SUSTAINABLE ARCHITECTURE: HARNESSING BUILDING AUTOMATION SYSTEM AS A VIABLE TOOL FOR BUILDING ENERGY COST REDUCTION

[1]ELIZABETH OJELABI AND [2]ABAYOMI AMUDA
[1&2]DEPARTMENT OF ARCHITECTURAL TECHNOLOGY,
THE FEDERAL POLYTECHNIC, ILARO, OGUN STATE, NIGERIA.
[1]elizabeth.ojelabi@federalpolyilaro.edu.ng
[2]abayomi.amuda@federalpolyilaro.edu.ng

ABSTRACT

In today's environment of rising energy costs and environmental degradation, the design discipline of sustainable architecture is entering a new stage where innovation has become paramount for addressing these issues. In this paper, we propose using building automation systems (BAS) to harness various benefits, such as reduced energy consumption and improved resiliency, introducing an intelligent building component that autonomously controls the temperature, lighting, ventilation and air conditioning (AC) systems. By integrating this component within some common-use application programs within the architectural field, energy consumption patterns throughout the year could be predicted and regulated, thereby reducing unnecessary energy usage during peak periods. This proposal was validated using data collected from 224 respondents of a survey, and the finding results could help researchers better understand the numerous benefits of the intersection of architectural sustainability and building automation systems.

KEYWORDS: ***Building Automation Systems, Sustainable Architecture, Technology, Integration, Energy Consumption***

1.0 INTRODUCTION

Sustainable architecture is a design field that seeks to capture, appropriate and share natural advantages to deliver immediate multiple benefits to today's society and future generations. Building automation systems (BAS) have the potential to reduce energy consumption while also simplifying utility management tasks (A.N Volkov et al., 2017). With this in mind, we demonstrate the feasibility of using BAS as part of a comprehensive strategy for energy efficiency improvement in buildings (Mischa Schmidt et al., 2018). Technology has been evolving to meet the increasing needs of architects. The emergence of automation technologies assists in building fancier homes with greater control over lighting and heating systems, which help buildings, adjust and meet occupants' needs without requiring human interaction; these smart buildings can adapt by depending on their environments with sensor networks and indoor environments. In the nearest future, buildings will learn to respond to their ever-changing surroundings (Milos Manic at al., 2016).

Automation is an essential part of achieving sustainability. However, the challenge is ensuring that automation and security systems are explored most effectively and efficiently as possible. A wide range of automation solutions is available to architects today, and they can be used in various

ways, depending on the goals of each design project. In the United States, conventional wisdom holds that automation has played a substantial role in enabling the country's economy to grow and prosper, despite the relative scarcity of natural resources. Today, however, the role of automation in achieving sustainable architecture is well-known but less often discussed on how it can achieve this goal. This article will discuss the role automation plays in achieving sustainable architecture, its relationship with security systems automation and robotics and some of its challenges. How can architects use new technologies to achieve sustainable architecture?

Achieving sustainable architecture requires designers and builders to plan for, design and implement measures that balance the needs of people, nature, and the economy. There is a long way to go before the rounded impact of automation on sustainable architecture becomes glaring.

Evolving technologies have changed the architecture profession, making it relatively easier to design adaptive, adaptive, and autonomous structures. Organizations are becoming automated in the 21st century, and more employees are being replaced by computer systems daily; the resulting outcome is cost-saving for organizations and customers through technological innovation. An application of autonomous systems is autonomous automobiles. These vehicles play a crucial role in improving transportation methods by lowering the number of accidents caused by human mistakes and reducing the overall cost of owning and maintaining an automobile. Google has played a significant role in the development of self-driving vehicles and has achieved considerable success by logging more than 500,000 miles without incident (Ali, K. M., 2017). With the amount of money saved each year and the number of road accidents preventable, it would not be hard for people to adopt this new way of travelling if their everyday lives changed overnight. Companies such as Google, Apple and Tesla have a competitive advantage because of their ability to create and implement sustainable infrastructure by building an AI platform based on machine learning and deep learning cluster; this allows the companies to secure themselves from disruptions via constant monitoring. It is hard to predict how automation will affect sustainable design in the future; however, it has proven to be a critical asset in the fight against climate change.

Architectural automation refers to the process of incorporating computer-based control in all the building subsystems. Architectural automation merges systems, components and devices essential for day-to-day operations, all under a central command. For example, better lighting systems can adjust lamps to ensure that they are not brighter than what a particular space needs. Heating systems can learn to respond automatically to a changing climate and modify their settings without any input from human beings. HVAC (heating, ventilation, and air conditioning) systems and lighting could use automation and sensors. Systems like this make buildings work better; for example, heating systems could ensure that a building heats up to a comfortable temperature without wasting energy by heating rooms farther away from direct solar radiation.

To reach the state of sustainable architecture, designers and builders must consider human, economic, and environmental concerns when planning new building projects. Architects may use automation to create sustainable architecture in the following ways:

- Automation can help reduce the human effort required to correct errors or implement new features without disrupting operations. For example, a study by Jain et al. (2017) found that automation in software development can lead to significant reductions in human effort and improvements in efficiency and reliability.
- Autonomous robotic systems can be helpful in the planning and design stages of a project to help minimize waste by measuring and optimizing human performance. A study by Kim et al. (2019) demonstrated the use of autonomous robotic systems in construction, leading to increased productivity and reduced waste.
- 3D printing could produce more accurate models and models with less material consumption than traditional manufacturing methods such as milling or casting. A study by Tiwari et al. (2016) found that 3D printing can lead to improved accuracy and reduced material consumption compared to traditional manufacturing methods.
- Integrations with other technologies, such as remote sensors, LiDAR systems, and gait/posture analysis, can allow for more efficient functioning within an architecture space.

For example, a study by Chen et al. (2018) explored the use of LiDAR technology in architectural design and found that it can lead to improved efficiency and accuracy.The office of architecture has evolved through technology that allows easier automated control in homes. With easy accessibility to the internet, architects and companies have developed better systems for automation inside our homes. They can now be able to adjust lighting systems and heating systems as well as monitor temperature levels for a more comfortable environment inside the house. Intelligent lighting systems, for example, control bulbs so they are not brighter than what is necessary for a given area.

Automation has been an integral part of the construction industry for decades, with the introduction of power machinery and technology. With increasing responsibility for sustainability concerning the environment and natural resources, there is a dire need to explore how conventional building automation systems could contribute to positive change. The societal impact of automation is a challenge to the field of sustainable architecture - a powerful economic force outside the domain of this paper.

2.0 LITERATURE REVIEW

2.1 Sustainable Architecture

Sustainable architecture is a new form of architecture that attempts to balance social, environmental, and economic needs. It applies natural and ecological principles to the creation of buildings and urban spaces. Sustainable architecture designs and constructs buildings in order to limit their environmental impact, with the objectives of achieving energy efficiency, positive impact on health, comfort and improved livability for inhabitants; all of this can be achieved through the implementation of appropriate technologies within the building (Federico Garofalo, 2018).

Among a range of established techniques for countering the effect of rising temperatures in urban areas, the following proved to be particularly efficient: reducing building densities; changing building height, spacing and street orientation to increase shade and reduce insolation receipt;

enhancing natural ventilation through a variation of building height and density; achieving effective solar shading using trees and vegetation; use of high-albedo (reflective) building materials; improved building and cooling system design and incorporation of large areas of vegetation and water features within the urban landscape (Sijakovic and Peric, 2014, 2018; Sijakovic, 2015).

In conclusion, the environmentally friendly design will shape the built environment in the future. Architects must design sustainable and energy-efficient structures for their clients and the neighborhood. Being an architect at this moment is exciting because we can try to create buildings that are beautiful, and minimize our carbon footprint.

2.2 Building Automation and Intelligent Architecture

Building automation is most times used to describe the integrated operation of all home gadgets and appliances, as well as their control and configuration via computers, tablets, or even cellphones with internet connections. Smart home automation systems allow the user to monitor and change the functional status of the electric home appliances - lighting, ventilation, heating, and air-conditioning devices - and the functional state of the sensors as well (Ojelabi, E. & Amuda, A., 2022). Building automation systems are an increasingly viable tool for utility cost reduction, but their application to green building is limited by a lack of interoperability. This report takes a critical look at the potential of building automation systems as a strategy for utility cost reduction. Building automation is an important field in building industry. Green Building Automation can be considered as a method of improving indoor environmental quality by integrating automation from the design get-go.

An intelligent architecture means a building system and technology using less or no toxic material (Haitao Yu., 2021). Furthermore, it should have efficient and environmental friendly systems to control lighting, HVAC, communication and security system (L. J. Lo & A. Novoselac., 2010). Automation in buildings can significantly contribute to the minimization of the buildings' energy losses (Haris Doukas et al., 2007). Technology options offered by automated control, through the use of sensors or communication networking system, have contributed to a greater awareness about energy consumption, particularly for buildings and major appliances. Through these systems, it is also possible to control mechanical building components such as security systems, elevators and door entry systems.

2.3 Building Automation Systems: A Viable Tool for Energy Cost Reduction

In recent years, building automation systems have been a hot topic. Also, the current energy crisis and the need for optimizing energy consumption are widely discussed in the public media. This is because of their potential to create significant cost savings and improve the energy efficiency of building (Mischa Schmidt & Christer Åhlund., 2018). Due to this, there has been increased interest in investigating new technologies that will allow for more efficient use of energy resources. One such technology that has received much attention is building automation systems (BAS). When using these automation systems we can control the environment more efficiently by reducing energy consumption in buildings and at the same time improving their comfort level (Lam Joseph C et al.,

2008). Sustainable building automation systems are one of the most effective tools for energy cost reduction. Their primary objective is to reduce energy consumption for lighting, ventilation and heating through control system manipulation, in favor of better environmental conditions (A.N. Volkov et al., 2017). These systems can also increase the level of comfort and save money by optimizing lighting levels, eliminating unnecessary heat production through ventilation, schedule lights or even turn off electrical appliances during the night. The installation and utilization of modern and integrated building technology systems is required for a smart building. Building automation, life safety, telecommunications, user systems, and facility management systems are examples of these systems. Smart buildings acknowledge and reflect technology improvements and building system convergence, common system elements, and the added functionality that integrated systems give. Smart buildings give actionable information about a building or area within a building, allowing the owner or occupant to manage the structure or space. By building bridges between design professionals, material procurement professionals and technical experts, sustainable building automation systems provide designers with more reliable control over building energy bills. To achieve this goal we need to look beyond features alone and start thinking in terms of performance.

3.0 RESEARCH METHODOLOGY

A study was conducted to determine the feasibility of using automation systems to reduce energy consumption in buildings. Questionnaires were used to collect data. Summarizing and interpreting the gathered results, we analyzed the data and interpreted into results.

4.0 RESULTS AND FINDINGS

There were 224 respondents: 39.3% (88) were female 1 57.1% (128) were male 3.6% (8) preferred not to declare their gender. All respondents were from Nigeria. 120 respondents were from Osun State, 8 from Enugu, 64 from Ogun State, 24 from Lagos and 8 from Oyo state.

Table 1: Demographic Details of the Respondents

Location of respondents by State	No of Respondents	Percentage of Respondents per location (%)
Osun	120	53.6
Enugu	8	3.6
Ogun	64	28.6
Lagos	24	10.7
Oyo	8	3.6

Table 2: Awareness of Building Automation

Yes	184	82.1%
No	16	7.1%
Maybe	24	10.7%

Source: ***Authors' Field Survey, 2022.***

Table 3: Involvement in Automated Building Activities

Yes	48	21.4%
No	168	75%
Maybe	8	3.6

Source: ***Authors' Field Survey, 2022.***

Even though over 80% of respondents claimed they are aware of what building automation is, a very large percentage (75%) have not worked or been involved in the construction of an automated building. In fact, none of the female respondents (0%) have been involved in the design and/or construction of an automated building. Even while there might not necessarily be an issue due to the absence of female participation in construction and design using automation, additional research on this subject might be beneficial.

Table 4: Taxonomy and Measurement of Research Constructs

	Research Questions	**Yes**	**No**	**Maybe**
A	Do you know what building automation is?	184 (81.2%)	16 (7.1%)	24 (10.7)
B	Have you been involved in the design and/or construction of an automated building?	48 (21.4%)	168 (75%)	8 (3.6%)
C	Does Automation enhance architectural sustainability?	160 (71.4%)	16 (7.1%)	48 (21.4%)
D	Do Architects have any role to play in building automation?	216 (96.4)	8 (3.6%)	-
E	Should existing buildings be automated?	120 (53.6%)	56 (25.0%)	48 (21.4%)
F	Is Automation too expensive?	104 (46.4%)	16 (7.1%)	104 46.4%)
G	Have you lived or are living in an automated building in Nigeria?	48 (21.4%)	176 (78.6%)	-
H	Should new buildings be automated?	96 (42.9%)	56 (25.0%)	72 (32.1%)
I	Automation bolster security systems	192 (85.7%)	24 (10.7%)	8 (3.6%)

Source: ***Authors' Field Survey, 2022.***

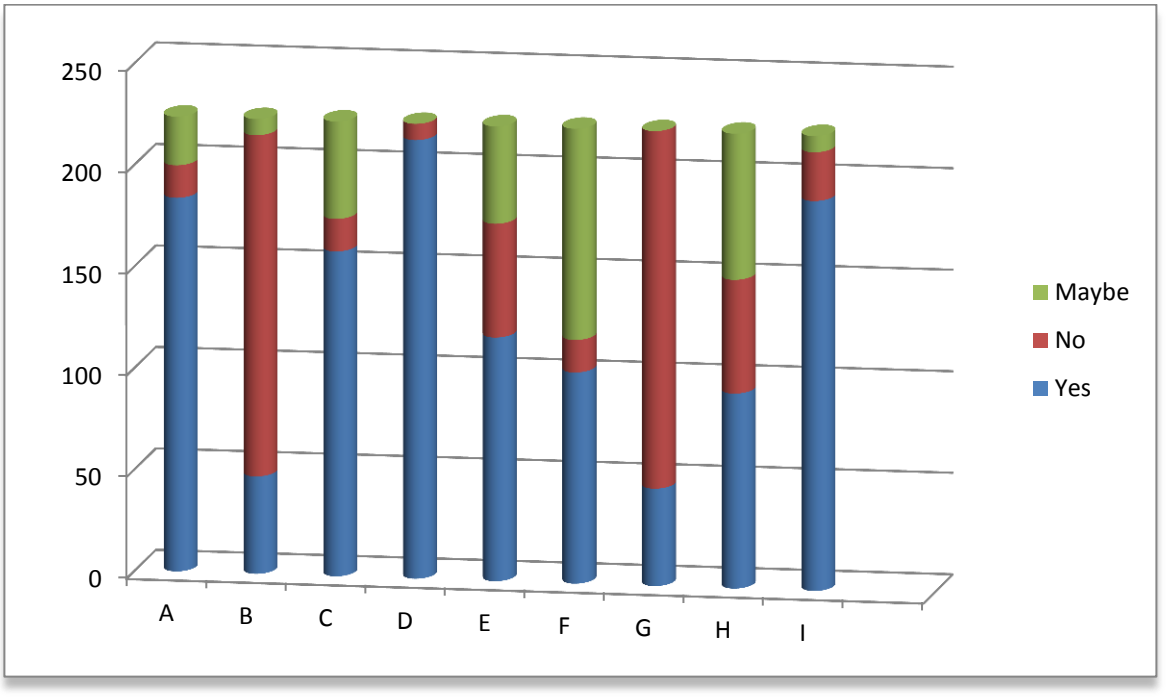

Fig. 1: Graphical Display of Research Construct Responses

71.4% of the respondents believe that automation enhances architectural sustainability while 16 of them believed that it doesn't and 48 were unsure. 96.4% of the respondents think that architects have a major role to play in building automation while 3.6% believe that architects do not have anything to do with building automation. In the survey, 104 respondents thought that automation is too expensive while 16 think that it is not, and the remaining 104 respondents are not sure. This could be because they are not aware of the cost implication of automating the building construction.

The majority of the respondents have not lived in automated building before. 96 of the respondents think that all new buildings should be automated while 56 said that they should not and 72 were undecided. It's a 5.7% of the respondents believe that automation bolster security system while 10.7% suggested that automation has nothing to do with the overall security of a building. The results of the case study indicate that it is inevitable that building automation will become a generally accepted phenomenon as all the respondents (100%) answered yes to the question that if given the opportunity would they like to automate their office or residence.

In order for energy firms to succeed, they must create a modern operating environment (D.Patlitzianas, et al. 2007).

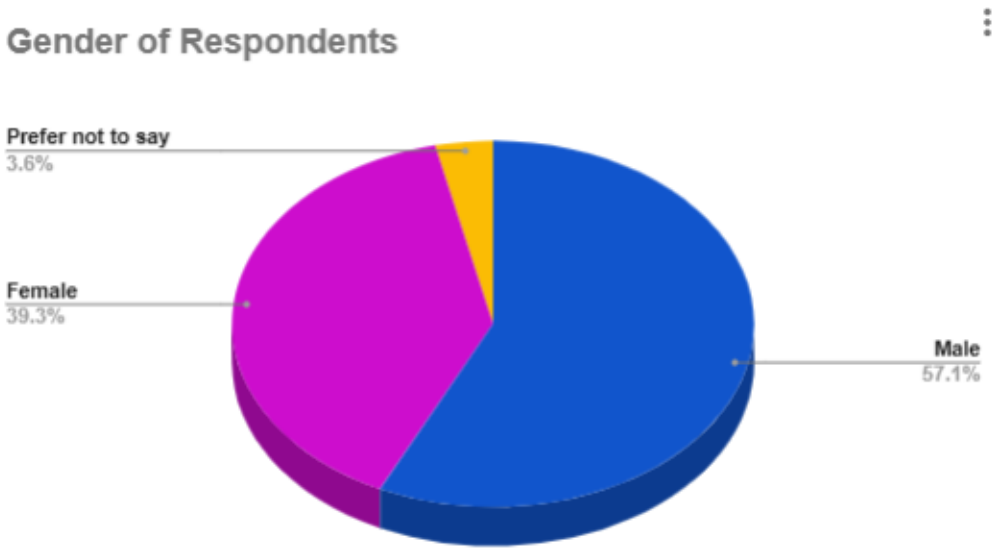

Fig. 2: Gender of First-Hand Living Experience in Automated Building

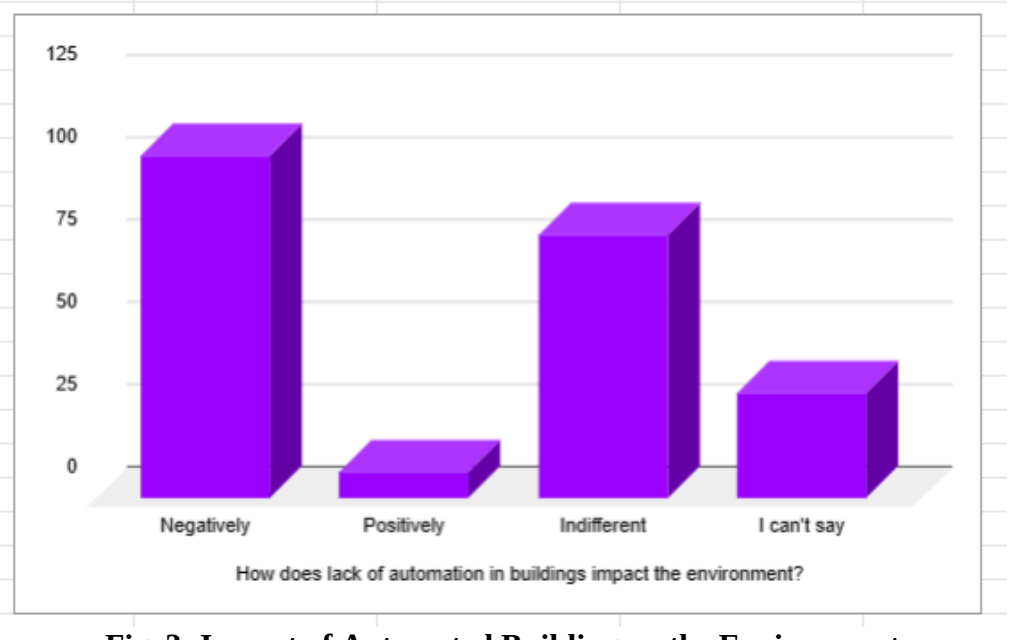

Fig. 3: Impact of Automated Building on the Environment

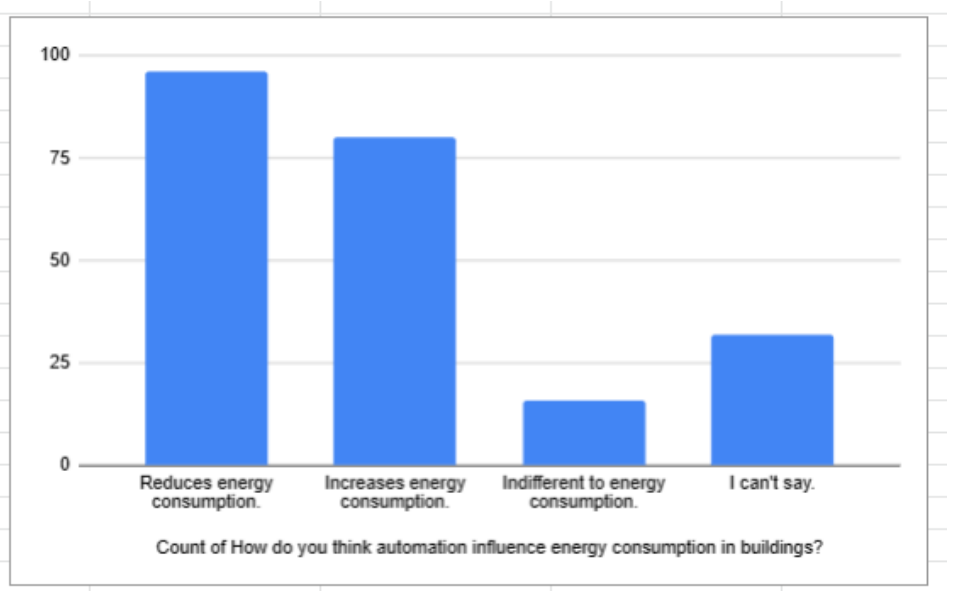

Fig. 4: Understanding of Energy-Use Implications of Automation on Building

5.0 CONCLUSION AND RECOMMENDATION

As environmental concerns and energy costs continue to grow, organizations are looking for ways to reduce their utility bills. Building automation systems are one of the techniques that can potentially save significant amounts of money. It's important to note that while building automation can help save money, it is not a silver bullet solution. While increased automation can certainly improve overall energy efficiency, it does not address other energy-related factors like lighting or ventilation. In addition, more complicated systems are more difficult to install and maintain. The assumption of the respondents about the cost of automation in buildings may be based on facts or on speculation; however, more detailed research about what people think about it could be done to find out.

The sustainable architecture has some of the key elements that can be found in existing buildings. When applying these concepts, architects can use building automation system as an effective tool to reduce utility costs and improve security system. Therefore, when designing existing buildings, architects should incorporate sustainable elements such as building automation system for enhanced energy-saving and cost reduction.

REFERENCES

Agarwal, Y., Balaji, B., Gupta, R., Lyles, J., Wei, M., & Weng, T. (2010). Occupancy-driven energy management for smart building automation. Proceedings of the 2nd ACM Workshop on Embedded Sensing Systems for Energy-Efficiency in Building. *BuildSys*, *10*(1). doi:10.1145/1878431.1878433.

Ali, K. M. (2017). *An intelligent intrusion detection system for external communications in autonomous vehicles* (Unpublished PhD thesis). University of Essex.

Aste, N., Manfren, M., Marenzi, G. (2016). Building Automation and Control Systems and performance optimization: A framework for analysis. *Renewable and Sustainable Energy Reviews, 3*(4), S1364032116307365. doi:10.1016/j.rser.2016.10.072.

Chen, L., Zhang, Y., & Zhang, D. (2018). A review of LiDAR technology and its applications in architecture. *Automation in Construction, 91*, 12-22.

D.Patlitzianas, Konstantinos, Konstantinos Ntotas, Haris Doukas, and John Psarras (2007). Assessing the renewable energy producers' environment in EU accession member states. *Energy Conversion and Management (Elsevier) 48*, No. 3: 890-897.

Haris Doukas, Konstantinos D. Patlitzianas, Konstantinos Iatropoulos, John Psarras, (2007): Intelligent building energy management system using rule sets; *Building and Environment*, *42*(10), Pages 3562-3569, ISSN 0360-1323, https://doi.org/10.1016/j.buildenv.2006.10.024.

Ippolito, M. G., Riva-Sanseverino, E., & Zizzo, G. (2014). Impact of building automation control systems and technical building management systems on the energy performance class of residential buildings: An Italian case study. *Energy and Buildings, 69*(2), 33–40. doi:10.1016/j.enbuild.2013.10.025.

Jain, S., Arora, P., & Paul, J. (2017). Automated software testing: A review. *Journal of Software Engineering and Applications, 10*(03), 1-14.

Kim, Y. H., Lee, H. J., & Kim, J. H. (2019). Autonomous robotic systems for construction. *Automation in Construction, 102*, 250-260.

Manic, M., Amarasinghe, K., Rodriguez-Andina, J. J., & Rieger, C. (2016). Intelligent Buildings of the Future: Cyberaware, Deep Learning Powered, and Human Interacting. *IEEE Industrial Electronics Magazine, 10*(4), 32–49. doi:10.1109/MIE.2016.2615575.

Ojelabi, E., & Amuda, A. (2022). *The Role of Automation in Achieving Sustainable Architecture*. Paper presented at the 3rd international conference, the Federal Polytechnic Ilaro, Ogun State, Nigeria.

Riadh Habash (2022). Sustainability and Health in Intelligent Buildings; Woodhead Publishing Series in Civil and Structural Engineering

Sijakovic, M., Peric, A. (2020). Sustainable architectural design: towards climate change mitigation. Archnet-IJAR: *International Journal of Architectural Research*, ahead-of-print(ahead-of-print), –. doi:10.1108/arch-05-2020-0097

Sinopoli, J. (2010). Smart Building Systems for Architects, Owners and Builders; Butterworth-Heinemann; ISBN: 978-1-85617-653-8; https://doi.org/10.1016/C2009-0-20023-7.

Tejani, Dhiren; Al-Kuwari, Ali Mohammed A. H.; Potdar, Vidyasagar (2011). [IEEE 2011 5th IEEE International Conference on Digital Ecosystems and Technologies (DEST) - Daejeon, Korea (South) (2011.05.31-2011.06.3)] *5th IEEE International Conference on Digital Ecosystems and Technologies* (IEEE DEST 2011) - Energy conservation in a smart home. , (), 241–246. doi:10.1109/dest.2011.5936632.

Tiwari, A., Kumar, A., & Jain, S. (2016). A review of 3D printing technology. *Journal of Software Engineering and Applications*, *9*(03), 1-13.

Vangelis Marinakis; Haris Doukas; Charikleia Karakosta; John Psarras (2013). An integrated system for buildings' energy-efficient automation: Application in the tertiary sector. doi:10.1016/j.apenergy.2012. 05.032.

Xiao, F., & Fan, C. (2014). Data mining in building automation system for improving building operational performance. *Energy and Buildings*, *75*, 109–118. doi:10.1016/j.enbuild.2014.02.005.