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Review of Smart Buildings Based On Adoption of Internet of Things Application Enablement Platform

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***Abstract*— Many traditional building materials have benefited from innovative technologies in both manufacture and application. These developments have made several traditional building materials more financially feasible, environmentally friendly and technically sound. Application enablement platforms are designed to accelerate and simplify the development of IoT solutions that can be re-used across industries and market segments such as Smart Buildings in the construction industry. The purpose of this paper is to review technologies required in Smart buildings determinants and the IoT components and capabilities that can be used to mitigate the climate change upheavals in Smart Buildings.**

***Index Terms*— Application Enablement Platform (AEP),Climate Change, Global Warming, Internet of Things, Web of Things.**

I. INTRODUCTION

“Smart” is a combination of smart infrastructure and building automation, real time data, seamless integration, and the real “smart” comes with workflow engines when the building integrates with people in an intelligent way. Smarter buildings are well managed, integrated physical and digital infrastructures that provide optimal occupancy services in a reliable, cost effective, and sustainable manner. With the incessant progress of ICT and sensor networks, new applications to improving energy efficiency are constantly emerging.

Because of the rapid rise of the population density inside urban environments, substructuresand services have been needed to supply the requirements of the citizens. The Internet of Things (IoT) is the ever-expanding network of physical devices, vehicles, home appliances, and other items embedded with electronics, software, sensors, actuators, and connectivity. These objects connect to and exchange data with each other and with the end user. With the Internet expected to connect more than 20 billion devices by 2020, managing these huge networks is a complex task. The overall environments within these objects are connected and business value created is called the “Internet of Things” (IOT), according to Heavy reading White Paper.

There are several factors creating demand for smart buildings. One of the most potent are the results from building owners that have already deployed smart building technology. These building owners have found reductions in energy consumption, enhancements to operations and a very attractive return on investment. Another element driving the market for smart buildings is our global society’s habituation to ubiquitous real-time information and communications technology; people not only accept piecemeal cutting-edge technology as an integral part of our buildings but expect that their buildings will be smart [1].

Kenya Smart buildings go far beyond saving energy and contributing to sustainability goals. They impact the security and safety of all resources, human and capital. Smart buildings are a key component of a future where information technology and human ingenuity combine to produce the robust, low-carbon economy, [2]. The construction industry is a pillar and a fundamental enabler of Kenya’s vision 2030. There is a serious need for developing an optimized solution of sustainability and intelligence in buildings that will help the agenda of living in a healthy, comfortable, technologically advanced world. Energy security is one of the main concerns of the future in the world today.

Smart buildings are a recipe for mitigating global warming thus climate change,the technologies to do that exists in the Machine to Machine (M2M), Internet of things (IoT) Application Enablement Platforms (AEP). Smart building can benefit countries through carbon credit program. The global adaptation of smart building technology marks a historic opportunity for a single technology class, Internet of Things - Application Enablement Platform, to significantly reduce the energy consumed by cities around the world. Researchers and academic article writers will borrow from the review ofsmart buildings based on internet of things application enabled platform when developing theoretical and conceptual frameworks applicable to those who seek to further their research in this emerging political and social pertinent hot-bed area of research that needs drastic and urgent solutions to fix it.

The study considered eight determinants, eight Internet of Things- AEP components and five Internet of Things-AEP capabilities that influence adoption of smart energy buildings. The eight determinants in the adoption of Smart Building Technologies in buildings that were considered in the research are; Awareness and Knowledge of Smart Building Technology, Relative Advantage, Perceived Fee, Building Codes, Technicality, Perceived Usefulness and Enjoyment, Peer Firm Influence and lastly, Intention to Use. The eight IoT – Application enablement platform components are; External Interfaces, Analytics, Additional Tools, Data Visualizations, Processing & Action Management, Device Management, Connectivity & Normalization and Database and finally; the five IoT – Application enablement platform

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capabilities are; Data Management, Scripting Engine, Integration Framework, Software Development Kits and Web Services. Majorly IoT-Application enablement components and capabilities are discussed in this paper though all the twenty one latent variables are analyzed.

1.1 Study Objective

The objective of the study was to review smart buildings based on adoption of internet of things application enablement platform determinants, components and capabilities.

1.2 Research Question

How do smart Internet of Things application enablement platformdeterminants, components and capabilities aid in Adoption of Internet of Things Based Smart Energy Building?

II. LITERATURE REVIEW

A. SMART BUILDINGS

The research adopts the definition of smart buildings as defined by European Commission, “Smart buildings mean buildings empowered by ICT (information and communication technologies) in the context of the merging Ubiquitous Computing and the Internet of Things: the generalisation in instrumenting buildings with sensors, actuators, micro-chips, micro- and nano-embedded systems will allow to collect, filter and produce more and more information locally, to be further consolidated and managed globally according to business functions and services. ”

A smart building has a number of components which are discussed below;

Telecom and Data System (ITS)

This is an important component of smart building;it is telecommunications and data systems which nowadays are very advanced with emergence of GPS, CCTV and fiber-optics technology to perform the data streaming in real time. The primary function of the ITS (Telecom and Data System) is to generate, process, store and transmit information in the smart building [3]. The key components of the modern ITS include PABX (Public Automatic Branch Exchange), total building integration cablings, broadband Internet access and CATV (Cable TV) connections, and public address systems. The latest building communication system development involves the wireless network and smart control system, technologies that employ Bluetooth, LonWorks, C-Bus, RF (Radio Frequency), IR (Infra-Red), Internet technology, Wi-Fi (Wireless Fidelity), Java, soft-computing for system diagnosis and monitoring as well as universal plug and play [3]. The use of Web-enabled devices allows remote monitoring of the building by interaction of the central IBMS (integrated building management system) or BAS (building automation system**)** workstation with the remote dial-up system via modem. The data from sensors and controllers can be relayed in real time networks from the IBMS or BAS workstation and the settings of actuators that control the services can be adjusted either in the building or at remote station [3]. Web-enabled devices, which provide a low cost mechanism for reporting building performance remotely without the need for on-site computers, help to reduce the security and maintenance costs associated with running an IBMS or a BAS and telecommuting. The IBMS help you plan operations and assess performance; make operation easier; improve building comfort, enhance safety, improve efficiency, save energy, and protect your assets. The term Building Management Systems encompasses a wide variety of technologies which include energy management systems and building controls. Their function is to control, monitor and optimise building services, such as heating, ventilation, air conditioning, lighting, alarm systems and certain electrical appliances [4].

1. Addressable Fire Detection and Alarm System (AFA)

The immediate reaction and the reliability of fire detection and alarm systems are very important to maintaining the safety of the occupants in the buildings and safety is the key to either the people occupying the building or the entire neighborhood or ecosystems. At the moment, there is very sophisticated and latest smart fire detection system which involves the use of microprocessor-based distributed process system; this adds intelligence to the fire alarm control unit to reduce the problems of false-alarming and to improve system reliability and flexibility [5].

Fire detection is critical in modern buildings as has always been, even in case of traditional building models. Prompt fire control in real-time is not an option since safety is the key to intelligence. On another note, secure advanced smart fire detection unit, is critical as it can contribute significantly to the success of rescue operations and to limiting the degree of damage [5].

The component of fire detection unit depends on the type of the building. A Stand-alone smart fire alarm uses smart initiating circuit sensors while smart indicating circuit devices are also used to provide software driven fire alarm notification. Each smart building circuit sensor and indicating circuit device contains a custom integrated circuit, enabling two-way communication to a stand-alone smart fire alarm system control unit [5].

2. Heating, Ventilation and Air-Conditioning (HVAC) Control System

Another component of smart building is what is referred in acronym as HVAC (Heating, Ventilation and Air-Conditioning) control system. A heating, ventilation and air-conditioning (HVAC) system is extensively considered as a critical service in modern buildings, which provides a comfortable indoor environment for people to live and work [6].

The HVAC system is very critical and has a significant impact on the external environment as it consumes energy to maintain a comfortable and healthy internal environment, this is beyond the comfort of the inhabitants of the house as it also gives the outlet from inward energy contagion [7]. To proof the importance of HVAC, a research on building energy usage found that HVAC systems on their own generally account for between 25 to 30 percent of the total building energy usage [7]. Another also illustrated that the HVAC systems consumes up to 50 percent of the total electricity consumption of a building which is a proof that energy efficiency is a key issue in the design of the control of the

HVAC system so much so that a conventional control of HVAC relies on measuring devices such as thermostats and humidistat's to monitor the temperature and humidity of the supply and return air of an air-conditioned space [7].

3. Digital Addressable Lighting Control System (DALI)

Digital addressable lighting control system is what engineers refer to as "personality of the building", for it consists of ambience, beauty, aura and texture of the building. The quality of lighting is a critical aspect in the building as the illumination and contrast values have a direct impact on the well-being, motivation and productivity of persons in the building [6].

While mentioning about smart buildings, lighting level control is generally accomplished by two different methods, one as a multi-level lighting and the modulated lighting, which calls for specifically designed control ballasts [7]. It has been observed by building experts that the use of occupied-unoccupied lighting control can schedule the on/off time of luminaries for a building or zone to coincide with occupancy schedules [5]. In addition, the hardware devices have been so advanced to work together with the control program to provide lighting control, including light sensors, motion detectors, photocells, touch switches, and dimmable ballasts such devices are connected to the controller and provide discretionary control of frequently unoccupied areas which has been observed to increase energy illumination and therefore reducing energy consumption in the same avenue [6].

4. Security Monitoring and Access Control System (SEC)

A building location and security have been described as the panacea of what smart building is all about, this is because security systems are designed to anticipate, recognize and appraise a crime risk and to initiate actions to remove or reduce that risk. With increased interoperability of many smart devices, the presence detection of intruders is now built in as comprehensive control and protection systems [7]. In smart buildings, use of multiple security devices which are synchronous to ensure that security systems involve automatic functions such as access monitoring, card access control, guard tour monitoring and/or motion detectors, networked digital closed-circuit TV and person identification systems, for example sensor systems are designed to inform the users about the state of windows, doors, entrances and exits of the building at any time for intrusion detection [7]. Biometric security systems are nowadays encouraged as design choices in upcoming, internet ready smart buildings as this takes security to another level.

5. Smart and Energy Efficient Lift System (LS)

Any lift installed in a building has a purpose of transporting passengers to their requisite location or floor in a building quickly, safely and with comfort. However smart and energy efficient lift control systems have been designed to promote a higher handling capacity, improved riding comfort and a better man-machine interface. The advanced lift control technology driving these smart lifts have advanced drives and artificial intelligence based supervisory control, which make it possible for lift group control systems to respond to the necessity of providing efficient control of a group of automatic lifts, servicing a common set of landing calls. They also have technology which gives them the capability of estimating the number of passengers waiting at each lobby and travelling in each lift car through image processing and understanding [5].

B. INTERNET OF THINGS (IoT) - APPLICATION ENABLEMENT PLATFORM (AEP)

How do we monitor the carbon footprint of a vehicle? How can we track and trace cargo on the move? How do we know when a vending machine needs to be refilled? How do we remotely monitor the consumption of energy? How do we remotely control street light and house light usages? The answer is making these objects intelligent by adding devices to them that provide valuable information in real-time or allows the controlling of assets. This will allow billions of objects across the globe to generate valuable business information. Machine-to-Machine (M2M) is the technology that makes all this possible. M2M is a technology that allows both wired and wireless devices to communicate with each other without manual intervention. The overall environments within these objects are connected and business value created is called the "Internet of Things" (IOT), according to Heavy reading White Paper. The architecture of an IoT application development platform can consist of a software platform, an application development platform and/or an analytics platform [8].

Application Enablement Platform works on set business rules. Business rules are one of the main milestones for your application; they translate and answer your concrete business problems and constraints. One can set up business parameters such as thresholds or geofence rules, but also generate functions related to your data such as accumulation, linear functions. One is in control over your data [9].

The IoT Platforms are the key for the development of scalable IoT applications and services that connect the real and virtual worlds between objects, systems and people. However, as the IoT Platform market represents a truly new segment that was almost non-existent a few years ago, the landscape is complex and changing very quickly [10].

Traditionally, streaming data from connected devices was sent directly from networks to applications that not only processed the data, but also stored and managed it, while maintaining mechanisms for application security, scalability and flexibility. This traditional approach was time-consuming and complex since application developers always had to start from scratch to create applications that focus on baseline application infrastructure rather than on higher-level business logic. Furthermore, application reliability and robustness are often compromised since most developers are not accustomed to dealing with the unique nature of connected device traffic patterns [11].

This has led in the past years to the development of Application Enablement Platforms that have enabled M2M application developers to create applications that incorporate, and draw from, multiple M2M devices. However, today's

AEP solutions do not provide adequate support to all the emerging M2M market trends. In order to support market demands the next generation of Smart Building Technology – which we call AEP2.0–must be able to provide data management and analytics functionality for M2M applications and possess the following characteristics: Increased scope, scale and scalability of M2M deployments; Low-cost, open access systems that enable simplification of deployments and Utilization of M2M data to provide more accurate and finely detailed business information.

To do that and maximize business potential from M2M, solution providers (including connected product makers) must transform themselves into value-added players in the M2M business landscape. For that, their ability to manage data securely becomes very critical. Their underlying Smart Building Technology must then be capable of not only securely managing captured M2M data, but also of transforming that data into relevant information based on business knowledge and rules. This data-driven approach has the potential to open up further opportunities for enterprises by allowing them to be more intimate with the needs of their end customers, thereby successfully elevating the value proposition for their high-value customers.

Also, since focusing on consumer demands a long tail of applications, very similar to the Internet model, reducing the time to create market applications becomes increasingly important. Enterprises, therefore, need solutions that can help them differentiate themselves by allowing them to provide services and create applications with a superior quality of experience (QoE). Smart Building Technologies are solutions that enterprises use to manage and launch services-intensive industrial business-to-business (B2B) use cases. These platforms were previously focused on securely collecting data from remote devices with very limited custom application for enterprise customers [11].

In a smart building, the digital and physical integration and automation of building, technology and energy systems reduce operating costs, improve occupancy services, and minimize the building's impact on the environment [12].Application enablement platform simplifies development of IoT apps, with capabilities such as data management, scripting engine, integration framework, SDKs (Software Development Kits) and web services for accessing data and apps in the cloud. Connected machine management applications facilitate remote monitoring, management, service and control of remote devices. Capabilities also include software (client, firmware) distribution and configuration management [13].

The world of machine-to-machine (M2M) communication is gradually moving from vertical, single purpose solutions to multi-purpose and collaborative applications interacting across industry verticals, organisations and people – a world of Internet of Things (IoT). It is difficult to make a clear and practical distinction between M2M and IoT. Increasingly complex IoT solutions require more advanced communication platforms and middleware that facilitate seamless integration of devices, networks and applications. There is a wide range of software platforms developed for the purpose of supporting and enabling IoT solutions. The intention is to enable rapid development and lower costs by offering standardised components that can be shared across multiple solutions in many industry verticals. Third party IoT platforms are relatively new in the market and display a great diversity in terms of functionality and application areas. Broadly speaking, most IoT platforms fall into one of the following three categories: connectivity management platforms, device management platforms and application enablement platforms [14].

Connectivity management platforms facilitate the delivery of data communication services on mobile networks and other communication networks. Features like private APNs (Access Point Name), fixed IP addressing and secure VPN (Virtual Private Network) communication offer more flexibility and better reliability. Device and subscription management features including automated provisioning, activation and deactivation, as well as activity reporting provide improved visibility and control. Many leading mobile operators still use proprietary connectivity platforms developed in-house, while other operators have adopted third-party solutions from vendors such as Jasper, Ericsson, Amdocs and Comarch. Several M2M managed service providers also provide connectivity management platforms as an integral part of their offerings [15].

Device management platforms enable remote management of IoT devices. Purpose-built device platforms enable a rich set of functionalities for remote management, diagnostics, OTA (Over-The-Air) software updates and application lifecycle management. It is often difficult to make a clear distinction between the most fully featured device management platforms and application enablement platforms, although the latter category is intended to be truly network and device agnostic. Many platforms from device vendors including Digi International, Eurotech, Gemalto, Sierra Wireless and Telit, as well as platforms from companies like BlackBerry, Bosch, Cumulocity and M2Mi could be described as device clouds or IoT integration platforms that provide both device management and application enablement functionality [15]. Application enablement platforms are designed to accelerate and simplify the development of IoT solutions, providing common horizontal solution components that can be re-used across industries and market segments. Smart Building Technology enable companies to focus on differentiation created by unique capabilities and insights from data rather than duplicating non-differentiating functionality such as connectivity integration, device management, data collection, data storage and analytics. Application enablement platforms also provide integration frameworks adapted for common enterprise IT systems such as ERP, CRM and analytics. In order to protect data and enable data exchange across multiple applications and data sources, Smart Building Technology needs strong security architectures and user authorisation management systems. The market for AEP services is in an early phase with a limited number of specialised providers like PLAT. ONE, PTC, SeeControl, Xively and 2lemetry (acquired by Amazon). These companies primarily face competition from system integrators and companies that develop similar functionality in-house [14].

A key question arises when considering connectivity of plenty of nodes that need to intercommunicate. What kind of applications and implications are relevant to Smart Buildings? Just scratching the surface, there's HVAC control, lighting control, employee engagement, optimized janitorial routes, asset tracking, fire and safety, CRE (Commercial Real Estate) optimization, accessing shared resources, security event tracking, process compliance, voice-enabled services, cafeteria operations, remote monitoring, social collusions, the list goes on and on. The best way to approach the problem of plenty is to narrow your focus. Don't try to do everything at once; pick a few things and stay on-course [16].

Smart Buildings enable Optimization of lighting, utilities and HVAC where systems can be dynamically adjusted to save money by matching occupancy patterns and desired comfort levels to energy use, real-time monitoring of building systems to prevent loss of critical assets whereby intelligent sensors can be able to detect temperature changes or water pressure variations and alert operational systems to take action before catastrophe strikes and dynamic power consumption where by receiving signals from energy suppliers and altering usage in response, a smart building can generate revenue by selling load reductions back to the grid. Smart buildings transform facilities management and ensure compliance with green building standards [12].

Offices and commercial spaces are undergoing a smart transformation connecting and linking HVAC, lighting, environmental sensors, and security and safety equipment, along with external inputs such as the smart grid and weather. User-driven and automated business processes can now leverage real-time IoT information from people, systems and devices to maximize resource efficiency, reduce cost and risk, and increase visibility across all operations [17].

Solution providers looking to build and sell new smart building IoT applications, equipment manufacturers looking to add additional value with IoT to their building customers, and facility managers and real estate executives understand that they can capitalize the opportunity IoT presents to capture value. AEP Vendor equipment speeds the development and deployment of "smart" applications dramatically increasing return on investment and providing the data framework that enables connected intelligence to uncover new opportunities through better management of building operations, security and energy saving [17].

Overcoming the challenges of Smart building implementation is possible when you take a scalable approach. In this approach, multi-sensor units are facilitated by a wireless backbone supported by a cloud infrastructure. The cloud infrastructure is what connects the vertical-specific applications (like space utilization, asset tracking, shopper routes, etc.) and other applications (security systems, BMS, etc.) to the sensors gathering the data points.

It's no secret that Smart Building delivers value in a multitude of ways. They decrease a variety of costs, increase productivity and collaboration, enhance security and provide peace-of-mind on several levels. But that's only if the right approach is taken and challenges are overcome in the buying process [16].

The IoT Platform can help you to; Easily collect and manage data from people, sensors, connected equipment and existing enterprise systems and external system information; Quickly build and bring to market new innovative IoT applications at 10 times the speed of other approaches with rapid application development environment; Utilize big data and analytics to provide new insights and recommendations to drive better decisions and provide facility managers and real estate executives role based access to easily visualize data, receive alert notifications and take action on insights and recommendations across all relevant building operations [17].

EIGHT COMPONENTS OF IOT – APPLICATION ENABLEMENT PLATFORM

<table>
<tr><td rowspan="6">***Database***
(Repository that stores important data sets)</td><td colspan="2">***External Interfaces***
(API's, SDK'S and gateways that act as Interfaces for third party systems e.g., CRM and ERP)</td></tr>
<tr><td>***Analytics***
(Algorithms for advanced calculations and machine learning)</td><td>***Additional Tools***
Further development tools (e.g App prototyping, access management, reporting)</td></tr>
<tr><td colspan="2">***Data Visualization***
Graphical depiction of (real-time) sensor data</td></tr>
<tr><td colspan="2">***Processing & Action Management***
Rule engine that allows for (real-time) actions based on incoming sensor and device</td></tr>
<tr><td colspan="2">***Device Management***
Backend tool for the management of device status, remote software deployment and updates</td></tr>
<tr><td colspan="2">***Connectivity & Normalization***
Agents and libraries that ensure object connectivity and harmonized data formats</td></tr>
</table>

Figure 1: The Eight Components of an IoT Application Enablement Platform; IoT Analytics [10]

Connectivity & normalization: brings different protocols and different data formats into one "software" interface ensuring accurate data streaming and interaction with all devices. Device management: ensures the connected "things" are working properly, seamlessly running patches and updates for software and applications running on the device or edge gateways.

Database: scalable storage of device data brings the requirements for hybrid cloud-based databases to a new level in terms of data volume, variety, velocity and veracity. Processing & action management: brings data to life with rule-based event-action-triggers enabling execution of "smart" actions based on specific sensor data. Analytics: performs a range of complex analysis from basic data clustering and deep machine learning to predictive analytics extracting the most value out of the IoT data-stream.

Visualization: enables humans to see patterns and observe trends from visualization dashboards where data is vividly portrayed through line, stacked, or pie- charts, 2D or even 3D-models. Additional tools: allow IoT developers prototype, test and market the IoT use case creating platform ecosystem apps for visualizing, managing and controlling connected devices and lastly, External interfaces: integrate with third-party systems and the rest of the wider IT-ecosystem via built-in application programming interfaces (API), software development kits (SDK), and gateways [10].

The intelligent buildings market has been defined by the convergence of controls and automation and information technologies. The competitive landscape has shifted as software analytics have become foundational to commercial building optimization. The technology is ahead of the curve when considering the business transformation these solutions can enable. There is a huge addressable market for intelligent buildings, but executives, building operators, and facilities managers are still learning the business value and practical implications of technology deployment. The chasm between technology and user maturation can be thought of as the people problem; Ian Campbell, technologies services director at Grosvenor Services, clarifies the point: “The concept of a smart building is meaningless unless you apply Technology, People, and Process. It’s nothing without people” [18].

Year after year, the individual price of connectable sensors has been dropping significantly to the point that they now cost only a fraction of what they previously did just five years ago. In fact, they are becoming so affordable that instrumenting every “thing” has become the new normal.

This new ubiquity of connectable sensors brings tremendous opportunities and the promise of a better world in the built industry. But, two new challenges are quickly becoming apparent: First, A new IoT Tower of Babel: How can you get various sensors that use different protocols and different data formats to work together? Second, How and where to connect them to get the most out of them? We need a platform that makes it easy to get insight from the data. We need a platform that can evolve quickly in a world where everything changes quickly. New ideas, new connections, new potential applications come all the time.A number of companies have worked together to build a solution that addresses both challenges, [19] by developing the IOT Application Enablement Platforms.

C. PILLARS AND CAPABILITIES OF SMART BUILDINGS

Pillars of Smart Buildings

When the term ‘smart buildings’ was first coined in the 1980s, it simply meant providing individual telecommunications services to tenants under shared tenant services. Connectivity had finally come to the fore as an important reason for the selection of buildings as offices, homes, manufacturing or retail sites. So, what does a ‘smart building’ really mean today? The technologies have evolved over the years to a point where their integration and interoperability using internet-of-things (IoT) protocols is finally realising the pillars of a truly smart building.

The needs of a building’s occupants, as well as other criteria from an environmental or a scalability perspective, can be categorised into three essential pillars: being secure, being green and being connected [20].

Smart is Secure: - Security and control is primary to the basic definition of domain. Whether the domain is your home or business office, humans have to feel complete privacy and security about who else has what level of access to the space. What was originally keys and locks along with a security guard translates in a smart building to a sophisticated cloud-based security system that thrives on centrally managed and remotely accessed video surveillance and access control systems, built to be scalable for multiple locations.In the wake of increased IT penetration, it must also deploy best-in-class network security measures at all times [20].

Smart is Green: - Improved energy efficiency is a bare minimum goal of a smart building. It involves taking a top-down holistic perspective in looking at every aspect of a customer’s operation that has the potential to impact energy requirements. Technologies like an interrupt-operation mode on air conditioners while continuing to ensure comfort of residents, solar panels, motion-triggered light switches, sensor-based alerts if a refrigeration unit door is left ajar are all examples of initiatives designed to optimise consumption of energy or schedule its timing for load on the electric grid [20].

Smart is Connected: - Interoperability is the key here. Linking building systems together and then connecting the building automation system to enterprise systems is enabling facility executives to reap smart-building benefits. Integration between access control and video verification, for instance, allows a user to see live video as well as the cardholder’s picture when a given access card is presented at a door reader.

Another example is using data from the building security system to turn off lights, reduce cooling when occupants are not present or even unlock doors from your mobile to permit entry to maintenance personnel. Proximity beacons, cameras or sensors to track foot traffic in retail is another example of how connected technologies are yielding insights that in turn inform the design and use of building space [20].

Key Smart Building capabilities

AEP2.0 solutions enable M2M solution providers to leverage the most precious part of their solutions: data. AEP2.0 allows enterprises to easily and cost-effectively access high-value business data for their operations and establish disruptive models for their business. The next generation of Smart Building Technology must be data-driven and seamlessly

allow enterprises to build and deploy M2M applications that leverage the connected world of devices. AEP2.0 inherits the basic functionalities of the first-generation enablement platform (AEP1.0) like connectivity, vertically integration, limited analytics capability, etc., and builds up on it to make the new platform more data-centric and analytics-driven. AEP2.0 solutions need an abstraction layer between connected devices and applications to make it simple for application developers to collect and store data, mine the data for critical business insights and securely publish the data to applications and third parties. AEP2.0 solutions will need to possess complex event processing capabilities as they must be able to process huge quantities of data and conduct both batch and real-time analytics.

With more and more operators planning to support M2M services in the cloud, the AEP2.0 platform must be a virtualized, cloud-based platform. As more and more companies look toward the cloud to support M2M services it is critical for these next-generation M2M enablement platforms to be cloud enabled. Cloud-based approaches reduce cost of ownership for companies and help them to build innovative, flexible and scalable applications quickly, easily and at a fraction of the cost of on-premises alternatives, [11].

Today's Smart Building Technologies are delivered as a cloud service, they do power advanced load balancing and have auto-scaling capabilities to offer unlimited data capacity expansion and unparalleled scalability to M2M solutions. With today's Smart Building Technology, M2M solutions can scale for billions of devices and support requests from millions of subscribing applications. They also offer advanced failover capabilities, including computation nodes and data storage redundancy in multiple regions, to ensure seamless service and no data loss in case of network interruption, hardware failure or unexpected events. Because of its long-term experience as a trusted partner with M2M solution providers, Aeris has understood the need to architect its new infrastructure as a truly open system. Today, AerCloud can connect with any device via any communication technology (cellular, Wi-Fi, Ethernet) and uses the market-leading protocols (HTTP, HTTPS, MQTT (Message Queuing Telemetry Transporting)) [11]. Machina Research, (2010), predicts that M2M connections will rise from two billion in 2012 to 12 billion in 2020.

Intelligent business operations, machine learning and RFID for logistics and transportations are foreseen as the earliest facilitators (within 5 years). Industrial sectors expect a significant impact of IoT on factory floors; this impact will be driven in a short term by enterprise manufacturing intelligence and facilities energy management (within 5 years) [21].

Obviously, all these devices and technologies need a platform which will act as a command centre in homes, workplaces and factory floors. Google Nest and Apple Homekit are some of the examples of "home" aggregators, IoT platforms capable to implement home automation functionality.

Smart Building Technology can connect any type of device over any network; Combine real-time device data with contextual information from cloud applications and enterprise systems to create actionable business intelligence and Design, build and manage applications with ease using pre-built services and tools [21].

D. SMART BUILDING TECHNOLOGIES

Big Data and Internet of Things

The phrase "Internet of Things" is widely credited to Kevin Ashton; he's indicated that he coined the term in 1999 while at Proctor and Gamble, but it didn't take off until 2009 with an article in RFID Journal. At a very basic level, "Internet of Things" means devices that can sense aspects of the real world – like temperature, lighting, the presence or absence of people or objects e.t.c. and report that real-world data, or act on it. Instead of most data on the internet being produced and consumed by people (text, audio, video), more and more information would be produced by machines, communicating between themselves to (hopefully) improve the quality of our lives, [22].

Big data refers to a process that is used when traditional data mining and handling techniques cannot uncover the insights and meaning of the underlying data. Data that is unstructured or time sensitive or simply very large cannot be processed by relational database engines. This type of data requires a different processing approach called big data, which uses massive parallelism on readily-available hardware, [23].

In theory, smart buildings can deliver services that make occupants more productive at the lowest cost and environmental impact over the building lifecycle (e.g. illumination, thermal comfort, air quality, physical security, sanitation and many more). As a result, energy and operations can potentially be managed more efficiently, [2].

Turning this vision into a reality requires adding intelligence from the beginning of design phase through to the end of the building's useful life. Developing a fully-functional smart building is thus based on combining the Internet of Things (IoT) with Big Data technology. Internet of Things technologies enable sensors to communicate with one another, allowing for the quick completion of tasks. High speed analytics that support smart buildings aggregate information from Internet-connected devices. These sensors create process and deliver information to a central command hub that provides rapid databases with the raw data needed to make decisions. After the data is combined it needs to be modeled in order to adjust for seasonality, measurement scales and other factors that may skew the findings. Once combined and modeled, the opportunities for Big Data can emerge. Analytics and algorithms can be run on the data to identify operational and energy savings. Fault detection and building optimization are the two primary methods to drive savings and provide quick payback on the cost of installing the solution, [2].

Finally, the Big Data analysis must be presented to stakeholders. The facilities team needs a dashboard to show where the faults are, or will be. In contrast, the chief financial officer requires a dashboard to reveal where the savings are being made. What makes a smart building "smart" is the combination of Big Data analytics and IoT technology, [2].

The use of IP to communicate with and control small devices and sensors opens the way for the convergence of large, IT-oriented networks with real time and specialized network applications [24].

The fundamental characteristics of IoT are as follows;

Interconnectivity: With regard to the IoT, anything can be interconnected to the global information and communication infrastructure. Things-related services; The IoT is capable of providing Thing-Related services within the constraints of things, such as privacy protection and semantic consistency between physical things and their associated virtual things. In order to provide thing-related services within the constraints of things, both the technologies in the physical world and the information world will change. Heterogeneity: The devices in the IoT are heterogeneous as based on different hardware platforms and networks. They can interact with other devices or service platforms through different networks [24].

Dynamic Changes; The state of devices change dynamically, e.g. sleeping and waking up, connected and/or disconnected as well as the context of devices including the location and speed. Moreover, the number of devices can change dynamically. Enormous scale; The number of devices that need to be managed and communicate with each other will be at least an order of magnitude larger than the devices connected to the larger Internet. The ration of communication triggered by devices as compared to communication triggered by humans will noticeably shift towards device-triggered communication. Even more critical will be the management of the data generated and their interpretation for application purposes. This relates to semantics of data, as well as efficient data handling [24].

The Internet of Things is not a single technology, it's a concept in which most new things are connected and enabled such as street lights being networked, and things like embedded sensors, image recognition functionality, augmented reality, near field communication are integrated into a situational decision support, asset management and new service. These bring many business opportunities and add to the complexity of IT, [25].

To accommodate the diversity of the IoT, there is a heterogeneous mix of communication technologies, which need to be adapted in order to address the needs of IoT applications such as energy efficiency, security and reliability. In this context, it is possible that the level of diversity will be scaled to a number of manageable connectivity technologies that address the needs of IoT applications, are adopted by the market; they have already moved to be serviceable, supported by a strong technology alliance. Examples of standards in these categories include wired and wireless technologies like Ethernet, WI-Fi, Bluetooth, Zigbee and Z-Wave [26].

Distribution, transportation, logistics, reverse logistics, field service e.t.c. are areas where the coupling of information and "things" may create new business processes or my make the existing one highly efficient and more profitable. The Internet of Things provides solutions based on the integration of Information Technology, which refers to hardware and software used to store, retrieve, and process data and communications technology which includes electronic systems used for communication between individuals or groups. The rapid convergence of information and communications technology is taking place at three layers of technology innovation: the cloud, data and communication pipes/networks and devices, [27].The synergy of the access and the potential data exchange opens huge new possibilities for IoT applications. Already over 50% of internet connections are between or with things. In 2011, there were over 15 billion things on the web, with 50 billion+ intermittent connections. By 2020, over 30 billion connected things, with over 200 billion with intermittent connections are forecast. Key technologies here include embedded sensors, image recognition, and NFC (Near Field Communication). By 2015, in more than 70% of enterprises, a single executable oversaw all internet connected things. This became the Internet of everything (IoE) [28].

Facilities management is not a cutting edge adoption. Even as the intelligent buildings market has developed, customers have been conservative in implementation, learning through pilots and demonstrations of business value. The Internet of Things (IoT) is changing the game for the intelligent buildings market with dramatically lower total cost of ownership, ease of deployment and implementation, and broad business effects. Those IoT solutions can deliver value to stakeholders across an organization while meeting their technology and investment requirements sets the stage for tipping more widespread and rapid adoption [18].

Web of Things (WoT) Architecture

By definition, the Web of Things is a refinement of the Internet of Things by integrating smart things not only into the Internet (network), but into the Web Architecture (application). Just like the OSI layered architecture organises the many protocols and standards of the Internet, the WoT architecture is an attempt to structure the galaxy of Web protocols and tools into a useful framework for connecting any device or object to the Web. The WoT architecture stack is not composed of layers in the strict sense, but rather of levels that add extra functionality. Each layer helps to integrate Things to the Web even more intimately and hence making those devices more accessible for applications and humans! [29].

Connecting every Thing to the Internet and giving them IP addresses is only the first step towards the Internet of Things. Things could then easily exchange data with each other, but not necessarily understand what that data means. This is what Web protocols like HTTP brought to the Internet: a universal way to describe images, text, and other media elements so that machines could "understand" each other. The Web of Things – or WoT – is simply the next stage in this evolution: using and adapting Web protocols to connect anything in the physical world and give it a presence on the World Wide Web! [29].

The Open Web Platform is the collection of open (royalty-free) technologies which enables the Web. Using the Open Web Platform, everyone has the right to implement a software component of the Web without requiring any approvals or waiving license fees, [30].W3C CEO Dr. Jeff

Jaffe commented, "There are huge, transformative opportunities not only for mobile operators but for all businesses if we can overcome the fragmentation of the IoT. As stewards of the Open Web Platform, W3C is in a unique position to create the royalty-free and platform-independent standards needed to achieve this goal."

Extending the concept of the IoT, the Web of Things as explained by [29] and [31] is a notion where everyday devices and sensors are connected by fully integrating them to the Web. Based on the success of the Web 2.0, this concept is about reusing well-accepted and understood Web standards to connect constrained devices. In furthering the growth of market for IoT devices and services, W3C has launched the Web of Things Working Group to develop initial standards for the Web of Things, tasked with the goal to counter the fragmentation of the IoT; reduce the costs of development; lessen the risks to both investors and customers; and encourage exponential growth in the market for IoT devices and services.

"The W3C Web of Things Working Group will develop cross-domain Linked Data vocabularies, serialization formats, and APIs. The approach builds upon W3C's work on Linked Data as a lingua franca for comparison of data and metadata in different formats and data models. Analysis of a broad range of IoT platforms has shown the practicality of exposing things to applications as objects based upon machine interpretable descriptions of their properties, actions, events and metadata. Application platforms, at the network edge or in the cloud, provide software drivers for each class of IoT platform [32].

E. Internet of Things – Application Enablement Platforms Capabilities

The five Internet of Things – Application Enablement Platforms Capabilities are: Data Management: M2M and IoT solutions bring together complex device connectivity, application and data management processes. Within each area, new requirements and capabilities are emerging, enabling a dynamic value chain and expanding ecosystem of service providers which will together grow the M2M and IoT. The combination of abstraction and agnosticism allows for the scale and heterogeneity (of devices and protocols) to be managed through fewer platforms, and enables developers to focus more on application development rather than specific communications technologies or device characteristics. Next Generation AEP platforms must be data-centric and make it simple for application developers to collect, store and mine that data for critical business insights. The collected data can be securely published to applications. Application enablement platforms are designed to accelerate and simplify the development of IoT solutions, providing common horizontal solution components that can be re-used across industries and market segments [15].

Scripting Engine: Scripting is quite good at event-driven applications. In event driven applications, every device listens to various other events and responds to concerned events. Event loops in JavaScript allow you run numerous tasks without waiting for other tasks to complete. This helps in responding to events in real time, handling multiple tasks parallelly, and allowing multiple devices to respond to the same event. This contributes to a great extent in saving precious battery power. With the increased use of JavaScript in various applications, there are many JavaScript development resources available, such as; JavaScript libraries like Underscore.js, lodash, traverse, and Async; Testing tools like Blue Ridge, SugarTest, FireUnit, JSLint etc.; Client-side development framework and Server-side JavaScript APIs and others. JavaScript developers in IoT have sophisticated frameworks and engines like CycloneJS, IoT.js, JerryScript, Duktape, etc. specifically designed for constrained devices, [36].

Integration Framework: It enables agile IoT systems to be rapidly deployed to solve evolving business needs. The framework is an IoT solution enablement ranging from industry specific applications to advanced data marketplaces. There are multiple ecosystem partners providing IoT platforms, data services and enterprise data systems, [37].

Software Development Kits: There exists Open Source SDK for "building secure IoT gateway data and control orchestration applications." It supports applications in collecting data from the devices, transferring that data to data centre as well as performing control signals from the Data Centre Components (DCC). It has device libraries that contain source code that facilitates developing applications that connect to and are managed by certain IoT Hub services. The IoT Gateway SDK enables developers to create and deploy gateway intelligence customized to their specific needs. It provides source code that simplifies the development of a gateway application, including dynamic module loading, configuration, and data pipelining. The IoT Device SDK includes open source libraries, for building IoT products and solutions on different hardware platforms, [38].

Web Services: According to the Internet of Things (IoT) vision, everyday objects such as domestic appliances, actuators and embedded systems of any kind in the near future will be connected with each other and with the Internet. These will form a distributed network with sensing capabilities that will allow unprecedented market opportunities, spurring new services, including energy monitoring and control of homes, buildings, industrial processes and so forth, [39]. Web services are distributed application components that are extremely available. We can use them to integrate computer applications that are written in different languages and run on different platforms. Web services are a framework for building distributed applications. They have typically been used to build applications that either interact using a web browser, or are somehow related to the World Wide Web. But the technology that makes up web services is not tied to the World Wide Web or the particular technology that typically is associated with it, such as web browsers, [40].

F. FACTORS THAT HINDER IOT ADOPTION

The study was grounded on three main theories namely: the theory of things as developed by [41] which borrows from Heidegger's distinction between objects and things, which posits that an object becomes a thing when it can no longer function according to the use to which it is commonly put; Diffusion theory of Internet of Things, whereby like many evolving IT and networking technologies, the Internet of

Things will encounter multiple barriers to adoption. Traditional inertia, budget priorities, risk aversion and other factors will prevent some companies from adopting IoT in the near future; and, Adaptivity Theory as postulated by [42] that "adaptivity is the cause of the emergence of a perspective for social-ecological adaptation, therefore it can be generally defined as the capacity for a socio-ecological system to: absorb stresses and maintain function in the face of external stresses imposed upon it by climate change; and adapt, reorganize, and evolve into more desirable configurations that improve the sustainability of the system, leaving it better prepared for future climate change impacts.

III. DATA ANALYSIS

Validate the Model for Adoption of Internet of Things Based Smart Energy Building

The objective of the study was the review of smart buildings based on internet of things application enablement platform determinants, components and capabilities. The objective was achieved by testing hypothesized model using three regression analyses which were validated using SEM thereafter, based on the critical ratio (C.R) a suitable conceptual model for an Internet of Things Based Smart Energy Building in the World was developed.

a) Determinants in the Adoption of Internet of Things Based Smart Energy Building

The study was interested in knowing the effect of each of determinants in the Model for Adoption of internet of things based smart energy building when all these dimensions were entered as a block on the model. The results are presented in Table 1 using unstandardized coefficients, standardized coefficients, t statistic, and significant values to assess the significance of the results. More results are presented in the Table 2 on the overall summary of the model. It is suggested that in order to compare different variables, we use standardized coefficients, which means that these values for each of the different variables have been put on the same scale so that they can be compared. Interest in the regression model would mean that the unstandardized coefficient values are used.

Table 1: Coefficients on Effect of Determinants that Influence Adoption Framework

Model	**Unstandardized Coefficients**		**Standardized Coefficients**	**T**	**Sig.**
	B	**Std. Error**	**Beta**		
(Constant)	3.713	.565		6.574	.000
Awareness & Knowledge of Stake Holders	- .169	.093	.091	1.815	.001
Relative Advantage	.161	.047	.171	3.464	.001
Perceived Fee	.421	.050	.468	8.502	.000
Building Codes	.105	.048	.110	2.174	.030
Technicality, Compatibility & Complexity	.404	.059	.350	6.852	.000
Perceived Usefulness & Enjoyment	.137	.054	.123	2.522	.012
Peer Firm Influence	.138	.070	.104	1.965	.050
Intention to Use	.078	.034	.091	2.319	.035

a. Dependent Variable: Adoption framework for internet of things based smart energy building
(Data Analysis, 2019)

Table 1 presents the findings on the contribution of each of the dimensions of determinants in the adoption of Internet of Things Based Smart Energy Building. The beta column indicates the values for the standardized coefficients. Focusing on the standardized coefficient column, out of eight factor dimension, only one had insignificant effect on the adoption of Internet of Things Based Smart Energy Building.

The largest beta coefficient was 0.421, which is coefficient perceived fee. This values is significant (β=.421, p=.000) and also positive. This means perceived fee has the strongest unique contribution to explaining the adoption of Internet of Things Based Smart Energy Building, when the variance explained by all other variables in the model is controlled. The second largest beta coefficient was 0.404, which is coefficient value for Technicality, Compatibility & Complexity. This values is significant (β=.404, p=.000) and also positive. This means that Technicality, Compatibility & Complexity has the second strongest unique contribution to explaining the adoption of Internet of Things Based Smart Energy Building, when the variance explained by all other variables in the model is controlled.

Another variable that also had a unique significant contribution to the model was the value for Awareness and Knowledge of Stake Holders (β=.169, p=.001) and it was followed closely by relative advantage (β=.161, p=.001). Perceived Usefulness & Enjoyment also had using significant contribution to the model (β=.137, p=.012) while building code had least significant contribution to the model (β=.105, p=.030). The other variable, which is Peer Firm Influence (p=0.050) did not make statistically significant contribution to the model. This can be attributed to the overlap with the other independent variables in the model.

The study further sought to determine the model summary findings in order to determine the overall percentage change in the Adoption of Internet of Things Based Smart Energy Building that was explained by twenty one latent variables entered in the model as a block. This was also to counter the results obtained from the part correlations, which represents only the unique contribution of each of the variables with any overlap or shared variance removed. The findings for the model summary are presented as shown in Table 2 that follows.

Table 2: 1Model Summary of Influence of the determinants in the AdoptionModel for Internet of Things Based Smart Energy Building

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	$.550^a$	.303	.288	1.045	.303	19.749	7	318	.000

a. Predictors: (Constant), AN, RA, PF, BC, TCC, PUE, PFI, IU

(Data Analysis, 2019)

The results from the model summary in Table 2 give us information on the overall summary of the model. Looking at the R square column, we can deduce that all the dimensions of twenty one latent variables jointly account for 30.3% significant variance in Adoption of Internet of Things Based Smart Energy Building, (R square =.303, F(7, 318)= 19.749, p=.000). Therefore, the determinants used in this jointly are significant predicators of Adoption of Internet of Things Based Smart Energy Building.

b) Internet of Things-Application Enablement Platform Components

The study was keen in knowing the influence of each Internet of Things-Application Enablement Platform Components when all these dimensions were entered as a block on the model. The findings are presented in Table 3 using unstandardized coefficients, standardized coefficients, t statistic, and significant values to assess the significance of the results. The results are presented in the Table 3 without its representation on the model equation.

Table 3: Coefficients of Components

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	5.659	.688		8.228	.000
External Interfaces	.119	.067	.088	1.783	.076
Analytics	.391	.046	.393	8.426	.000
Additional Tools	.419	.073	.296	5.778	.000
Data Visualizations	.681	.095	.350	7.145	.000
Processing & Action Management	.631	.122	.262	5.186	.000
Device Management	.752	.069	.536	10.936	.000
Connectivity & Normalization	.341	.052	.303	6.533	.000
Database	.090	.057	.081	1.572	.117

a. Dependent Variable: Adoption framework for internet of things based smart energy building

(Data Analysis, 2019)

Table 3 shows the findings on the contribution of each of the component on the adoption of Internet of Things Based Smart Energy Building. From the standardized coefficient column, out of eight components, only two components had insignificant influence on the adoption of Internet of Things Based Smart Energy Building.

The largest beta coefficient was 0.752, which is coefficient of device management. This values is significant (β=.752, p=.000) and also positive. This means device management component has the strongest unique contribution to explaining the adoption of Internet of Things Based Smart Energy Building, when the variance explained by all other variables in the model is controlled. The second largest beta coefficient was 0.681, which is coefficient of Data Visualizations. This value is significant (β=.681, p=.000) and also positive. This means data visualizations component has the second strongest unique contribution to explaining the adoption of Internet of Things Based Smart Energy Building, when the variance explained by all other variables in the model is controlled. The third largest beta coefficient was 0.631, which is coefficient value for Processing & Action Management. This value is significant (β=.631, p=.000) and also positive. This implies that Processing & Action Management has the third strongest unique contribution to explaining the adoption of Internet of Things Based Smart Energy Building, when the variance explained by all other variables in the model is controlled.

Other variables that also had a unique significant contribution to the model were Additional Tools (β=.419, p=.000), analytics (β=.391, p=.001) and Connectivity & Normalization (β=.341, p=.001). However, Database (P=0.117) and External Interface (P=0.076) did not make statistically significant contribution to the model. This can be attributed to the overlap with the other independent variables in the model.

The study also sought to determine the model summary findings in order to determine the overall percentage change in the Adoption of Internet of Things Based Smart Energy Building that was explained by eight components entered in the model as a block. This was also to counter the results obtained from the part correlations, which represents only the unique contribution of each of the variables with any overlap or shared variance removed. The findings for the model summary are presented as shown in Table 4 that follows.

Table 4: Model Summary of Influence of the Components on the Adoption of Internet of Things Based Smart Energy Building

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.719[a]	.517	.505	.871	.517	42.385	8	317	.000

a. Predictors: (Constant), EI, AN,AT,DV,PAM,DM,CH,DA

(Data Analysis, 2019)

The results from the model summary in Table 4 give us information on the overall summary of the model. From R square column, it can be deduced that all the eight complements jointly account for 50.5% significant variance in Adoption of Internet of Things Based Smart Energy Building, (R square =.505, F (8, 317) = 42.385, p=.000). Therefore, the eight components jointly are significant predicators of Adoption of Internet of Things Based Smart Energy Building.

c) Internet of Things-Application Enablement Platform Capabilities

The study was interested in knowing the effect of each of the capabilities that influence the Adoption of Internet of Things Based Smart Energy Building of when all these five capabilities were entered as a block on the model. The results are presented in Table 5 using unstandardized coefficients, standardized coefficients, t statistic, and significant values to assess the significance of the results. The results are presented in the Table 5 without its representation on the model equation.

Table 5: Coefficients of Capabilities

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.
	B	Std. Error	Beta		
(Constant)	2.399	.298		8.065	.000
Data Management	.320	.052	.320	6.138	.000
Scripting Engine	.223	.058	.204	3.844	.000
Integration Framework	.200	.060	.184	3.338	.001
Software Development Kits	.099	.052	.102	1.911	.057
Web Services	.058	.050	.058	1.159	.247

a. Dependent Variable: Adoption framework for internet of things based smart energy building

(Data Analysis, 2019)

Table 5 presents the findings on the contribution of each of the capabilities on the adoption of Internet of Things Based Smart Energy Building. Focusing on the standardized coefficient column, out of five capabilities, only two had insignificant influence on the adoption of Internet of Things Based Smart Energy Building.

The largest beta coefficient was 0.320, which is coefficient of data management. This values is significant (β=.320, p=.000) and also positive. This means data management capabilities has the strongest unique contribution to explaining the adoption of Internet of Things Based Smart Energy Building, when the variance explained by all other variables in the model is controlled. The second largest beta coefficient was 0.223, which is coefficient of scripting engine. This value is significant (β=.223, p=.000) and also positive. This means scripting engine capabilities has the second strongest unique contribution to explaining the adoption of Internet of Things Based Smart Energy Building, when the variance explained by all other variables in the model is controlled. The third largest beta coefficient was 0.200, which is coefficient value for integration framework capabilities. This value is significant (β=.200, p=.001) and also positive. This implies that integration framework capabilities have the third strongest unique contribution to explaining the adoption of Internet of Things Based Smart Energy Building, when the variance explained by all other variables in the model is controlled. The other variables, which is Software Development Kits (p=0.057) and web services (P=0.247) did not make statistically significant contribution to the model as compared to the others. This can be attributed to the overlap with the other independent variables in the model.

The study further sought to determine the model summary findings in order to determine the overall percentage change in the Adoption of Internet of Things Based Smart Energy Building that was explained by five components entered in the model as a block. The findings for the model summary are presented as shown in Table 6 that follows

Table 6: Model Summary on influence of capabilities on the Adoption of Internet of Things Based Smart Energy Building

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.499	.249	.238	1.081	.249	21.259	5	320	.000

a. Predictors: (Constant), WS, DM, SE, SDK, IF

(Data Analysis, 2019)

The results from the model summary in Table 6 give information on the overall summary of the model. Looking at the R square column, we can deduce that all five capabilities jointly account for 24.9% significant variance in Adoption of Internet of Things Based Smart Energy Building, (R square =.249, F(5,320)= 21.259, p=.000). Therefore, the five capabilities jointly are significant predicators of Adoption of Internet of Things Based Smart Energy Building.

1. Study Model

To draw conclusions on the objectives of the study, inferential analysis of the data collected was carried out. Inferential analysis involved statistical model estimation to explore the causal effects of determinants, components and capabilities of Adoption of Internet of Things Based Smart Energy Building with statistical significance. The statistical approach used for inferential analysis in this study was structural equation modeling (SEM) which is a collection of techniques that combine both confirmatory factor analysis and regression analysis to fit statistical models. Structural equation modelingwas carried out with the use of Analysis of Moments Structures (AMOS) software version 23.

One of the strengths of SEM is its flexibility, which permits examination of complex associations, use of various types of data (e.g., categorical, dimensional, censored, count variables), and comparisons across alternative models. However, these features of SEM also make it difficult to develop generalized guidelines regarding sample size requirements [43]. Using both Factor analysis and regression analysis, SEM explores the measurement and structural models during estimation of model coefficients.

2. Measurement Model Validity and Reliability

SEM requires reliability and constructs validity of the data to be used to be tested. The measurement model relates the measured variables to the latent variables using factor analysis. The measured variables are the observed items which are the indicators based on the data collection instrument. The latent variables are the unobserved larger constructs to which the observed indicators belong. Latent variables are unobserved and are uncovered by exploring the underlying structure of a set of observed variables.

Factor analysis is a statistical dimension reduction technique used to explore the underlying structure of a set of observed variables. There is a unidimensionality basic assumption of measurement theory that a set of items forming an instrument measuring one thing in common. To explore the relationships between a variable and another, the variable must be unidimensional; the various items underlying the data must measure the same traits. Exploratory factor analysis identifies underlying factors and categorizes items that are closely related without considering any hypothesised priori model or theories. By this, a large number of variable items are collapsed into a few interpretable and manageable underlying factors. Table 7 shows a summary of the proportion of variances explained by the extracted components from EFA.

Table 7: Factor Extraction under Exploratory Factor Analysis

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	12.867	16.083	16.083	12.867	16.083	16.083
2	6.562	8.203	24.286	6.562	8.203	24.286
3	3.323	4.154	28.440	3.323	4.154	28.440
4	3.165	3.956	32.396	3.165	3.956	32.396
5	3.070	3.838	36.234	3.070	3.838	36.234
6	2.848	3.560	39.793	2.848	3.560	39.793
7	2.489	3.111	42.904	2.489	3.111	42.904
8	2.366	2.957	45.862	2.366	2.957	45.862
9	2.236	2.796	48.657	2.236	2.796	48.657
10	2.186	2.733	51.390	2.186	2.733	51.390
11	2.110	2.638	54.028	2.110	2.638	54.028
12	1.911	2.388	56.417	1.911	2.388	56.417
13	1.776	2.220	58.636	1.776	2.220	58.636
14	1.698	2.122	60.758	1.698	2.122	60.758
15	1.642	2.053	62.811	1.642	2.053	62.811
16	1.597	1.996	64.807	1.597	1.996	64.807
17	1.525	1.907	66.714	1.525	1.907	66.714
18	1.462	1.828	68.541	1.462	1.828	68.541
19	1.341	1.677	70.218	1.341	1.677	70.218

20	1.320	1.650	71.868	1.320	1.650	71.868
21	1.261	1.576	73.444	1.261	1.576	73.444
22	1.091	1.363	74.807	1.091	1.363	74.807
23	1.053	1.316	76.123	1.053	1.316	76.123
24	1.002	1.253	77.376	1.002	1.253	77.376
25	.985	1.231	78.607			
26	.926	1.157	79.764			
27	.877	1.096	80.861			
28	.858	1.073	81.933			
29	.827	1.034	82.967			
30	.804	1.005	83.972			
31	.761	.951	84.923			
32	.722	.903	85.826			
33	.704	.880	86.706			
34	.642	.803	87.509			
35	.630	.787	88.296			
36	.580	.725	89.022			
37	.548	.685	89.707			
38	.520	.650	90.357			
39	.509	.636	90.993			
40	.479	.599	91.592			
41	.448	.560	92.152			
42	.420	.525	92.677			
43	.413	.516	93.193			
44	.400	.500	93.693			
45	.370	.462	94.155			
46	.342	.428	94.583			
47	.338	.423	95.006			
48	.320	.400	95.406			
49	.310	.387	95.793			
50	.294	.367	96.161			
51	.265	.331	96.492			
52	.247	.308	96.800			
53	.215	.269	97.069			
54	.205	.256	97.325			
55	.193	.241	97.566			
56	.183	.229	97.795			
57	.172	.215	98.010			
58	.143	.179	98.189			
59	.134	.167	98.356			
60	.126	.157	98.513			
61	.119	.148	98.661			
62	.116	.145	98.806			
63	.111	.139	98.945			
64	.098	.123	99.068			
65	.090	.112	99.180			
66	.086	.107	99.287			
67	.081	.101	99.388			
68	.073	.091	99.480			
69	.060	.075	99.555			
70	.054	.068	99.623			
71	.053	.067	99.690			
72	.045	.056	99.745			
73	.042	.052	99.797			
74	.036	.045	99.842			
75	.033	.041	99.884			
76	.027	.034	99.917			
77	.019	.024	99.942			
78	.018	.023	99.965			
79	.016	.020	99.984			
80	.013	.016	100.000			

Extraction Method: Principal Component Analysis.

(Data Analysis, 2019)

All the indicators were subjected to EFA where possible components are extracted. There were 24 retained latent variables that had Eigen values greater than 1 which is an implication of possible extraction of 24 unidimensional latent variables from the items. The 24 retained latent variables explain up to 77.376% of the total variations from the items. From the initial extraction, the first component explained up to 16.083% of the total variance.

Table 8, shows the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity which were also used under exploratory factor analysis (EFA). The KMO is a measure that ranges from 0 to 1 and was used for the proportional variance in the observed items that could have been caused by their underlying factors. A KMO value that is very low is an indication of a likely inappropriateness of factor analysis. It shows likely diffusions in the patterns of correlations since the sum of partial correlation is large relative to the sum of correlations.

Table 8: KMO and Bartlett's Test

Test		Value
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.738
Bartlett's Test of Sphericity	Approx. Chi-Square	7196.994
	Df	435
	Sig.	0.000

(Data Analysis, 2019)

The KMO value was found to be 0.738 which is a high figure that is close to 1 and acceptable. The Bartlett's test of sphericity is to test for a significant relationship among the observed indicators. A significant relationship is evident with the confirmation that the correlation matrix of the indicators is not an identity matrix which would be an indication of unrelated indicators. For the Bartlett's test in this study, the Chi-square statistic of the Bartlett's test was found to be 7196.994 with a p-value of 0.000. The p-value that is less than 0.05 is a confirmation at 0.05 level of significance that the correlation matrix of the indicators is not an identity matrix thus the indicators have an evident significance relationship as is expected for appropriate factor analysis. Further analysis of reliability and validity of the measurement model were carried out considering confirmatory factor analysis and measures of internal consistency. Table 9 shows reliability test results of internal consistency.

Table 9: Internal Consistency

Constructs	Cronbach alpha	Number Items	Status
Awareness and Knowledge	0.786	6	Reliable
Relative Advantage	0.764	8	Reliable
Perceived Fee	0.708	7	Reliable
Building Codes	0.819	8	Reliable
Technicality, Compatibility & Complexity	0.784	8	Reliable
Perceived Usefulness & Enjoyment	0.900	8	Reliable
Peer Firm Influence	0.750	8	Reliable
Intention to Use	0.777	7	Reliable
External Interfaces	0.793	8	Reliable
Analytics	0.832	4	Reliable
Additional Tools	0.844	5	Reliable
Data Visualizations	0.816	9	Reliable
Processing & Action Management	0.833	4	Reliable
Device Management	0.777	6	Reliable
Connectivity & Normalization	0.880	5	Reliable
Database	0.867	6	Reliable
Data Management	0.722	8	Reliable
Scripting Engine	0.717	4	Reliable
Integration Framework	0.728	4	Reliable
Software Development Kits	0.899	5	Reliable
Web Services	0.812	4	Reliable

Reliability analysis of the data collected was carried out using Cronbach alpha measurement of internal consistency which found the data on all the constructs reliable with Cronbach alpha statistics above 0.7. Cronbach alpha ranges from 0 to 1 where values higher than one imply high reliability and values above 0.7 are considered acceptable.

Confirmatory factor analysis (CFA) is adopted as a coherent part of SEM considering its use in verification of factor structure of a set of observed variables. It is a verification technique of priori and hypothesised structures and relationships that are based on theoretical and empirical information. Under CFA, the observed variables are subjected to factor analysis to verify that they belong to the latent variable that they are purported to be based on theoretical and empirical research. Under CFA, the observed items are expected to load the latent variable above 0.4.

Table 10: **Confirmatory Factor Analysis**

Item	**AVE**	**Squared Multiple Correlation**	**Factor loadings**				
			Factors	**Components**	**Capabilities**	**Policies and Regulations**	**Adoption**
D1	0.770	0.382	0.763				
D2		0.288	0.720				
D3		0.686	0.815				
D4		0.602	0.846				
D5		0.697	0.806				
D6		0.438	0.745				
D7		0.499	0.788				
D8		0.768	0.675				
CO1	0.725	0.516		0.762			
CO2		0.383		0.722			
CO3		0.477		0.757			
CO4		0.049		0.668			
CO5		0.455		0.834			
CO6		0.160		0.575			
CO7		0.490		0.758			
CO8		0.356		0.720			
CA1	0.810	0.049			0.804		
CA2		0.455			0.827		
CA3		0.160			0.818		
CA4		0.490			0.785		
CA5		0.356			0.818		
PR1	0.789	0.518				0.831	
PR2		0.590				0.721	
PR3		0.563				0.874	
PR4		0.556				0.839	
PR5		0.624				0.791	
PR6		0.535				0.731	
A1	0.779						0.750
A2		0.410					0.778
A3		0.723					0.792
A4		0.605					0.799
A5		0.570					0.821
A6		0.567					0.736

(Data Analysis, 2019)

As shown in Table 10, the factor loadings are all above 0.4. Thus none of the indicator was expunged out during further analyses, meaning all indicators were retained.

The results of CFA were also used to confirm construct validity of the data collected as is required under SEM. Construct validity is confirmed by exploration of both convergent and discriminant validity. Convergent validity is a measure that confirms that the items that are meant to have relationships are actually related while discriminant validity gives a confirmation that items that are not meant to be related are actually not related. Convergent validity was measured by determining the average variances extracted (AVEs) from CFA. Average variances extracted measure the total amount of variance that can be ascribed to the latent construct. The average variance extracted should be higher than the minimum threshold of 0.5. However, according to

[44], even if AVE is less than 0.5, but composite reliability is higher than 0.6, the convergent validity of the construct is still adequate. The exploration of discriminant validity involves the comparison of the AVEs and the squared multiple correlations. The data is said to exhibit discriminant validity if all the squared multiple correlations are less than the relative constructs AVE as was found in this study. These results thus showed a confirmation of both convergent and discriminant validity thus a confirmation that the data collected and used had construct validity.

IV. CONCLUSION

The purpose of this paper was to review the literature on smart buildings based on adoption of internet of things application enabled platform determinants, components and capabilities. Because a smart building is designed with open systems, it is easier to introduce innovative, new technologies and utilize a variety of different manufacturers and vendor equipment.Building owners can keep abreast of trends in demand response, curtailment and smart grids. It enables the building owner to utilize new revenue models, new technologies and provide occupants with additional amenities. This is a simplistic overview and not exhaustive of the full capabilities in the hands of the right designer and engineer. All the twenty one latent one variables studied were found to have significant influence on adoption of Internet of Things based smart energy building.

This paper has reviewed the determinants, components and capabilities to consider in adoption of internet of things based smart energy building, a technology that is making great inroads in smart building arena. These are; Traditional inertia, budget priorities, risk aversion, reductions in energy consumption, enhancements to operations and a very attractive return on investment.

This review is significant because it informs how Internet of Things Application Enablement Platform can be used in smart building design to help improve energy efficiency.

References

[1] Jim Sinopoli, Tahir Sharif, (2014)-Defining a Smart Building: Part Five; the IBMHub; https://thebimhub.com/2014/07/05/defining-smart-building-part-five/#.Wagk0MgjHIU

[2] Gidon Ben-Zvi, 2016.Big Data and Internet of Things Combine to Produce Smart Buildings;http://sqream.com/big-data-and-internet-of-things-combine-to-produce-smart-buildings/

[3] Ancevic, M. (1997), Smart building systems for airport, *ASHRAE Journal*, November, pp. 31-35.

[4] Voltas, 2010- Integrated Building Management Systems (IBMS)

[5] G. Platt. G, J. Li, R. Li, G. Poulton, G. James, J. Wall Adaptive HVAC zone modeling for sustainable buildings Energy Build., 42 (4) (2010), pp. 412–421

[6] Guo. W (2010) Setback and setup temperature analysis for a classic double-corridor classroom building Energy Build., 42 (2) (2010), pp. 189–197

[7] Bálint, L. (1995), Adaptive human-computer interfaces for man-machine interactions for man-machine interaction in computer-integrated systems, *Computer Integrated Manufacturing Systems*, Vol. 8, No. 2, pp. 133-142.279

[8] Nasscom, (2012); Tech Savvy Series;The world of connected machines - The Internet of Things' (IoT); http://www.nasscom.in/world-connected-machines

[9] Vertical M2M (2017); Enabling IoT M2M Applications; http://www.vertical-m2m.com/commonsense-iot-platform

[10] Padraig Scully, (2016);5 Things To Know About The IoT Platform Ecosystem; https://iot-analytics.com/5-things-know-about-iot-platform/

[11] Ari Banerjee (2013); The Future of M2M Application Enablement Platforms; http://cdn2.hubspot.net/hub/246745/file-326224805-pdf/Heavy_Reading_-_The_Future_of___M2M_Application_Enablement_Platforms_-_September_2013.pdf?t=1406838830743

[12] Telit, (2017), SMART BUILDINGS, Transform building management and efficiency, http://www.telit.com/solutions/industries/smart-buildings/

[13] Milan Zdravkovićet. al, 2016, MiroslavTrajanovic, JoãoSarraipa and HervéPanetto Survey of Internet-of-Things platforms, https://hal.archives-ouvertes.fr/hal-01298141/document

[14] André Malm, (2017), M2M Research Series, IoT Platforms and Software, http://www.berginsight.com/ReportPDF/ProductSheet/bi-platforms-ps.pdf

[15] Clare, (2015), IoT Platforms and Software, https://www.bizjournals.com/prnewswire/press_releases/2015/05/07/BR02035

[16] SatpritDuggal, (2018); 5 Common Hurdles in Smart Building Implementation; WxWeekly

[17] Intelzone, (2017); IoT for Connected BuildingsStreamline building automation. Conserve ***energy, reduce cost and increase security; http://intelzone.com/connected-buildings/***

[18] Casey T (2016) Tackling the people problem, another promise of IoT (December 2, 2016)

[19] Arnoud M, (2015), SOGETI SMART BUILDING, https://www.ibm.com/blogs/bluemix/2015/05/sogeti-high-tech-and-ibm/

[20] Rajeev Kak, (2015) – IFSEC Global - Secure, Green and Connected: Three Pillars of a Truly Smart Building

[21] Gemalto, (2017), Build and deploy IoT applications faster and easier, http://www.gemalto.com/m2m/solutions/application-enablement

[22] Geoff D., (2014) - You Can't Avoid The 'Internet Of Things' Hype, So You Might As Well Understand It, Geoff Duncan, Updated July 24, 2014 5:46 am

[23] Technopedia, (2019); Web Service**;** **https://www.techopedia.com/definition/25301/web-service**

[24] IPSO Alliance, 2010- Technology Connected - The Internet of Things and the Convergence of Networks , *http://www.rtcmagazine.com/articles/view/101879*

[25] John Soldatos, Martin Serrano, Manfred Hauswirth, 2012- "Convergence of Utility Computing with the Internet-of-Things" IEEE 2012 Sixth International Conference on innovative Mobile and Internet Services in Ubiquitous Computing (IMIS 2012), (ISBN: 978-1-4673-1328-5. DOI:10/1109/IMIS.2012/135).

[26] Nitishree (2016), A Review on IOT Based Smart GPS Device for Child and Women Safety Applications

[27] Ivan HuangrocGuoharryXiezhengxiang Wu, et. al. (2012); The Convergence of Information and

[28] Communication Technologies Gains Momentum; Huawei Technologies; The Global Information Technology Report 2012; http://www3.weforum.org/docs/GITR/2012/GITR_Chapter1.2_2012.pdf

[29] Parwekar P, 2011, "From Internet of Things towards cloud of Things", 2nd IEEE International Conference on Computer and Communication Technology (ICCCT), September 2011.

[30] GuinardD. (2017) - What is the Web of Things?-**http://webofthings.org/2017/04/08/what-is-the-web-of-things/**

[31] Guess A.R, (2017) - W3C Begins Standards Work on Web of Things to Reduce IoTFragmentation, www.w3.org

[32] Erik Wilde, (2007). Putting things to REST.Technical Report UCB iSchool Report 2007-015, School of Information, UC Berkeley, November 2007.

[33] Karen Myers, 2017- W3C Begins Standards Work on Web of Things to Reduce IoT Fragmentation

[34] Edler, J. and Wang, W., 2006. Wireless! building automation unwired, AutomatedBuildings.com, March 2006, available at www.automatedbuildings.com.

[35] Sam C. M. Hui, (2007) Pg 5; Latest Trends in Building Automation and Control Systems; https://web.hku.hk/~cmhui/CAI-2007_SamHui.pdf

[36] Verena Weber (2009)-OECDSmart Sensor Networks: *Technologies and Applications for Green Growth*
[37] Vasudhendra Badami, (2017); Why JavaScript is used in IoT; **https://www.hackerearth.com/blog/internet-of-things/javascript-in-iot/**
[38] InterDigitalInc, (2016);InterDigitalIoT Solutions; IoT integration framework
[39] KiarashIrandoust, (2018); IT Next; Best SDK's for the Internet of Things
[40] Angelo P Castellaniet. al., (2011); Web services for the Internet of Things through CoAPand EXI; Conference Paper **(PDF Available)** · July 2011 *with* 2,024 Reads DOI: 0.1109/iccw.2011.5963563 · Source: IEEE Xplore ; Conference: Communications Workshops (ICC), 2011 IEEE International Conference on
[41] Jean-Philippe Vasseur and Adam Dunkels(2013); Building an IoT web services framework with smart objects.
[42] Justin McKeown (York St John University)**,** Rob Van Kranenburg and Joachim Walewski, (2014) ;http://internetofthingsphilosophy.com/
[43] Folke, C., 2006. Resilience: the emergence of a perspective for socialecologicalsystemsanalyses. Global Environmental Change 16 (3), 253–267.
[44] MacCallum RC, Widaman KF, Zhang S, Hong S. Sample size in factor analysis. Psychological Methods.1999;4:84–99. [Google Scholar]
[45] Fornell, Claes, and David F. Larcker. 1981. Evaluating structural equation models with unobservable variables and measurement error. Journal of Marketing Research 18: 39–50. [Google Scholar] [CrossRef]

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