MODEL FOR UBIQUITOUS APPLICATION ENABLEMENT PLATFORMS (AEPs) FOR SMART BUILDINGS

Nicodemus Aketch Ishmael

PhD Student, Business Information Systems, Jaramogi Oginga Odinga University of Science & Technology, Kenya

Dr. Solomon Ogara

Jaramogi Oginga Odinga University of Science & Technology, Kenya

Dr. George Raburu

Jaramogi Oginga Odinga University of Science & Technology, Kenya

Received: 14th March 2016

Accepted: 25th March 2016

Full Length Research

Available Online at: http://www.iajournals.org/articles/phdse_v1_i1_13_65.pdf

Citation: Ishmael, N. A., Ogara, S. & Raburu, G. (2016). Model for ubiquitous application enablement platforms (AEPS) for smart buildings. *International Academic Journals PhD Serial Edition, 1* (1), 13-65

LITERATURE REVIEW

Concept of Smart Buildings

The research adopts the definition of smart buildings as defined by European Commission, "Smart buildings means 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." The smart building can also be defined as an implicit logic that effectively evolves with changing user requirements and technology, ensuring continued and improved smart operation, maintenance, and optimization. It exhibits key attributes of environmental sustainability to benefit present and future generations (IBM, 2014).

Therefore, smarter buildings are well managed, integrated physical and digital infrastructures that provide optimal occupancy services in a reliable, cost effective, and sustainable manner. Smarter buildings help their owners, operators and facility managers improve asset reliability and performance that in turn reduces energy use, optimises how space is used and minimises the environmental impact of their buildings. Smart buildings transcend integration to achieve interaction in which the previously independent systems work collectively to optimize overall performance and constantly create an environment that is most conducive to the occupants' needs and goals. Additionally, fully interoperable systems in smart buildings tend to perform better, cost less to maintain, and leave a smaller environmental imprint than individual utilities and communication systems. Clean energy will also help reduce heavy impacts of climate change. Peer-to-peer information, social networking and pervasive computing are combining to create new modes of collaboration and decision making. People, information, and technology are becoming more connected, distributed and pervasive enabling the convergence of physical and virtual worlds.

The field of Intelligent Buildings, Intelligent Homes and Building Management Systems (BMS) encompasses an enormous variety of technologies, across commercial, industrial, institutional and domestic buildings, including energy management systems and building controls. The function of Building Management Systems is central to 'Intelligent Buildings' concepts; its purpose is to control, monitor and optimise building services, eg., lighting; heating; security, CCTV and alarm systems; access control; audio-visual and entertainment systems; ventilation, filtration and climate control, etc.; even time & attendance control and reporting (notably staff movement and availability). Smart buildings are energy independent; many are built with Solar panels that produce the green energy. With good design, there is no need for either heating or cooling in buildings. Since air conditioning and central heating are both huge consumers of energy and very expensive, this is a great bonus when you're designing a building that aims to be energy neutral.

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. Such examples and stories validate the approach, verify the likely results and reduce the risk for other building owners to plan to deploy the technologies. Another element driving the market for smart buildings is our global society's habituation to 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. The Smart building is a huge improvement on existing facilities. There are better bathrooms, better cafeterias, comfortable office temperatures and an outlook on to green space from everywhere in the building. The excellence of the environment will have a massive positive impact on people's working lives. Heating and cooling are the biggest consumers of energy in most buildings. Smart buildings engage simple chimney design that ensures good airflow and comfortable internal temperatures, operable windows that give occupants some control over their environment and help airflow and temperature regulation. For office blocks, cooler office spaces are cooler as well as more convivial places to work. Smart buildings are planned to make maximum use of natural light, simultaneously reducing costs and energy consumption, while creating an attractive working environment.

Lighting is a major consumer of energy in offices. We need to ensure everyone has adequate light to work by but also to make dramatic reductions in energy use, for both cost and sustainability reasons. A smart building endeavours to harvest rain water on its entire roof. Sewage and wastewater goes to the new state-of-the-art sewage processing plant where it is purified by aeration and emerges clean, ready to join the rainwater in the lagoon. This harvested and recycled water is then used to irrigate the landscaped areas around the new building, so no fresh water is required to maintain the gardens and trees that make the smart building so beautiful and sustain so much biodiversity. Water can be recycled seven times, as in 102 acre Two Rivers Project in Ruaka, a clear good economy of the scarce resource. Ultimately all water processes in the smart building are monitored by the automated building management system. Any problems or wastage are seen very quickly and responded to immediately, which makes our water efficiency even better.

The most obvious IT difference in the new building will be the shift from desktop to notebook computers over the coming months, yielding an immediate energy saving of around two thirds. ICT needs to be integrated into intelligent building planning from outset to optimize solutions and ensure users' current and future needs are met, not only in terms of equipment and access points but also with regard to adaptability of net ICT. Green strategies and technologies include a design based on local climate and ecology, natural light and temperature regulation, renewable energy and waste management.

THEORETICAL FRAMEWORK

Things Theory

The study is grounded on the theory of things, (McKeown and Walewski, 2012) 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. Things theory is a branch of critical theory that focuses on human-object interactions in literature, culture and technological adaptation. Thing operates through observing, reasoning and then taking action. Thing's observations and reasoning are based on knowledge of the family that it has gained over time through understanding and learning what type of tasks they require assistance with on a regular basis. Thing expands the agency of family members and greatly enhances their experience within their rather complex home by acting as an agent on behalf of a wide range of different services and facilities the house has to offer, connecting these to intentions of the family. Thing transforms a complex jumble of services into a successful technological context. We argue that successful technological contexts are those that users use to expand their agency outside that technological context proper; the technology expands their general capacity to choose.

The theory of things is the philosophy behind the internet of things according to McKeown and Walewski, (McKeown and Walewski, 2012). The Internet of Things (IoT) is an umbrella term used to describe a next step in the evolution of the Internet. While the first phase of the web can be thought of as a combination of an internet of hyper-text documents and an internet of applications (think blogs, online email, social sites, etc.), one of the next steps is an Internet of augmented 'smart' objects – or 'things' – being accessible to human beings and each other over network connections. This is the internet of Things. Underpinning the development of the Internet of Things is the ever increasing proliferation of networked devices in everyday usage that have become ubiquitous. Such devices include laptops, smart phones, fridges, smart meters, RFIDs, etc. The "big data" revolution, a step change in digital memory and data storage, has occurred alongside significant advancements in energy storage. The number of devices in common usage is set to increase worldwide from the current level of 4.5 billion to 50 billion by 2050 and may even include human implants.

We can try to specify how our Thing agent might improve a Location Aware Smart Environment (LASE) by specifying some principles that Thing must satisfy. Foremost, we would argue that a Thing agent will facilitate people exercising agency. Agency is the capacity to make and execute non deterministic choices intended to advance to a goal as events unfold. For example, humans exercise agency when deciding whether to turn on a light or to walk across a street to avoid a possible obstacle. Agency implies that agents' future choices are not intrinsically fixed or stochastically predicable except on the basis of secondary principles of reasoning for ubiquitous application enablement platforms (AEPs), such as rationality, cooperation or enmity. Such social relationship requires a mutual presumption of agency on the part of the other; social relations require that each party assumes the other has some level of agency. In any given circumstance; people have a set of options upon which they could base choices. In many cases they will not be aware of some options, a situation that discovery might advance. In other cases they will lack the means to usefully enact an option because of a lack of skill or knowledge, even though they are aware of it. In still other cases, options might not be available because the contexts within which these would be available cannot be deployed. By dint of the above, life as we know it on the planet will undergo a multitude of minuscule but incredibly significant changes that will alter not only how we relate to each other and the world, but also how we conceive of ourselves as beings within it.

This situation proposes a pressing question: do we want to simply leave market forces to shape our reality? Or is there a deeper need, given the significance of this technology, to consider its ramifications within a philosophical context? For as computational devices become ever more central to how we relate to and interface with each other, so too do they begin to create new systems of power relations between people. To create a system of power is to impose a social dynamic. The design and deployment of the Internet of Things is thus not simply a matter of software/hardware architecture but also of politics; ethics; belief; citizenship; and social and civic relations. It is to this end of examining these issues more deeply that we can converge the different technological innovations to achieve the Internet of Things.

Diffusion theory of Internet of Things

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. Expect to see early adopters led by innovative CIOs or by business leaders identify and pursue specific opportunities to better serve their customers, open new businesses reduce costs and provide new value that result in increased revenues. With multiple platforms, numerous protocols and large numbers of APIs, IoT systems integration and testing will be a challenge to say the least. The confusion around evolving standards is almost sure to slow adoption. The rapid evolution of APIs will likely consume unanticipated development resources that will diminish project teams' abilities to add core new functionality. Slower adoption and unanticipated development resource requirements will likely slip schedules and slow time to revenues, which will require additional funding for IoT projects and longer "runways" for startups. Lack of clear use cases or strong ROI examples will slow down adoption of the IoT. Although technical specifications, theoretical uses and future concepts may suffice for some early adopters, mainstream adoption of IoT will require well-grounded, customer-oriented communications and messaging around "what's in it for me". Detailed explanations of a specific device or technical details of a component won't cut it when buyers are looking for a "whole solution" or complete value-added service. Evolving architectures, protocol wars and competing standards have come to pave the way forward. With so many players involved with the IoT, there are bound to be ongoing turf wars as legacy companies seek to protect their proprietary systems advantages and open systems proponents try to set new standards. There may be multiple standards that evolve based on different requirements determined by device class, power requirements, capabilities and uses. In addition to the technical challenges around power, latency, integration and storage, there are a number of other issues critical to IoT adoption. These challenges will also provide new business opportunities for technology companies, middleware and tools developers, system integrators, device builders and cross-platform integration companies.

Adaptivity Theory

Folke (Folke, 2006) postulate 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: (1) absorb stresses and maintain function in the face of external stresses imposed upon it by climate change and (2) adapt, reorganize, and evolve into more desirable configurations that improve the sustainability of the system, leaving it better prepared for future climate change impacts. With the rising awareness of climate change impacts by both national and international bodies, building climate resilience buildings has become a major goal for these institutions. The key to smart building is the focus of climate resilience efforts and is to address the vulnerability that communities, states, and countries currently have with regards to the environmental consequences of climate change. Currently, climate resilience efforts encompass social, economic, technological, and political strategies that are being implemented at all scales of society".

Over recent years, the notion of 'resilience' has been increasingly associated with climate change adaptation (Cano and Ermoliev, 2014), indeed, has been the sentimental foundation of many legislative agenda in Countries which contribute more green house gases, for example the overall aim of the EU Strategy on adaptation to climate change (European Commission, 2013) is noted as being to support progress towards a 'climate-resilient Europe' (Abdel-Kader & Dugdale, 2001). Another dimension is that although the framework had its roots in ecology and notions of persistence of systems and the relationships that support them, the concept of resilience has broadened and is now applied to a diverse range of agendas and is receiving increasing attention in academia and policy (Abdel-Kader & Dugdale, 2001) add that resilience framework now also encompasses; "…broader matters of the governance of linked social-ecological systems." The United Nations Office for Disaster Risk Reduction (UNISDR) defines resilience as (UNISDR, 2012, p. 92): In colloquial terms, resilience simply means the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of the hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions (Atif and Galasiu, 2003),

More recently, 'risk governance' has emerged in response to climatic changes which differentiates between risks caused by decisions, and those that are independent of decision-making such as natural disasters (Cano & Ermoliev, 2014). Climate change risks are often a product of an interrelation between the two; they arise where the outcomes of decisions, for example linking to the development and use of land, interact with a natural disaster, for example a storm surge, to generate negative socioeconomic impacts (Cano & Ermoliey, 2014).

A conversation about climate resilience is incomplete without also incorporating the concepts of adaptations, vulnerability, and climate change. If the definition of resiliency is the ability to recover from a negative event, in this case climate change, then talking about preparations beforehand and strategies for recovery (aka adaptations), as well as populations that are more less capable of developing and implementing a resiliency strategy (aka vulnerable populations) are essential. This is framed under the assumed detrimental impacts of climate change to ecosystems and ecosystem services. The Internet of Things models should be inspiring and provided on a level of abstraction that will facilitate their application across industries, while remaining concrete enough to be actionable for innovators in business and society at large.

Figure 1: Urban climate change vulnerability and risk assessment framework

EMPIRICAL REVIEW OF GLOBAL ENERGY AND CLIMATIC CHANGE CRISIS AND SMART BUILDINGS TECHNOLOGY ADAPTATION

This section outlines the current status of smart building technologies. Key features are presented, and the architectural issues associated with the incorporation of the new technologies are discussed. Particular emphasis is given to examining technological advances in day-lighting, electric lighting, and HVAC systems. The theory part underlines that legislation should promote small-scale renewable energy production systems. Standardizing smart buildings will enhance and accelerate the deployment of such technology. The role of end-users to realize the energy efficiency potential is highlighted and different feedback strategies are presented. In order to facilitate data exchange between the home and the grid, communication technologies must be developed. To this end, data safety and data privacy are of major concern as well as the ownership and access to data (Morgan & King, 2007).

Somewhat ironically, the interest in accommodating intermittent renewable on the supply side has triggered the desire to have more flexible demand, i.e. a smart grid that can respond to the fluctuations in power generation. In effect, rather than being passive consumers, building managers are to be equipped and sensitized to respond to real-time market and weather conditions by taking advantage of advances in information and communications technologies (Guo &Nutter, 2010). Still, the expertise required to benefit from smart grid opportunities is beyond the capabilities of most building managers who rely on commercially available building energy management systems (BEMS) that typically have static set-point temperatures for the heating and cooling equipment regardless of external conditions. Indeed, adjusting the operations of heating, ventilation, and cooling (HVAC) equipment is likely to result in substantial reductions in energy consumption (Guo &Nutter, 2010).

Buildings are the largest contributor to global carbon emissions, accounting for above 40 percent of the world's total carbon footprint. In developed countries, commercial buildings alone represent close to 20 percent, about half of the total (Guo &Nutter, 2010). A more efficient building portfolio can improve the value of real estate assets, help the bottom line, cut emissions, and bolster the corporate image. In recent decades, most commercial buildings have been equipped with an increasing number of sensors, controls and other devices (Guo &Nutter, 2010). Modern buildings have built-in control systems, referred to as building management systems (BMS) or building automation systems (BAS), allowing building engineers, facility managers and real estate management to control their infrastructure. In this model, disparate building management systems and control panels are the access points to observe and manage building equipment; In addition, this provides a foundation for tighter integration with a smart utility grid that manages energy supply and demand dynamically on a local or regional level. Among building services, the growth in HVAC systems energy use is particularly significant (50% of building consumption and 20% of total consumption in the USA) (Arbel & Vargas, 1993).

The dovetailing of potentially devastating climate change impacts and urbanization by mid-century is of great concern to municipal leaders. The portion of the world living in cities is slated to rise to two-thirds of the global population (or 6.4 billion), up from 54% today, according to the United Nations (Guo &Nutter, 2010). In tandem, the frequency and severity of floods, storms and drought as a result of climate change are expected to rise significantly in the coming decades, particularly in coastal areas, where many large cities are located (Guo &Nutter, 2010). Forging preparative responses for these changes has thus taken on a new sense of urgency for government officials, non-governmental organizations and business leaders. For business, the executive survey, supported by the Rockefeller Foundation, finds that the biggest perceived market and operational risk from climate change is the disruption of energy supplies, which could severely impact on a company's ability to operate (Guo &Nutter, 2010). Growth in population, increasing demand for building services and comfort levels, together with the rise in time spent inside buildings, assure the upward trend in energy demand will continue in the future. For this reason, energy efficiency in buildings is today a prime objective for energy policy at regional, national and international levels (Guo &Nutter, 2010).

Concerns about climate change stemming from increased emissions of greenhouse gases such as CO_2 have encouraged a transition to more sustainable energy systems. In many westernized and industrialized countries, the policy makers have set standards and targets, e.g., the EU's 20-20-20 by 2020 directive, which stipulates a 20% reduction in energy consumption by 2020, 20% reduction in CO2 emissions and 20% of all energy produced by renewable technologies. Typically, supporting the attainment of these targets are policy measures such as feed-in tariffs (FIT) or renewable portfolio standards, which effectively subsidies' renewable energy technologies (Guo &Nutter, 2010).

As world temperatures raise, permafrost, a layer of permanently frozen soil found in Polar Regions will start to melt. When this happens, the ground can become softer or change shape, which can damage buildings and cause trees to lean or topple over. Just about every aspect of life contributes to carbon emissions. Climate change is caused by carbon emissions in the atmosphere and humans are pumping out carbon at an unprecedented rate. Scientists have high confidence that global temperatures will continue to rise for decades to come, largely due to greenhouse gasses produced by human activities. The world over, coastal cities are in danger of being wiped out by floods (Guo &Nutter, 2010).

Sensor networks play an important role in tackling environmental challenges. Sensor applications in smart power grids, smart buildings and smart industrial processes make significant contributions to more efficient resource use and reduce greenhouse gas emissions and other pollutants. Clean technologies and smart ICT applications are key to effectively fight climate change, protect biodiversity and manage our water resources. Buildings represent a key area where ICT advances can dramatically reduce carbon dioxide (CO2) emissions. 'Smart building' technologies that make building design, construction and operation more energy efficient, depend on ICT systems. These include building management systems that run heating and cooling systems according to each occupant's needs, or software systems that automatically turn off PCs and monitors when users are absent. As an essential element in sustainable development, the struggle against climate change depends on a sharp reduction in usage of carbon-based fuels. While dramatically more efficient ICT networks do not represent a panacea, they do hold the potential to enable substantial, sustainable reductions in greenhouse gas emissions across broad sectors of human activity on a global scale.

An Information system manages a building from remote servers, using software that constantly generates algorithms that indicate if building temperature, cooling and energy use are straying from benchmarks. A smart building can be summed up as an automated or largely automated self monitoring building, or defined as a building that includes "integrated design of infrastructure, building and facility systems, communications, business systems and technology solutions". It helps us monitor our energy usage making it possible to be smarter about it. The Internet of Things can save energy and carbon footprints with things as simple as using an app to turn off the lights or with apps like IFTTT (IF This Then That), which hooks up to many different types of systems. The IoT can also involve monitoring your sprinkler system to save water, or use sensors to tell you to take a different route when driving to avoid idling in traffic and wasting petrol. The life cycle is generally the life of the building although many building management systems are designed to monitor maintenance and can significantly reduce the cost of repairs.

Smart home devices, such as thermostats and lighting systems, can recognize patterns in usage data, automatically adjusting to save energy during times they are not typically in use. Such devices can help you save money on your power bill, but more importantly, they can reduce individual households' carbon emissions. Once such devices reach critical mass, they could have a significant impact on reducing our reliance on the power grid which contributes a lot to global warming. Energy-efficient buildings are seen by climate change experts as one of the least-cost approaches to mitigating greenhouse gas emissions. Smart buildings will also gather individual user data, aggregate behaviour of people and use this information to respond to their needs. They will also be able to use real-time tracking information to optimize their operational management, ambient noise levels, security and fire response. Smart buildings should be active and smart; they are living and responsive and should be environmentally responsible.

You don't have to look too hard to see the arrival of a new era—the convergence of building science, big data analytics and IT telecommunications to make buildings smarter. The era of smart buildings is a manifestation of a much larger megatrend in the "Internet of Things" or the "machine to machine" (M2M) revolution, in which machines can interact with one another to transmit data and to act on that data without human intervention. Today's smart building systems can automatically interact and adjust themselves without human intervention. The same technology is harnessing the predictive power of big data to help solve congestion problems in cities, for example, or achieve small, but powerful, efficiency gains across very large fleets of commercial jets, is now being deployed in buildings. This technology can link entire portfolios of buildings and their automated systems with far-flung remote operations centers where facilities experts can analyze ongoing data streams from building equipment and optimize each building system's use of energy, electricity and water.

As seen with President Obama's 2009 stimulus package, carbon capture technologies, developing "Smart Grid," and patent pools addressing climate change based on the open source and creative commons models, the issues are pressing. The World leaders assembled in Conference of the Parties, Twenty-first session Paris, 30 November to 11 December 2015 for COP21, a crucial conference, as it needs to achieve a new international agreement on the climate, applicable to all countries, with the aim of keeping global warming below 2°C. In his opening speech, the US president advocated for a legally binding agreement from all the participants and not lip service rhetoric that would not help stem climate change. Many speakers talked of real worries about rising temperatures and catastrophes that are bedeviling their nations across continents. No part of the world is safe from the adverse climatic conditions. Some of the resolutions of the climate change conference in France are: "*Decides* to strengthen the Technology Mechanism and requests the Technology Executive Committee and the Climate Technology Centre and Network, in supporting the implementation of the Agreement, to undertake further work relating to, inter alia:

(a) Technology research, development and demonstration; (b) The development and enhancement of endogenous capacities and technologies; *Requests* the Subsidiary Body for Scientific and Technological Advice to initiate, at its forty-fourth session (May 2016), the elaboration of the technology framework established under Article 10, paragraph 4, of the Agreement and to report on its findings to the Conference of the Parties, with a view to the Conference of the Parties making a recommendation on the framework to the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement for consideration and adoption at its first session, taking into consideration that the framework should facilitate, inter alia:
(a) The undertaking and updating of technology needs assessments, as well as the *enhanced* implementation of their results, particularly technology action plans and project ideas, through the preparation of bankable projects; (b) The provision of enhanced financial and technical support for the implementation of the results of the technology needs assessments; (c) The assessment of technologies that are ready for transfer; (d) The enhancement of enabling environments for and the addressing of barriers to the development and transfer of socially and environmentally sound technologies". (FCC/CP/2015/L.9, 2015)

The UN assembly held in New York city in September 2015 came out with the Sustainable Development Goals and goal number 13 states; "Take Urgent Action to Combat Climate Change and its Impacts". It has various targets i.e. one: Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries; two: Integrate climate change measures into national policies, strategies and planning; three: Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning; four: Implement the commitment undertaken by developed-country parties to the United Nations Framework Convention on Climate Change to a goal of mobilizing jointly $100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency; and five: Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities (UN.Org, 2015).

Greenhouse gas emissions from buildings primarily arise from their consumption of fossil-fuel based energy, both through the direct use of fossil fuels and through the use of electricity which has been generated from fossil fuels (Guo &Nutter, 2010). Significant greenhouse gas emissions are also generated through construction materials, in particular insulation materials, and refrigeration and cooling systems. The good news is that the Building Sector has the largest potential for significantly reducing greenhouse gas emissions compared to other major emitting sectors (Guo &Nutter, 2010). This potential is relatively independent of the cost per ton of CO2 achieved (IPCC, 2007).

Figure 1, from the IPCC's Fourth Assessment Report, shows that the potential for greenhouse gas reductions from buildings is common to both developed and developing countries, as well as countries with economies in transition. What this means is that with proven and commercially available technologies, the energy consumption in both new and existing buildings can be cut by an estimated 30 to 80 percent with potential net profit during the building life-span. In a world where changes have never been occurring fast, energy security is one of the main concerns for the future. Fossil fuel resources are decreasing in quantity, while prices of fossil fuel are increasing more rapidly than predicted. Today, barrel price is around 120 US$/b (OPEC, 2012), whilst it was predicted to be around 71.88 US$/b at this time (Capros et al., 2009). Today's oil overall stock is estimated at 1,467 billion barrels across the world while the daily consumption of oil was around 88 million barrels in 2008 (OPEC, 2011).

Based on the projections of daily oil consumption until 2035, the Organization of the Petroleum Exporting Countries (OPEC) deduced that the world would run out of oil by 2050. Similar projections can be made for natural gas, whereas by 2045 we would have consumed the world's known natural gas reserves (OPEC, 2011; CIA, 2012). Thus only three decades are between present days and the day where world fossil fuel reserves will be depleted. As much as such efforts are laudable, a lot need to be done in balancing both the supply side and demand side of the scenario in stimulating the adoption of renewable energy technologies, the demand side's role in facilitating this desired transition to sustainability has been often overlooked (Guo & Nutter, 2010).

Another transformation that is occurring very rapidly is climate change. This phenomenon may be explained by different factors such as environmental (solar radiation, atmospheric composition, motion and land cover) but can also be attributed to human activity (IPCC, 1997). Since the industrial revolution (1750 – 1850; Dean, 1979), fossil fuel based energy has been used in such intensity as if it was infinite. Fossil fuel based energy (coal, oil, natural gas) is now known as a highly polluting source of energy. This is now understood at the international level and 192 nations have adopted the Kyoto protocol in 1997, in which all ratifying countries committed to increase the energy efficiency in buildings and industry, and carrying out research on the use of renewable energy and the capture of CO2 as well as a wide range of other topics related to agriculture or greenhouse gas emissions (UNFCCC, 1998).

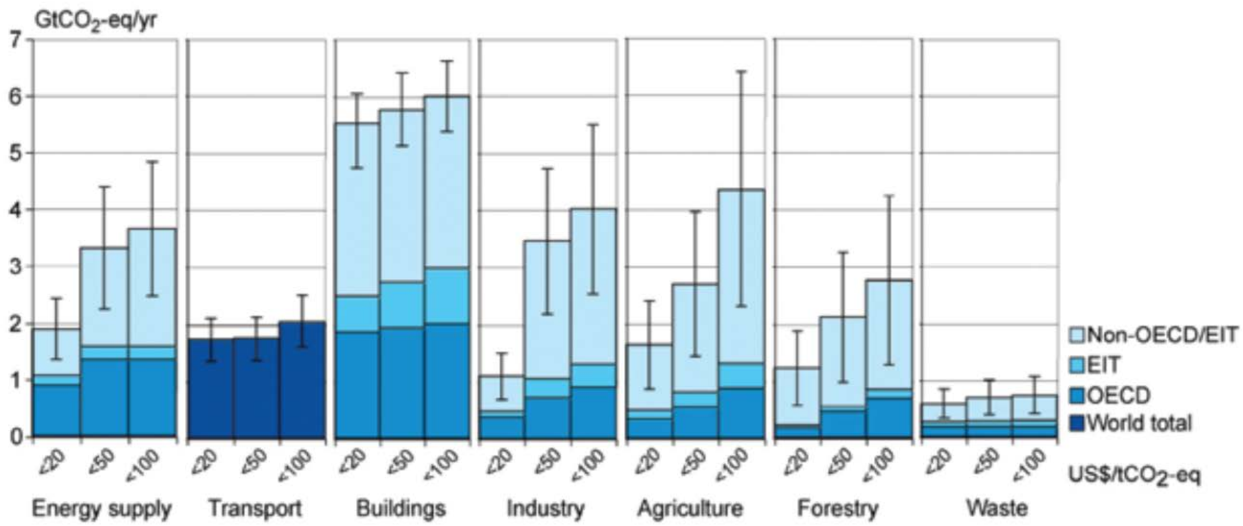


Figure 2: Estimated economic mitigation potential by sector and region using technologies and practices expected to be available in 2030. The potentials do not include non-technical options such as lifestyle changes. Source: IPCC, 2007a.

Making Smart Building Technology Adaptations through Legislations

The European Union (EU) has established a roadmap to achieve the Kyoto protocol's commitments. The EU published a green paper to introduce the 20-20-20 target that is now one of the key drivers of EU energy policy: reducing the greenhouse gas emissions by 20 % below 1990 levels, 20 % of EU energy consumption to come from renewable resources and 20 % reduction in primary energy use through improvement in energy efficiency (COM (2006), (Arbel & Varga,1993). Considering that 30% of the current energy generation capacity will diminish by 2020 due to end of the installations life span, one of the solution to overcome this problem is to adapt to renewable energies. The European market consists of five different electricity grids between Ireland (RG Ireland), the United Kingdom (RG United Kingdom), Nordic countries (RG Nordic), Western European countries (RG Continental) and the Baltic countries (RG Baltic) (ENTSOE, 2012). Smart grids have been defined by the European Smart Grid Task Force as "an electricity network that can cost-efficiently integrate the behaviour and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety" (EU Commission Task Force for Smart Grids, 2010) (Arbel & Vargas, 1993).

The main idea of a smart grid consists of building up links between dwellings, companies, which can both be consumers and producers depending on their configuration, and the energy suppliers. Exchange of energy happens within the distribution grid and between the distribution lines and the transmission lines. Part of the energy comes from the energy suppliers and the production is centralized in parks (wind, solar, bio, nuclear, gas, oil, coal and hydro). This energy is directly fed to the transmission grid and is re-distributed to the different distribution lines and act as a backup when the distribution cannot be self-sufficient. In other words, the smart grid handles the energy flux between the distribution grids (Arbel & Vargas, 1993).

Although some cities are making progress on adaptation, with 'global' cities such as London and New York potentially recognizing the threat that climate change poses to their economic competitiveness, adaptation is by no means firmly embedded throughout the activities of the majority of cities and urban areas. It is valuable; therefore, that research institutes and capacity building organisations are generating an increasingly rich framework of scientific knowledge and practical insights to support the creation of adaptation responses. Examples include the UK Climate Impacts Programme and Germany's Klimzug initiative (Arbel & Vargas, 1993).

Both are comprehensive programmes aimed at building capacity to adapt to climate change, and cover themes ranging from managing the process of developing adaptation responses, good practice case studies and stakeholder engagement. Primary research into these issues is progressing via national and supra-national research programmes, for example projects funded through the UK's Adaptation and Resilience in a Changing Climate (ARCC) programme and the European Framework Programme. At the European scale, projects including PREPARED (which looks at water and sanitation under climate change), CORFU (with a focus on flood resilience in urban areas) and SUDPLAN (which concentrates on adaptation via long term urban planning) demonstrate the richness of ongoing research and capacity building in the theme of urban adaptation (Arbel & Vargas, 1993).

Secondly, the design of cities creates unique micro-climates that affect variables including temperature and wind. The urban heat island effect is a key example, where cities are warmer than their surrounding hinterlands due to the complex topography and mass of buildings, replacement of pervious vegetated surfaces with impervious built surfaces and the emission of heat from anthropogenic activities (Arbel & Vargas, 1993).

Also, sealed surfaces exacerbate flood risk due to reduced infiltration and consequent enhanced rainwater runoff. (Wilbanks et al., 2007) add that within cities, development is increasingly located where exposure to climate change hazards is potentially high, for example in coastal areas, on slopes and within flood plains.

Thirdly, it is recognised that due to factors including their heavy reliance on interconnected networked infrastructure, high population densities, large numbers of poor and elderly people and major concentrations of material and cultural assets, cities are particularly threatened by climate change. Social, economic and political processes, such as poor governance structures or inadequate urban design, can exacerbate climate change risks (Arbel & Vargas, 1993).

For reasons such as these, cities often suffer from weather and climate hazards. A recent report on urban adaptation in Europe focused on heat, flooding, water scarcity and drought, which affected cities in the past and continue to do so. A range of other climate hazards are relevant, from sea level rise to wild fires, and there may be new and, as yet unforeseen, challenges arising from the interaction between increasingly extreme and erratic weather patterns and other socioeconomic and biophysical forces shaping the future of cities (Arbel & Vargas ,1993).

The Need for Extensive Smart Building Development

There is no dispute that smart building has become a prevailing form of building development over the past decade or so (Morgan & King, 2007). For many centuries, buildings have been designed, built and occupied without the introduction of a perception of intelligence, and it can justifiably be questioned why the concept of smart building has been pertinent in recent years (Morgan & King, 2007). In general, the emergence of smart buildings can be explained by three notable changes in our environment. In the first stance, the major global environmental problems facing mankind over the last few decades are dominated by the imminent risk posed by the greenhouse effect and the consequential impact of climate change (Arbel & Vargas 1993).

Buildings have been criticized as a major burden and let down on the war towards climate change and therefore several proponents of this technology have continued to voice their concern on energy consumption of building from both the demand and supply side on the environment and on efforts to lower energy consumption has been assimilated in this new emerging technology of smart buildings therefore have an important role to play in the collective efforts required to avoid significant and possible disastrous environmental degradation (Ancevic,1997).

As reported by (Wigginton and Harris, 2002), a U.K based study found that buildings alone accounted for 46 percent of the total energy consumption and, in turn, are responsible for about half of the greenhouse emissions, besides the environmental concerns, transformations in societal attitudes which reflect a higher standard of living and working have highlighted issues associated with the effect due to carbon dioxide emissions. There is an increasing recognition that buildings cannot be designed in traditional way anymore without consideration for energy conservation which implies that energy demands have to be reduced not only because of the demand that is made on non-renewable fossil fuels, but also due to the large amounts of carbon dioxide emitted from the buildings, emissions which constitute almost half of the greenhouse effect (Ancevic, 1997).

Application Enablement Platform

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 environment within these objects are connected and business value created is called the "Internet of Things" (IOT), according to Heavy reading White Paper.

According to ABI Research, IoT middleware platforms have continued to gain momentum in 2014 as a critical element in the IoT solution enablement and nowhere is this trend more evident than in the Application Enablement Platform (AEP) market. The core value proposition of these platforms is to ease connectivity, device management, and data collection activities of any IoT solution. The evolution to this age of connected devices, sensor-embedded objects and other smart objects has led to a swarm of new innovative offerings. With advances in communication networks and cloud services, there has been a marked trend where enterprises want to exploit the communication capabilities between the devices and harness real-time information from these to create differentiation in services and enhance profitability. Device management platforms typically manage M2M devices deployed by single device vendor, ensuring the use of correct drivers to connect through multiple networks, and managing the firmware and software requirements of those connected devices.

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 (AEPs) 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. AEPs 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.

System Composition of Smart Building

Prior to the invention of smart building technologies, buildings were monolithic structures build so that power supplies, air-conditioning systems, lighting, security systems, communications and computers would all operate independently, allowing little or no flexibility (Morgan & King, 2007), Guo and (Nutter, 2010), (Ancevic, M. 1997), (Platt, Li, Poulton, and James, 2010). One would argue that the traditional building concept were personification of a vacuum, since humans were only interested with a structure where to occupy. As argued by Wigginton and Harris in a conference held in school of engineering Wisconsin University, "humans must satisfy conflicting demands from the building and their organization, as well as personal demands" (Guo & Nutter, 2010).

It was these inability of architectural design to be adaptable to changing world lifestyles coupled with the challenges of climate change that have brought the innovation towards 'smart building". The inability of passive inert buildings to provide comfortable conditions has led to a demand for efficient building systems to overcome these inadequacies. In fact, smart buildings are distinct from conventional buildings as the former are fundamentally equipped with advanced and smart control technologies in order to provide the qualities that create a productive and efficient environment, such as functionality, security and safety; thermal, acoustical, air-quality and visual comfort; and building integrity (Platt, Li, Poulton, & James, 2010).

To anchor this transformation towards a sustainable building as is the results of threat of global warming, policymakers have been approving measures to improve energy efficiency as well as promoting smart technologies. In this setting, building managers are encouraged to adapt their energy operations to real-time market and weather conditions. Yet, most fail to do so as they rely on conventional Building Energy Management Systems (BEMS) that have static temperature set points for heating and cooling equipment. However the challenges have been lack of a sustainable model that can be replicated in every situation that require this technology. There is a lack of an integrated optimization model mimicking the smart BEMS that combines decisions on heating and cooling systems operations with decisions on energy sourcing (Guo & Nutter, 2010).

The commercial and residential building sector accounts for 40% of carbon dioxide (CO2) emissions in the United States per year, more than any other sector. U.S. buildings alone are responsible for more C02 emissions annually than those of any other country except China. Most of these emissions come from the combustion of fossil fuels to provide heating, cooling and lighting, and to power appliances and electrical equipment. By transforming the built environment to be more energy-efficient and climate-friendly, the building sector can play a major role in reducing the threat of climate change (Cano & Ermoliev, 2014). With buildings accounting for around 30-40% of global energy related CO2 emissions and offering the most cost-effective mitigation potential, the sector has become a focus for climate change policy-makers. Yet as this research highlights, our current building energy policies are not on-track to deliver the sector's CO2 mitigation or energy savings potential.

In the U.S. alone, buildings account for 40% of all energy use and 38% of all carbon emissions. Smart buildings give way to smart environments. The buildings considered are residential units and social infrastructures that include schools, social halls, health centers', market centers' and other recreational facilities (Jansen & Overpeck, 2007). Buildings have a key role to play in energy and climate policies. Globally, they account for 30% to 40% of total final energy demand and over 30% of all energy-related CO2 emissions. The four priority GBPN (Global Buildings Performance Network) regions – China, Europe, India and the United States – together represented more than 60% of global final building energy use in 2005. China and India, in particular, are growing at a rapid pace (Jansen & Overpeck, 2007).

The GBPN activities cover the four regions responsible for about 65% of the world's GHG mitigation potential from energy savings in buildings: China, Europe, India and the United States. These regions also represent geographic zones and gather economic sectors that have the greatest potential for reducing greenhouse gas (GHG) emissions from the use of energy in buildings. "Buildings are a cornerstone of human development.

They also represent a large and growing share of energy use and emissions globally. Policy and innovative investment can help us make buildings more efficient and comfortable. GBPN plays a critical role in linking the world's experts on building energy efficiency and providing best practice policy advice," (Meredydd, 2015).

Increasing energy efficiency is the quickest and least costly way of addressing energy security, environmental and economic challenges. Governments play a crucial role in setting up cross-sectional frameworks for energy efficiency and ensuring that the frameworks are put to good use and the results can help reap energy efficient systems. Using data from Britain, USA, France, Singapore, Seoul, Japan, Austrian and a Spanish building, earlier researchers found that the smart BEMS results in greater reduction in energy consumption than a conventional BEMS with policy measures (Guo & Nutter, 2010). In general, the smart building is characterized by a hierarchical presentation of the system's integration. The top level of building control usually refers to the integrated building management system (IBMS) or the building automation system (BAS), and underneath it, a number of control systems manage building services (Ancevic, 1997).

These services include the addressable fire detection and alarm system (AFA), heating, ventilation and air-conditioning control system (HVAC), digital addressable lighting control system (DALI), security monitoring and access control system (SEC) and smart and energy efficient lift system (LS) (Ancevic,1997). The telecom and data system (ITS) acts as a communication network backbone to allow the building management and control systems to interrelate with one another in a natural way, allowing for the input and output between systems and the control of that system. An overall overview of the functions and latest development of each of these building management and services control systems in the smart building otherwise called "smart building technologies' are outlined and described in the preceding sections.

A smart building will have an advanced building management system with an open programming language where all integration is accomplished via software. It requires middleware to normalize and standardize all data from sub-systems into an open, standardized database using SOAP/XML or other computer software exchange architecture. The database would include all physical, virtual and calculated points. The user interfaces to the advanced systems are displays and dashboards completely configurable and customizable by users, with access via a browser. The system would be capable of data exchange with information in enterprise and business level software, providing a suite of software applications such as energy management, building performance analytics, alarm management, and automatic fault detection and diagnosis.

Building Automation Systems

Building automation systems have a hierarchical structure consisting of field, automation and management layers (Kastner et al., 2005b) as shown in figure 2.3. The field layer comprises of temperature, humidity, light level, and room occupancy sensors. The actuators are made up of automated blinds, light switches, flow valves etc. The automation layer consists of direct digital controllers (DDC's) which provide precise automated control of building processes using digital devices (Newman & Morris, 1994), while the management layer provides centralized management of the entire system. It provides a view of the whole building, facilitating centralized control, data collection and analysis.

A primary function of building automation systems is energy management. This goal is achieved by means of schemes such as the duty-cycling of loads to conserve energy; peak load management to regulate total power consumption during peak hours; scheduled start/stop of building HVAC systems at the beginning and end of each day; and real time control of building systems in response to occupancy detection (Merz et al., 2009).

The use of BAS has enabled buildings to dynamically respond to current weather conditions, room occupancy, time of day and various other inputs, resulting in significant reductions in building energy usage. Sensors and actuators are an integral part of home and building automation networks. These devices serve as the eyes, ears, hands and feet of the system. Unfortunately, wiring costs frequently exceed the cost of sensors (Gutierrez, 2004), so the availability of low-cost wireless communication schemes such as Zigbee (Zigbee Alliance, 2008) enables cost effective and rapid deployment of wireless sensors and actuators throughout a building. Wireless nodes also provide flexibility, easy re-deployment and reconfiguration, all of which are very important features for commercial buildings as they are often re-partitioned and modified to meet differing occupant requirements.

Integrated Building Management System (IBMS)

The IBMS is the most critical element and considered as the core or 'soul' of smart building. The critical primary function of the IBMS is to provide automatic functional control and to maintain the building's normal daily operation. Other functions include power, quality monitoring and analysis, distribution analysis of electricity, gas and water consumption, which is performed by the Building Automation System (BAS) which is a component of IBMS. In essence BAS is an automatic functional control of building services systems to maintain the building's normal daily operation with the emphasis on standalone, decentralised function units rather than centralized control and monitoring function. Therefore IBMS integrates all essential building services systems to provide an overall strategic management in all aspects with the capability to systematically analyse and report the building performance and connect with multiple sites/locations to give the corporation a portfolio view of the situation (Ancevic, 1997).

Trends in Building Automation System

Building automation is a programmed, computerized, intelligent network of electronic devices that monitor and control the building services systems in a facility. The aim is to create an intelligent, effective building and reduce energy and maintenance costs of the facility. Nowadays, modern buildings often implement the automation based on direct digital control (DDC) which consists of microprocessor-based controllers with the control logic performed by software. For further description about DDC for building automation, the website “www.ddc-online.org” provides unbiased information on it and would be a good information source for study.

Nowadays, efforts to make buildings smarter are focusing on cutting costs by streamlining building operations like air conditioning and lighting. Building automation is crucial to these efforts, mainly because it could reduce the annual operating costs of buildings through effective monitoring and optimization. Most of the recent developments in building automation are on the system integration part (EMSD, 2002) and the automation trends in large buildings are affected by communication technologies (Sinclair, 2001). Yesterday's hierarchical systems with vertical information flows are being replaced by systems that have a flatter structure and more diverse information flow patterns.

Telecom and Data System (ITS)

Another important component of smart building 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 is to generate, process, store and transmit information in the smart building (Ancevic, 1997). The key components of the modern ITS include PABX, total building integration cablings, broadband Internet access and CATV 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, IR, Internet technology, Wi-Fi, Java, soft-computing for system diagnosis and monitoring as well as universal plug and play (Ancevic,1997). The use of Web-enabled devices allows remote monitoring of the building by interaction of the central IBMS or BAS workstation with the remote dial-up system via modem (Ancevic, 1997). The data from sensors and controllers can be relayed in real time 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 (Ancevic, 1997). 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.

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 either of 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 (Platt, Li, Poulton, & James, 2010).

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 (Platt, Li, Poulton, & James, 2010).

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 (Platt, Li, Poulton, & James, 2010).

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 (Guo, 2010).

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 (Bálint, 1995). To proof the importance of HVAC, a research on building energy usage found that HVAC systems on its own generally account for between 25 to 30 percent of the total building energy usage (Bálint, 1995). 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 (Bálint, 1995).

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 (Guo, 2010).

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 (Bálint, 1995). 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 (Platt et al, 2010). 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 (Guo, 2010).

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 (Bálint, 1995). 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 (Bálint, 1995). Biometric security systems are nowadays encouraged as design choices in upcoming, internet ready smart buildings as this takes security to another level.

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 system 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 (Platt et al, 2010).

Environmental Issues

We are facing new challenges over global warming and long-term supply of fossil fuels. This, combined with the pressure of an aging electrical generation infrastructure, is putting the onus on new programs for high efficiency and even zero-energy buildings. Mitchell (1998), (Gray, 2006), Ehrlich (2007), Rios-Moreno et al. (2007), Moore (2009a), and Liu et.al. (2010) observe programs promoting energy efficiency need to have an intelligent system design as one of their core elements. They account their hypothesis to the varied functions of intelligent control systems such as stop and start equipment when needed; monitoring space conditions and occupancies; and implementing sophisticated strategies to reduce overall energy use. Intelligent buildings also improve indoor air quality through continual ventilation adjustments and air-quality monitoring; and maximise day lighting by automating shading systems.

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). In order to achieve this, occupancy sensors are used that provide enhanced presence detection and accurate localised occupancy information to provide solutions that are energy-efficient without compromising on occupant comfort and productivity (Dounis et al., 2011 and

Pandharipande and Caicedo, 2011). Although the cost of occupancy sensors varies by the type of sensor used, it is observed that they can usually pay for themselves through energy savings within a few years. Thus, in most cases, occupancy sensors offer greater energy savings and more flexibility than other forms of control and have proved to work effectively in a variety of applications. (Barnes et al., 1998 and Wu and Noy, 2010).

The SMART 2020 programme, informs that intelligent buildings and accompanying smart grids will save around 4 gigatonnes of CO2 equivalent emissions in 2020. (Futureagenda, 2011). IBM estimates intelligent buildings can reduce energy consumption and CO2 emissions by 50% to 70% and save 30% to 50% in water usage (Moore, 2009b). Johnson Controls, leading producer of energy-saving equipment, says companies can cut energy bills by 20% to 25% by using efficiently programmed and monitored building management systems (BMS) and other intelligent controls (Mazza, 2008). Peter Ferguson, Director from Johnson Controls, explains 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).

Despite all the potential energy saving benefits that have been highlighted, (Matsunawa and Nohara, 1994) claim that intelligent buildings use a lot of energy. Sunil Shah, head of sustainability at engineering and construction company, Jacobs, asserts that incorporating methods such as better building design and passive or natural energy-saving solutions can save more energy (Damodaran, 2006). Bob Hayes, director at architecture firm, Architype, argues passive solutions are more sustainable because they don't need to be updated or refreshed during their lifetime and continue doing their job as long as the building lasts (Elkadi, 2000).

Two scenarios of a smart Home

Scenario One: A scenario such as 'I'm Home' could be triggered by pressing one button on a key-ring remote-control from your vehicle as you approach the driveway. The control system receives the key-ring remote-control command. This will then trigger a pre-programmed sequence of functions, for example starting by turning on the lighting in the driveway, garage, hallway and kitchen. It then disarms the security system, opens the garage door, unlocks the interior garage entry door, adjusts the heating to a preset temperature and turns on the whole house audio system playing your favourite CD whilst drawing you a bath (Berner, 2004). In this case the control system is programmed to meet specific user requirements, initiating sequential automatic operation of the home systems, in response to 'one button' commands based on the situation and on time.

Scenario two: It's 7.30am and you wake to the sound of your favourite CD playing in the background, the lights in your bedroom switch on; 'fading up' to allow you to wake up in your own time. The downstairs intruder alarm system is de-activated. In the kitchen, the coffee machine turns on to make a drink. The ground floor curtains and blinds open; the towel heater in the bathroom warms the towel. And you haven't even got up yet (Berner, 2004)

Strengths of a smart building for climate change mitigation

Smart building for climate change mitigation: Successful climate mitigation policy must address building efficiency for two reasons: first, because commercial and industrial facilities in the US contribute nearly half of the country's total greenhouse gas footprint; and second, because smart building technologies take energy efficiency to the next level and effectively combat energy waste while generating economic value – a critical benefit for political and business acceptance. The EPA's Energy Star program has long focused on facility energy consumption. It's also targeted awareness, technology and innovation to reduce buildings' environmental impact. Energy Star Fast Facts conclude that in the U.S., 45 percent of greenhouse gases (GHGs) are generated by building energy consumption. If building operators could achieve energy efficiency improvements of just 10 percent, national energy costs would shrink by $20 billion -- equivalent to removing 30 million vehicles off the streets.

A smart building incorporates information from occupancy and daylight sensors, equipment meters and the insight of building operators to adapt in real time to internal policies and external signals to reduce the energy needed to operate the facility, while still meeting crucial occupant requirements. Smart building technologies can be effective tools of climate change mitigation because the advanced controls and automation that define these solutions simultaneously save the overall energy demands and associated GHG emissions -- as well as generate significant business value. (IDC Energy Insights web site*)*

Smart buildings and Earth quakes: The first early months of 2015, we had the misfortune of witnessing one of the worst natural disasters of the century…the Nepal Earthquake. The horrors suffered post the near apocalyptic destruction not only instill fear but also, makes you realize the significant co-relation between earthquakes and building construction (IPCC, 2015). The first thing that needs to be clear is that an Earthquake does not directly lead to loss of life…the shaking of the ground results in destruction of buildings & infrastructure which may lead to injury or loss of life…People generally die due to building collapse, many times without warning or giving enough time for people to evacuate. Hence we may conclude that inappropriate construction practices for buildings have led to its inability to withstand the force of an Earthquake (IPCC, 2015).

Malpractices and professional indiscipline are so rampant in the built sector that sanity is required today rather than tomorrow. Due to this, there are buildings that look better during construction but look worse when or before completion, and those are the collapsed buildings. Quack Architects, quack Quantity Surveyors and quack Electrical engineers, quack Masons among other quack building professionals, when done with the building, the building most of the times comes quacking down. Cheap is very expensive. It's better to bring down a poorly done building beforehand than loosing lives and property when it comes down in case of an earthquake or just by itself due to professional misfits. There is need to inculcate level of professionalism in the construction industry as today, buildings built over 400 years ago are still intact, why should a building built this year or last year collapse? If it can go down on its own, what of if an earthquake strikes?

Unfortunately, unlike predicting tornadoes, cyclones and even tsunamis, science has not yet come up with a full proof method of predicting earthquakes. But even if it is not possible to predict earthquake with accuracy, it is always possible to minimize loss of material and life by constructing buildings which can safeguard its inhabitants as well as people outside, from an earthquake, simply by following scientific design principles and use of smart building materials.

All advanced countries and most developing nations, including India, have predefined building codes which if strictly followed, can help prevent large scale disasters. Unfortunately in developing nations, very minute percentages of such buildings are ever made, making people more susceptible to calamities (IPCC, 2015). The terms "building codes" or "energy standards" for new buildings generally refer to energy efficiency requirements for new buildings whether they are set in building codes, specific standards or other ways, unless otherwise stated. In some countries, building codes and standards for energy efficiency are set at a national level. In countries with large climatic differences the national building codes might include values which are adjusted to the local conditions.

Walls built with heavy walling materials tends to render the building more rigid and less flexible to seismic forces…when an earthquake occurs, the building can sway horizontally or vertically and if the building is too rigid, the propensity to develop cracks will be higher, ultimately leading to collapse. On the other hand, light weight walling materials like Porotherm Smart Bricks, by virtue of its perforations/hollows, are typically 60 % less weight than conventional materials, can make the building more flexible to ground movements… It will swing and sway and it might be damaged. But the possibility of collapse is comparatively minimized. An earthquake resistant building, which has been damaged, could, most of the time be repaired (IPCC, 2015).

Web-based Control Networks: (Sinclair, 2001) has pinpointed 11 revolutionary automation trends in large buildings and he put the World Wide Web as the first point. Needless to say, the Web is influencing every other industry in the world and affecting many aspects of our everyday life. Generally speaking, the Web can act as a catalyst for accelerating the process of system integration and standardization, because technologies for all businesses are converging on the Web and taking advantage of the market potential that it represents (McGowan, 2001).

Current trends to work from home and to have more global traveling encourage remote interaction with building communications and services. Even within the same territory or campus, Web-based control networks that communicate over the Internet using standard Web browsers can offer a convenient access and a familiar, effective interface to building managers, operators, users and visitors. It is believed that the Web is transforming the interface of building control and will have a significant impact on the way the building owners manage facilities and building equipment.

The Web interface capability makes building data available to everyone in the organization and this function will enable a host of management advances. Control based on real-time data that may come from anywhere in the Web is exciting, and the only limitation is creativity (McGowan, 2001). Having said that, the potential of Web-based BACS has not been fully explored at present. Some pilot research studies have been done in Hong Kong on integrating BACS and facilities management on the Internet (Wang and Xie, 2002; Wang, S., et al., 2007). It is believed that future BACS will make frequent use of the IT (information technology) or IP network as a backbone network.

Wireless and Mobile Technologies: Wireless technology can offer many conveniences and be a cost effective solution for BACS (Edler and Wang, 2006). For example, with wireless mobility, building operators and maintenance personnel can track building operations wherever they are. Also, wireless connectivity can save wiring, simplify future changes and enhance system performance. With careful planning, using one wireless backbone for several systems can reduce engineering, construction, commissioning and operating cost over the entire life of the building. Of course, to make this control network convergence possible, the wireless network should provide sufficient bandwidth and Quality of Service (QoS) required for all the related applications.

There are many scenarios where wireless is a viable and preferable option, such as locations which are difficult or expensive to wire, interconnecting multiple buildings, and need for mobility. Usually, wireless sensors and transmitters are deployed for inaccessible or hazardous areas or special aesthetical requirements. Also, wireless access is interesting for management functions like log file access for service technicians or presenting user interfaces to tenants on their personal mobile devices. Today, mobile telephones are well established, allowing mobile communications in many other forms. This technology has value for in-building applications. In particular, for the occupants/tenants and the operators, mobile technologies can yield substantial efficiencies.

The Benefits of Implementing Smart Building Technologies

From the literature review in the section covered so far, it is clear that smart building design is the future of building industry for both developing and developed nations. It is plausible that smart buildings often encompass a set of advanced and smart control systems. Another observation is that there is an upward interest in smart buildings in recent years both for potential benefits that it delivers to developers and end-users but also as a response to climatic changes worldwide. Outlined here are key benefits as reviewed from various scholarly and empirical research findings.

Enhanced Operational and Energy Efficiency

The most functional and critical benefit of the smart building is in creating a sustainable building in the age of climate change, the building is build to balance both the consumption and emission of green house effect as well as to ensure that the installed building control systems have the capacity to handle expected user requirements (or can be readily modified to do so) and to cope with likely changes of user requirements in the future (Guo, 2010). In a nutshell, the end-users expect good lighting, thermal comfort, and a clean and adequate supply of fresh and re-circulated air that is free of odours as well as contaminants and therefore such a building is built smartly to respond promptly to meet the needs of end-users or occupiers in a timely and consistent manner by embedding knowledge, and should possess the ability to reason through its automation systems and ecosystem of adaptable features (Guo, 2010). It has some inbuilt control systems designed to improve operational efficiency by providing tools that help operation and maintenance staffs target their efforts more effectively as much as balancing the demand and supply side of total energy consumed and emitted (Guo, 2010). It is a sore for one to enter a building and meet a strong stench of unkempt washrooms. A smart building should ensure good air circulation for healthy occupants.

Enhanced Cost Effectiveness

It has been a long journey since evolution and acceptance of smart building model, at first, the technology was considered way out of reach of ordinary buildings, but with reality of the long-term benefits versus the initial costs the emphasis has changed in favour of the smart building model. With respect to this, some scholars have argued that when one examines the true cost of a smart building, one should take the initial capital costs as well as all of the whole life costs into consideration (Antsaklis, 2000). Technology in other sectors has advanced more rapidly than in building sector.

Whole life costing helps to justify decisions that have beneficial health and safety, environmental and sustainability implications. Over the last decades, end-users are continuously demanding high quality, more sophisticated and more reliable building services, including, for example, high-speed Internet access and improved internal security. However, the use of modern technology to enhance the effectiveness of a building is associated with additional capital costs when compared with those of less sophisticated buildings (Bálint, 1995).

Increased System Robustness and Reliability

There is also enough evidence both from scholarly and empirical review that smart buildings in addition to improved operational/energy efficiency and lower whole life cycle costs, literature also suggests that smart technology can further help to enhance reliability and reduce the level of maintenance required (Cano & Ermoliev, 2014). The advancement of smart technology has also been necessitated by continuous advances in information technologies which provide new technologies by which high quality, flexible environmental control can be ensured, and thus enhance system robustness while still appreciating that life span of building is 'narrow' since building services wear out relatively quickly and need space and regular maintenance. Therefore one can as well say that the risk of current technology becoming obsolete is a potential risk of the smart building and so it is incumbent upon the industry to be adaptable (Antsaklis, 2000).

Improved User Comfort and Productivity

It is clear that buildings are made for people and so user comfort which is determined by a range of psychological as well as physiological factors is the most explicit beneficiary of a smart building (Antsaklis, 2000). User comfort is associated with the well-being and productivity of human beings, whereas productivity relies on a general sense of high morale and satisfaction with the environment which are directly related to each other (Antsaklis, 2000).

All of these arguments suggest that the building and its service systems are closely related to the well-being of occupants inside the building. Smart building ensures that poor air that can affect the health of building users and the method of ventilation has implications for air quality issues are taken care by ensuring ventilations are effective and good air reach the breathing space of building occupants. In addition, thermal discomfort has detrimental effect on performance and noise levels can affect concentration, ease of communication between staff and privacy of communications. Inadequate illumination levels, poor colour rendering, inappropriate directional effects and lighting systems that result in glare problems can lead to deterioration of visual acuity.

Climate Change Control

The significant shifts in climate variables projected for the 21st century, coupled with the observed impacts of ongoing extreme weather and climate events, ensures that adaptation to climate change is set to remain a pressing issue for urban areas over the coming decades. To anchor this transformation towards a sustainable building as a result of threat of global warming, policymakers have been approving measures to improve energy efficiency as well as promoting smart technologies (Antsaklis, 2000).

In this setting, building managers are encouraged to adapt their energy operations to real-time market and weather conditions. There is now planning that seeks to contribute to the widening debate about how the transformation of cities to respond to the changing climate is being understood, managed and achieved. Recent developments in building technologies in the USA, Europe and Japan reflect the trend towards more smart and energy-efficient buildings. A variety of building products with automatic features are being developed and electronic building systems and computerized building components are being manufactured (Guo, 2010).

Virtually all buildings being built today are equipped with some degree of advanced technologies: for example, electronic control devices and communication systems, automated building facilities, and office automation facilities. Emerging transferable learning with potential relevance for adaptation planning in other cities and urban areas is drawn out to inform this rapidly emerging international agenda. Approaches to build adaptive capacity challenge traditional approaches to environmental and spatial planning, and the role of researchers in this process, raising questions over whether appropriate governance structures are in place to develop effective responses.

Inhibitors to Smart Building Adoption

Despite such benefits, corporate uptake of smart building implementations has remained relatively limited to date especially in developing countries which are likely due to several factors and challenges which continue to have inhibited adoption of BIM intelligence (Becker, 2002). The most immediate challenge lies in poor data infrastructure which makes smart building technology difficult to implement since accessing and disseminating the data from the existing building management systems and sending to disparity of systems, of varying designs and different communication protocols make the entire smart technology not to function easily. Even where the smart building solution may be hosted externally, a secure connection may need to be established, which can complicate the data exchange and delay the rollout. Data volumes can be significant and can conflict with available capacities for extraction, transfer, storage and processing (Becker, 2002).

Another challenge is depth and breadth of available other smart technology example CCTV, Sensors, GIS, GPS, fiber optics which is a huge investment especially where none is available for example, air conditioning usage needs to be mapped against weather conditions to distinguish savings simply due to favorable weather from real improvements. Internal data, such as the number of occupants, is similarly needed for meaningful analysis (Becker, 2002).

Another challenge is technical knowhow of engineers which constitute usability challenges which is a common barrier to adoption, as many engineers have had limited exposure to advanced analytics tools. Some applications run the risk of overwhelming users with too many features, presented via a non-intuitive or unfamiliar user interface. The IoT deal with millions of sensors, thus the data analysed in this case is enormous. Another identified challenge of adoption of smart building has to do with Organizational support and change management since implementing a smart building system require specially trained experts and special rollout which relies on many stakeholders. One particular challenge is the need for full commitment and close collaboration between all stakeholders – executives, building engineers, IT staff and external vendors. Engineers can be faced with conflicting workloads from both old and new responsibilities, which can inhibit uptake and delay payback period (Benzon & hays 2008).

This coupled by budget constraints whereby although the cost of implementing a smart building solution can be modest compared to the operating cost of the building, budgets are often tight and facilities teams may find it challenging to secure funds for such programs. Real estate leaders face the challenge of demonstrating both cost and sustainability benefits in their business case. Implementations for small portfolios are harder to justify as they lack economies of scale (Becker, 2002).

Proposed factors for Ubiquitous Application Enablement Platforms for Smart Buildings

A review of literature in the areas of smart building and engineering has indicated that it is a fragmented one which lacks a general agreement on the factors and sets of crucial factors for implementing the building control systems for the smart buildings. Both the theoretical review as well as empirical review has suggested the variables that might influence the type and nature of smart building systems which form the basis of the current study. These factors are now presented as seven factor grouped according to their contribution towards enabling environment for smart building architecture and model, they are; Financing/cost Effectiveness, Work Efficiency (Functionality), User Comfort, Architectural Value, Environmental, Technological, Safety and Risk-related factors. By mitigating the challenges associated with similar traditional solutions through its cost-efficiency and simplicity, the application enablement platform has paved the way for new application areas, which were previously not possible with other competing solutions.

Financing/Cost Effectiveness Factor

From the literature review, financing/cost effectiveness has been regarded as a key factor in selecting the components for a smart building in applying application enablement platform. Investment in smart building is a life cycle cost from developer's stakeholders and end-users. The main concern of building developers is to search for ways to reduce costs of operating and maintaining of the building and to increase its value. The 20/80 rule applies, whereby 20% of cost is spend on design and implementation, whilst 80% on operation and maintenance features as a smart building will reduce the 80% cost of operation and maintenance for a smart building as compared to the traditional one. It has been argued from the literature that since the greatest savings in the adoption of a smart building are seen in a reduction in energy consumption and operational costs, and given the higher initial capital investment compared to a traditional building, the cost benefits of a smart building would not be immediately appreciable.

Therefore the importance of the life cycle cost is more important than the consideration of the initial cost in a building or developing the property since any planning and monitoring of the assets of a building should cover the entire life cycle from the early development stage to the final disposal stage. In general, life cycle cost is referred to as the total cost of owning, operating, and maintaining a planned project over its useful life. For selecting the appropriate building control systems for the smart buildings, some authors argue that the financial decisions should consider the whole life cycle cost instead of the initial cost alone which suggests that the scale of cost savings in the smart building ranges from 10 to 40 percent of the operating and maintenance costs of a traditional building. Others also point out that the initial set up cost covers only 25 percent of the total cost over the lifetime of a building, while the operating and maintenance costs cover approximately 75 percent.

Smart building technology, while requiring some capital expenditure (cap-ex), is helping to reduce operational expenditures (op-ex) on the other side of the ledger. The resulting savings, according to two major corporate energy management studies done last year by The Economist Intelligence Unit (EIU) and Deloitte, have become increasingly essential to remaining financially competitive in the global marketplace according to Deloitte Company. Investors in commercial property are beginning to see the upside of smart building technology. Christopher Wilson, managing director at LaSalle Investment Management, is confident that operational savings from smart building technologies play into an overall competitive strategy that will help his company's bottom line. "We believe that our buildings will be seen as more competitive," he says. "They will lease faster because of lower operating expenses than their peer set and will command better pricing on sale."

"If we can reduce energy usage and keep equipment from starting during (peak) time, it can mean hundreds of thousands of dollars saved "says John Leslie, MGM Resorts International. "(A smart building) is still a cost premium. But by spending upfront, it‘s possible to reduce costs dramatically, "says Robert Knight of Environmental Systems Design. Legislative measures in the U.S. Congress could encourage the aggregation of project financing across and within sectors. For instance, using green banks and large mortgage organizations would allow for more efficient allocation of capital. According to the EIU report, Achieving scale in the US: A view from the construction and real estate sectors, the mood for such measures is shifting favorably toward the smart building sector.

Work Efficiency (Functionality)

Another observation made from the literature in addition to the cost factor is what has been described as work efficiency factors, which constitutes the capabilities of a system in managing the complexity and ensuring functionality of the building. These are widely considered as indispensable factors in the decision on the smart building components selection since the overriding function of the smart building systems is to support the capabilities inherent in it. Developers need to deliver the building's desired capabilities with the adaptability and functionality desired by the end-users.

There is importance of work efficiency in the smart building, because the fundamental purpose of adopting the smart building systems is to offer improved operational effectiveness and efficiency, as well as reduced maintenance also maintains that the essence of the automation systems in the smart building is to enhance service reliability, improve building management, tailor requirements, increase the lifespan of equipment, and ease data collection. Work efficiency criteria include reliability, efficiency, system grade or level, service life, possibility of system further upgrade, compatibility with different network protocols since it has been argued that it is important for an IBMS to demonstrate its ability to integrate products from different vendors. An efficient IBMS is also expected to be able to achieve total integration by requiring all building systems to communicate with the control server using a common protocol supported by the LAN as well as the interoperability of the various building systems.

A smart building management system, combining data analytics with facilities management experts, can detect such breakdowns immediately and even send an alert for a facility management professional to address issues that otherwise would go undetected for months. None of this, of course, removes facilities management (FM) from the equation. Rather, smart building technology helps increase FM productivity. Allowing machines to monitor machines 24 hours a day releases building engineers to address more pressing tasks with greater worker efficiency, thus adding to portfolio value.

User Comfort Factor

The basic intention of a building is for it to be planned, designed, built and managed to offer an environment in which occupants can carry out their work, feel well and to some extent feel refreshed by the environment. A truly smart building must address occupant well-being and health, and it needs to take the quality of the working and living environment into account when bringing in new technology for the purpose of improving the performance of business organizations. Thus, maintaining a stable and comfortable internal environment for the end-users becomes a crucial objective in the design and selection of building control systems as the smart building needs to provide the people working and living in it a good sense of well-being. While it is important to ensure a permanently healthy environment for the end-users and allow an optimal performance in their activities, (De Wilde et al., 2002) indicates that the conditions in the indoor environment must be adjusted as to ensure and maintain five main comfort conditions. These are thermal comfort, air quality, visual comfort, acoustical comfort and vibration control.

Architectural Value

In the case of new construction and most building renovations the architect is the main interface for the building owner. It's the architect that develops the owner's facility program and assembles a design team, both of which are critical to the overall success of the project. With such a prominent role, the architect heavily influences just how smart the building will be. Surely architects understand that the control, monitoring and automation systems are an essential aspect to a smart building. Those systems are the dynamic components or facet of the building, the nervous systems allowing for adjustments in the building's environment as well as optimal operational performance related to life safety, comfort, security, energy and a healthy atmosphere.

However architects also understand that it's not just control systems that comprise a smart building. The "fixed" attributes of the building such as the initial siting, the structure, the envelope, windows, interior layout, etc. also play a major part in how smart the building is and how the building will operate. The best building control systems cannot compensate for the worst building structure and layout; and in the same way, the best structure cannot compensate for the worst building control systems. Both are critical in creating a smart and well-designed building. What follows are some of the functions and responsibilities of the architect and how they play a role in designing, constructing and operating smart buildings.

Architectural management aims to facilitate the creation of value through the strategic management, process design and control of the collaborative multidisciplinary design of buildings. Given the different object worlds of the parties' involved, architectural design can be seen foremost as a social process (Sebastian et al., 2007) with the aim of developing a shared understanding of the design problem (Kvan, 1997; Hill et al., 2001; Emmitt and Gorse, 2007) to create and enhance architectural values. Architects work together and with other actors in the process such as engineers, developers, clients and users to arrive at a design that is convincing to the client and that satisfies the constraints and goals of the project, and all the directly and indirectly involved stakeholders. All of these actors bring different values, goals, methods and languages to the project. The agreement of goals, the sharing and creation of values, the coordination of design activity, the allocation of risk, the exchange of information and the resolution of differences can all be possible areas of conflict, frustration and ineffectiveness within the design process. The outcome of architectural design is a building, fulfilling the client's needs, which exists and expresses itself within the public domain. The values to be addressed within architectural design cover a wide range and differ from cultural, ethical, aesthetical, philosophical and societal dimensions (mainly having their expression within the public and professional domain) to organisational, functional, technical and economic aspects (mainly influenced by the clients, users and project partners involved).

The main axiomatic assumption stated in this chapter is that value creation, in particular architectural value, is the ultimate aim of every architectural design. To explore this assumption the concept of architectural value is discussed by addressing its complexity. From this, it is concluded that depending on one's viewpoint and stakeholder perspective, the language and concepts behind architectural value are, and ought to be, different. (Dewald Booysen, 2012)

Architects frequently help the building owner in selecting and acquiring the building's site for new construction, or for existing buildings, in assessing current conditions and updating a survey. Why is the site selection process important to being a smart building? Because it is a long lasting, a 40 to 100 year decision, the specifics of a site, the topography, climate and available public utilities will affect the design and construction of the building, possibly including the deployment of specialized building systems such as seismic, tilt, corrosion, and ground pressure monitoring. Also, the general area surrounding the specific site is critical; proximity to transportation infrastructure, to other businesses, schools and to skilled labor pools may be important to the long term success of the building.

Environmental Factor

In recent years, carbon emissions have been recognized as a cause of global climate change. A number of studies have identified buildings as being responsible for about half of all energy consumption, and, in turn, as responsible for about half of the greenhouse effect due to carbon dioxide emissions. This has aroused a growing awareness of the need for energy-efficiency in the design of the modern buildings. It has been well argued that the smart building technologies should contribute to greater energy efficiency in buildings, and should control the contribution of the building sector to atmospheric carbon concentrations maintaining that attention needs to be given to minimising unnecessary consumption of energy, water usage and waste production in the selection of the building components for the smart building. Of all the building services concerned, HVAC and lighting systems are regarded as the most energy-intensive (So et al., 1997).

Point out that it is important for building control systems to conserve energy while providing satisfactory performance. For example, an efficient HVAC control should not only provide an efficient control scheme to maintain human comfort under any load conditions, but should also reduce energy usage by keeping the process variables (i.e., temperature and pressure) to their set points (Benzon & hays 2008).

Technological Factor

For the past decade, it has been observed that there have been an increasing number of developers considered adding "intelligence" to their buildings. According to (Wan and Woo, 2004), a main stimulus for the development of smart buildings is that the building developers are more receptive to new technologies. They not only desire to create product differentiation and to project their high-tech building image by incorporating innovative and smart building components, but they also struggle to meet demands of end-users for access to rapidly changing information technology services (Armstrong et al., 2001).

To retain the tenants (i.e., the end-users), it is necessary to keep up with changes in information technology and provide for upgrades as technology evolves. As argued by (Neubauer, 1988), the phenomenon of demanding a high-tech building can be explained by the Hierarchy of Human Needs, which was developed by Maslow in 1954. To apply this theory to the concept of smart building, people initially use buildings to meet their basic physiological needs in terms of heating, air conditioning, ventilation, lighting and water. The next stage involves the requirements of satisfying their safety needs from the standpoint of security and fire protection. Building intelligence then appears in the form of information systems designed to better meet physiological, psychological and safety needs by automatically monitoring and managing energy consumption, security, fire protection and the ever-rising needs of building end-users (Neubauer, 1988).

Safety Related Factor

The other proposed factor for smart building components selection relates to the safety issue. For the protection of human beings, safety is considered as an important goal that cannot be tampered with in the design of the building systems of the smart building (Benzon & Hays, 2008). Of all the building services concerned, the safety issues of lift control systems (LS) and fire detection systems (AFA) are a major concern in the smart building. For example, (AIIB, 2004) argues that it is important for a lift control system in the smart building to detect and identify trapped passengers inside a lift car. A few building component selection models, besides the worlds of AIIB and BRE, have also been documented in the construction literature. For example, (Lutz et al., 1990) proposed a model for the evaluation of new building technologies, but the assessment is limited to the evaluation of the workability of the technologies.

(De Wilde et al., 2002) also developed a model of energy saving building components selection and suggest six general factors of building components selection. Specifically, these factors include comfort, functionality, safety, architectural value, financing and environmental impact, often capital-intensive and disruptive to operations. By using software, designers ensure infrastructure runs more efficiently, requires minimal capital investment and results in little or no disruption for occupants. From an economic standpoint, this should make it the preferred starting point for increased energy efficiency in a real estate portfolio.

Risk Factors and Adaptation

Risk assessment framework is the principle behind the theory of resilience and adaptation towards climatic changes which is emerging as an admirable concept to support this broad approach to adaptation in urban areas, where identifying and subsequently reducing risks from extreme weather and climate hazards acts to lessen the frequency and intensity of shocks to urban systems (Benzon & Hays, 2008). This broadly follows the work of Ulrich Beck, which charts the progressive evolution of industrial society into a risk society, where risks are described as "… systematically caused, statistically describable and in that sense predictable types of events, which can therefore be subjected to supra-individual and political rules of recognition, compensation and avoidance" (Neubauer, 1988).

During short-term events, building infrastructure is impacted by major structural damage, damage to a building's support and utility systems, closure and loss of revenue among other items. Over the long term, severe weather and more extreme temperatures lead to accelerated degradation of a building's envelope, utility systems and infrastructure. Steps need to be taken to maintain the building exterior and envelope to prevent damage to the building and its' equipment. At the same time, the design and intelligent infrastructure of the intelligent building can assist with minimizing the effects of extreme events. According to www.theguardian.com, the climate change is taking a dangerous trend, the year, 2015; the death toll in India's heat wave has climbed towards 1,500 as the country sweltered in one of the worst bouts of hot weather for several years.

Southern India has borne the brunt of the sudden spell of hot, dry weather. So far more than 1,000 people have died in the state of Andhra Pradesh, more than double the total number of heat-related deaths last summer, authorities said. "This is the highest death toll due to heat wave ever in the state," said Tulasi Rani, the special commissioner for disaster management in Andhra Pradesh. "Last year around 447 people died due to heat. This year the heat wave is continuing for a longer period than in previous years." The extreme heat is melting the roads in Delhi, more than 1,400 people have died in a continuing heat wave in India that has seen extreme temperatures melt roads, dry wells and crack parched land. Road markings were distorted in Delhi after days of temperatures hitting 45^0C turned asphalt liquid and the government is urging people to stay inside (EPA, 2015).

More recently, 'risk governance' has emerged in response to climatic changes which differentiates between risks caused by decisions, and those that are independent of decision-making such as natural disasters (Neubauer, 1988). Climate change risks are often a product of an interrelation between the two; they arise where the outcomes of decisions, for example linking to the development and use of land, interact with a natural disaster, for example a storm surge, to generate negative socioeconomic impacts (Neubauer, 1988). Therefore these can be described as climate change vulnerability and risk assessment framework which offers an effective means of understanding climate risks and framing the development of corresponding adaptation strategies and actions. It is also underpinned by World Bank research and recommended to be applied in a range of cities internationally.

Comparison between Green and Smart Buildings

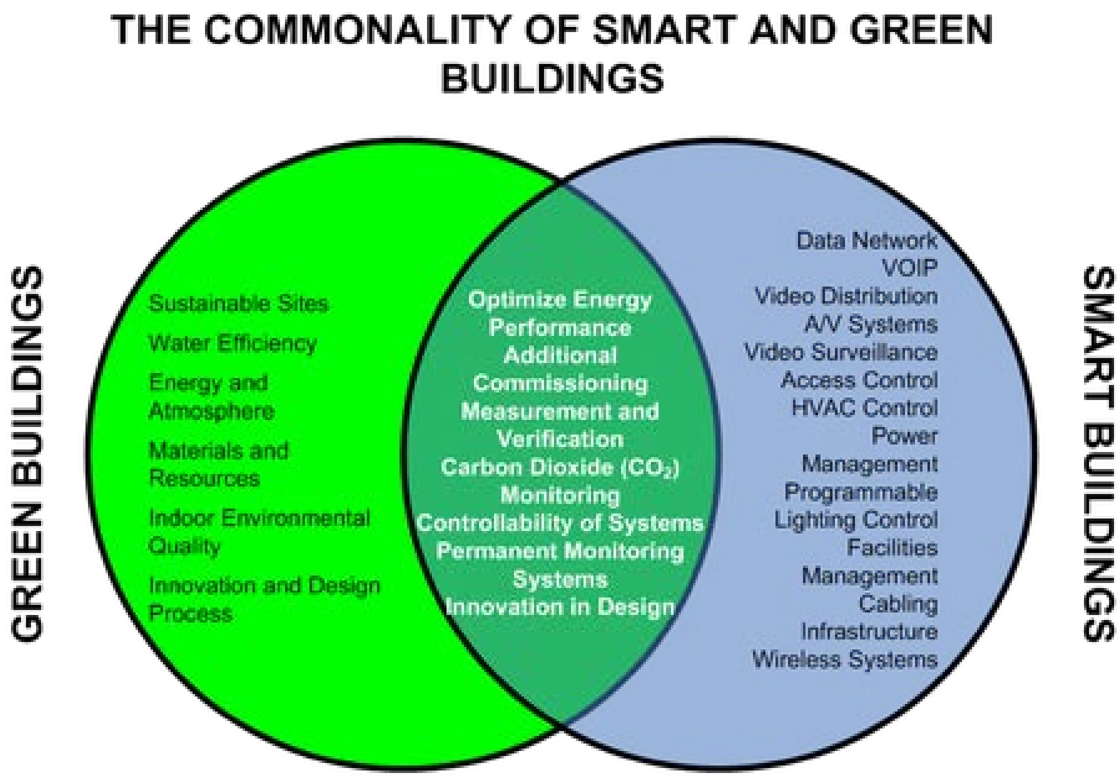


Figure 3: Comparison of Green and Smart Buildings

Green buildings and smart buildings have different focuses but they also overlap. Integrating a building's technology systems and constructing a sustainable or "Green" building have much in common. Green buildings are about resource efficiency, lifecycle effects and building performance. Smart buildings, whose core is integrated building technology systems, are about construction and operational efficiencies and enhanced management and occupant functions. Part of what a smart building will deliver is energy control and energy cost savings beyond that of traditional system installation, due to the tighter control system integration. Smart and green buildings deliver the financial and conservation benefits of energy management. One question then is how do smart buildings make a building green? More specifically, how can smart buildings support and effect the LEED (Leadership in Energy and Environmental Design) certification of a green building?

Buildings can receive LEED certification by submitting documentation of meeting or exceeding certain technical requirements of the U.S. Green Building Council. One or more points are earned towards certification for each technical requirement that is attained. Four different levels of certification can be achieved based on the total points earned. So how does a Smart Building approach align and support the Green Building approach, and more specifically, how does a Smart Building approach facilitate meeting or exceed the technical requirements of the credits and points of the LEED rating system?

The Smart Building can be assessed and earn points that can in effect elevate it to a Green Building as listed below; Optimize Energy Performance (1-10 points), Additional Commissioning (1 point), Measurement and Verification (1 point), Carbon Dioxide (CO_2) Monitoring (1 point), Controllability of Systems: Perimeter and Non-Perimeter Spaces (1 point each), Thermal Comfort: Permanent Monitoring System (1 point) and Innovation in Design (1-4 points). High performance buildings need not be green or smart, but must be both. Smart buildings make green buildings greener, and green buildings make smart buildings smarter. The result is that building owners and managers have enhanced performance and functionality in their buildings (Sinalpoli, 2007)

"Smart buildings enable green buildings, and green buildings are invariably smarter," says Sinalpoli. "The green building predicates an integrated design approach, and the resultant holistic assessment of technologies is the transformational agent that enables this vision, with connectivity as the critical attribute it creates. In this context, connectivity can be thought of as the ability to facilitate interaction among devices and systems to enable new services. A prerequisite for a green building is intelligence in the building, so a converged network is therefore essential." (Stinnes, 2015)

Building Codes

Energy performance requirements can be used to set performance targets in building codes. Building codes have been found to be one of the most effective and cost-effective policies in reducing greenhouse gas emissions from both existing and new buildings. Almost all developed countries have Building Codes which include energy efficiency standards, while many developing countries are now passing legislation for such codes. In most cases, these codes tend to regulate new buildings, but recently many developed country governments have amended their codes to cover renovations and refurbishments of existing buildings. Most building codes are performance based: that is, they set a maximum limit for level of heat transfer through the building envelope and the level of heating/cooling demand, as well as require building equipment such as heating and air conditioning systems, ventilation, water heaters and even pumps and elevators to meet certain energy performance standards.

Building Codes can also be used in conjunction with standards on equipment or materials. Building Codes are almost always more successful when mandatory rather than voluntary. When they are mandatory, they help overcome the perception that energy efficiency investments are an option. Any additional investment costs carried forward from the investment stage to the user stage are often off-set by lower construction or operating costs. The US and EU member states have stepped up efforts in using building codes to reduce their energy emissions by strengthening existing codes, i.e. increasing their energy efficiency requirements. In its revision of the 2002 Energy Performance of Buildings Directive (2002/91/EC), for example, the EU harmonized the standards for energy performance and certification in buildings and now requires a mandatory revision of these standards to be conducted every five years (European Commission, 2008). This study will look at NCA building codes and research on how they can be used to enhance the application of AEP for smart buildings and updated to enable ICT to be used as a mainstay to enable smart buildings to be easily developed.

Some governments combine codes with other information based instruments or introduce additional incentives, such as tax rebates or other concessions. The Energy Performance of Buildings Directive in the EU (2002), for example, required the obligatory energy certification of new and existing buildings as well as prominent display of this certification and other relevant information in public buildings (Geissler et al., 2006). Building certification can help overcome the “first cost” barrier of energy efficiency measures by integrating the operational costs of each building into its market value.

Building codes are not a new invention and building codes or standards for new buildings address several concerns, such as construction safety, fire safety, engress, that is fire exit, access for person’s with disability and occupants’ health. One of the earliest examples of regulations for buildings is Hammurabi’s law from Mesopotamia, established around 1790 BC. Among the 282 rules or contracts, which regulated every part of society, six concern the construction of houses and the penalties for builders. The most important issues in making standards more effective are; increasing training (of code officials, builders, and other building professionals), the rigorous updating of the standards to promote the development and use of new, efficient technology, announcing new codes early on so that the industry can prepare for more stringent codes and, demonstrating the feasibility of constructing progressively more efficient buildings that are cost effective.

Building energy codes establish minimum energy-efficiency standards for the design, construction, and renovation of buildings. Although the United States does not have a uniform national building energy code, the federal government has taken an active role in developing national model energy codes and in encouraging state governments to adopt and implement codes as well as providing education, training, and tools to assist state and local agencies, builders, and contractors in meeting code requirements.

During the past quarter-century, federal legislation has required states to initiate energy-efficiency standards for new buildings and to review and consider adoption of national model energy codes (EP Act, 1992). Most recently, the U.S. Congress stipulated that any state receiving supplemental state energy program funds under the American Recovery and Reinvestment Act (ARRA) of 2009 (the "stimulus bill") must pledge to adopt codes that meet specific stringency requirements15 and to create plans to achieve and measure 90% compliance with the codes by 2017. All 50 states and the District of Columbia have submitted letters of assurance in accordance with the ARRA requirements.

Conceptual Foundation of Smart Technologies Development Models

A number of studies have been conducted to examine the developing of smart buildings technologies as well as Internet of Things (IOT) and technology related products/services. Thus, there is a variety of terminologies in this research stream. Broad terminology commonly found in the literature includes AEP – Application Enablement Platform Information Symmetry (AEP - IS), and Internet of Things (IOT). These terms are not definitely distinct from each other. They are connected to technology and sometime substituted and used interchangeably. Thus, it could be said that all the terms relate to studies related to development of smart building technology which are applicable to the present study. The main objective is to develop a model for ubiquitous application enablement platforms (AEPs) for smart buildings using a variety of theoretical perspectives. Literature shows that the widely used theoretical constructs in smart technology include the Wilde's, Aston and Lee ubiquitous application enablement model (2002), the Theory of Internet of Things (TIOT), (Burns, Bone, Ellen model, 2001), risk assessment and capacity Model. Smart building technology is at nascent stage in many developing countries which has partly been contributed by lack of customized model for Smart Building technology which can be tailored to our unique environment. It is that they are considered to be useful theories and therefore the following models are the researchers' foundation and are used as a theoretical foundation in developing a comprehensive research conceptual framework for this study.

For example, (Lutz et al., 1990) proposed a model for the evaluation of new building technologies, but the assessment is limited to the evaluation of the workability of the technologies. (De Wilde et al., 2002) also developed a model of energy saving building components selection and suggest six general factors of building components selection. Specifically, these factors include comfort, functionality, safety, architectural value and financing. Since IOT has been introduced, it has been the most influential and widely used model in predicting and explaining the usage behavior of technology related to smart buildings technologies, products/services. Nevertheless, it has been criticized for possible limitations since it emphasizes only the effect of technology and the environmental adaptation of the buildings. In fact, the smart building is also influenced by other things surrounding them. Thus, there are a number of extension models of the same which have constructs related to environmental adaptation. The De Wilde model originators are also aware of the criticism, so they are in the process of improving the model. Figure 2.4: Illustrates (Dewilde and Morgan, 2002) model that considers selection of optimal energy saving Buildings Components which are; Financing, Functionality, Comfort, Safety, and Architectural Value.

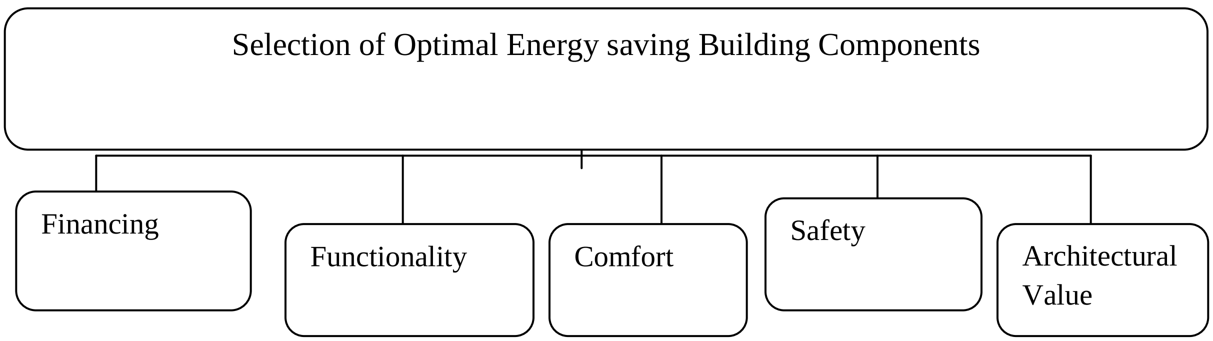


Figure 4: Dewilde and Morgan (2002) AEP Model

Empirical studies indicate that (Burns, Bone &Ellen, 2001) also developed a model of energy saving building components selection Automation, Efficiency, Interactivity, Adaptivity and Multi-functionality. To apply this theory to the concept of smart building, people initially use buildings to meet their basic physiological needs in terms of heating, air conditioning, ventilation, lighting and water. The next stage involves the requirements of satisfying their safety needs from the standpoint of security and fire protection. Building intelligence then appears in the form of information systems designed to better meet physiological and safety needs by automatically monitoring and managing energy consumption, security, fire protection and the ever-rising needs of building end-users (Benzon & Hays, 2008).

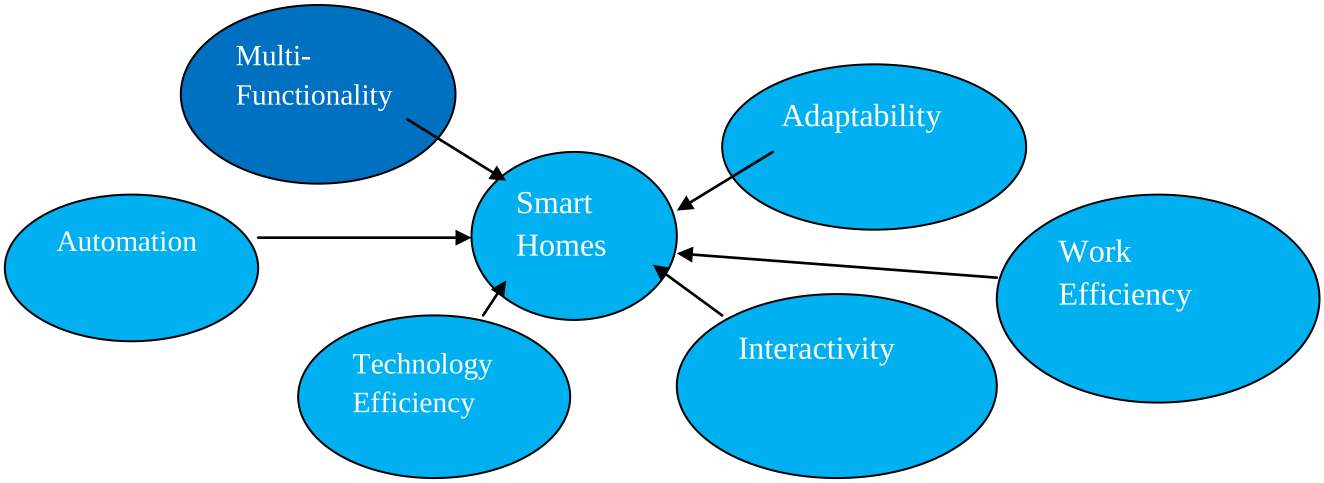
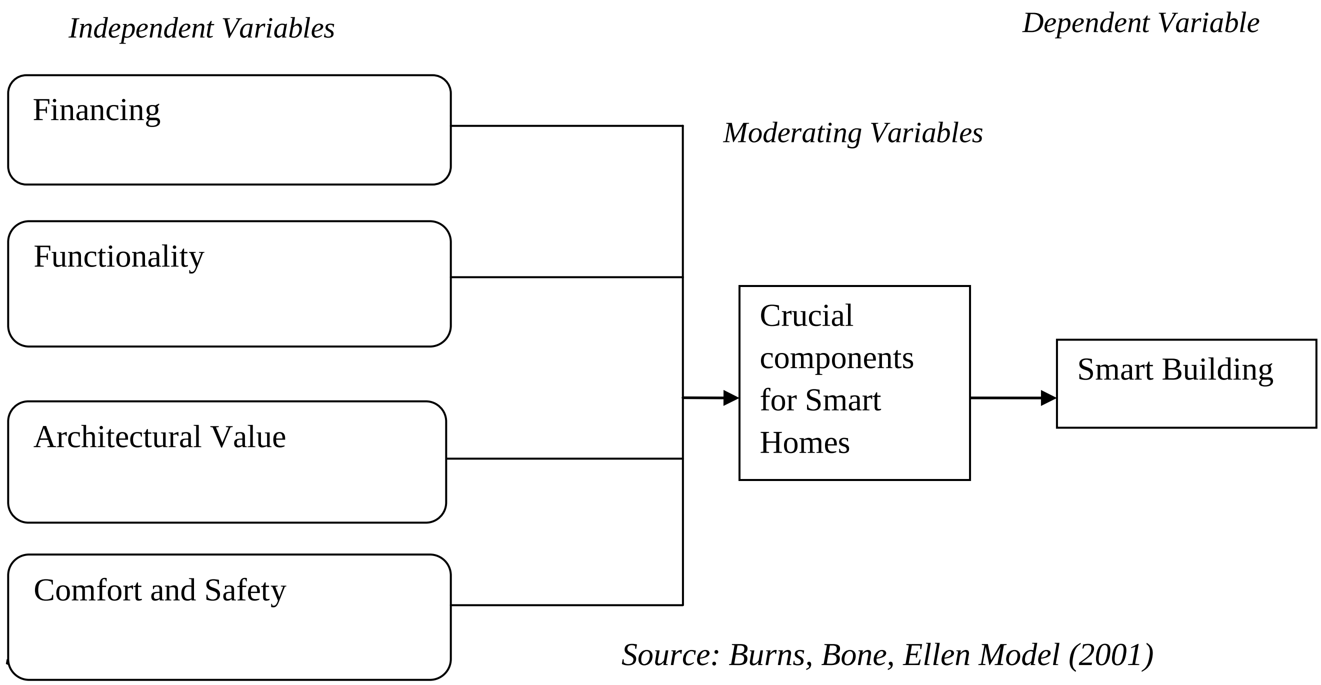


Figure 5: Burns, Bone, Ellen model (2001)

The review of their theoretical constructs shows that similarities and differences exist among these two models which seems to cause a constructs overlap and close to each other. The present study uses these two models as a background for developing a comprehensive research framework in subsequent sections. The theoretical constructs of Dewilde appear extensively in the technology of smart building while the Burns, Bone, Ellen model deals with the use of the smart building as a technology to enable adaptation of building to the environment. Bearing in mind that buildings are build for people and at the same time using the technology to reduce energy consumption, the research recommend the merging of the two models to better explain the adoption of technology related products/services at both individual and organizational levels. A vast number of studies using these models have been conducted to determine factors influencing the adoption of specific technology related products/services.



Source: Burns, Bone, Ellen Model (2001)

Figure 6: Conceptual Framework Diagram

The proposed conceptual framework for this study was developed incorporating key variables derived from a review of the research literature on smart building technology. The dependent variable is the smart building technology adoption while the independent variables are financing, functionality, architectural value, and user comfort and safety for smart buildings as indicated by (Dewilde and Morgan, 2002) Model. The moderating variables will consist of six crucial components indicated in Burns, Bone and Ellen Model for smart homes which are; Mutli-functionality, Automation, Technology Efficiency, Interactivity, Work Efficiency and Adaptability. If the smart building technology market is expected to grow rapidly as there is increasingly broad market awareness of the business values generated by deploying smart building solutions, several factors may be the factors which have been suggested to influence the application of Ubiquitous Application Enablement Platforms (AEPs) for smart buildings. Therefore the Smart buildings will be the convergence of information technology and building automation. Smart building solutions are valuable technologies for deploying energy management strategies that generate operational efficiencies, cost containment, and sustainability benefits that appeal to key stakeholders in building management. The conceptual framework is illustrated in figure 6.

REFERENCES

Abdel-Kader, M.G. and Dugdale, D. (2001), Evaluating investments in advanced manufacturing technology: a fuzzy set theory approach, *British Accounting Review*, Vol. 33, pp. 455-489.

ABSIC Group (2001), *Project #00-2 Final Report: Building Investment Decision Support (BIDS)*, available at http://gaudi.arc.cmu.edu/bids, (accessed on 01/05/2015).

Alcalá, R., Casillas, J., Cordón, O., González, A. and Herrera, F. (2005), A genetic rule weighting and selection process for fuzzy control of heating, ventilating and air conditioning systems, *Engineering Applications of Artificial Intelligence*, Vol. 18, No. 3, pp. 279-296.

AIIB, 2001, The Asian Institute of Intelligent Buildings (AIIB). The intelligent building index anual. 2nd ed. October 2001.

Alibaba, H.Z. and Özdeniz M.B. (2004), A building elements selection system for architects, *Building and Environment*, Vol. 39, pp. 307-316.]

Albus, J.S. (1991), Outline for a theory of intelligence, *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. 21, No. 3, May/June, pp. 473-509.

Albus, J.S. (2000), Features of intelligence required by unmanned ground vehicles, in *Proceedings of the Performance Metrics for Smart Systems Workshop*, NIST, Gaithersburg, MD, August, 2000, pp. 1-10.

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

Antsaklis, P.J. (2000), At the gates of the millennium: are we in control?, *IEEE Control Systems Magazine*, February, pp. 50-66.

Arbel, A. and Vargas L.G. (1993), Preference simulation and preference programming: robustness issues in priority derivation, *European Journal of Operational Research*, Vol. 69, pp. 200-209.*Architects Journal* (1983), 23 November, Vol. 178, No. 47, pp. 114-130.

Atif, M.R. and Galasiu, A.D. (2003), Energy performance of daylight-linked automatic lighting control systems in large atrium spaces: report on two field-monitored case studies, *Energy and Buildings*, Vol. 35, pp. 441-461.

Aygün, M. (2000), Comparative performance appraisal by multiple criteria for design alternatives, *Architectural Science Review*, Vol. 43, March, pp. 31-36.

Ayyub, B.M. (2001), *Elicitation of Expert Opinions for Uncertainty and Risks*, Boca Raton, Florida: CRC Press.

B. Xu, L. Fu, H. Di (2008), Dynamic simulation of space heating systems with radiators controlled by TRVs in buildings Energy Build., 40 (9) pp. 1755–1764

Baldwin, R., Leach, S.J., Doggart, J.V. and Attenborough, M.P. (1990), *Building Research Establishment Environmental Assessment Method, (UK BREEAM)*

Version 1/90 for New Office Designs, Garston, Watford: Building Research Establishment (BRE).

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

Barnes, N.M., Edwards, N.H., Rose, D.A.D. and Garner, P., 1998. Lifestyle monitoring-technology for supported independence. *Computing & Control Engineering Journal* **9**(4), pp.169 - 174.

Bassi, R. (2005), MATOOL: a matrix tool for assessing the performance of smart buildings, in *Proceeding of the BRE Seminar on Smart Buildings*. UK: Building Research Establishment Ltd.

Beevis, D. and Slade, I.M. (2003), Ergonomics – costs and benefits, *Applied Ergonomics*,Vol. 34, pp. 413-418.

Becker, R. (2002), Implementation of the performance approach in the investigation of innovative building systems, *Building and Environment*, Vol. 37, pp. 923-931.

Bell, P.C. (1999), *Management Science/Operations Research: A Strategic Perspective*, Ohio: South-Western College Publishing.

Benzon, W.L. and Hays, D.G. (1988), Principles and development of natural intelligence, *Journal of Social and Biological Structures*, Vol. 11, pp. 293-322.

Bernard, T. and Kuntze, H.B. (2001), Sensor-based management of energy and thermal comfort, in *Sensor Applications Volume 2: Sensors in Smart Buildings*, (eds. O.

Chan M., Campo E., Estève D., Fourniols J.Y**.** (2009), *Smart homes - Current features and future perspectives*, Elsevier Ireland Ltd, Maturitas 64 (2009) 90–97.

Crawley, D. B, Lawrie, F.C. Winkelmann, O. (2001), EnergyPlus: creating a new-generation building energy simulation program Energy Build., 33 (4), pp. 319–331 http://dx.doi.org/10.1016/S0378-7788(00)00114-6

CCSP (2008). *Analyses of the effects of global change on human health and welfare and human systems* . A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Gamble, J.L. (ed.), K.L. Ebi, F.G. Sussman, T.J. Wilbanks, (Authors). U.S. Environmental Protection Agency, Washington, DC, USA.

D. King. D,Morgan, M (2007) Adaptive-focused assessment of electric power microgrids J. Energy Eng., 133 (3) (2007), pp. 150–164

Dounis, A.I., Tiropanis, P., Argiriou, A. and Diamantis, A., 2011. Intelligent control system for reconciliation of the energy savings with comfort in buildings using soft computing techniques. *Energy and Buildings*, **43**(1), pp.66-74.

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

Ehrlich, P., 2007. *Intelligent Buildings Today* [online]. Available at: http://www.greenintelligentbuildings.com/Articles/Cover_Story/BNP_GUID_9-5-2006_A_10000000000000056794 [Accessed 9 May 2010].

Elkadi, H., 2000. Ecological approach for the evaluation of intelligence energy features in a building's skin. *Renewable and Sustainable Energy Reviews*, **4**(1), pp.91-103.

E.L. Cano, J, Y. Ermoliev Energy efficiency and risk management in public buildings: strategic model for robust planning Comput. Manage. Sci., 11 (1–2) (2014), pp. 25–44

EMSD, 2002. *Guidelines on Application of Central Control and Monitoring Systems*, Energy Efficiency Office, Electrical and Mechanical Services Department (EMSD), Hong Kong, available at www.emsd.gov.hk.

Engdahl. F, D. Johansson (2004), Optimal supply air temperature with respect to energy use in a variable air volume system Energy Build., 36 (3) pp. 205–218

Directive 2009/28/EC of the European parliament and of the council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing directives 2001/77/EC and 2003/30/EC Off. J. Eur. Union, L140 (2009), pp. 16–62

FCC/CP/2015/L.9, 2015, http://unfccc.int/resource/docs/2015/cop21/eng/l09.pdf

Futureagenda, 2011. *Intelligent Buildings* [online]. Available at: http://www.futureagenda.org/pg/cx/view#415 [Accessed December 2011].

Gray, A., 2006. *How Smart are Intelligent Buildings?* [online]. Available at: http://www.facilitiesnet.com/buildingautomation/article/How-Smart-Are-Intelligent-Buildings--5222 [Accessed January 2012].

Green, S. B. (1991). How many subjects does it take to do a regression analysis?. Multivariate Behavioral Research, 26, 499-510.

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

Gassmann, H. Meixner, J. Hesse, J.W. Gardner, and W. Göpel), Wiley-VCH, Weinheim, pp. 103-126.280 https://sustainabledevelopment.un.org/?menu=1300

Gutierrez, J. A. (2004). On the use of IEEE 802.15.4 to enable wireless sensor networks in building automation. *Personal, Indoor and Mobile Radio Communications, 2004. PIMRC 2004. 15th IEEE International Symposium on* (Vol. 3, pp. 1865 - 1869 Vol.3).

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

Jansen, E., J. and Overpeck, K.R (2007). *The Physical Science Basis . Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Karl, Jerry M. Melillo, and Thomas C. Peterson (eds.). United States Global Change Research Program. Cambridge University Press, New York, NY, USA.

Kastner, W., Neugschwandtner, G., Soucek, S., & Newmann, H. M. (2005a). Communication Systems for Building Automation and Control. *Proceedings of the IEEE*, *93*(6), 1178- 1203. doi:10.1109/JPROC.2005.849726

Kothari(20040 Determining sample size for research activities. *Educational and Psychological Measurement, 30, 607-610*

Kok K., Karnouskos S., et Al. (2009), *Smart houses for a smart grid*, 20th International Conference on Electricity Distribution, Prague, 8-11 June 2009, Paper 0751

Leedy, P.D., Newby, T.J. and Ertmer, P.A. (1997), *Practical Research: Planning and Design*, Upper Saddle River, N.J.: Merrill.

Liang Y, Levine, Z.-J. Shen (2012 Thermostats for the SmartGrid: models, benchmarks, and insights Energy J., 33 (4)), pp. 61–96

Liu, K., Nakata, K. and Harty, C., 2010. Pervasive informatics: theory, practice and future directions. *Intelligent Buildings International*, **2**(1), pp.5-19.

Livengood.D, R. Larson (2009), The energy box: locally automated optimal control of residential electricity usage Serv. Sci., 1 (1) http://dx.doi.org/10.1287/serv.1.1.1

Moore, C.A., 2009a. *The Role Of Lighting And HVAC Sytems In Green Campuses* [online]. Available at: http://www.facilitiesnet.com/educationalfacilities/article/The-Role- of-Lighting-and-HVAC-Sytems-in-Green-Campuses--10658# [Accessed December 2011].

Moore, C.A., 2009b. Intelligent Buildings Are Green [online]. Available at: http://www.facilitiesnet.com/educationalfacilities/article/Intelligent-Buildings-Are-Green--10657 [Accessed December 2011].

Mugenda, O. M. and Mugenda, A. G. (2003), Research methods: Quantitative and qualitative approaches. Nairobi: Acts press.

McGowan, J. J., 2001. DDC's Future 1-01, *AutomatedBuildings.com*, January 2001, available at www.automatedbuildings.com.

Marnay. C, Venkataramanan.G, Stadler. M,. Siddiqui, R. Firestone, B. Chandran(2008) *Optimal technology selection and operation of commercial-building microgrids* IEEE Trans. Power Syst., 23 (3) pp. 975–982

Matsunawa, K. and Nohara, F., 1994. Intelligent building saves energy. *ASHRAE Journal* January, pp.38-40.

Mazza, P., 2008. *Making green buildings intelligent: how to link green buildings and the Smart Grid* [online]. Available at: http://www.smartgridnews.com/artman/publish/Industry/Making_green_buildings_intelligent_how_to_link_green_buildings_and_the_Smart_Grid_printer.html [Accessed December 2011].

Merz, H., Hansemann, T., & Hübner, C. (2009). *Building Automation: Communication Systems with EIB/KNX, LON und BACnet*.

NRC (2010). *Advancing the Science of Climate Change*. National Research Council. The National Academies Press, Washington, DC, USA.

NRC (2002). *Abrupt Climate Change: Inevitable Surprises* . National Research Council. The National Academies Press, Washington, DC, USA.

Pandharipande, A. and Caicedo, D., 2011. Daylight integrated illumination control of LED systems based on enhanced presence sensing. *Energy and Buildings*, **43**(4), pp.944-950.

Rios-Moreno, G., Trejo-Perea, M., Castaneda-Miranda, R., Hernandez-Guzman, V. and Herrera-Ruiz, G., 2007. Modelling temperature in intelligent buildings by means of autoregressive models. *Automation in Construction*, **16**(5), pp.713-722.

Romano, N.C. Jr, Nunamaker, J.F. Jr (1997), "User driven design of a Web-based group support system", Proceedings of the 30th Annual Hawaii International Conference on System Sciences, Maui, HI, IEEE Computer Society Press, CD-ROM

Sinclair, K., 2001. 11 Revolutionary automation trends in large buildings, *AutomatedBuildings.com*, May 2001, available at www.automatedbuildings.com.

Stadler, A. Siddiqui, C. Marnay, H. Aki, J. Lai (2011), Control of greenhouse gas emissions by optimal DER technology investment and energy management in zero-net-energy buildings Eur. Trans. Electr. Power, 21 (2) pp. 1291–1309

Standardization Mandate to European Standardisation Organisations (ESOs) to Support European Smart Grid Deployment, Mandate M/490 European Commission (2011) Sinalpoli et al… 2007. Comparison of Green and smart buildings

Tanaka. M, Chen. Y (2013), Market power in renewable portfolio standards Energy Econ., 39 pp. 187–196 http://dx.doi.org/10.1016/j.eneco.2013.05.004 Article

Taylor E, (2004). Efficient Performance Management 2nd edition MC Raw Hill Publisher Ltd. UK

UNEP/WMO (2011) *Integrated Assessment of Black Carbon and Tropospheric Ozone: Summary for Decision Makers*. United Nations Environmental Programme and the World Meteorological Society.

USGCRP (2009). *Global Climate Change Impacts in the United States*. Thomas R.

Wang, S., et al., 2007. A middleware for web service-enabled integration and interoperation of intelligent building systems, *Automation in Construction*, 16 (1): 112-121.

Wang, S. and Xie, J., 2002. Integrating building management aystem and facilities management on the Internet, *Automation in Construction*, 11 (6): 707-715.

Woodman, B, C. Mitchell .C (2011) Learning from experience? The development of the renewables obligation in England and Wales 2002–2010 Energy Policy, 39 (7) (2011), pp. 3914–3921 http://dx.doi.org/10.1016/j.enpol.2011.03.074

Wong, J. K. W., Li, H., & Wang, S. W. (2005). Intelligent building research: a review. *Automation in Construction*, *14*(1), 143-159. doi:10.1016/j.autcon.2004.06.001

Wu, S. and Noy, P., 2010. A conceptual design of a wireless sensor actuator system for optimizing energy and well-being in buildings. *Intelligent Buildings International*, **2**(1), pp.41-56.

Zigbee Alliance. (2008, January). Zigbee Specification: ZigBee Document 053474r17