ARTIFICIAL INTELLIGENCE FOR SUSTAINABLE DEVELOPMENT OF INTELLIGENT BUILDINGS

Conference Paper · February 2016

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Abstract
This paper examines innovative ways of supporting the application of Artificial Intelligence (AI) so as to achieve sustainable development of intelligent buildings. 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 within a given context or constraints. 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. The concepts in this paper proposed for supporting Artificial Intelligence in buildings are Nanotechnology, Building Information Modeling and Lean Construction. This work is important in that it examines support systems for Artificial intelligence in buildings as part of smart cities and presents a case-study of the on-going Eko Atlantic project in Lagos, Nigeria. The paper recommends Integrated Project Delivery and innovative Green Architecture for optimal implementation of these concepts so as to support the sustainable development of AI in buildings. Our recommendations could help to minimize negative impacts such as built environmental degradation and global warming due to pressure from rapidly growing global populations.

Keywords: Artificial Intelligence (AI), Green Architecture (GA), Integrated Project Delivery (IPD), intelligent buildings

1 Introduction

Intelligent building refers to any structure designed to incorporate a combination of electronic systems for the convenience, comfort, security or safety of its occupants. Such systems include networks, facilities for data processing, office automation, telecommunications and building management systems (Lobb 1988). Today, intelligent buildings are closely linked with Artificial intelligence (AI). The central goals of AI research include reasoning, knowledge, planning, learning, natural language processing (communication), perception and the ability to move and manipulate objects. Current popular approaches include statistical methods, computational intelligence and traditional symbolic AI. There are a large number of tools used in AI, including versions of search and mathematical optimization, logic, methods based on probability, neural networks, etc. The AI field is interdisciplinary, in which a number of sciences and professions converge, including computer science, mathematics, psychology, linguistics, philosophy and neuroscience, as well as other specialized fields such as artificial psychology.

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. The field was founded on the premise that a central property of humans, human intelligence—the sapience of Homo sapiens—"can be so precisely described that a machine can be made to simulate it." This raises philosophical issues about the nature of the mind and the ethics of creating artificial beings endowed with human-like intelligence, issues which have been addressed by myth, fiction and philosophy since antiquity. An intelligent building is one that provides a productive and cost-effective environment through continuous optimization of its four basic elements - structure, systems, services and management and the interrelationships between them. Intelligent buildings help building owners, property managers and occupants realize their goals in the areas of cost, energy management, comfort, convenience, safety, long term flexibility and marketability (Caffrey 1985 - Intelligent Buildings Institute, Washington DC). An intelligent building demands application of intelligence at the concept, construction, and operation stages of a project by clients, design consultants, contractors, manufacturers and facilities managers. Our aim is to enumerate the conditions, facilities and technologies that need to be deployed or utilized to realize intelligent buildings that meet user needs; providing required service and safety during the product lifecycle. According to a report by the international Renewable Energy Industry Institute based in Germany, the total levels of global greenhouse gas emissions reached a record high in 2013 at 34 billion tons. China accounts for the lion’s share with 8.9 billion tons. The United States places second at 6.0 billion tons, with India ranking third with 1.8 billion tons, followed by Russia at 1.7 billion tons, Japan with 1.3 billion tons, and Germany at 804 million tons. With climate change affecting everything from weather patterns to satellite operation, governments and international organizations are becoming increasingly concerned over man’s influence over the environment. A report released by the World Bank titled “Turn Down the Heat” details the devastating impacts of a world in crisis. If current policies and trends continue, the planet could become an average of 4 degrees Celsius (39.2 degrees Fahrenheit) hotter by the end of the century. This scenario would result in a “new normal” of extreme temperatures, massive flooding and devastation among the poorest nations.

2 Literature Review

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 are likely to be information and communication technologies, robotics, smart materials, sustainable issues technology and social change.In Intelligent buildings, typical examples of resource efficiency, security monitoring, fire detection and access control in intelligent buildings include 1- light switches off automatically when no one is in the space 2- permission must be obtained from the owner before a visitor can enter designated spaces. 3- If there is an emergency such as a bomb blast, the building commences emergency procedures by auto-contacting the authorities, securing the safety and well-being of occupants and extinguishing fire or any other threat, including gun fire. 4- Voice activated commands 5- wireless network systems 6- huge quantum processing computer power.

Windapo and Rotimi (2012) established that the approach to construction by industry stakeholders in Nigeria does not match sustainable principles, and contributes to general under performance of buildings. Their study revealed that 39.7% of reported cases of collapsed buildings in Nigeria from 1974 to 2010 were residential buildings. Green sustainable buildings have existed for years in advanced nations. Intelligent buildings based on advanced technologies have also existed for years in developed nations. Yet the rate of global warming continues at an alarming rate. It is when there is a global vision based on Internet of things (IOT) that intelligent buildings can collectively begin to make a positive impact on the built environment.

For example, an internet based website called Inhabitat stated on 27th January, 2014 that Delhi's Air Pollution was Even Worse than Beijing's Smog. It noted that China gets all the attention when it comes to terrible air quality, but the truth is that the worst day in Beijing is really just an average day in Delhi. Though it gets far less notice, the air in Delhi is some of the most polluted on the planet. In fact, India's citizens have some of the weakest lungs, highest rates of asthma and highest mortality rates from respiratory issues of any nation in the world. In January 2014, Beijing closed major highways and issued urgent health warnings to those living within its borders. On the other hand, life in Delhi has gone on like normal, despite the fact that on average the city's harmful air particulates are nearly double that of Beijing. Delhi averaged a measurement of 473, while Beijing averaged 227. But that's just an average day – Beijing reached its worst day, a measurement of above 500 (the highest range that the scale can reach) on January 15. Delhi, on the other hand, had reached that measurement range 8 times by mid-January. Even more concerning, Delhi's peak pollution levels have increased 44% over the past year. In the past, researchers have assumed that the Indian's diminished air capacity was genetic, but studies show that children of Indian immigrants born and raised in the US have better lung function than those born and raised in India. Even more shocking, about half of all doctor visits in India are related to respiratory problems. The issue has gotten so bad that some wealthy citizens are actually considering leaving the country. Some citizens, however, when interviewed by the New York Times, claimed to be unaware of the city's pollution problem. With little pressure on the government to resolve air quality issues from citizens or the media, Delhi's air will continue to cause harm until people demand something better.

2.1 Technologies for Intelligent Buildings

Cattell (1968) suggested that there was crystallized Intelligence (breadth and depth of knowledge and skills) and fluid Intelligence (ability to reason quickly without specific reference and distinguish patterns of relationships). Sternberg (1985) has tried to identify cognitive process that underly cognitive abilities and has narrowed down multiple Intelligences to just three: analytic, creative and practical. "Success in creating AI would be the biggest event in human history," wrote Stephen Hawking in an op-ed, which appeared in The Independent in 2014. 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 (NLP), follow the author's argument (reason), know what is being talked about (knowledge), and faithfully reproduce the author's intention (social intelligence). Machine perception is 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 is the ability to analyze visual input. A few selected sub-problems are 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 artificial intelligence for buildings.

Nanotechnology is the engineering of functional systems at the molecular scale. It refers to the means and ability to construct items from the bottom up, using techniques and tools being developed today to make complete, high performance products. One nanometer (nm) is one billionth, or 10^{-9}, of a meter. By comparison, typical carbon-carbon bond lengths, or the spacing between these atoms in a molecule, are in the range 0.12–0.15 nm, and a DNA double-helix has a diameter around 2 nm. On the other hand, the smallest cellular life-forms, the bacteria of the genus Mycoplasma, are around 200 nm in length. By convention, nanotechnology is taken as the scale range 1 to 100 nm following the definition used by the National Nanotechnology Initiative in the US. The lower limit is set by the size of atoms (hydrogen has the smallest atoms, which are approximately a quarter of one nm diameter) since nanotechnology must build its devices from atoms and molecules. Materials reduced to the nanoscale can show different properties compared to what they exhibit on a macroscale, enabling unique applications. For instance, opaque substances can become transparent (copper); stable materials can turn combustible (aluminum); 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 nanoscales. Much of the fascination with nanotechnology stems from these quantum and surface phenomena that matter exhibits at the nanoscale. Nanotechnology may be able to create many new materials and devices with a vast range of applications, such as in medicine, electronics, biomaterials and energy production. Most applications are limited to the use of "first generation" passive nanomaterials which includes titanium dioxide in sunscreen, cosmetics, surface coatings, and some food products; Carbon allotropes used to produce gecko tape; silver in food packaging, clothing, disinfectants and household appliances; zinc oxide in sunscreens and cosmetics, surface coatings, paints and outdoor furniture varnishes; and cerium oxide as a fuel catalyst. The Japanese manufacturer Toto uses a thin film of titanium dioxide to coat the surface of the wash hand basins and toilet bowls they produce to minimize the surface tension, thus reducing the possibility of particles adhering to the surface. This film can also be used to prevent the steaming up of mirrors and tiles and to prevent condensation droplets forming on the surface. Since 2002 Active glass has been available from Pilkington's. Surface 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 in the science of photonics. This is linked with opto-electronics and production facilities to make fiber-optic communication and switching devices.

The **Building Information Model (BIM)** is primarily a three dimensional digital representation of a building and its intrinsic characteristics. It is made of intelligent building components which includes 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. According to the National BIM Standard, Building Information Model is "a digital representation of physical and functional characteristics of a facility and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition. It 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. No matter which delivery approach is chosen, the general contractor or the construction manager can use BIM. Construction managers or general contractors can use BIM to extract quantities of work to prepare cost estimates. Furthermore, they can provide powerful 3D renderings. Moreover, schedule integrated BIM known as 4D BIM can be used for simulations, animations, safety analysis, and to prepare site logistic plans. 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. In the traditional approach, the design, bid, and build phases follow each other. The architect, typically the lead designer in building projects and construction manager works directly for the owner. The engineering consultants are part of the designer's team. The engineer and the architect first design the building. Upon, the completion of the design phase, the construction managers also known as general contractors in the traditional approach bid for the job. Once the bid is awarded, then the construction starts. It is not a fast track project delivery method. In other words, the approach does not involve early participation of the construction team during design. If the designers generated a 3D parametric model for the project, the BIM will lack the knowledge of the contractors during the design phase. Overall, Design-Bid-Build eliminates the benefits of having the construction input during design phase when the ability to influence the cost is the highest. The architects and the engineers may not want to share their models due to risks, liability concerns, unauthorized reuse of intellectual properties and misinterpretation of the information included in the model.

Lean construction is a system of maximizing value, improving efficiency, enhancing quality, ensuring cost-effectiveness and reducing waste in a building project. 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. They are: 1- Value: There is a need to clarify the customer's needs, and the agents involved in all stages from inception to the delivery process, in order to clarify activities or products that signify value. 2- Value stream: By mapping the whole value stream, establishing cooperation between the participants, and identifying and eliminating waste, the construction process can be improved. 3- Flow: Business flow includes project information (specifications, contracts, plans, etc.). Job site flow involves the activities and the way they have to be done. 4- Supply flow: the materials used in a project. 5- Pull: The efforts of all participants stabilize pulls during the construction process. 6- Perfection: Work instructions & procedures are developed, quality controls are established. Four main principles of Lean construction system: 1) minimal use of building materials. 2) Minimal cost for affordability. 3) Maximum quality of building. 4) Minimal wastage of building materials and energy. These principles are examined from the design stage and through the whole management process. A holistic approach instead of the usual practice where design management and lean construction are examined separately should be adopted. Today's prefabrication industry is currently under the pressures to produce a more-flexible manufacturing technology along with prefabricated systems that allow entire structures to be constructed out of a single system of parts (Evans, June 22, 1995). The critical aspects in achieving more efficient buildings lies in the wall construction details, the method of connecting building components to the walls and the type of building materials used. The thickness of the walls and the type of materials used for wall construction will affect the size, design flexibility and cost of each space. For example, Ballard and Howell 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. The Last Planner is based on three levels of schedules and planning tools: 1-The master pull schedule serves as the overall project schedule, as contrasted with the detailed critical path schedule that is the more traditional management tool. In some cases, a critical path chart may also be used. 2- The look-ahead schedule reflects major work items that need to be completed for the milestone dates in the master pull schedule to be met. This schedule is usually based on a six to eight week time frame, and uses items "pulled" from the master pull schedule; they are carefully reviewed to ensure that they are free of constraints that cannot be removed within a given time. 3- The weekly planner schedule delineates the work activities or assignments "pulled" from the look-ahead schedule that must be initiated to meet the completion dates in that schedule. Eligible activities or assignments are those that have no current constraints, and that have resources available and assigned. The so-called Last Planner is the foreman or other professional who prepares the weekly planner schedule. This schedule also includes a buffer of work activities based on future work. The weekly accomplishment is measured as "Percent Planned, Complete (PPC). Incorporating these measures into traditional building systems will enhance the quality of monitoring progress and quick response to deviations. Like most industrial processes, current construction practices are linear. They use energy and natural resources, convert them to the built environment, and discharge waste. The large quantities of debris left over from demolished buildings are examples of waste from a linear process. Experts recommend a cyclical construction process that puts a greater emphasis on recycled, renewed, and reused resources. This approach will be accompanied by reductions in energy and resource use. The cyclical method could conceivably reuse much of a discarded building to erect a new one in its place.

3 Proposed Methodology

We recommend the combined adoption of Integrated Project Delivery (IPD) and Innovative Green Architecture.

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: a- conceptualization phase (expanded programming), b- criteria design phase [expanded schematic design, c- detailed design phase (expanded design development), d- implementation documents phase (construction documents), e- agency review phase, f- buyout phase, g-construction phase and h- closeout phase. Facilities management is the final part.

Integrated project delivery (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 profits. Otherwise, they all lose their fee. This incentive promotes all the participants to work together towards a common goal. They share all the Building Information Model, share decision making, and share the responsibility. This joint project management approach results in pure collaboration and no litigation. Overall, Building Information Modeling makes IPD achievable. (Handler, 2010).

The problems in contemporary construction include buildings that are behind schedule and over budget as well as adverse relations among the owner, general contractor, and architect. Using ideas developed by Toyota in their Toyota Production System and computer technology advances, the integrated project delivery method is designed to solve these key construction problems. 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. 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. The first working definition of IPD was established in May 2007 by the AIA California Council Integrated Project Delivery Task Force comprising representatives of owners, architects, contractors, engineers and lawyers. Integrated project delivery is a delivery system that seeks to align interests, objectives and practices, even in a single business, through a team-based approach. The team primary Team Members would include the Architect, key technical consultants as well as a general contractor and key subcontractors. The IPD system is a process where all disciplines in a construction project work as one firm, creating faster delivery times, lower costs, no litigation and a more enjoyable process for the entire team – including the owner. IPD combines ideas from integrated practice and lean construction to solve several problems in contemporary construction such as low productivity and waste, time overruns, quality issues, and conflicts during construction among the key stakeholders of owner, architect and contractor. The growing use of building information modeling in the construction industry is allowing far greater information collaboration between project participants using IPD and considered an important tool to increasing productivity throughout the construction process. Unlike the design–build project delivery method which places the contractor in the leading role on a building project, IPD represents a return to the "master builder" concept where the entire building team including the owner, architect, contractor, engineers, and subcontractors work collaboratively throughout the construction process. However, as most construction projects involve disparate stakeholders, traditional IT solutions are not conducive to collaborative working. Sharing files behind IT firewalls, large email attachment sizes and the ability to view all manner of file types without the native software all make IPD difficult. The need to overcome collaborative IT challenges has been one of the drivers behind the growth of online construction collaboration technology. Since 2000, a new generation of technology companies evolved using SaaS to facilitate IPD in a smooth and efficient manner. This collaboration software streamlines the flow of documentation, communications and workflows ensuring everyone is working from 'one version of the truth'. Collaboration software allows users from disparate locations to keep all communications, documents & drawings, forms and data, amongst other types of electronic file, in one place. Version control is assured and users are able to view and mark up files online without the need for native software. Since 2000, advancement in cloud technology has made some building spaces obsolete while increasing pressure on some strategic older buildings to be redesigned to meet up with demands of the information age.

Innovative Green Architecture (IGA) is the adaptation of green architecture to the local environment using strategic innovation. Pressures for innovation are usually strongest when there is demand for radically different types of buildings, driven by widespread technological and economic change. The most recent period of such change began in the late 1970s, taking hold throughout advanced industrialized countries during the early and mid-1980s, because of the need to provide a new infrastructure and facilities to support activities based on the use of information and communication technology (Gann, 2000).

Green Architecture basically refers to environmentally friendly buildings that are energy efficient. Green architecture may have many of 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. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. Although new technologies are constantly being developed to complement current practices in creating greener structures, the common objective is that green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by: 1- Efficiently using energy, water, and other resources. 2- Protecting occupant health and improving employee productivity.3- Reducing waste, pollution and environmental degradation. A similar concept is natural building, which is usually on a smaller scale and tends to focus on the use of natural materials that are available locally. Sustainable housing helps to address global pollution and rapidly depleted natural resources. Miyatake (1996) quotes Norway's prime minister – "Sustainability is leaving sufficient resources for future generations to have a quality of life similar to ours". At The First World Conference for Sustainable Construction, Dr. Charles J. Kilbert identified six principles: Minimize resource consumption; maximize resource use; use renewable or recyclable resources; protect the natural environment; create a healthy, nontoxic environment; and pursue quality in creating the built environment. At Eko Atlantic city, the following questions are being given to Developers to assist them in ensuring that Green Architecture is fully implemented there. The questions are based on the 10-point criteria for Green Architecture by the American Institute of Architects. 1.0 - SUSTAINABLE DESIGN INTENT & INNOVATION 1.1 - What are the Key environmental issues, Key ecological goals and concepts for Eko Atlantic City? 1.2 - How were these goals and concepts expressed in the design of Eko Atlantic City? 1.3 – What sustainable design innovations are there in Eko Atlantic? 1.4 – Based on your process of program analysis, what are the resource efficiencies realized by innovative programming. 1.5 – What efforts to "right size" the project and to reduce unnecessary square footage. 2.0 - REGIONAL / COMMUNITY DESIGN & CONNECTIVITY – 2.1 – How has the sustainable design of Eko Atlantic City valued the unique cultural and natural character of a given region? 2.2 - How has the design of Eko Atlantic City related to the local context and to larger regional issues? 2.3 - How has the design of Eko Atlantic City (EAC) promoted regional and community connectivity and sense of place, public space and community interaction? 2.4 – What are Transportation policies and infrastructure at EAC to limit automobile use? 3.0 - LAND USE & SITE ECOLOGY 3.1 – How does the sustainable design of EAC protect and benefit ecosystems, watersheds, and wildlife habitat in the presence of human development? 3.2 - How does the development of EAC respond to its ecological context, air and water quality at different scales from local to regional level? 3.3 - How does the development of EAC contribute to environmental quality? 3.4 - How does EAC accommodate wildlife habitat preservation and creation? 4.0 - BIOCLIMATIC DESIGN 4.1 - How does the sustainable design of EAC conserve resources and maximizes comfort through design adaptations to site-specific and regional climate conditions? 4.2 - How does EAC respond to local climate, sun path, prevailing breezes and seasonal and daily cycles through passive design strategies? 4.3 – What are the design strategies of EAC that reduce or eliminate the need for non-renewable energy resources? 5.0 - LIGHT & AIR 5.1 - How does the sustainable design of EAC create comfortable interior environments that provide daylight, views, and fresh air? 5.2 – What are design strategies of EAC for day-lighting, task lighting, ventilation, indoor air quality, views, and personal control systems? 5.2 – What is EAC approach to integration of natural systems and appropriate technology? 6.0 - WATER CYCLE - 6.1 - How does the sustainable design of EAC conserve water and protect and improve water quality? 6.2 - How does EAC design strategy manage site water and drainage, and capitalize on renewable sources (such as precipitation) on the immediate site? 6.3 – What are the reuse strategies at EAC for water including use of rainwater, gray water, and wastewater? 7.0 - ENERGY FLOWS & ENERGY FUTURE 7.1 - How does the sustainable design of EAC conserve energy and resources and reduce the carbon footprint while improving building performance and comfort. 7.2 - How does EAC anticipate future energy sources and needs? 7.3 - How does EAC reduce energy loads for heating, cooling, lighting, and water heating? 7.4 - How does the design of EAC contribute to energy conservation? 7.5 - How does EAC encourage reduction in use of fossil fuels, reduction in greenhouse gas emissions and reduction in other pollution? 7.6 – What techniques are used at EAC for systems integration use of controls and technologies? 7.7 – What efficient lighting strategies are used at EAC? 7.8 – What on-site renewable and alternative energy systems are used at EAC? 7.9 - What strategies are used at EAC to reduce peak electrical demand? 8.0 - MATERIALS & CONSTRUCTION 8.1 – What selection of materials and products are used at EAC to reduce product-cycle environmental impacts and optimize occupant health and comfort? 8.2 – What efforts are made to reduce the amount of material used at EAC? 8.3 – What are the materials selection criteria in view of optimizing durability, maintenance and energy use? 8.4 – What are the construction waste reduction plans for EAC? 8.5 – What are the strategies at EAC to promote recycling during occupancy? 9.0 - LONG LIFE, LOOSE FIT 9.1 - How does the sustainable design of EAC enhance and increase ecological, social, and economic values over time? 9.2 – In what way was EAC designed to promote long-term flexibility and adaptability? 10.0 - COLLECTIVE WISDOM & FEEDBACK LOOPS 10.1 – How are EAC design strategies, performance and best practices evolved over time documented? 10.2 - How will you evaluate the performance of the built results at EAC? 10.3 –What are the major lessons learned so far during the design and construction of EAC? 10.4 – How would these lessons change your approach to this project if starting over, or to future projects? 10.5 – How do you organize on-going monitoring of building performance and occupant satisfaction at EAC?

Innovation is when creative, new ideas are applied in a commercially successful way such that it makes a positive impact on the world. These are goods, services and inventions such electricity, computers and motor vehicles. In view of this, strategic innovation is essential in bringing together the five concepts in this study to support the optimal development of artificial intelligence in intelligent buildings. Figure 1 encapsulates the above into a model for generating innovative ideas

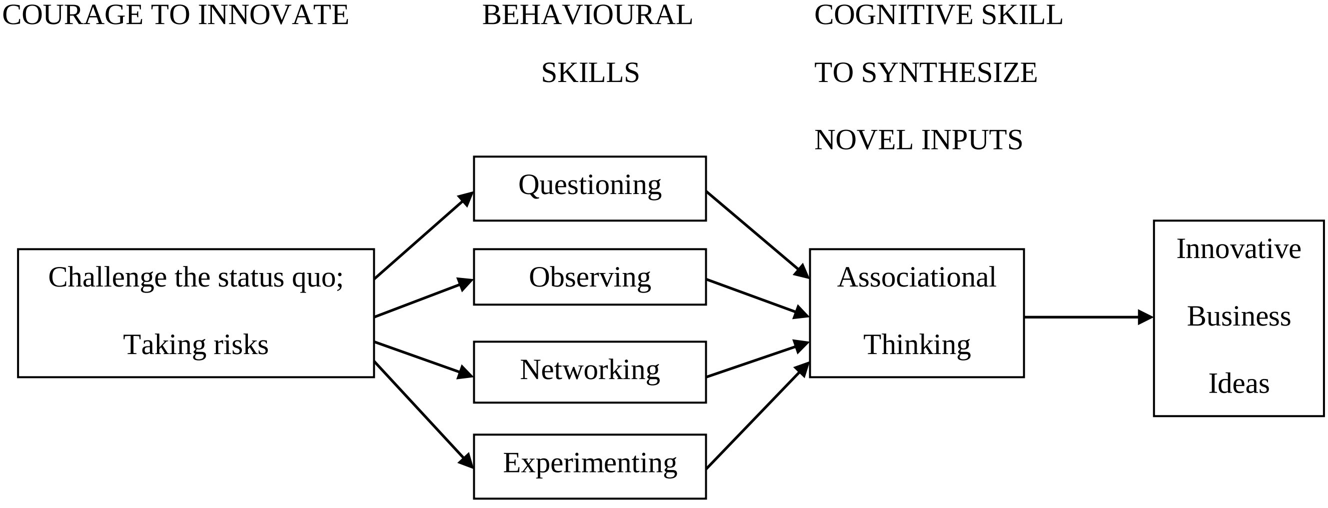

Figure 1 - MODEL FOR GENERATING INNOVATIVE IDEAS (Adapted from Christensen, Clayton M.; Jeff Dyer; Hal Gregerson-2011)

IDEO's Five Step Methodology for Innovation is: 1- Understand the market, the client, the technology, and perceived constraints. 2- Observe real people in real-life situations. 3-Visualize new-to-the-world concepts and the customers who will use them. 4- Evaluate and refine prototypes 5- Implement the new concept (Tom Kelly, The Art of Innovation). The Figure below illustrates key concepts.

Figure 2 - SUGGESTED INNOVATION FRAMEWORK (From Delivery versus Discovery: Nurturing The Seeds of Innovation by Tunji Olugbodi)

The research approach recognizes that innovation is the main drive to implementing new technologies. The literature reviews have shown that the techniques used in accessing new technologies can be more sustainable if the innovative thinking is extended into the realms of sustainability. The simple analogy is that when green architecture is applied innovatively by professionals using integrated Project Delivery, a sustainable foundation is laid on which advanced technology can thrive. Nanotechnology, Building Information modelling and lean Construction are already forms of innovation. However, what makes them sustainable in intelligent buildings is the innovative way green architecture has been applied from the onset.

4 Conclusion and Further Research

The research findings in this study revealed the importance of laying a sustainable foundation for advanced technologies in intelligent buildings based on green Architecture and Integrated project delivery. This should be done before Nanotechnology, Building Information Modelling and Lean Construction can be applied with Artificial Intelligence to achieve intelligent buildings. Despite the advanced technology and intelligent buildings present in developed Countries, the problem of global warming is still a major issue. In Africa, we must therefore ensure that advanced technologies in the form of artificial intelligence and intelligent buildings are first examined in terms of sustainability using green architecture. Integrated Project Delivery also ensures that the various forms of information documented in Building Information modelling and lean construction are properly implemented through the involvement of various types of professionals at conceptual stage. For example, Information technology experts are now part of the integral design team from conception stage. Eko Atlantic City as a case study revealed that the Great Wall of Lagos sea revetment, which is being built more than two kilometres offshore, is now protecting over 5 million square meters of Eko Atlantic City and Victoria Island. The threat of serious flooding was a major concern. Before the Great Wall, tidal surges used to regularly cause water and debris to spill over on to the main coastal highway named Ahmadu Bello Way. Developers of the new city plan to use eco-friendly building materials and advanced technologies during its construction. Further research should reveal the nature of intelligent buildings and extent of Integrated Project Delivery on the site when the first buildings are completed.

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