Review Paper

Benefits of adopting smart building technologies in building construction of developing countries: review of literature

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Abstract
Smart building technology has received a broad audience due to digitalisation and benefits in the construction industry. With global interest, the construction of smart buildings has become a new trend in development. Many studies identified a significant interest in the smart building technology application more than in conventional buildings. However, in developing countries, construction professionals have paid little attention to the adoption of smart building technology. Therefore, this paper aims to identify the benefits that are attached to the adoption of smart building technology (SBT) in the construction industry. The study is based on a systematic review of published articles in peer-reviewed journals and conferences. A total of 55 papers comprising conferences and journal articles retrieved from Scopus database were utilised for the study. The study's findings revealed efficient energy consumption, cost-effective building maintenance and operation, job creation, health care management, real-time monitoring, safety and security, among others, as benefits of smart building technologies (SBTs). For smart building technology to thrive in emerging economies, a comprehensive understanding of its benefits is highly imperative. This will not only promote construction professionals' knowledge of its concept but also enhance its successful adoption in these regions. Thus, the paper provides some insights into the benefit of smart building technology in developing countries while suggesting the formation of a synergic structure between the research community and practitioners in the construction sector.

Article highlight

- Smart building promotes sustainability in the construction industry.
- Productivity, collaboration and security increase smart building adoption.
- Rigorous studies on smart building benefits are limited in developing countries.

Keywords Sustainable building · Digitalisation · Construction industry · Benefits

1 Introduction

The construction and maintenance of conventional buildings are estimated to consume about 30–40% of the world's final energy and release greenhouse gas emissions in the built environment [1, 2]. Building-related anthropogenic activities harm the environment due to the high energy and resources consumed in buildings [3]. For instance, the building energy consumed in regions such as the European Union, United States, Hong Kong, Saudi Arabia, and Africa accounts for 40%, 20%, 90%, 73%, and 56%, respectively [4–8]. Consequently, the building stock in

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these same regions is responsible for 36%, 40%, 60%, 33%, and 32% CO_2 emissions, respectively. Buildings account for 40% and 39% of total global energy use and carbon emissions [9]. Due to the skyrocketing population growth, urban sprawl, and globalisation, the building industry is confronted with the challenge of providing adequate and holistic built infrastructures such as efficient energy management, good water supply, occupants' indoor comfort, and management of construction wastes [10]. So far, progress has been achieved to a certain extent due to sustainable construction practices in the built environment [11]. Different techniques for sustainable construction have been introduced in developed and developing countries [12]. These sustainable techniques include green roofs and buildings, modular construction, information modelling, and smart building technology (SBT) [1, 13–15].

The global construction industry greatly impacts the environment, economy, and social development [16]. The need for economic, environmental and social consideration in the context of smart building technologies as part of the future of the built environment [16]. Smart buildings can be expressed as intelligent and self-sustainable buildings by exploiting sensors, technologies, and innovative materials to achieve energy management and occupant comfort [17]. Furthermore, a subset of smart environments enables a building to obtain information about the environment and apply knowledge about the environment to reduce greenhouse gas emissions in the environment [18].

Sustainable development in construction has enabled proper management systems and the integration of the earth's natural resources through multidisciplinary knowledge, thus, providing a pathway for ecosystem balance and socio-economic development [13, 17]. Globally, the interest in smart building technology has progressively increased over the years [19–21]. The adoption of smart buildings has recently come to the spotlight due to the benefits of adopting smart buildings in the construction industry for developed and developing countries. The products of the built environment is constructed in the best practical ways toward efficient energy usage, raw material recycling, and realising a sustainable and carbon-free environment, which has demonstrated the technology application in the construction industry [18, 19, 22].

There are many barriers and challenges for a developing country to adopt SBT to achieve sustainable construction [23]. For instance, Ghansah et al. [24] revealed the high cost of smart, sustainable materials and equipment, technical difficulties during construction processes or lack of technical skills regarding smart technologies and techniques, and resistance to change from traditional practices in the Ghana construction industry. Gobbo et al. [25] pinpointed the lack of a regulatory environment to adopting the concept of a smart building, lack of finances and financial incentives for adopting SBT, and problems with the availability of skilled and specialised jobs in smart buildings concepts, devices and solutions in the Brazilian social housing.

The construction industry's response, introduces efficient energy usage, encourages locally available raw materials, and advances conventional building techniques [20, 21]. Accomplishing smart buildings requires promoting efficient technologies and the practice of smart buildings in the built environment [26]. Sustainable construction practices are crucial for achieving the three pillars of sustainable development namely economic, social, and environmental goals [27]. According to Vattano [28], sustainable building technology aims to provide a living and working environment that consumes fewer resources, produces less waste, and retrofits existing buildings to be innovative, energy-saving, and water-efficient. It is not easy to think smart without associating it with sustainability in the construction industry [29]. Over time, building practitioners have become vibrant in energy management, protecting and restoring ecological balance, increasing economic efficiency, and improving human comfort and satisfaction through a technology application [30]. However, little effort has been made to enlighten the construction professionals of developing countries on the benefits of adopting smart buildings. Therefore, the study aims to identify the benefits that are associated with adopting SBT in the construction industry for developing countries in project delivery, considering the social, environmental and economic impact of adopting SBTs.

In the next section, Section two indicates the methodology, section three presents the result and discussion, and the last section four shows the implication and five conclusions from the findings.

2 Methodology

A thorough literature review of scientific research is the foundation for advancing knowledge in a particular field such as building and construction, and so on [1, 25]. This study adopted a systematic review approach to analyse the existing literature comprehensively. The type of literature review described by Denyer and Traffield [31] systematic review is adopted when increasing the demand to organize knowledge into a rigorous and reliable format and makes a difference in practices. The Scopus search engine was employed to conduct a literature search to select relevant papers due to data recovery precision and accuracy in performance [26, 32, 33]. This strategy has traditionally been used to discover relevant publications for investigations [1]. The search of relevant keywords in the Scopus database utilising the parenthesis (TITLE-ABS-KEY

("smart building technology" OR "benefit") AND TITLE-ABS-KEY ("smart home benefit" OR "developing countries" OR "Construction Industry") AND TITLE-ABS-KEY ("Sustainable constriction" OR "building technology" OR "Digitalization") AND TITLE-ABS-KEY ("Adoption" OR "Sustainable Development" OR "SBTs")).

During the initial systematically conducted search (searched in October 2021), 63 articles were discovered. The inclusion and exclusion criteria for the selection of the paper were applied. All the papers were written in English, and the papers from engineering, computer science and environmental sciences were included, while other papers outside engineering, computer science and environmental sciences were excluded. The review focused on smart building technology and the adoption of benefits as reported in academic journals and conference papers. However, not all the papers discovered are relevant to the study on the benefits of smart building adoption. The current study aimed at assessing literature on the benefits of smart building technology adoption in developing countries. Hence, it was required to filter out unrelated articles. Figure 1 shows the systematic review flow chat.

Furthermore, a content review was used to filter in the most relevant papers to the study, focusing on the topical analysis of the article, followed by the abstract and the article's findings [34, 35]. After the screening, 55 articles were considered worthy of analysis.

3 Results and discussion

3.1 Bibliometric analysis outcomes of the paper

The papers selected about the benefits of technology adoption by years, present an overview of the topic's evolution and research from 1988 through mid-October 2021. The year 2021 papers are not the total reflection of the year's publication, as shown in Fig. 2. The trend in research regarding the study shows a zigzag pattern, which means that research into the study area is springing up, but 2019 and 2020 show a constant pattern. This can be attributed

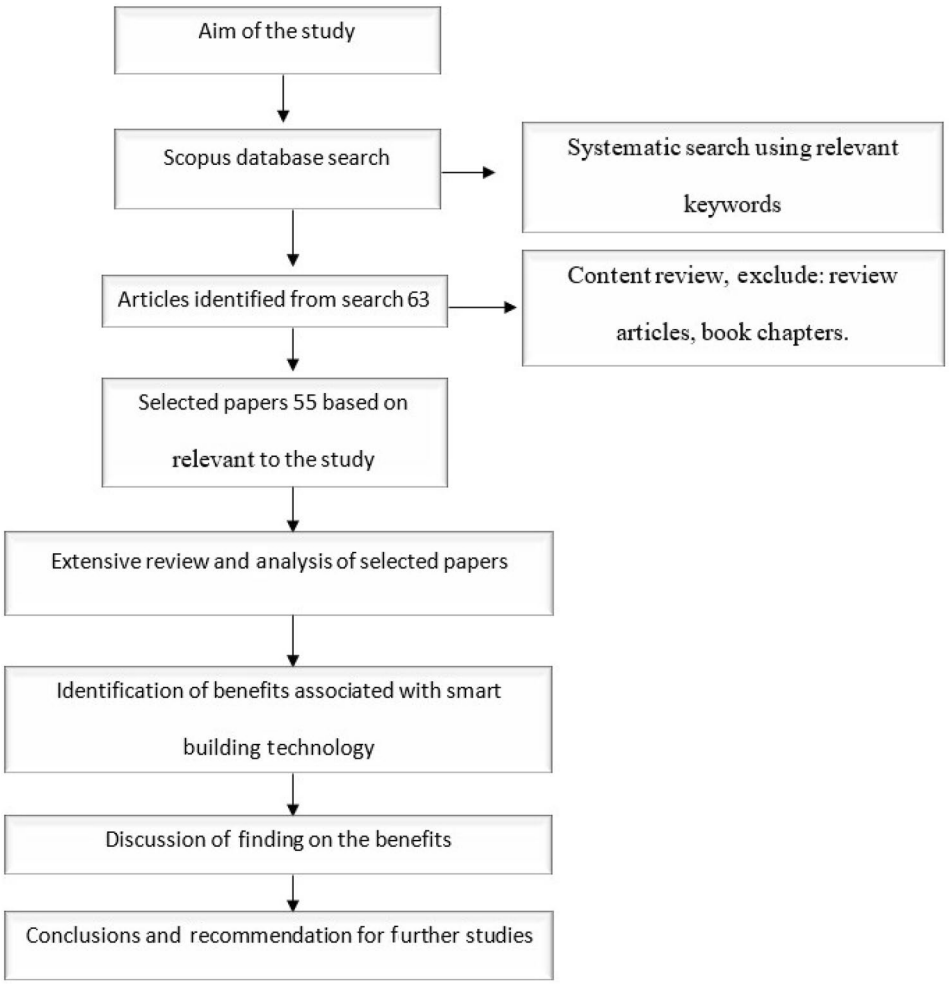

Fig. 1 Overview of the research approach

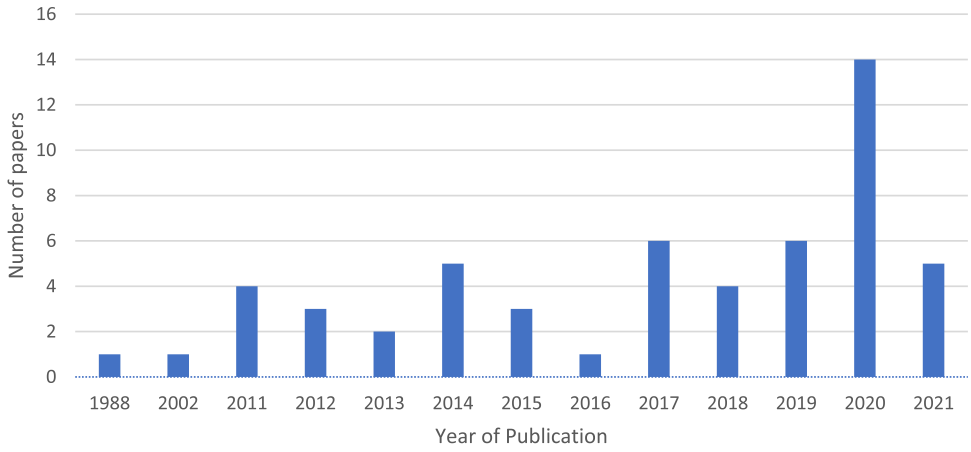

Fig. 2 Papers in selected journals about the benefits of technology adoption (SBTs) by year

to the desire to achieve comfort and energy-saving in the built environment. Furthermore, the research looked at the literature on technology adoption, sustainable construction, and benefits in the construction sector and how they relate to smart building. Most papers were published in 2020 (14 papers), 2019 (6 papers), 2017 (6 papers), and 2014 (5 papers); all of which are considered contemporary because they are less than ten years old.

3.2 The smart building technology

According to Sherif, Sherif and Eissa [36:p15], smart buildings are "automated buildings, intelligent buildings, and buildings with smart technology". It is a term used to describe structures that include technologies such as digital infrastructure, energy efficiency measures, intelligent building management systems, wireless technologies, remote monitoring, information and communications networks, adaptive energy systems, networked appliances, data gathering devices, assistive technologies and automated systems.

Furthermore, Smart building technology is the collaboration of building automation systems, integration systems, and telecommunication systems for smart building's efficiency, functionality, optimisation, comfort, and economic stability [10]. A Smart building is a building that optimises its structures, systems, services, and management including the interrelationships between them to deliver a productive and cost-effective environment [37]. In their study Buckman, Mayfield, and Beck [38] identified Smart building technology in four significant accounts: intelligent, enterprise, control, and materials and construction, which should- be adaptable to building to meet building advancements in energy efficiency, comfort, satisfaction, and longevity (life cycle). In smart buildings, microchips, actuators, and sensors are utilised to collect data and manage it according to the tasks and services of the company [39]. This infrastructure also helps building owners, operators, and managers increase asset reliability and performance, maximise space usage, decrease environmental impact, and provide security, comfort, energy efficiency (low operating costs), and convenience [36].

3.3 The benefits of smart building technology in developing countries

Adopting smart building technology in the construction industry of developing countries is beneficial to professionals, clients, and the entire country. Vattano [28] states that using Smart buildings in sustainable construction allows the industry to produce less waste while using resources efficiently and without harming the environment. In terms of achieving sustainability goals for project delivery, smart building technology may succeed but fail in adopting the practice in the construction industry [1]. Therefore, it is vital to consider looking at the benefits of SBT for successful adoption. Bandara, Abeynayake, and Pandithawatta [27] identify the benefit of SBT for project delivery in three sustainability goals: economic, social, and environmental.

Sovacool and Furszyfer Del Rio [40] discovered that smart building's environmental benefits involve reducing greenhouse gas emissions, which is achieved through better monitoring of energy usage and control over carbon emission of CO_2 related materials in buildings. According to Honeywell and IHS [41], smart building's economic benefit over traditional convectional structures is that the investment pays off quickly, and

failure of appliances and equipment in the building is avoided, thus, avoiding fire outbreaks and energy difficulties. According to Balta-Ozkan, Boteler, and Amerighi [42], the social benefit of a smart building is a concern with safety, healthcare management, and security. Sherif, Sherif and Eissa [36], in their study, identify the benefits of SBT in general as a strategy for reducing energy costs, increasing the productivity of staff, improving building operations, providing web-based security, and improving the safety of life and security of occupants. A smart building can be compatible with existing buildings, offering comfort and time-saving. Honeywell and HIS [41] also discovered benefits such as health and safety, data infrastructure connectivity, detecting faults in the system, and cost-saving. This paper discusses only the top five (5) benefits. Table 1 illustrates the benefits based on the number of times researchers are mentioned and the top six mentioned benefits.

3.3.1 Energy saving

Smart building technologies improve energy efficiency and maximises energy savings over time of the building [41–43]. In the study conducted by [44, 45], smart building ensures that energy consumed in the building is controlled and monitored in real-time to improve the performance of the building and makes it to be environmentally friendly. As reported in the literature, smart buildings contributed to energy saving and reduced power consumption from 765,228.16 to 499,067.01 kWh, leading a reduction of 34.78% [2, 37]. Therefore, this study identifies energy saving as a significant benefit of adopting smart building technology in developing countries.

3.3.2 Safety and security

According to Honeywell and IHS [41], the way a building responds to threats, manages access to the facility, secures lives and assets, and makes it comfortable and productive; these are all examples of safety and security systems (illumination, thermal comfort, air quality, connectivity, energy availability). Security and safety in smart buildings are paramount. Humans require complete safety and security, whether the facility is a residential building or commercial building [34, 46]. Therefore, safety and security are vital benefits of adopting SBT in developing countries.

Table 1 The benefit of smart building technology

Code	Benefits	References	Number of times mentioned	Rank
B01	Energy saving management	[10, 27, 36, 40, 41, 43–46]	9	1
B02	Safety and security	[10, 27, 36, 38, 40, 43, 45, 46]	8	2
B03	Maintenance cost-saving	[10, 36, 43, 46, 47]	5	3
B04	Improve building comfort	[10, 38, 43, 46]	4	4
B05	Productivity and collaboration	[36, 38, 41, 43]	4	5
B06	Improve building efficiency,	[10, 41, 43]	3	6
B07	Reduce global warming	[27, 41, 43]	3	7
B08	Health care improvement	[27, 40, 41]	3	8
B09	Water Management	[41, 43, 46]	3	9
B10	Conserving Natural Resources	[41, 46]	2	10
B11	Optimising asset utilisation	[41, 45]	2	11
B12	Maximise technical performance	[46, 48]	2	12
B13	Vertical transportation	[46, 49]	2	13
B14	Time-saving in creating market application	[27, 41]	2	14
B15	Creation job(marketable)	[46]	1	15
B16	Improvement of education service	[40]	1	16
B17	Improve return on investment (ROI)	[41]	1	17
B18	Improve property value	[49]	1	18
B19	Real-time Data management	[43]	1	19
B20	Data connectivity integration	[43]	1	20
B21	Web- based security	[36]	1	21
B22	Quick response to the occupants	[41]	1	22
B23	Reduce redesign cost by detecting faulty situations	[48]	1	23

3.3.3 Maintenance cost-saving

According to Iwuagwu, Chioma, and Iwuagwu [44], Smart buildings gain that the total cost of a facility is not just its construction cost but also the operating and maintenance costs during the lifecycle of the building. The authors explained that buildings could save money by improving automated control, communication, and management systems by sharing equipment among numerous users. Also supported by Honeywell and IHS [41], smart buildings reduce the cost of energy at home and control how much energy is used, such as lowering the costs of operations and maintenance or even lowering the costs of fixed appliances. Further explained by Honeywell and IHS [41], Smart buildings use modern technology to connect these elements (safe, green and productive), and systems are more integrated, dynamic, and functional fashion, rather than saving money on maintenance alone.

3.3.4 Improve building comfort

According to Buckman, Mayfield, and Beck [38], a smart building is significant in learning, which occurs over time as the building systems interpret data from the previous usage and adapt, allowing the occupant's preferences to be used to create a higher degree of comfort and satisfaction. The authors further explained that SBT predictions provide helpful information to help occupants save money on energy while improving comfort. Smart buildings optimise lighting, utilities, and Heating, ventilation, and air conditioning (HVAC) systems to save money by matching occupancy patterns and desired comfort levels to save energy usage and real-time monitoring of building systems to minimise crucial asset loss [34, 47].

3.3.5 Productivity and collaboration

According to Ishmael, Ogara, and Raburu [43], lighting is vital for smart building technology because illumination impacts occupants' well-being, motivation, and productivity. [31, 36] revealed that smart building technology provides a platform for increasing employee productivity and collaboration, improving building operations, and promoting sustainability. System integration in smart buildings improves the quality of life of workers and occupants while also increasing sustainability, safety, and productivity [41]. The productivity and collaboration driven by SBT can influence the adoption in developing countries.

4 The study implications

The smart building technology application in construction practice addresses the needed change in the built environment, especially in developing countries. The adoption of the smart building improves the practices of professionals in the built environment and also involves changing the mindset of the professionals to the advancement of technologies era in the construction industry. The professionals require new techniques and understanding to promote the adoption SBT in the construction industry, especially the increasing concern of energy efficiency and comfort of the occupant in the building as it increases the attention of smart building adoption in the construction industry. Most of the research on smart buildings was conducted in developed countries, despite the increasing benefits of the technology application in the construction industry, which has shown a concern to indicate the benefits of adopting these technologies in the construction industry of developing countries to improve the practice's productivity of the professionals and achieve sustainability in the construction industry.

5 Conclusions and recommendations

This study focused on the benefits of adopting smart building technology in sustainable construction in developing countries. The Scopus search engine was utilised to acquire relevant academic (peer-reviewed) articles and conference papers for this study. The study reveals that several SBTs benefits such as energy saving, safety and security, cost-saving maintenance, improved building comfort, increased productivity and better collaboration among the building occupants are the benefits of smart building technologies. Moreover, this study reveals that SBTs offer a potential answer to some sustainability concerns that developing countries face. Understanding the benefits of SBTs in the construction industry will not only stimulate the interest of both clients and professionals in developing countries but will go a long way to promoting the adoption SBT. Consequently, this study recommends that empirical research be undertaken to establish the primary benefits of adopting SBTs for project delivery in developing countries. The study further recommends the establishment of a robust collaboration framework between construction industry professionals and academia to grow innovation that will promote greater adoption of SBTs in developing countries.

Declarations

Conflict of interest The authors do declare that they have no competing interests.

References

1. Ghansah FA, Owusu-Manu DG, Ayarkwa J (2020) Project management processes in the adoption of smart building technologies: a systematic review of constraints. Smart Sustain Built Environ 10(2):208–226. https://doi.org/10.1108/SASBE-12-2019-0161
2. Lin Q et al (2020) Design and experiment of a sun-powered smart building envelope with automatic control. Energy Build. 223:110173. https://doi.org/10.1016/j.enbuild.2020.110173
3. Wang X, Dong X, Fan W, Xu Z, Wang Y (2019) Air pollution terrain nexus: a review considering energy generation and consumption. Renew Sustain Energy Rev 105:71–85. https://doi.org/10.1016/j.rser.2019.01.049
4. Liu Z, Liu Y, He B, Xu W, Jin G, Zhang X (2018) (2019) "Application and suitability analysis of the key technologies in nearly zero energy buildings in China." Renew Sustain Energy Rev 101(August):329–345. https://doi.org/10.1016/j.rser.2018.11.023
5. Pallante A, Adacher L, Botticelli M, Pizzuti S, Comodi G, Monteriu A (2020) Decision support methodologies and day-ahead optimization for smart building energy management in a dynamic pricing scenario. Energy Build 216:109963
6. Fazli T, Dong X, Fu JS, Stephens B (2021) Predicting US residential building energy use and indoor pollutant exposures in the mid-21st century. Environ Sci Technol 55(5):3219–3228
7. DEMS, "Hong Kong Energy End-use Data 2018 (Table 01): key energy end-use related data," 2018. https://data.gov.hk/en-data/dataset/hk-emsd-emsd1-energy-end-use-data-2018/resource/edff2fca-f2b7-4d12-8ed8-dee60238150e
8. Mejjaouli S, Alzahrani M (2020) Decision-making model for optimum energy retrofitting strategies in residential buildings. Sustain Prod Consum 24:211–218. https://doi.org/10.1016/j.spc.2020.07.008
9. World Green Building Council, "Bringing Embodied Carbon Upfront," (2020) Accessed Mar 02, 2022 https://www.worldgbc.org/embodied-carbon
10. Indrawati RY, Amani H (2017) Indicators to measure a smart building: an Indonesian perspective. Int J Comput Theory Eng 9(6):406–411. https://doi.org/10.7763/ijcte.2017.v9.1176
11. Feige A, Wallbaum H, Krank S (2011) Harnessing stakeholder-motivation: towards a Swiss sustainable building sector. Build Res Inf 39(5):504–517. https://doi.org/10.1080/09613218.2011.589788
12. Darko A, Chan APC, Gyamfi S, Olanipekun AO, He BJ, Yu Y (2017) Driving forces for green building technologies adoption in the construction industry: Ghanaian perspective. Build Environ 125:206–215. https://doi.org/10.1016/j.buildenv.2017.08.053
13. Berardi U, GhaffarianHoseini AH, GhaffarianHoseini A (2014) State-of-the-art analysis of the environmental benefits of green roofs. Appl Energy 115:411–428. https://doi.org/10.1016/j.apenergy.2013.10.047
14. Wa A, Akbarnezhad A, Wu P, Wang X, Haddad A (2019) Building information modelling-based framework to contrast conventional and modular construction methods through selected sustainability factors. J Clean Prod 228:1264–1281. https://doi.org/10.1016/j.jclepro.2019.04.150
15. Okoye PU, Okolie KC (2014) Exploratory study of the cost of health and safety performance of building contractors in south-east Nigeria. Br J Environ Sci 2(1):21–33
16. Alaloul WS, Musarat MA, Rabbani MBA, Iqbal Q, Maqsoom A, Farooq W (2021) Construction sector contribution to economic stability: Malaysian GDP distribution. Sustainability 13(9):5012
17. Mewomo M, Ejidike C (2021) Smart building as key driver in the elimination of greenhouse gas emission in the less economically developing country (LEDC). In: Exploring contemporary issues and challenges in the construction industry: (CCC2021). 5th CU Construction Conference, 2021, pp. 162–168
18. McGlinn K, O'Neill E, Gibney A, O'Sullivan D, Lewis D (2010) Simcon: a tool to support rapid evaluation of smart building application design using context simulation and virtual reality. J Univers Comput Sci 16(15):1992–2018
19. Crespi M (2020) An economic feasibility study of smart building investments: the Italian scenario
20. Casini M (2016) Smart buildings: advanced materials and nanotechnology to improve energy-efficiency and environmental performance. Woodhead Publishing, Sawston
21. Minoli D, Sohraby K, Occhiogrosso B (2017) IoT considerations, requirements, and architectures for smart buildings—Energy optimization and next-generation building management systems. IEEE Internet Things J 4(1):269–283
22. Baleta J, Mikulčić H, Klemeš JJ, Urbaniec K, Duić N (2019) Integration of energy, water and environmental systems for a sustainable development. J Clean Prod 215:1424–1436. https://doi.org/10.1016/j.jclepro.2019.01.035
23. Ejidike CC, Mewomo MC (2022) A review of barriers to the adoption of smart building concepts (SBCs) in developing countries. In: Construction in 5D: Deconstruction, Digitalization, Disruption, Disaster, Development: Proceedings of the 15th Built Environment Conference, 2022, vol. 245, p. 29
24. Ghansah FA, Owusu-Manu DG, Ayarkwa J, Edwards DJ, Hosseini MR (2021) Exploration of latent barriers inhibiting project management processes in adopting smart building technologies (SBTs) in the developing countries. Constr Innov 21(4):685–707. https://doi.org/10.1108/CI-07-2020-0116
25. Gobbo Junior JA, De Souza SCDO, Gobbo MGZN (2017) Barriers and challenges to smart buildings' concepts and technologies in Brazilian social housing projects. Int J Sustain Real Estate Constr Econ 1(1):31. https://doi.org/10.1504/ijsrece.2017.10005278
26. Darko A, Zhang C, Chan APC (2017) Drivers for green building: a review of empirical studies. Habitat Int 60:34–49. https://doi.org/10.1016/j.habitatint.2016.12.007
27. Bandara KTW, Abeynayake M, Pandithawatta T (2019) Applicability of smart building concept to enhance sustainable building practice in Sri Lanka
28. Vattano S (2014) Smart buildings for a sustainable development. Econ World 2(5):310–324
29. Akadiri PO, Chinyio EA, Olomolaiye PO (2012) Design of a sustainable building: a conceptual framework for implementing

sustainability in the building sector. Buildings 2(2):126–152. https://doi.org/10.3390/buildings2020126
30. Tan SY, Taeihagh A (2020) Smart city governance in developing countries: a systematic literature review. Sustainability. https://doi.org/10.3390/su12030899
31. Denyer D, Tranfield D (2009) Producing a systematic review. The SAGE handbook of organizational research methods. pp. 671–689
32. Riley DR, Thatcher CE, Workman EA (2006) Developing and applying green building technology in an indigenous community: an engaged approach to sustainability education. Int J Sustain High Educ 7(2):142–157. https://doi.org/10.1108/14676370610655922
33. Omer AM (2017) Sustainable development and environmentally friendly energy systems in Sudan. Int J Phys seciences Eng 36(1):1–39
34. Evangelopoulos N, Zhang X, Prybutok VR (2012) Latent semantic analysis: five methodological recommendations. Eur J Inf Syst 21(1):70–86. https://doi.org/10.1057/ejis.2010.61
35. Liu X (2013) Full-text citation analysis : a new method to enhance. J Am Soc Inf Sci Technol 64(July):1852–1863. https://doi.org/10.1002/asi
36. Sherif SA, Sherif MA, Eissa DHA (2018) Implementation of smart building (a complete end to end solution for smart building system), vol. 38, pp. 15–20
37. Omar O (2018) Intelligent building, definitions, factors and evaluation criteria of selection. Alexandria Eng J 57(4):2903–2910. https://doi.org/10.1016/j.aej.2018.07.004
38. Buckman AH, Mayfield M, Beck SBM (2014) What is a smart building? Smart Sustain Built Environ 3(2):92–109. https://doi.org/10.1108/SASBE-01-2014-0003
39. Enshassi A, Ayash A, Mohamed S (2018) Key barriers to the implementation of energy-management strategies in building construction projects. Int J Build Pathol Adapt
40. Sovacool BK, Furszyfer Del Rio DD (2019) Smart home technologies in Europe: a critical review of concepts, benefits, risks and policies. Renew Sustain Energy Rev 120(May):109663. https://doi.org/10.1016/j.rser.2019.109663
41. Honeywell and IHS, Put your buildings to work : a smart approach to better business outcomes, p. 27, 2015, [Online]. Available: http://www.krcresearch.com/wp-content/uploads/2015/11/Honeywell_Smart_Building_Whitepaper-10-28-15.pdf
42. Balta-Ozkan N, Boteler B, Amerighi O (2014) European smart home market development: public views on technical and economic aspects across the United Kingdom, Germany and Italy. Energy Res. Soc. Sci. 3:65–77. https://doi.org/10.1016/j.erss.2014.07.007
43. Ishmael NA, Ogara S, Raburu G (2020) Review of smart buildings based on adoption of Internet of Things application enablement platform. no. 1, pp. 115–132
44. Iwuagwu U, Iwuagwu M (2014) Adopting intelligent buildings in Nigeria: the hopes and fears. Vol. 234, no. 0, pp. 0–3, 2014, doi: https://doi.org/10.15242/iie.e0514560
45. Froufe MM, Chinelli CK, Guedes ALA, Haddad AN, Hammad AWA, Soares CAP (2020) Smart buildings: systems and drivers. Buildings 10(9):1–20. https://doi.org/10.3390/buildings10090153
46. Berawi MA, Miraj P, Sayuti MS, Berawi ARB (2017) Improving building performance using smart building concept: benefit cost ratio comparison. AIP Conf Proc. https://doi.org/10.1063/15011508
47. Chang BL, Hancher DE, Napier TR, Kapolnek RG (1989) Methods to identify and assess new building technology. Vol. 114, no. 3, pp. 408–425
48. ARCADIS (2020) Smart buildings |Adapting to change
49. Oke AE, Omole O, Aigbavboa C (2020) Benefits of adopting intelligent building system. FIG Working Week 2020 on Smart Surveyors for land and Water Management, pp 1–13