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Review of Smart Based Building Management System

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***Abstract*-In Nigeria, the need for more energy efficient (smart) buildings cannot be overemphasized considering the epileptic power situation which has significantly kept the country from assuming its position as a true giant of Africa in terms of economics and infrastructure.Energy demand far exceeds its supply, and has necessitated the need for more proactive measures to ensureenergy conservation usage. Thus, this study reviewpapers on Building Management Systems (BMS)with particular interest. on incorporation of building automation systems in new buildings and the retrofitting of existing building to make them suitable for automation tools. Reviewing the use of BMS for optimization of energy consumption of building's electromechanical systems and highlighting its remarkable cost saving effectiveness in both operations and maintenance will persuade stakeholders and facility owners to embrace the automation for their facilities for buildings (residential, commercial and industrial).**

***Index Terms*-BAS, IoT, Smart, Protocols**

I. Introduction

This literature review presents a conceptual framework that creates questions to guide the purpose of this study. It involves review of a number of publications and referred academic journals organized under central themes.This will lead to reduction in energy consumption in buildings –most especially commercial buildings such as factories, hospitals, hotels, office complexes, shopping malls etc. by 30 – 40% (ARUP, 2016). This research investigates the importance of building management systems (BMS), its processes, workflows, current trends, available technologies, and the future of BMS utilization. Specific areas to determine which factors may predict successful adoption, integration and deployment in commercial buildings was also reviewed. In this era, where energy management is the concern of everyone, buildings are being constructed in a manner to provide maximum comfort and ease to the people with minimum energy utilization. This is only possible with the help of controlling devices that are to be installed in a building during construction. This control can be of any type, from simple switching on and off of lights, to water motor control and many more. Therefore the main idea of designing this system is to automate these building operations in the most resourceful manner (Swarnalatha, 2011). Besides controlling, security factor has also been kept as a concern with password protection. Cameras, fire alarms systems, main gate security and main gate barrier automation has been put at priority in this systems (BMS). Another feature which is required in a multiple story building is elevator, which can also be found in building systems. Building Management System (BMS), otherwise known as Building Automation System (BAS), is a computer-based control system installed in buildings that controls and monitors building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire and security systems. BMS consists of software and hardware; the software program, usually configured in a hierarchical manner, can be proprietary, using such protocols as C-Bus, Profibus, and so on. Vendors are also producing BMS that integrates the use of internet and open standards such as DeviceNet, SOAP, XML, BACnet, LonWorks and Modbus. It analyses specific necessities of a particular building by controlling the associated plant installed in it and helps save energy (DaintreeNeworks, 2009). Devices installed outside the buildings are connected with panels which can be switch on or off over different sets of instructions. The working of BMS is totally based on the input in form of information by the devices such as sensors.Once the information is collected it can be processed with the help of controller that will further instruct the system to perform a specific task. In BMS technology, switching on and off of the plant can be controlled in the same manner.Plant can be set to a respective temperature in order to provide heating and cooling with respect to the temperature outside the building. BMS serves as a tool for potential increase in economics and energy efficiency, and thus, must be clearly defined and understood before its implementation in both private and commercial buildings, especially in the later where it seems to provide enormous cost savings due to minimized energy consumption it yields when installed in a building. The evolution, benefits, limitations, efficiency, application and adoption of BMS are reviewed.

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II. REVIEW OF BMS TECHNOLOGY

While BMS have become smart in recent years, the concept is certainly not new and has gradually evolved over the last 50+ years and into the 21st century systems as at today. BMS has always been boosted by technological developments of the time, but today's smart building technology is influencing BMS like nothing before. BMS is essentially a computer-based control system that monitors and manages building's mechanical and electrical equipment, including ventilation, lighting, power, fire and security systems. Various subsystems in a building have traditionally been operated separately, each with their own IT structure. However, as the number of subsystems increased the case for integrated solutions also grew. In particular, the addition of fluctuating renewable energy generation and energy storage capacity added a new level of complexity, one which demanded a new form of management in buildings, in order to reduce rising overall costs (Memoori, 2017). The driving force of this evolution is energy efficiency. With 40% of total energy consumption coming from buildings the case for greater efficiency is strong. Modern BMS systems allow for historical trend analysis to be paired with real-time data collection to optimize subsystems such as lighting and HVAC. These mountains of 'big data' are continuously growing, and ability to analyze them give more meaning to the data, thus the greater the application of intelligence and optimization in terms of energy utilization. By constantly observing and controlling air quality, for example, BMS can create indoor environment that boosts employee health and productivity. Furthermore, by monitoring different machine health parameters, BMS can optimize maintenance scheduling and reduce costly downtime (Memoori, 2017). Connectivity also enables remote monitoring and control of BMS. Not only does this create greater flexibility for building managers, it also increases safety and security for building's occupants and assets. Alarms coupled to connected HVAC, fire, security systems, as well as access control permit immediate and effective responses to a wide variety of emergency situations. All of these developments can be attributed to the emergence of Internet of Things (IoT) in smart buildings in recent years. The trends promoting growth in BMS market are now directly linked to IoT movement(ISO (2004). Similar and simultaneous development in the industrial IoT has advanced data and connectivity for industrial purposes. This is also feeding back into BMS development in the form of lower cost of 'things' with embedded intelligence, advances in predictive analytics, as well as the growth of cloud based services (i-Scoop, 2018). It is worthy to note that there are tremendous changes at the construction phase of buildings through the rise of building information management (BIM) as shown in figure 1.0. Each generation of BIM further eases the integration of complex building systems into architecture, engineering, and construction workflows. BIM allows for the incorporation of BMS solutions at the project design phase. This enhances BMS integration, thus reducing building operating cost. As BMS and IoT continue to grow, there will be greater cost savings and novel features, thus creating unparalleled value from the building. The rise of BMS to become the core of smart buildings is inevitable since the future of buildings is unequivocally data and connectivity.

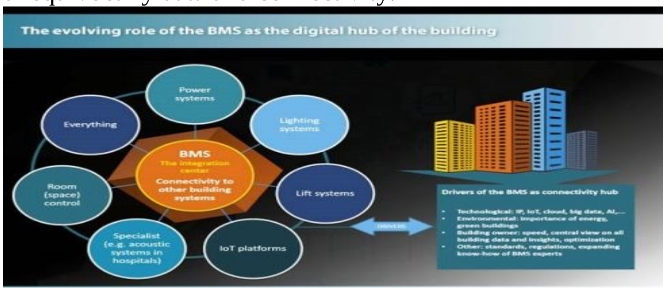

Figure 1.0: The Evolving Role of BMS (Source: i-Scoop, 2018

It is observed that BMS is gaining popularity in the built environment. Though initial cost may cause some hesitation at first glance, however, when the benefits of investment becomes clear, implementing BAS often become a no-brainer, especially for owners of commercial and industrial buildings, such as ware houses, office buildings, schools and government buildings etc.

III. RESEARCH METHODOLOGY

A. *Reduction in Building Expenses*

Building owners can expect to save substantial amount of money in the long run with BMS. BAS especially help to save on utility bills by implementing various monitoring and control strategies for electromechanical equipment:

- BAS can predict the building or room occupancy by gathering data about the demand for lighting, heating or cooling. It can then meet that demand more effectively by dialing back the output when demand is lower. Even this basic occupancy range monitoring function can cut energy usage by as much as 10 to 30 percent. For larger buildings (Iwuagwu, 2014).
- BAS can synchronize up with the outdoor environment. For example, during summer and spring, there is more ambient light from windows and other openings and can adjust artificial source of lighting either by dimming or turning off lamps in areas with high ambient light to minimize energy required for lighting.
- BAS can report failures within building features immediately. Without such notification, an ample amount of time could be spent in manually diagnosing the problem and reduce operations down time and maintenance cost.
- BAS helps to optimize the operations of buildings facilities. It can extend the lives of electromechanical equipment by quickly identifying and reporting faulty systems thereby reducing the risk of damage to such equipment due to fault and reduce the potential of breakdown and replacement costs.

The financial gain from the use of these functions is perceived by Domingues (2005) to typically offset installation and implementation of the building automation system within a short payback period.

Improved Comfort and Productivity

By improving the control of a building's indoor environment, building owners will have more control over the comfort of the building's occupants. Not only will the building be heated and cooled more effectively and efficiently, air ventilation will improve as well, which is likely to have big impact on productivity of building occupants.

Greenhouse Rating

Greenhouse gas (sometimes abbreviated GHG) is a gas in an atmosphere that absorbs and emits radiation within thermal infrared range. This process is the fundamental cause of greenhouse effect. Because BAS reduces energy usage, its implementation will make buildings environmentally friendly through reduction in energy consumption, and reduction in the output of greenhouse gases.

BMS and Energy Conservation Potential

According to Energy Performance of Building Directive (EPBD), "Energy efficiency is the actual consumption, calculated or estimated amounts of energy required to cover various requirements relating to the standardized use of a building". The following thermal and electrical forms of energy are considered when determining energy efficiency of a building:

- ✓ Heating

- ✓ DHW (Domestic Hot Water)
- ✓ Cooling
- ✓ Ventilation
- ✓ Lighting
- ✓ Auxiliary energy

Until recent years, energy efficiency has been of low priority and low perceived opportunity to building owners and investors. However, with increase in the awareness of energy use concerns and the advances in cost effective technologies, energy efficiency is fast becoming part of real estate management, facilities management, and operations strategy (Pervez et al. 2017). The concept of energy conservation is also making significant inroads into the residential building sectors. With a well implemented BMS, it is observed that lighting energy savings can be up to 75% of the original circuit load, which represents 5% of total energy consumption of residential and commercial sectors. Also, Energy savings potential from air conditioning or hot water production can be up to 10%, which represents up to 7% of the total energy consumption of residential and commercial sectors (Papadopoulou, 2012).

B. Stages of Evolution

I. Open Protocols

Protocols are best described as the 'languages' by which objects communicate with each other. Technically, they enable communication between servers within a network.The early BMS consist of multiple subsystems that were not interconnected. Building operators or managers had to collect aggregate data from different systems in single, or across multiple buildings to make sense of it (BTL, 2018).The limitations of early BMS were mitigated, in part, with the establishment of communication protocols for buildings.

II. Proprietary protocols

The first building automation protocols were proprietary or closed. A proprietary protocol is like an exclusive language: in order for the devices and systems within a BMS to communicate and understand one another, same protocol must be used. Due to the restrictive nature of proprietary protocols, building owners were held captive to a single protocol which limits their choice of building automation equipment; hence the integration of individual subsystems that operate using different protocols was grossly limited.Each protocol has its own advantages and proper adherence is an effective way to optimize building system and meet the particular needs and budgets of building owners. It is therefore common practice for BMS to utilize more than one open protocol (BTL, 2018).

III. Wireless Communications

BMS users are increasingly adopting wireless communication technology since going wireless translates to less cables, less wires, and less conduits. Wireless communication protocols mitigate the limitations of traditional hardwired circuits, particularly in the realm of infrastructure challenges. Fig. 2.1 shows various connectivity channels to wireless communication in a commercial building

Figure 2.2: Wireless Communication System in BMS (Source: BTL, 2018)

The benefit of wireless evolution in BMS includes the following:

a) ***Increased use of Sensors:*** In large commercial buildings such as hospital which is spread across large geographical area, the need for physical wiring is an hindrance to connectivity; hence wireless technology presents suitable alternative. Likewise using wireless communication technology is appropriate for devices that are not stationary such as automobiles and mobile equipment.

b) Enhanced Flexibility and Adaptivity:Adopting wireless communication in place of characteristically inflexible wired networks enhanced the ease with which BMS can be configured especially when modifying existing buildings. According to Swarnalatha (2011), the adoption of wireless connectivity has reduced the capital expenditure of installing BMS in new and existing buildings by 34% and 55% respectively

c) ***Remote Usage:*** Wireless networks enable remote controls and accessibility to BMS. Mobile devices such as smartphones and tablets can be linked to BMS, and thus enables users to view, access and control BMS anytime, anywhere, regardless of physical location.

These days, building automation equipment and devices are available with either wired or wireless communications. As wireless connectivity inevitably supersedes wired in the building sphere, the phenomenon of IoT represents the next significant breakthrough in BMS connectivity (BTL, 2018).

C. Internet of Things (IoT)

IoT refers to a hyper-connected network of 'things' that can gather and communicate data using Internet Protocol (IP). In simple terms, it means machines talking to machines and you (the user). The advent of IoT in today's world has risen to new heights building automation integration and connectivity.

Figure 2.3: IoT in BMS (Source: BTL, 2018)

In relation to buildings, IoT can be defined as a large number of data points in a building that, via the internet, transfer information between themselves and to the cloud. Here, analytical tools and applications use that data to generate actionable information that enhances building performance (i-Scoop, 2018). In addition to users and facility staff being able to access, share and control data remotely, other benefits of IoT-enabled buildings (BIoT) include the following:

a) Increased Data Points throughout the BMS

IoT significantly increases the number of data points within a building. This enhances the variety and volume of information that can be collected and communicated.Another exciting advantage is that data points that exist independently of, and external to, the building environment can also be accessed, communicated and analyzed to further influence building controls and decision-making (BTL, 2018).For example, data on the short-term weather forecast is aggregated and analysed alongside data generated via BMS and will automatically optimize the building environment by varying temperature controls to generate energy efficiencies, enhance occupant comfort and productivity, and generate cost savings.

b) Big Data Analytics

The cloud is a storage container for massive amounts of data generated by a building. This data comes from a variety of sources and across extensive timeframes. This is extremely valuable for building owners and managers, but only if that data is actually utilized. That is why the cloud is also a processing platform for big data analytics. Big data analytics refers to advanced analytical software that runs on large, complex data sets to generate meaningful, actionable information (BTL, 2018).In the context of building automation, big data analytics can search the data to uncover trends, relationships, correlations and patterns. This is an automated process which provides the user with never-before-seen levels of visibility and control over a building's devices, systems and facilities, and sets the stage for intelligent decision-making.Traditional BMS systems are structured for reactive decision-making. An exciting feature of big data technology is the enhanced capacity for proactive decision-making. For example an IoT connected HVAC system will not only trigger maintenance alerts when components are approaching end-of-life, it will also order replacement parts online and book an engineer to perform maintenance, all before the component dies. Fig. 2.3 shows various components of IoT which is driving the future of BMS in today's world.

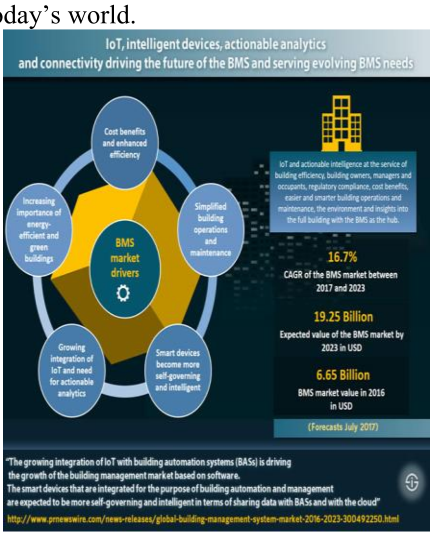

Figure 2.4: BMS Market Drivers (Source: i-Scoop, 2017)

Today, there are on-going big changes which are exceedingly transformational for the industry as the IoT, advanced analytics, artificial intelligence (AI), cloud and an increasing movement towards the edge and IP are all essentially driving BMS to unprecedented heights.The essence of these changes include hyper-connectivity for integrated BMS in order to ensure that it takes centre stage as IP and IoT, as well as other related technologies is essential in these evolutions and continue to change the market.BMS and associated systems are not only cutting costs but also creating value. Enhanced safety, security and flexibility are creating a competitive advantage for advanced BMS enabled buildings. Smart building owners can attract better tenants at higher rates, largely because smarter buildings can attract smarter employees.BMS has evolved to be the central platform for coordination of data gathering and the subsequent use of intelligence.Moreover, with the continual evolution of IoT and technologies such as big data analytics and AI, there is bound to be increased integration of these technologies to give rise to smart buildings which are more energy efficient in the nearest future.

IV. ADOPTION OF BMS IN NIGERIA

Though BMS has been fully embraced in developed countries such as USA, UK, France, Japan etc., but not yet in most African countries. In Nigeria today, the most prominent automation in buildings are sensor-controlled glass doors which are available in most public buildings. Coupled with the epileptic power generation in the country, high energy consumption in commercial buildings has resulted in the unavailability of power to over 60% of its population. Though recently, there has been a warmer embrace towards the automation of buildings in other to optimize its energy consumption as seen in most newly built hotels and organizational buildings such as NCDMB headquarters, Total Nigeria HQ, Chevron HQ etc., the overall adoption of BMS in Nigeria has been terribly poor as highlighted by Ben and Margaret (2014).

A. The complexity of the Nigerian state calls for the need for it to embrace BMS in order to address the following prevalent issues:

a) Sustainable Built Environment

Globally, the biggest challenge faced by communities is controlling and monitoring the performance of built environment facilities in a sustainable way.This is even more pronounced in a developing nation like Nigeria where sustainability is not considered as a primary issue. From this dimension, effective use of BMS in the built environment is representing a significant strategy in relation to economic, environmental and social perspectives (Kumara and Waidyasekara, 2013). Higher energy efficiency, lower operating and maintenance costs, better indoor quality, greater occupant comfort and productivity are the major achievements of a successful BMS. Therefore, it is pertinent that individuals/organizations/government be enthusiastic to allocate substantial investment, in order to install, commission, operate and maintain BMS. As investigated by Forsberg and Malmberg in 2004, built environment plays vital role in the society of today, being a result of a number of social and economic processes that are central to sustainable development. From recent years, the pursuit of sustainability has become a mainstream of building design objectives as the physical environment of the earth is deteriorating.

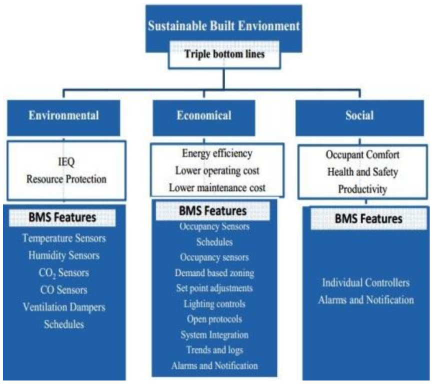

Fig2.5:BMS Contribution in Sustainable Built Environment(Source:Kumara and Waidyasekara, 2013)

b) Urbanization

With present population of about 197,000,000 and an annual change rate of 2.6% (World Bank, 2018) of which about 51% resides in the urban area and a continual migration of people from the rural areas, it is necessary to ensure that building infrastructures are designed and managed in such way that there is maximum optimization of energy. Energy is a very limited resource in Nigeria hence the need for proper urban planning through the use of BMS

c) Deregulation

Deregulation can be used as a tool for improving efficiencies and competitiveness within the economy. Among the sectors that have been or that are still being transformed are telecommunication and energy sectors. The transformation of energy industry is particularly important, and government should make effort to also explore the area of alternative energy, particularly solar energy, thus encouraging developers within and outside the country to develop and operate intelligent buildings at low cost (Ben and Margaret, 2014).

d) Matching Up with the Developed Nations

Nigeria is already far behind in terms of adopting new technologies. In order to be truly considered as a developed nation in the nearest future, it must seek to become increasingly technologically driven while achieving sustainable development. While other developed nations have actively employed IoT to further optimize their BMS, Nigeria has not fully maximized the potential in IPs and wireless sensors in optimizing energy consumption in commercial and industrial infrastructures. This has to be remedied as soon as possible to ensure a sustainable environment.

B. CHALLENGES OF ADOPTING BMS IN NIGERIA

Though BMS has been in vogue in developed nations for over 50 years, there are several factors which have resulted in its limited applications in Nigeria and Africa as a whole. Some of these challenges include:

a) Technical Know-how

BMS is still not a widely accepted technology in Nigeria, and hence, there is still large skill-gap needed to be filled in the area of capable manpower that can proficiently install BMS especially in existing buildings. Also, because BMS professionals are few, their services are quite expensive to procure, and coupled with the fact that the equipment are ordered from overseas and not produced in Nigeria, the overall cost of installations of BMS is a turnoff for most Nigerian developers.

b) Awareness

The level of awareness as regards the use and benefits of BMS such as cost savings, energy efficiency and environmental friendliness is quite low in Nigeria. Even among professionals, BMS is still not apopular feature because the adoption of modern computing in buildings is just evolving, and considering that computing is central to integration of intelligent technologies, it poses an important challenge to their adoption.

c) Power Supply

With maximum power generated averaging about 4,000MW, electricity is inadequate and hence, a greater part of the population generates its power largely through diesel generators or solar panels. This inadequacy/interrupted power supply makes the installation of BMS expensive since a dedicated uninterrupted power supply will be needed for the seamless operation of BMS. Coupled with increased cost, the environmental advantage of using BMS could be defeated through the use of fossil fuel to power generators. This is because burning fossil fuel emits greenhouse gases and there is potential risk of exposure to health challenges.

d) Maintenance & Upgrade

Poor maintenance has been a ravaging culture in Nigeria's residential and commercial buildings. Most building equipment suffers from maintenance because of lack of upgrade and planned maintenance. The modules used for BMS are quite expensive and need to be maintained over their life time in order for them to serve their installation purpose.Also, because of the continuous improvement in BMS, there is constant need for upgrade of equipment. This is discouraging for most Nigeria developers as they do not want to spend money on upgrade, hence, these equipment will become obsolete after a while.

e) Economy

The state of Nigerian economy is another turnoff for most Nigerian developers. Developers of both residential and commercial building have found it difficult to raise capital to finance their projects, and even when it is done, there are few who are willing to pay for lease or purchase. This poor economic state has made most developers consider BIoT to be a luxury, hence failure to install them in buildings.

C. Impact of BMS on Sustainable Built Environment

In today's present world, BMS has evolved to the point where the keyword "Intelligent or Smart" is the term used to describe new residential and commercial buildings in major cities worldwide. According to EIBG (2015), Intelligent Buildings (IB) maximizes the efficiency of its occupants and allows for effective management of resources with minimum life costs. IB should provide productive and cost-effective built environment through optimization of its four (4) basic components.These include, structure, systems, services and management and the interrelationships between them. It focuses on benefits of owners and their desired indoor environment to maximize the efficiency of its occupants whilst creating desired indoor environment for occupants. As such, the built environment should be productive, safe, healthy, and thermally/aurally/visually comfortable; and the building should render sustainability and adaptability for future generations.The world is changing fast because of the catastrophic rise in global warming, hence a paradigm shift about the thinking of energy. Buyers and tenants are looking for much energy efficient buildings, especially commercial ones in order to avoid growing future energy expenses.IB is perceived as a long-term and value-added investment, with the following benefits:

- ✓ Provide better and more comfortable environment for occupants, leading to improved working efficiency with the aid of modern IT.
- ✓ Ensure lower life-cycle costs, in particular for maintenance and upgrades.
- ✓ Guarantee greater flexibility in modifying building's functions.
- ✓ Maintain relatively higher value for building in terms of marketability and productivity; thus establishes a renowned image to the public which fulfill users' requirements.
- ✓ Uphold the concept of environmentally friendly building (Chan, 2016).

So *et al* in 2017 divided IB into two perspectives, i.e. the needs of building developer/owner/occupants and the enabling technologies and concluded that integration of these two dimensions will generate measurable long-term building values such as productivity, market value, energy conservation, environmental friendliness and high working efficiency. These values have resulted into increase in revenue as reported by Navigant Research (2017) in which global BMS market revenue is expected to grow from $4.0 billion in 2017 to $13.1 billion by 2026. Through wise integration of building services, a single system is explored to monitor gas, electricity, water, air and steam installations. All these utilities can be tracked and monthly reports can be automatically generated. These data can be accessed via web browser, allowing immediate access to diagnostics and remote device interrogation. The integration of building services helps in the initial phases of building infrastructure. The management and control can be regarded holistically; whilst installation costs for cable runs and shared networks can be reduced. Remote accesses to such detailed diagnostics allow Facilities Managers (FMs) to easily track and control building's utilities. It is amicable to preset lighting and heating controls via web browser and alter these settings if required. By means of careful metering and recording of building utilities, reporting becomes easier. It is no longer necessary to physically go to each meter and record the readings. Moreover, intelligent metering system provides real-time data that allows FMs to easily identify trends and to mitigate/diagnose problems effectively. With the ability to capture events and greater access to diagnostics, it is simple to identify where, when and why an unusual reading occurred. For example, it is possible to determine if a power-quality problem lies with the utility supplier or within the building. Such system can also determine if suppliers have provided equipment that adheres to specified rates. Transients, which can damage electronic equipment, can be pinpointed and power quality issues highlighted. This is particularly important in factories, hospitals, data centers, etc.; where electrical disruptions can lead to unexpected financial loss and unsafe situations. By effectively monitoring electrical and piped utilities, equipment life can be increased and trend information utilized for further cost-savings. It is equally possible to quickly identify areas where energy is being wasted. Moreover, empirical studies of metering solutions show an average of 5% reduction in utility bills in different buildings. Savings of 2 to 5% can be achieved by better equipment utilization, and even up to 10% savings potential can be reached by improving the reliability of systems. FMs incorporates computerized system which controls building operations, energy and life safety. Evidence shows that operating costs typically amount to almost three times the capital cost. Maintenance has traditionally been done which is not economical (Chan, 2016).Intelligent building-control systems can help maintenance to be proactively scheduled, budgeted, and programmed. Modern facilities are the smart brain for these proprietary systems, providing singlecontrol point.A simple, intuitive icon style layout is presented to the user, removing the requirement to be technical-master to operate these control systems. The Advanced Control Corporation (ACG, 2013) opines that Intelligent Building Management System (IBMS) provides integrated management features similar to building's brain; monitoring, interacting and management for all the building's other automation system at real-time; including access control, audio/video intercom, wireless networking infrastructure, structure cabling system, CCTV/DVR surveillance system, computer room facilities, electrical distribution, lighting control and information display system, etc. Energy Savings Trust (EST, 2015) reveals that installing technology to meter and monitor energy consumption has an average payback period of less than six months. A small increase in capital expenditure can reduce operational expenditure significantly. Empirical studies of metering solutions show an average 5% reduction in utility bills in different buildings. Savings in the region of 2 to 5% can be achieved by better equipment utilization and as much as 10% can be attained by improving the reliability of systems. For new and retrofit installations, an existing Ethernet network can be used. Wireless and Ethernet technologies enable 'plug-and-play' and convergence to allow centralized control.State-of-the-art IB employs many integrated mechanical and electrical systems that control the building's environment, lighting and security to maintain high-speed data networks and emergency backup power generators. Incorporating these systems into the building saves energy while increasing reliability, security and efficiency; making the building more desirable for prospective occupants. It is critical that these systems function continually and reliably. If not detected and repaired quickly, malfunctioning mechanical and electrical systems in an IB can pose serious consequences. For instance, unreliable lighting and network connections can impair worker productivity, while a malfunctioning fire or security system can potentially place human life at risk. There must be commitment from the developer / owner to maintain sustainable IB (Chan, 2016).

Cost savings and energy reduction can be realized in IB through the following:

a) Programmed start/stop b) Optimal start/stop c) Electric demand limiting d) Set point reset

e) Adaptive control f) optimal energy sourcing Emergency control of elevators, HVAC systems, doors

g) Uninterrupted Power Supply h) Duty cycling i) Boiler optimization j) Reduced manpower dependence k) Chiller optimization

The reduced operational cost-benefit of BMS and the superior indoor environment it provides makes it a profitable investment in the long run. Hence, the market demand for buildings with installed BMS is growing because it offers the following advantages:

a) Increase in productivity b) Reduction in overall O&M costs c) Quick payback periods
d) Savings in maintenance costs over the a building's lifetime e) Low vacancy rates f) Decrease in financial risk and a high financial return

D. LIMITATIONS OF BMS

With the growing excitement around the possibilities of tomorrow's buildings, there is no doubt that BMS is the backbone of smart buildings. Owners, developers and operators are visualizing ways in which traditional BMS can be expanded to become the source of data for how a portfolio of buildings is performing. Even for properties that have not installed BMS, advancements in sensor technology will make investment in it more cost effective.As such, a number of solutions have been developed to extract and visualize the dense BMS data for building operators. Armed with this data, there is an ongoing theory that operators will be able to produce the ideal environment for occupants in a more effective and precise way than currently possible whilereducing wasted operating costs.It is a well proven fact that building automation does not necessarily equate to building intelligence. There are certain limitations which raises concerns over this vision of the future of BMS. These include limitations with data that can be captured by BMS, and thus limitation on the extent to which BMS data can facilitate the future envisioned for tomorrow's buildings (Comly, 2017).

a) Expensive Acquisition and Utilization of Data

In recent times, cost of sensors has plummeted over the years. In 2004, average cost per sensor was $1.30, and it is forecasted to fall to about $0.38 in 2020. Regrettably, these cost reductions in the price of sensors have not translated into substantial drop in the cost of a full BMS installation. As of 2014, the deployment cost of a basic BMS was at least $2.50 per square foot and could be as high as $7.00 per square foot (Comly, 2017). While the cost of sensors has plunged, the cost of control equipment has remained high.Though BMS has continued to drive value and a return on investment, the fact is that as a collection method, the cost to acquire data is too high to justify (Comly, 2017). For example, solving a definite problem – such as basic lighting controls can cost as much to install as a dedicated data collection solution for an entire building.Beyond the costs of installing and maintaining BMS, there are costs associated with using the data. A dedicated building engineer needs to be focused on analyzing the data, and adjusting set points and configurations to derive value. Data analysis by highly skilled labor is time consuming and costly. If the property decides to hire a vendor to visualize the data in more intuitive software, there will be additional costs, either directly or through a "commission" on the savings discovered with the software (Comly, 2017).Hence, in order to swiftly bring about the future that smart buildings promise, the collection of data needs to be considerably less expensive than currently available through BMS.

b) Limited Value

The true value of data is inherent in the insights that can be derived from it, hence, data on its own, has no value. In the case of BMS data, insights usually involve equipment schedules, set points, and system configuration optimizations. For example, by identifying that HVAC system is running when the building is unoccupied, a building can make significant reductions to operating expenses through utility consumption. Likewise, highly granular data sets around startup and shutdown processes may yield optimization insights for system configuration.In reality, there are several poorly configured BMS that can yield significant savings if properly optimized. However, this is much more likely to be the case in unique building types, such as hotels and stadiums that have constantly varying occupancy rates and schedules. For office and multifamily apartment buildings, which have relatively consistent schedules and occupancy rates year-round, the BMS may already be close to optimized.While there is likely to be "performance drift" in any building type over time, the point is that no amount of data will yield significant results if the system is already close to optimized and rarely requires changes (Comly, 2017).

c) Operability of Small Equipment

For maintenance purposes, schedules in offices and multifamily buildings do require certain changes which may or may not be reverted after the completion of maintenance operation. This is a serious issue that can lead to large spikes in operating costs and put tenant health or comfort in jeopardy. As such, there should be a building performance solution in place to ensure that operators are notified immediately if any equipment remains on when it should be off or visa-versa (Comly, 2017).This function would be appropriate with software that utilizes BMS data but for the fact that large blind spots will be observed because most BMS do not control smaller equipment. Because the cost to install, maintain, and utilize is so high, most properties with a BMS only have it installed on the major loads, such as large HVAC equipment and lighting. With limited resources, it makes sense to focus on the building systems that will have the largest impact on operating expenses and tenant comfort.Schedule mishaps or equipment malfunctions can have significant impacts on tenant comfort as well. For example, if an exhaust fan breaks, the lack of ventilation can cause unwanted smells and other indoor air quality issues. If an elevator breaks down, tenants may be stuck inside. Buildings are made up of hundreds of pieces of equipment, it is severely limiting if operators can only gain visibility into a small fraction of the total.

d) Scalability

The lack of scalability is an integral limitation on the use of BMS data for the optimization of building portfolios. Though possible, it is highly unlikely that each building in a portfolio have the same BMS vendor. In most cases, each vendor will have its own set of proprietary data protocol with different processes and integrations. Not only is this hard to manage and maintain, but BMS vendors often have competing products and thus are incentivized to make their data inaccessible to third parties.While part of the difficulty of extracting BMS data may be competitive, there is also a legitimate concern about security. Building data is not only valuable to competitors, since it is tied to controls of building equipment, it can be particularly unsafe to occupancy if manipulated. Most BMS are restrained to the buildings intranet for this very reason. Any attempts to extract this data to a cloud-based solution will have severe security concerns, significantly higher costs for the appropriate security systems, or both.

There is also the consideration that a portfolio will contain a mix of properties with and without building management systems installed. Leveraging BMS data to find operational waste may be effective in portions of the portfolio, but a separate solution will be required for the buildings without a BMS. This requires an additional round of diligence and technology evaluations that will slow down rollout and stifle scalability (Comly, 2017). The fact is relying on BMS data to drive operational improvements will most likely run into scalability issues.Conclusively, though each building is different, the specific needs and goals of a building drive the use of BMS for its core functionality. However, in order to truly create a smart building that is fully optimized to produce the ideal sustainable environment for tenants while utilizing the least resources possible, a BMS should not be relied upon to provide data and insights.Limitations such as value, breadth, scalability and cost of BMS data are not compatible with tomorrow's buildings. Though precise controls enabled by BMS will always have a role to play in smart buildings, BMS should not be considered as the only requirement for achieving and maintaining top-performing building. A possible solution to insufficient data streams from BMS, sensors, utility meter, etc is to track every piece of equipment individually. This will allow for the affordable value derivation from data insights even in office and multifamily buildings that have consistent occupancy patterns.

V. APPLICATION OF ENERGY EFFICIENT ENERGY AND ITS ECONOMICS TOBMS

A building that knows when and where it is occupied can limit its own energy use by confining the operation of power-hungry HVAC and lighting systems to the hours and areas of the building they are needed (Wu and Noy, 2010). Intelligent buildings can also anticipate the energy loads needed, based on fuzzy logic and learning from the day before or previous weather conditions and understand what is needed to respond accordingly (Schultz, 2010). These tasks employ the use of various types of sensors for enhanced presence detection and accurate localized occupancy information to provide solutions that are energy-efficient (Dounis et al., 2011). It is observed that sensors can pay for themselves through energy savings within a few years. Thus, in most cases, sensors offer greater energy savings and more flexibility than other forms of control and have proved to work effectively in a variety of application (Wu and Noy, 2010). The SMART 2020 programme, informs that intelligent buildings and accompanying smart grids will save around 4 gigatonnes of CO_2 equivalent emissions in 2020 (Future Agenda, 2011). IBM estimates intelligent buildings can reduce energy consumption and CO_2 emissions by 50% to 70% and save 30% to 50% in water usage (Moore, 2009b). Johnson Controls, a leading producer of energy saving equipment, says companies can cut energy bills by 20% to 25% by using efficiently programmed and monitored BMS and other intelligent controls (Mazza, 2008). They explain that the biggest savings come through management of heating and cooling- "One degree centigrade down in heating temperature will provide around 7% savings on the energy necessary to heat the building." (Clarke, 2008).Frost and Sullivan (2009) studied certain buildings that were prominent examples of intelligent buildings in the US and Canada to determine the effect intelligent technologies has on energy savings, greenhouse gas and CO_2 emissions (Refer Table 2.1).

Table 2.1: Energy savings, annual GHG / CO_2 emission reduction and payback period
(Source: Frost and Sullivan, 2009)

Case Study	Energy Savings	Annual GHG / CO2 Emission Reduction	Payback Period	Technology Trade Names
State of Missouri, Missouri, USA	17% annual energy savings (post retrofit)	Eliminated 205 million pounds of CO2 equivalent emissions, an amount equal to the annual CO2 emissions of 40 coal-fired power plants	Payback in less than two years	Enterprise Asset Management & Building Information Management System
Rogers Centre, Toronto, Canada	76% savings on lighting energy costs (post retrofit)	Reduced CO2 emissions by 2797 tons annually, the equivalent to taking 465 passenger vehicles off the road	Phase One:Payback in three years Phase Two: Payback in two-and-a-half years	Energy Control System (ECS)
The Verve-High Rise Condominium, Toronto, Canada	35% annual energy savings compared to local energy code (similar to ASHRAE 90.1)	Annual GHG reductions due to energy efficiency measures equaling 887 tons, equivalent to CO2 emissions from 91,336 gallons of gasoline	LEED premiums Payback in seven years or less	Energy Management Systems (EMS)

Matthew et al. (2009) conducted a survey of intelligent and non-intelligent buildings in India, to provide insights on the comparative energy efficiency of buildings and to find out whether the investment on intelligent buildings has any impact on the long-term economy. Three office buildings were chosen with varying levels of intelligence such that Intelligent Building 2 (IB2) was the most intelligent among the three; Intelligent Building (IB1) was lower in intelligence than IB2; and the third building (non IB) was conventional with no inclusion of intelligent technologies. It was evident that IB2 has the least 'Annual Energy expense per sq.m while the non-IB has the maximum'. Also between the two intelligent buildings compared, IB2 saves almost two and a half times more money than IB1. This goes on to highlight that intelligent buildings reduce energy usage as compared to conventional ones and also the higher the level of intelligence of a building the greater are the energy savings.Economic sustainability is a tool that ensures business is making a profit while addressing environmental concerns and contributing to the financial welfare of the owners, the employees, and the community where the business is located.A probable stereotype of an intelligent building is that it is a possession of technologically advanced countries. This is a common presumption fostered due to the apparent economic burden that an intelligent building poses. Matthew et al. (2009) recognized the benefits of the 'Intelligent building concept' as decrease in building maintenance and energy costs; increase in productivity, rental incomes, investments, occupancy rates, retention; and accommodation of flexibility. Johnson Controls, speculates "over a period of 40 years, it is estimated that only 11% of the total cost of a facility goes into the initial construction of the building; 14% into financing; 25% into operations and 50% into operational expenditure" (IT-Online, 2012). They identify the true cost of an intelligent building as not simply its cost of construction but also the operation and maintenance costs over the structure's life span. Intelligent buildings also guard against productivity loss, revenue loss, and loss of customers to competitors. As all of these are critical factors for the success of a business, owners have an advantage by investing in an intelligent building to reinforce the future of their business (Tulika et al., 2014).As noted by the Intelligent Buildings International (IBI) Group, intelligent buildings yield cost reductions in operation and maintenance through optimizing automated control, communication and management systems. For example by using an intelligent security system one security guard can efficiently keep an eye on security functions; track people in the building; lock and unlock doors; and monitor the fire system from a single location, thus making the operation cost-effective by eliminating the need for a group of security personnel making rounds. (Clarke, 2008) The 46,450 sq.m. Campus of

Ave Maria University, Naples is also an example of reduced operating costs owing to the use of intelligent integrated systems. Ave Maria University saved over US$1 million in building costs by eliminating the redundant wiring and cabling of multiple isolated building systems; reduced staffing costs by US$350,000 annually by enabling IT to assume tasks of building maintenance staff; and enabled significant efficiencies in utility usage (Frost and Sullivan, 2009). The estimated cost of the project was between US$0.32 and US$0.38 per sq.m., but the operating costs stood at about US$0.28 per sq.m. for utilities, thus saving the university a lot of money (Madsen, 2008b).Intelligent Buildings can also provide an immediate return-on-investment and reduce the expected time of payback in terms of higher employee productivity and reduced operating expenses (Katz and Skopek, 2009). Frost and Sullivan (2009) reported an average expected payback time of intelligent building technologies to be three and a half years or less, after studying some buildings that were prominent examples of intelligent buildings in the USA and Canada (Refer Table 2.1). Hartman (2005) also evaluated the potential benefits of advanced technologies by a comparison between the electric energy usage of a cooling system, for an office building in south western USA, when an optimized conventional system (grey bars) is reconfigured to a network based system (black bars) of the same first cost. It was observed that the electric energy budget for cooling was cut about in half when the conventionally optimized cooling system was reconfigured for network controls, without increasing the cost of the system.

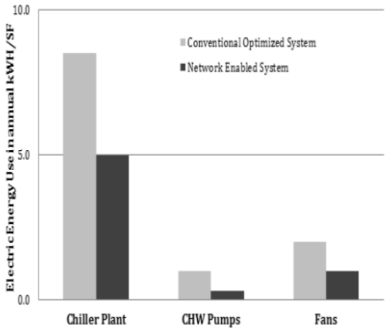

Figure 2.6: Conventional Optimized Control vs. Network Control: Cooling System Electric Use per Square Foot for an Office Building (Source: Hartman, 2005)

VI. CONC LUSION

Energy efficiency and economic benefit of BMS cannot be overemphasized, hence the need to promote the use of this technology in a developing nation such as Nigeria. By evaluating the economic advantages of utilizing BMS in commercial buildings in Nigeria, a lot of awareness will be created as to the need for Nigerian private and public developers to embrace the use of this technology to create building portfolios that are economically, socially and environmentally sustainable.

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