GREEN ARCHIECTURE FOR SUSTAINABLE DEVELOPMENT OF URBAN BUILDINGS

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Abstract
This Study examines innovative ways of supporting the application of Artificial Intelligence (AI) to achieve sustainable development of intelligent buildings. On 25 September 2015,193 countries of the UN General Assembly adopted a proposal on Sustainable Development Goals (SDGs) consisting of 17 goals with 169 targets as the 2030 Development Agenda titled 'Transforming our world'. Goal 4 is Make cities and human settlements inclusive, safe, resilient and sustainable. Goal 5 is Take urgent action to combat climate change and its impacts. Massive population growth in slums, built environment degradation, pollution from industrialization and global warming in Africa must be addressed. The main aim of this study is to evaluate ways of using artificial intelligence combined with green architecture to achieve sustainable intelligent buildings in smart cities. The objectives include examining the relationships between Artificial intelligence, Nanotechnology, Lean Construction and Green Architecture. Methodology involves literature reviews on Artificial Intelligence and BIM with primary and secondary data collection on Green Architecture in Lagos. The Study found that green building materials were the main aspect of green architecture in use and prefabricated system of construction was the main aspect of Lean construction technique in use in Lagos. The Study recommends Integrated Project Delivery and Building Information Modeling (BIM). This study is important in that it provides information on intelligent buildings and Smart Cities that will combine advanced technology with green, Lean buildings to achieve the SDGs.

Keywords: Green architecture, Integrated Project Delivery, Intelligent buildings

1 Introduction

Building Automation refers to the use of computer and information technology to control building appliances and features as well as the advanced functionality provided by the control system of an automated building (Gerhart, 1999). A building that is controlled by a building automation system is often referred to as an intelligent building or a smart home/smart house (Wikipedia 2013). 'Smart' planning of the urban environment has significant potential to improve quality of life and to reduce the carbon footprint of cities (Falconer & Mitchell 2012). Innovation can be viewed as the application of better solutions that meet new requirements, unarticulated needs, or existing market needs (Maranville 1992). Artificial intelligence (AI) in buildings is the intelligence exhibited by electronic devices and software driven systems which perceive their environment in buildings and take actions to optimize performance effectively within a given context or constraints. The central goals of AI research include reasoning, knowledge, planning, learning, natural language processing (communication), perception and the ability to move and manipulate objects. An intelligent building is a dynamic and responsive Architecture that provides every occupant with productive, cost-effective and environmentally approved conditions through a continuous interaction among its four basic elements: places (fabric, structure, facilities); processes (automation, control, systems); people (services, users); and management (maintenance, performance) and the interrelation between them (Clements-Croome 2004). An intelligent building is one in which the building fabric, space, services and information systems can respond in an efficient manner to the initial and changing demands of the owner, the occupier and the environment. High performance, green buildings are energy and resource efficient, non-wasteful and non-polluting, highly flexible and adaptable for long term functionality; they are easy to operate and maintain, and are supportive of the productivity and wellbeing of the occupants (Traugott 1999). An Intelligent building is a highly resource efficient, technologically advanced structure that provides a responsive support and effective environment for optimal performance and can accommodate future changes in use. The future drivers for intelligent buildings include information and communication technologies, robotics, smart materials, sustainable issues technology and social change. Building Energy Management System (BEMS) is an example of efforts aimed at achieving Artificial intelligence in intelligent buildings. The development of powerful microprocessors introduced Direct Digital Control (DDC) to building services and replaced analogue Electromechanical Devices. Nanotechnology is the engineering of functional systems at the atomic and molecular scale which involves manipulation of matter with at least one dimension sized from 1 to 100 nanometers thus giving people the ability to construct items from bottom up.

1.1 Problem Statement

The United States Green Building council (2016) states that the commercial and residential building sector accounts for 39% of carbon dioxide (CO2) emissions in the United States per year, more than any other sector. U.S. buildings alone are responsible for more CO2 emissions annually than those of any other country except China. Most of these emissions come from the combustion of fossil fuels to provide heating, cooling and lighting, and to power appliances and electrical equipment. By transforming the built environment to be more energy-efficient and climate-friendly, the building sector can play a major role in reducing the threat of climate change. Despite great advancement in technology for buildings, there is still a concern for global warming as buildings contribute significantly to pollution of the eco-system. It is therefore important that the use of advanced technology in buildings should be linked with sustainable development in line with SDGs.

This paper is important in that it examines support systems for Artificial intelligence in buildings as part of smart cities. This can help to minimize negative impacts such as built environmental degradation and global warming due to pressure from rapidly growing global populations.

1.2 Main objective

The main aim of this study is to evaluate ways of using artificial intelligence combined with green architecture to achieve sustainable intelligent buildings in smart cities. The objectives include examining the relationships between Artificial intelligence, Nanotechnology, Lean Construction and Green Architecture.

Figure 1. External view of the Endless City (Source: SURE Architecture Company, 2014)

Figure 2. Internal view of the Endless City (Source: SURE Architecture Company, 2014)

A good example where advanced technology is combined with sustainable development is "The Endless City". The "Endless City" proposal drawn up by Beijing-based SURE architecture Company is a 300 meters tower in Shoreditch, England (see figures 1 and 2). The proposed structure, which won the super skyscrapers award in 2014, has two continuous ramps, or "streets", spiralling up through the building, each lined with shops, apartments, parks and offices. Space between the ramps widens near the top of the building, letting in light and ventilation to filter down and save on energy costs, while rain water is collected and recycled.

Six big vertical tubes support the ramps and provide transport spaces for people, energy, waste, water and prefabricated modular steel elements for the skyscraper's ongoing growth.

2 Overview of Architectural Intelligence (AI)

The field of AI research was founded at a conference in the summer of 1956. AI involves the use of Machine perception – the ability to use input from sensors such as cameras, microphones, tactile sensors, sonar and others more exotic, to deduce aspects of the world; Computer vision – the ability to analyze visual input; Speech recognition, facial recognition and object recognition. Affective computing is the study and development of systems and devices that can recognize, interpret, process, and simulate human affects. These are aspects of AI for buildings. Intellectual capacities are grouped into practical, analytic and Creative. Hawking (2014) posits that success in creating AI would be the biggest event in human history and notes that it might also be the last, unless humans learn how to avoid the risks. Emotion and social skills play two roles for an intelligent agent or machine. First, it must be able to predict the actions of others, by understanding their motives and emotional states. This involves elements of game theory, decision theory, as well as the ability to model human emotions and the perceptual skills to detect emotions. Also, in an effort to facilitate human-computer interaction, an intelligent machine might want to be able to display emotions, even if it does not actually experience them itself in order to appear sensitive to the emotional dynamics of human interaction. A straightforward, specific task like machine translation requires that the machine read and write in both languages (Natural Language Processing), follow the author's argument (reason), know what is being talked about (knowledge), and faithfully reproduce the author's intention (social intelligence). In the 1990s, AI researchers developed sophisticated mathematical tools to solve specific sub-problems. These tools are truly scientific, in the sense that their results are both measurable and verifiable, and they have been responsible for many of AI's recent successes. The simplest AI applications can be divided into two types: classifiers ("if shiny then diamond") and controllers ("if shiny then pick up"). Controllers do, however, also classify conditions before inferring actions, and therefore classification forms a central part of many AI systems. A derivative of the Turing test is the Completely Automated Public Turing test to tell Computers and Humans Apart (CAPTCHA). As the name implies, this helps to determine that a user is an actual person and not a computer posing as a human. If research into strong AI produced sufficiently intelligent software, it might be able to reprogram and improve itself. The improved software would be even better at improving itself, leading to recursive self-improvement. The new intelligence could thus increase exponentially and dramatically surpass humans.

Quality Environment Fundamental Modules are Green Index, Space Index, Comfort Index, working Efficiency Index, Culture Index, High-tech Image Index, Safety and Security Index, Construction Process and Structure Index, Cost Effectiveness Index and Health and Sanitation Index. Four Main Aspects Of Hardware Components are – a- Facility management - Take care & maintain various functions for occupant comfort & operation; b- Information management - Office automation (OA), LAN, wiring; c- Communication - Tel/Fax, e-mail, video telecommunication and d- Control - DDC, building automation system. Common needs of intelligent building tenants include Built-in Internet wiring, LAN/WAN connectivity, Conduits for cabling, High-tech HVAC and Wiring for high-speed networks.

2.1 Nanotechnology for new building materials

Nanotechnology is taken as the scale range from 1 to 100 nm (National Nanotechnology Initiative) Materials reduced to the nanoscale can show different properties compared to what they exhibit on a macroscale thus enabling unique applications. For instance, opaque substances can become transparent (copper); stable materials can turn combustible (aluminium); insoluble materials may become soluble (gold). A material such as gold, which is chemically inert at normal scales, can serve as a potent chemical catalyst at nanoscale. Nanoscale materials such as nanopillars are sometimes used in solar cells which combats the cost of traditional Silicon solar cells. Development of applications incorporating semiconductor nanoparticles are to be used in the next generation of products. Such products include display technology, lighting, solar cells and biological imaging. Other applications are coating the surface of the wash hand basins and toilet bowls (minimizes surface tension thus reducing the possibility of particles adhering to the surface), preventing the steaming up of mirrors and tiles and preventing condensation droplets forming on their surfaces. On the surface of Active glass, grime is broken down by a daylight-activated reaction with a surface coating of titanium dioxide. The glass is also hydrophilic, which means that water spreads across it rather than forming droplets and thus can take the dirt with it. Rain effectively can thus clean the glass. Nanotechnology has led to developments in the science of photonics which is linked with opto-electronics and production facilities to make fibre-optic communication and switching devices. Cars are being manufactured with nanomaterials so they may need fewer metals and less fuel to operate in the future. There are however calls for stricter application of the precautionary principle, with delayed marketing approval, enhanced labelling and additional safety data development requirements in relation to certain forms of nanotechnology.

2.2 Building Information Modeling (BIM)

Building Information Modelling (BIM) is a set of interacting policies, processes and technologies generating a “methodology to manage the essential building design and project data in digital format throughout the building's life-cycle” (Penttilä 2006). It is made of intelligent building components which include data attributes and parametric rules for each object. For instance, a door of certain material and dimension is parametrically related and hosted by a wall. Furthermore, BIM provides consistent and coordinated views and representations of the digital model including reliable data for each view. This saves a lot of designer’s time since each view is coordinated through the built-in intelligence of the model. BIM is the process and practice of virtual design and construction throughout its lifecycle. It is a platform to share knowledge and communicate between project participants. High quality 3D renderings of a building can be generated from Building Information Models.

A collaborative BIM approach enables the sharing of the model between the engineer, architect, construction manager, and subcontractors. At the BIM meetings, the construction manager and subcontractor can provide their expert construction knowledge to the design team. Moreover, the construction manager can use the building information models to generate constructability reports, coordinate, plan, schedule and cost estimate. Traditional Design-Bid-Build, Design & Build and Integrated Project Delivery (IPD) methods are popular project delivery approaches that the industry currently practices. Construction managers can use BIM to extract quantities of work to prepare cost estimates. Construction managers can use BIM to coordinate work with subcontractors. They can also update schedule and costs with BIM. Lastly, they can turn over an as-built building information model to the owner’s maintenance team.

2.3 Lean Construction

Lean construction is concerned with the alignment and holistic pursuit of concurrent and continuous improvements in all dimensions of the built and natural environment: design, construction, activation, maintenance, salvaging, and recycling (Abdelhamid et al. 2008). This approach tries to manage and improve construction processes with minimum cost and maximum value by considering customer needs (Koskela et al. 2002). The term "Lean Construction" was coined by the International Group for Lean Construction in its first meeting in 1993 (Gleeson et al. 2007). It accomplishes these objectives through the use of Supply Chain

Management (SCM) and Just-In-Time (JIT) techniques as well as the open sharing of information between all the parties involved in the production process. Womack and Jones (1996) identified the key principles for lean construction systems as value; value stream (by mapping the whole value stream, establishing cooperation between the participants, and identifying and eliminating waste, the construction process can be improved); flow (business flow includes project information, job site flow involves the activities and the way they have to be done, while supply flow involves the materials used in a project); pull (the efforts of all participants stabilize pulls during the construction process); and perfection (work instructions and procedures are developed, quality control mechanisms are established).

Four main principles of Lean construction system are the minimal use of building materials; minimal cost for affordability; maximum quality of building; minimal wastage of building materials and energy. These principles are examined from the design stage and through the whole management process. Ballard and Howell (1994) designed the Last Planner System as one method for applying lean techniques to construction. It provides productive unit and workflow controls and facilitates quick response to correct for deviations from expected outcomes by using root cause analysis. Control is defined as causing events to conform to plan as opposed to the construction tradition of monitoring progress against schedule and budget projections.

2.4 Green Architecture

Green Architecture basically refers to environmentally friendly buildings with these characteristics: 1- Ventilation systems designed for efficient heating and cooling. 2- Energy-efficient lighting and appliances. 3- Water-saving plumbing fixtures. 4- Landscapes planned to maximize passive solar energy. 5- Minimal harm to the natural habitat. 6-Alternate power sources such as solar power or wind power. 7-Non-synthetic, non-toxic materials.8- Responsibly-harvested woods and stone. 9- Adaptive reuse of older buildings. 10 - Use of recycled architectural salvage. 11- Efficient use of space. While most green buildings do not have all of these features, the highest goal of green architecture is to be fully sustainable. Green Architecture is also Known As: Sustainable development, eco-design, eco-friendly architecture, earth-friendly architecture, environmental architecture, natural architecture.

Green building (also known as green construction or sustainable building) is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: design, construction, operation, maintenance, renovation, and demolition. Criteria for sustainable buildings are as follows 1- Natural light (level of natural light enhancement) - does the building enhance quality natural light for comfort and power efficiency? 2- Environmental impact (level of “greenness”) - how environmentally friendly is the building on the eco-system? 3- Architectural design (level of flexibility and versatility) - how innovative is the architectural design of the building? 4- Thermal comfort (level of resistance to heat load) - how resistant is the building to heat load? 5- Water cycle (enhancement of water cycle) - does the building enhance reuse of water? 6- Appropriate technology (level of efficient usage and availability) - can the building be built using appropriate technology which is readily available locally? 7– Waste management (cradle to cradle concept) - does the building generate waste over the years that can be recycled and re-used? 8- Feedback (level of affordability and cultural acceptability) - do people generally like the building? 9- Air quality (level of impact on human health with proper ventilation) - how toxic is the building to living creatures? 10- Durability (level of resistance to climate and usage) - is the building resistant to corrosion, wear and tear, warping, fading, leaking and tropical ocean-salty climate?

3 Integrated Project Delivery

Integrated Project Delivery (IPD) is a collaborative alliance of people, systems, business structures and practices into a process that harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction. There are eight main sequential phases to the integrated project delivery method: conceptualization (expanded programming); criteria design (expanded schematic design); detailed design (expanded design development); implementation documents (construction documents); agency review; buyout phase; construction; and closeout phases. Facilities management is the final part. IPD contractually requires designers, construction manager, subcontractors and owners to share the project risks. If the project stays within budget, then all the project participants receive their share of the profits. Otherwise, they all lose their fees. This incentive promotes all the participants to work together towards a common goal. They share all the Building Information Model data, share decision-making, and share responsibilities. This joint project management approach results in pure collaboration and no litigation. BIM facilitates IPD by uniting all professionals involved in the project. The new focus in IPD is the final value created for the owner, the finished building. Rather than each participant focusing exclusively on their part of construction without considering the implications on the whole process, the IPD method brings all participants together early with collaborative incentives to maximize value for the owner. (See Figure 4) This collaborative approach allows informed decision-making early in the project where the most value can be created. The close collaboration eliminates a great deal of waste in the design, and allows data sharing directly between the design and construction team eliminating a large barrier to increased productivity in construction. Research Methodology

Methodology involves a literature survey on Artificial Intelligence and BIM with primary and secondary data collection on Green Architecture in Lagos, Nigeria. The method of primary data collection involved site visits to four sites in order to identify the green building materials used (such as expandable polystyrene cement sandwich wall panel). Green building material is one of the main aspects of green architecture in use in Lagos. Prefab system of construction is one of the main aspects of Lean construction technique in use in Lagos.

4 Findings and Discussions

The study found that Lightweight concrete foam is used in expandable polystyrene (EPS) cement sandwich wall panel. Advantages are that EPS foam is an excellent energy efficient thermal insulation material; it is non-toxic, safe and contains no chlorofluorocarbons or hydro-fluorocarbons so as not to damage the ozone layer; EPS foam can be recycled in a number of ways; Minimal waste with pre-punched openings for electrical and plumbing; pre-cut and preassembled headers and jambs; sustainable material that does not rot, rust or decompose; it requires no maintenance; it is mold, insect and rodent resistant; doesn’t support mold growth; excellent resistance to moisture absorption; good sound insulation and sound-absorbing functions; good seismic performance; space saving, thickness of 60mm-180mm; and cost effective.

Figure 3. Service duct being inserted on site as worker on the right hammers box and barrel into each other

Innovative use of PVC and concrete a prefabricated system of construction by Royal Sanderton at Yaba College of Technology site (see Figure 3) provides evidence that the use of concrete and PVC casing (box and barrel) is three times faster than the conventional use of sandcrete blocks; waste on site is eliminated, thus the system is environmentally friendly; there is no need for columns and painting thereby reducing cost when mass produced; the quality of finished work is higher than conventional use of sandcrete blocks facilitating neater mechanical and electrical installations; the thermal comfort is better than conventional construction; the durability of PVC ensures that there is no need for painting in future thus saving maintenance cost; the PVC used comes in various tasteful colours which enhance the use of natural light; the building materials used are non-toxic to human beings and animals thus having a positive environmental impact with reference to air quality; the building materials used can be recycled and used again; the building materials can be used with any architectural design thus enhancing flexibility and innovative designs; the building materials used can be utilized on site by trained local workforce using appropriate technology; and this system of prefabricated housing construction is gaining popularity among investors in housing estates in Lagos

5 Conclusion and Recommendations

This study examines Artificial intelligence, Nanotechnology, Lean Construction and Green Architecture in order to find out whether these forms of technology and building materials are interrelated and used in the delivery of Green Architecture Projects in Lagos. The study found that there is an interconnection between advanced technologies (AI with Nanotechnology) and sustainable building construction, and Green Architecture, and the use of Integrated Project Delivery and BIM to form sustainable intelligent buildings and smart cities (see figure 4). The study identified the green building materials (such as expandable polystyrene cement sandwich wall panel) as one of the main aspects of green architecture in use and that the main aspect of Lean construction technique in use in Lagos is the prefabricated system of construction. However, Artificial intelligence nor nanotechnology and BIM were used on the project sites studied.

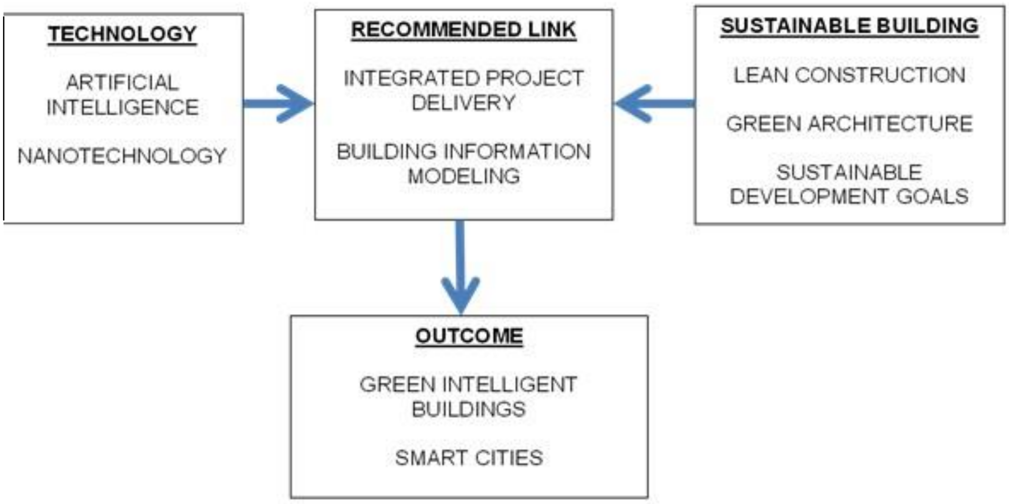

Figure 4. IPD and BIM bring together advanced technology with sustainable building to form smart cities

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