THE ROLE OF AUTOMATION IN ACHIEVING SUSTAINABLE ARCHITECTURE

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Abstract

Architecture should be an organic system with people as the primary agents rather than a collection of things that are programmed to follow predetermined rules. The emergence of new technologies has created a need for a new paradigm for architecture while at the same time raising questions concerning its sustainability. Automation within the building sector has gotten to the point where it will be considered essential for optimizing production processes and reducing operational costs. It will also allow the development of so-called "factory type" structures, with a minimal lead time for manufacturing activities and automated component production systems built and mounted on-site without any costly changes during assembly. To this end, we propose that the architectural community strive for sustainable designs and implementation. This goal is achievable through the application of automation in designing innovative buildings that aim to reduce energy consumption and greenhouse gas emissions while also following eco-design standards, addressing challenges caused by accessibility, safety and security alongside other necessary considerations for designing for sustainabability. This paper aims to explore how automation aids sustainability within architecture. The two case studies considered in this paper demonstrate how these systems could be applied automatically: a proposed design integrated home automation model and another intelligent house case model.The role of automation and robotic technologies will remain at the forefront of standardized design practices, and the demand for these systems will continue to grow.

Keywords*:* Automation, Sustainability, Architecture, Technology, Future Designs, Artificial Intelligence

Introduction

The technological advancements witnessed in the world are a clear sign that the future is one that has no limit and the proceeding of events over the years in technology, architecture, creativity, and its development is a testament to this. The changes witnessed happened in tandem with the increase in the application of technology tentacles in architecture, especially for Artificial Intelligence, Digital Technology, and automation. Integrating these technological products and applications has resulted in the formation of robust and sophisticated applications, previously not harnessed in architecture. We can make known the role of automation in bringing about sustainable architecture with the definition of the core concepts, which are automation and sustainable architecture. As a general definition, automation is everything that works on its own without the intervention or help of human subjects (Al-Tameemi & Toma, 2020). It is further explained as:

- Decision making and data processing by computer systems.
- The industrialization and incorporation of sensing of environmental variables.
- The mechanized action of devices and motors that place forces in the ecosystem (Sheridan, 2002).

The steady growth and advanced diversification of automation functionaries have come to a state where certain buildings that were constructed more than a decade ago may have become structurally unfit to adapt to the recent requirements of the connections in constructing advanced networks of communication and connective networks that are peculiar to these systems.

However, buildings that have automated systems installed in them are intelligent buildings so they have the requisite ability to respond, adapt, and take actions continually with the improvement of the comfort conditions of their inhabitants at the core of their performance through a fast automated response in order to achieve their utilitarian, psychological and graphical requirements, and give comfort and security, premised on the work of a set of service dynamics that comprises information and automated systems (Bernaden & Neubauer, 1988).

Automation: Past, Present and Future

The last two decades have seen major dynamic advances in Artificial Intelligence and, of course, robotics, which are the two major subsets of automation. The progress that will that recorded in the future would be more worthy of special notice and many researchers have predicted that it would radically transform the reality of the workplace all around the world and that would definitely affect architecture as well (Brynjolfsson & McAfee, 2014), (Manyika, et al., 2017). Over the years, we have confined the deployment of automation to the field of agriculture and industry, but software and AI-powered technologies can now coordinate logistics, retrieve and respond to information; traits that are valuable to sustainable architecture. Although robotics is more alluring and glamorous, automation, seen as the workhorse that is focused on production, has a serious impact on the economy at large. Automation has expanded beyond its starting point in manufacturing and has extended its tentacles to other fields of life's endeavours such as healthcare, security, construction, energy, transportation, and, of course, architecture despite its theoretical and rigorous aspects. We have also established it as a science (Goldberg, 2012).

There has been a growing generalization between robotics and automation, but the fact remains that the two are quite different. The Institute of Electrical and Electronics Engineers (IEEE) as well as the Robotics and Automation Society summarized the difference between the two concepts as follows;

"… Robotics focuses on systems incorporating sensors and actuators that operate autonomously or semi-autonomously in cooperation with humans. Robotics research emphasizes intelligence and adaptability to cope with unstructured environments. Automation research emphasizes efficiency, productivity, quality, and reliability, focusing on systems that operate autonomously, often in structured environments over extended periods, and on the explicit structuring of such environments." (IEEE).

Various researches previously carried out in automation emphasize quality control in the technical sense of the word. However, the definitions of this quality include being reliable, efficient, and productive. We can improve this quality through new techniques, models, and analysis leading to the presentation of papers on automation that show novel ideas, mechanisms, theory, or model for applications that are operated repeatedly (Goldberg, 2012). Bridging the gap between the virtual and the physical world is quite crucial in the 21st century and this is being masterminded by the Internet of Things (IoT). It is a perfect and unsullied system of information processing that includes sensors, smart technology, radio frequency identification, and other tech advances. The busy schedule of people is draining and getting ease and comfort in all aspects of life is the present need of an average individual in the digital age. Therefore, in automation, what readily comes to mind is home automation (Darianian & Michael, 2008). Achieving green and friendly environmental standards of sustainability has been the recent discourse in relevant bodies and world organizations and it is not farfetched that the Internet of Things can achieve this goal. Chief among these standards is the monitoring of energy consumption in the home environment and because of the increased use of the Internet of Things, myriads of applications made in security, city automation, smart homes, transportation, and of course sustainable architecture (Broll, Rukzio, Paolucci, Wagner, Schmidt, & Hussmann, 2009).

The Advent of Home Automation

The term "Home Automation," used often to define the interconnected functioning of all home devices and appliances and the control, setup using computers, tablets, or popular smartphones with internet connections. The fame and deployment of home automation in recent years has spread like wildfire and this is because people are searching for comfort and the ease of maintaining the status and, in other cases changing the status of their home devices remotely from any location around the world. This has become the need of an average person all around the world (Lobaccaro, Carlucci, & Löfström, 2016), (Sarwar & Soomro, 2013). The technology of home automation gives adequate security, convenience, energy-saving and efficiency, green technology, and a sustainable environment. This happens through the enabling of intercommunication between the devices present in the household through the smartphone or other connected devices around the world. Apart from this, security and healthcare are features operated and controlled by programs and platforms, though remotely; with gas, telecommunication, household water, and electric power controlled and monitored over a period. The internet of things therefore can help to reduce significantly the environmental load on society and people should adopt tech solutions that can assist in the development of energy-efficient edifices and homes (Broll, Rukzio, Paolucci, Wagner, Schmidt, & Hussmann, 2009).

The ever-increasing issue of global warming, increased energy consumption, and a disruption of the ecosystem sends an obvious message to researchers to curate new ways of overcoming the challenges. Increasing awareness about conservation practices in terms of energy use requires a lot of effort. However, the use of energy monitors and controls through the home automated systems is proposed already (Beckmann, Consolvo, & LaMarca, 2004), (Bonanni, Arroyo, Lee, & Selker, 2005). Wireless communication technologies are becoming widespread for the use

of smartphones used for access, monitor and control of those automated systems in the home. These automation systems used technologies such as GSM, Bluetooth, Voice Recognition, Wi-Fi, and Zigbee. Sen et al. (2015) proposed the use of voice recognition for home automation and the hardware design such that it uses a smartphone and Arduino UNO; and they achieved the wireless communication through Bluetooth (Sen, Chakrabarty, Toshniwal, & A., 2015). The home devices can recognize the voice commands of the user because of the inbuilt voice recognition feature of the Smartphone. The principle of operation is that the voice commands are first converted into texts and then transmitted to the module of the Bluetooth. Teymourzadeh et al. (2013) proposed the use of a GSM-based automation system. They remarked that using the Global System for Mobile Communication requires the availability of a GSM modem, a microcontroller, and a Smartphone. Relays are used to connect the home appliances to the microcontroller and serial communication established between the modem and the microcontroller using the RS232. The encoding and decoding of the short text messages received for the actualization of the particular commands by the microcontroller (Teymourzadeh, A., Chan, & Hoong, 2013).

Smart home automation systems allow the subscriber to monitor and change the functional status of the electric home appliances and the functional state of the sensors as well. These appliances include lighting, ventilation, heating, and air-conditioning devices. Apart from saving time, they provide comfort and energy-efficient solutions, as we know the device that consumes more power in your home (Majeed, Abdullah, Ashraf, Zikria, Mushtaq, & Umer, 2020). Smart meters used in homes would enable users to monitor and control the rate of energy consumption in their homes and the design of the new building by the architect would definitely make provisions for this. Using the meters would enhance the cost-effective approach and each household could make necessary adjustments to their energy consumption and the cost they incur. The model of integrating the Internet of things with smart metering would convert buildings and homes into an efficient energy-saving and energy-aware ecosystem (Song, Xiao, & van der Schaar, 2014). The rapid use of home automation vis-à-vis the emergence of the twenty-first century next-gen batteries for storage, energy monitors, artificially intelligent inverters, wind, and solar energy has joined the Internet of things for optimum energy efficiency and consumption (Ahmad, Mourshed, Mundow, Sisinni, & Rezgui, 2016).

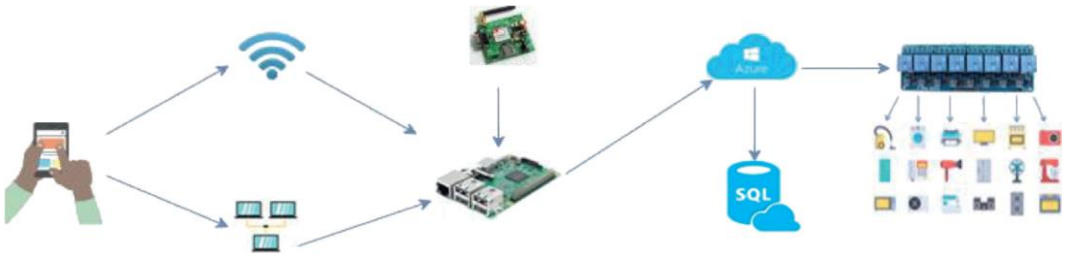


Figure 1: *Complete working structure of home automation*

Source*:* Majeed et al. (2020)

The Rise of Sustainable Architecture

Defining sustainability seems to be impossible because of the various preconceptions connected to the subject. It is one of the most used words in the modern day which has captured a particular reality that is yet to see the light of the day. Despite different breakthroughs recorded here and there, the whole concept must find a perfect fulfillment as conceived by the initiators. In the architectural worldview, the term sustainability carries between one hundred to three hundred definitions that suggest a wide range of aspirations that embodies the particular essence of "environmental and ecological design", "sustainable building" or "green architecture", used interchangeably (Geissdoerfer, Savaget, Bocken, & Hultink, 2017). Sustainability is a complex but comprehensive word that's of crucial importance to the survival of the biotic component of the ecosystem with emphasis on the human species and every other living creature. Eco-friendly practice, therefore, is one of the primary objectives that humans have made the major drivers of the present architectural design and practice. The migration towards green architecture is a well-thought plan for the good of all (Mahdavinejad, Zia, Larki, Ghanavati, & Elmi, 2014). The limited resources of the earth continually serviced the myriads of humans and without a change of behavior and plan, the future of human civilization and industrialization enfeebled.

The United Nations held a conference on Sustainable Development in New York (1997) and gave this definition. The body unanimously stated that we may use the development that pulsates with the demands of human beings without the destruction of potential to respond to the future demands of humans (United Nations, 1997). Based on this

provision, the purpose of sustainable architecture on a final note is to provide health and convenience for both the future and the immediate generations. We term any effort that gives adequate protection to the Earth and all that it holds acceptable (Ghorbanzadeh & Nezami, 2010). Reports have it that prior to the COVID-19 pandemic, the projection for CO2 emission between the years 2020 to 2050 would be fifty percent from constructions and that one billion houses would have been constructed by 2025 (Acharya, Boyd, & Finch, 2020) (Ellen MacArthur Foundation, Arup, 2019). Climate change, with an alarming rate of temperature rise in major regions around the world, is another pointer to why we must commit to achieving sustainability.

In other to comply with the dictates of a sustainable environment, a return to "mother nature" has emerged in architecture. Architects have designed houses with turf on the roof using logs and local brick as building materials, yet the new awareness comes with modest use of technology. Sustainable architecture deals with the thought processes, action plans, and methodologies that do not make use of the stereotypical approaches in the scheming, designs, building, and operation of the built environment which disregard the wider societal, ecological, and even economic aspects. According to Aliamin (2021), the path towards sustainable architecture has through two major routes, which are green architecture and the circular built economy (Aliamin, 2021). The context of this paper, however, deals with green architecture, automation, and artificial intelligence more than the circularity in architecture. Chief among the schools of thought in the green architecture path, which is otherwise known as sustainable architecture, is that of Frank Lloyd Wright. He proposed organic architecture, which entails the mutual interactions between "human nature and built" through natural airflows, natural lighting, and nature-driven design, among others (Graff, 2018).

Integrated Home Automation: A Proposed Design

Mahmood and his colleagues (2020) proposed a design concept for integrated home automation that ensures the optimization of energy consumption using sustainable strategies of IoT. The aim of these researchers is to optimize human effort, cut costs, beef up security, and optimize indoor activities and energy usage by making use of renewable resources for the residential sector. This concept is a drive towards sustainable architecture, which was designed by utilizing the technology in terms of wireless communication services, instruments, and devices through the house network. According to the proposal, the residential gateway can serve as the layer for data linkage, which is connected with the home electronics and the Internet, controlled and monitored using a remote user interface either on laptop computers, mobile devices, or other communication devices. Because of the IoT technology design, this system would be accessible and manageable from any part of the world (Mahmood, Kama, Azmi, & Ya'acob, 2020). They achieved a sustainable environment by integrating the monitoring system into the design and the renewable energy systems formed the core with incorporating techniques of home automation and smart metering. Also, accessing separate energy sources based on choice by the regular change of the energy system status for best energy consumption is a laudable part of the design. Using this approach, the control mechanism of the system is topnotch and affects several areas, including the use of a modern charging station for chargeable electronics. The addition of step-up and step-down transformers designed for safety and economic purposes.

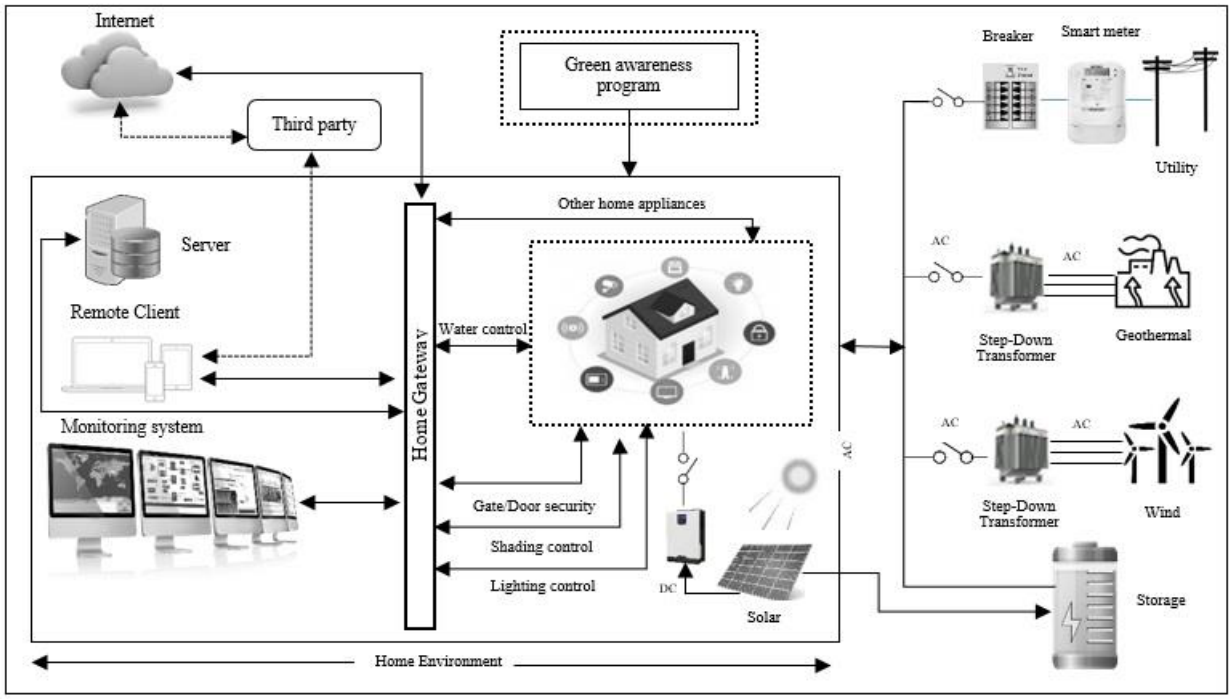


Figure 2: *Integrated Home Automation Conceptual Design and Architecture*

Source:Mahmood et al. (2020)

Although Mahmood et al. (2020) proposed a brilliant design, as shown above, there are other intelligent houses case models developed by educational and research institutions and independent researchers. Some of these include Gator Tech intelligent house, Matilda Intelligent house, Duke University Intelligent house, Drexel Intelligent House, MIT house, etc. The Gator Tech House will be reviewed in this discourse, as it offers an interesting linkage to the context of this work.

Gator Tech Intelligent House Case Model

Planned and developed by the University of Florida. The purpose is to provide a platform for the careful testing and functional analysis of the applications of smart technologies into a house that's responsive apart from the study of the response of the users. Premised on extensive and all-encompassing computing, the capacity to respond inherently in this built environment is vis-à-vis the integration of actuators and sensors on computers. Majorly, this model ensured a better life quality for the specially assisted people and the elderly people. There are diverse smart tech systems used in the gator tech model and these include intelligent laundry, displays, window blinds, bed, bathroom, front door, mirror, closet, projector, security system, mailbox, tracking device, etc. (GhaffarianHoseini, Dahlan, Berardi, GhaffarianHoseini, & Makaremi, 2013).

Using smart window blinds will afford the user the opportunity to handpick the level of lighting, ventilation, and, of course, privacy that is preferred. The intelligent mirror can serve as a reminder of important schedules and messages meant for the user. Also, the bed can recognize the sleeping pattern of the user and change order to give the user a comfortable sleeping experience. We can equip the bathroom with intelligence that ensures smart flushing, showers, and water temperature is available. Imagine the soap dispenser giving the exact volume of soap required. We can find these and many more in the gator tech house model and the design below shows the interior spaces of the model for a better grasp.

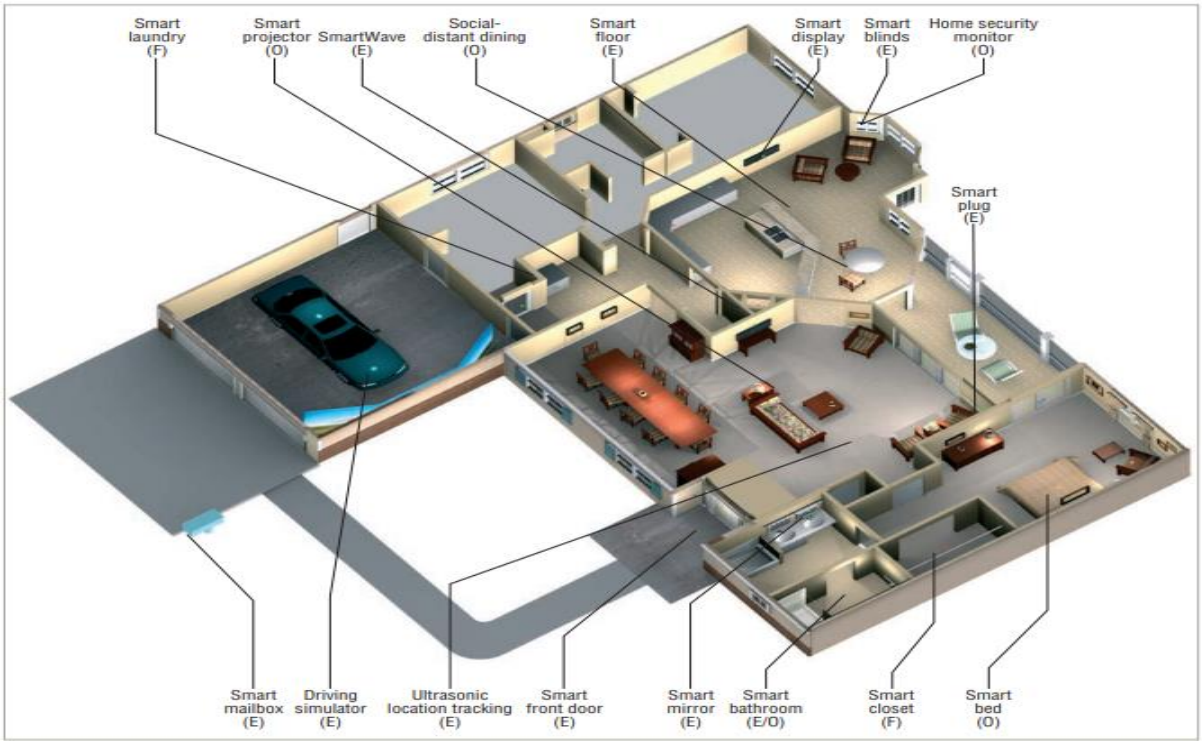


Fig 3: An Overview of the Interior Spaces of the Gator Tech House Model.

Source: Helal et al. (2005)

Intelligent Buildings and Structures

We can primarily define intelligent building as one that makes use of new technologies, with flexibility which depicts the ability of the building to change in function, considering the economic circumstances of the user and environmental conditions. Arkin and Paciuk (1997) made some modifications to the initial definition, as intelligence means not only to be satisfied with only a particular technology but it speaks about complete systems integration. In summary, intelligence in building management, automation and communication, environmental management, and social wellbeing using relevant technology (Arkin & Paciuk, 1997). Wong et al., (2005) made a brilliant submission that: *"Intelligent building accentuates a multidisciplinary effort to integrate and optimize the building structures, systems, services and management in order to create a productive, cost-effective and environmentally approved environment for the occupants."* (Wong, Li & Wang, S.W. 2005).

Intelligence involves the best response or behavior in different circumstances. Although some intelligent structures were conceptualized in the distant past, the level of development in the materials used in recent times makes the present activities quite interesting. Other things, such as measurement instruments signal processing, nanotechnology, cybernetics, artificial intelligence, information technology, sensors, and biomimetic being incorporated into buildings, have changed the face of architecture and construction (Wadhawan, 2005). The intelligence required or proposed in buildings is in the following areas;

- Safety infrastructure systems: these include functionaries such as warning tools and absorption materials
- Access regulatory system: this comprises an automatic door open-close system and anti-theft system
- Structure management systems, such as lighting control, fire alarm, heating, and cooling control, firefighting, earthquake alarm, and emergency power systems
- Surveillance systems with a closed-circuit digital camera being the major facility
- Communications setup: this includes satellite signals distribution and TV

Intelligent buildings ride on the wings of artificial intelligence and the flexibility and adjustability for the buildings provided by intelligent structures are to enable alignment with the environment. Regarding the concerns for the sustainability of the environment and specifically for sustainable architecture in the present world, artificially intelligent buildings play a vital role in the achievement of sustainability. They function to provide a healthier ecosystem and better efficiency for buildings based on sustainable architecture (Ghorbanzadeh & Nezami, 2010).

Inherent intelligence and artificial intelligence are two concepts upon which the automation of buildings runs. There are three major functionaries involved in how to live and these include machine, man, and nature. The improvement of their smartness or intelligence makes the propensity of machines to function biologically possible. The difference between inherent intelligence and artificial intelligence becomes more undefined as this phenomenon advances. Intelligent artifacts will therefore adjust, repair themselves, and dominate. If these intelligent structures are to possess understanding, the decision-making and learning abilities would have to be added to them, and this involves data collection. The human brain is more intelligent than the computer and this is because man can process massive data at the same time without failing. The human brain is the ultimate model of intelligent data processing and it bears 10^{11} neurons. Therefore, artificial neural networks simulate the model of the human brain and they can learn system structure in a dynamic and simultaneous way without having prior knowledge. Artificial or artificial neural networks possess a vast number of processing elements and, by design, use several combined behaviors without depending on each element's behavior (Wadhawan, 2005). Although we can achieve intelligence in structures through two distinct systems, namely open-circuit and closed-circuit, the intelligent structure itself functions through the combined functionality of sensors, actuators, and a control system. We can achieve better performance through the use of a control algorithm that will propel the actuators to perform in an optimum manner after the sensors have been able to recognize the changes and information passed across.

Sensors and Actuators

The ability to sense or recognize changes in a building is quite important in smart or intelligent structures. In a biological system, there are many outputs through which sensors can elicit responses; however, an electrical signal is the best know output for sensors in an intelligent structure. Therefore, the role of sensors in this kind of built environment is to convert recognized changes as input energy into electrical impulses or signals. They convert realities that are physical into measurable signals. Actuators are important parts of intelligent buildings as well, and they work by transducing various forms of energy into well-regulated mechanical motion. They typically react to the signals coming from the closure of circuits or varying electric loads intensity. These electric loads are physical devices, such as lamps or window blinds (Ghorbanzadeh & Nezami, 2010).

There must be a control system that ensures the seamless operation of the sensors and the actuators. The controller is typically hardware that's specific for an application, having integrated software that controls the actuators by the reason of the feedback given by inputs (ISO/DIS 16484-2, 2004). While we make them of ferric materials, sensors are essentially optic fibres. However, the future of intelligent buildings is attached to the effective synergy and deployment of ultramodern technologies, such as advanced materials, biotechnology, information technology, and biotechnology. With these things in place, buildings could adapt intelligently to weather, temperature, geological features, and energy consumption. These features will be inputted as data in programs and systems for the building waiting for execution command if there's a need to achieve a convenient environment (Abasalipour, 2008).

Drivers and Systems of Intelligent Houses

Sustainability issues have been a critical one that has gotten the attention of people and researchers all around the world. One thing that has interested the research community is the resilience of humans to climatic disruption. This has led to an increase in the risk factor of natural disasters. Considering this, building high-performance structures that can increase the resilience of the cities is very vital. Some drivers are impetus that would make structures more resilient by the enhancement of environment adjustments and the increase of comfort and quality of life for those who use it, especially in health and wellbeing (Zhang, Bayulken, Skitmore, Lu, & Huisingh, 2018).

There are relationships between the drivers and systems, sometimes to a greater extent and sometimes the other way round. For instance, health can be the major driver of particular automation and things like Fire prevention, lighting, HVAC, and hydraulic are the constituent of the system. The figure below shows the category of the drivers.

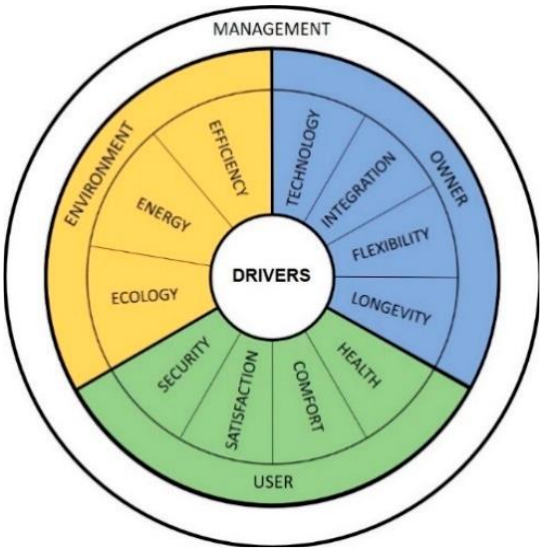


Figure 4: *Drivers of intelligent buildings*

Source: Froufe et al. (2020)

Automation Interventions

Houses that are built without provisions for automation can be worked on by integrating systems into it that would cause the emergence of an intelligent building. These interventions include:

Internal climate control: The use of sensors gave the building the capacity to respond to environmental shifts, controlling the heating, ventilation, cooling, and air conditioning system.

Lighting: The input of an automated system in buildings provides suitable light control that optimizes energy consumption.

Security and Safety: The use of advanced systems provided security, fire protection, access control, and safety mechanisms working on the premise of automation applications.

Kinetic Systems: Kinematics and operational systems are the basis of modern technologies that cause adaptation and response to the ever-dynamic needs of the user when deployed in a building (Al-Tameemi & Toma, 2020).

The Role of Automation in Achieving Sustainable Architecture

There are 3 categories of the goals of sustainable architecture namely:

1. Social goals, which entail the attainment of adoptability with the physical and the security of lives.
2. Environmental goals which have to do with better environmental quality with the utilization of more restorable and less transformable materials.
3. Economical goals have to do with reduced costs because of a reduction in energy consumption and comfortable performance (Ahmadi, 2003).

A building that would fulfill the goals of sustainable architecture must meet certain conditions and these include:

- Using nontoxic materials which have no negative impact on the environment
- Efficiency in the consumption of energy
- The durability and quality must be top notch
- There must be a design for the reutilization and restoration of systems and materials

The installation of sensors in buildings will ensure monitoring that would make the detection of faults and failures quite fast and the repairs done before causing further damage. This shows the sustainability that automation provides. The quality of the building affects human life and its quality. All standard bodies across the world support and

encourage the construction of automated buildings. Designers and architects must therefore provide intelligent building development upon the standards set by the regulatory bodies. These international bodies ensure not only and enforce safety practices in the construction of durable and quality buildings, but they are also leading to the development of new technologies that would make the building of intelligent and sustainable structures a worldwide reality. This study has showed that the deployment of automation to achieve intelligent buildings would help architecture to make flexible spaces available for different uses. Also, it stated that automated buildings provide real-time solutions that will improve the living conditions of people and the human environment as well (Ghorbanzadeh & Nezami, 2010).

Conclusion and Recommendations

The role of automation in achieving sustainable architecture depends on its impact on the environment and society. The degree to which automated systems are autonomous will ultimately impact their ability to be sustainable. Automation has emerged as a crucial tool for achieving sustainable architecture and changing how our society aspires to design and create. It has enabled architects to produce buildings that respond to their clients' needs while preserving environmental resources and cultural traditions. The knowledge of how to improve our systems is increasingly becoming an essential skill for architects and designers. Human involvement in the design process is critical to its success. Recent advancements in Computer Aided Design software, digital modeling and simulation enable us to create experiences that are as lifelike as they are believable. Automation is the future of architecture. It is a way to create more sustainable and functional buildings that address diverse needs and situations. Automation can boost efficiency, lower costs, reduce labor and make the creation process faster for continuous improvements in the real world. Technological development is a long-term approach to achieving sustainable architecture. Realizing the full potential of smart buildings requires a clear understanding of factors like automation, systems integration and energy efficiency. Architects will be able to design truly sustainable structures that are both more useful and aesthetically pleasing by using cutting-edge technologies like these. Given the complex nature of architecture and its relation to the environment, automation can help achieve more sustainable design. Automation will enable more realistic simulations in the construction process and planning phase. From energy saving, giving comfort in terms of operation of buildings and use, increase in safety and prevention of hazards, automation should be the next step in the future architecture. It is therefore recommended that

1. Buildings from now should be designed to incorporate the systems discussed in this paper.

2. More awareness should be created through various means to ensure that professionals in the built environment embrace these systems.

3. It is also recommended that further research should be carried out in the areas of improving the technology of automation,

4. Also, looking into how these technologies can be incorporated into much older buildings is encouraged.

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