, machines and other smaller parts of building service components. The regular design and modelling software may not possess adequate object library to meet the needs of the average architectural firm. Digital object libraries can be set up in an architectural firm through the deployment of Object Creation Wizard integrated within the CAD or Modelling Software (Quizen *et al*, 2002).

Design and virtual modeling

Before the introduction of the computer into the core services of architectural firms, physical architectural models served as the most effective ways of communicating design ideas to clients, construction professionals and builders. Since it is the closest form of representation of the building to reality, even the person with the least idea of construction quickly grasps what is being communicated. However, according to Emmit (2002) physical models are more time consuming and expensive to produce than virtual models. Therefore there is an observed decline in the use of physical models. Kruijff and Donath (2000) identified the potential for effective design and communication of conceptual design ideas through virtual reality modeling. De Amicis *et al* (2001) further explored 3D object creation, modification and manipulation as crucial activities for designing within the virtual reality environment. These activities involved the picking of topological elements such as a face, edge or vertex to perform such actions as rotation or translation as the case may be.

Animations and simulations

A host of design technologies ranging from CAD to BIM are useful for animations and simulations of architectural schemes. Designers now have opportunity to create state-of-the-art animations and simulation within a very short time (Longman, 2003; Clayton *et. al.,* 2001).

5D Modeling

The three dimensional (3D) presentations produced by architects may sufficiently communicate physical design and aesthetic information; it does not provide comprehensive information of design and management aspects of the project. The fourth dimension of time is essential as well as the fifth dimension of cost. Parametric design solutions have now been developed to provide 3D views as design progresses while the concept of time and cost are also being considered in a systematic manner. The dimensions of time and cost are linked to the 3D models within the program to effectively communicate construction relevant information through the use of 5D Virtual Construction.

ICT Deployment and Sustainable Architectural Practices

The deployment of ICT tools in Architectural firms has shown some great benefits. Administratively, there is a change in decision-making procedure. Decision making activity requires the adoption of a tool that incorporates all potentially relevant issues. With the use of ICT, the amount of information and the number of factors that should be considered are increased, as is and the manager's anxiety about decision-making. This new technology provides better information about project requirements from clients' points of view. This may also assist designers in understanding and managing the architectural design process; this can involve decisions in design analysis and selecting best design solutions. ICT tools impact the decisions made during the design process in a number of ways. The methods and order of design activities are changes, e.g. new simulation tasks are added, such as lighting simulation, simulation of evacuation of buildings in the event of fire. Therefore, bad decisions will be less easily excused by senior managers because crucial variables can be identified by ICT tools. The use of ICT tools in decision making has increased the speed of taking the right decision. These tools are also able to make information readily available at any time, anywhere, and can be organised in any required format. These have brought fundamental changes to the hierarchy of decision making.

ICT has impacted on the organization's structure of design practices in construction firms and architectural design process. There is a great change on the business environment as a result of ICT and how the business is run. These changes require modification of the business models. The critical element today in organization is making the link between the technology questions on one side and the strategy issue on the other side. A disconnect between these two elements may lead to serious misunderstanding between the organisation's top management and the ICT manager. The key requirement to proper management of the design and construction process is a definition of the general governance model thus leading to changing the existing design and construction process models with new models built around ICT tools. The Internet has destroyed time as well as location reducing the world to a global village. It was predicated that current Third World countries such as India and Pakistan might leap a generation in development to offer such service design or drafting facilities to European or US companies (Bridges, 1997). Design information was increasingly generated electronically; therefore, traditional paper storage has been substituted with digital storage. The other change was that standard letters have been substituted with e-mail and web based white boards.

There is improvement in buildings as a result of ICT. Computerised procedures have encouraged designers to be experimental and wide-ranging, hence allowing them to be more rational in their selection procedures. These changes could result in better buildings.

ICT has led to productivity gains in terms of man hour savings, designer efficiency, design speed, effective communication, cost savings, reduction in coordination headaches, high volume and high quality production (Autodesk, 2005a; 2005b; 2005c and 2006 cited in Dare-Abel, 2013). Autodesk (2005a) reported increase in revenue of fifteen percent as a result of the adoption of Revit Building in an architectural firm in the United States. Graphisoft (2006) in a global return on investment survey of architectural firms that deploy ArchiCAD found that it contributed 12% to firm's profit and generally increased productivity by 39%. Mays (1997) reported that at the adoption of CAD produced average productivity gains of 46%. WorldsView Technologies (2010) in a comparative study of productivity gains from the use of AutoCAD 2010 and AutoCAD 2007 found out the following facts. The PDF publishing feature in AutoCAD 2010 provides better visual quality with smaller file sizes and ability to attach PDF files to a drawing as an underlay. This feature is said to provide 63% productivity increase it also provides 43% productivity improvement for allowing a two-way with the extended design team. Secondly AutoCAD 2010 features new free-form design tools that enable users to create almost any shape imaginable by simply pushing and pulling faces, edges and vertices accounting for 62% productivity increase.

A 44% productivity increase was measured from Dynamic block modelling feature which affords designers the opportunity to create many variations from a single geometry. AutoCAD 2010 has parametric drawing tools that enable designers to define persistent relationships between objects, accounting for a 35% productivity increase in 3D drawing productivity (Dare-Abel, 2013).

Conclusion

This paper has presented some of the benefits of deploying ICT in architectural firms. It shows that the architectural design process had gone through some changes as a result of introduction of new technologies and deployment of ICT. The deployment of ICT has led to organizational shift, improved building, better collaboration between designers and clients. It has also led to increase productivity in terms of man hour savings, designer efficiency, design speed, effective communication, cost savings, reduction in coordination headaches, high volume, high quality production and increased revenue. Therefore, architects and other building engineers could accept and deploy ICT in their firms for sustainable architectural practices considering the great benefits it brings to the profession.

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