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Optimizing the Future: Critical Review on Smart Building Contraction Technologies

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Abstract: In order to enhance a building's functionality and energy efficiency, smart construction technology combines controlled reliable controllers and programs with connected sensors, smart energy products, and data analytics software to track ambient data and resident energy usage patterns. The integration of intelligent technologies and controllers in the construction sector is steadily expanding as a result of their growing significance in the fabrication, business-related; it and scholarly domains. This investigation uses a systematic strategy to review the related published literature between 2013 and 2023.Prior to investigating the rating of publications based on quality evaluation and yearly trend publication was done. The study further classifies the literature based on integration technologies and application. The finding reveals that most of the literature features with occupants an interface to schedule, monitor, and adjust energy consumption profiles. These developments also enable utilities to engage in an exchange with the grid by means of demand response strategies and automatic feedback interruption features.Potential study directions are also examined in the paper, particularly with regard to seamless integration, privacy, and security enhancements. It is also proposed that continuous surveillance of data and machine learning are two ways to enhance the intelligence of smart building technology.

I. Introduction

The advancement of Internet of Things (IoT) technological innovations and Machine Learning (ML) presents novel prospects for the creation of novel solutions across several industrial sectors. It encourages the development of a fresh wave of very trustworthy, accessible, secure, safe, and effective smart apps. These technologies have previously been partially or fully utilized to create applications that offer a number of advantages, including increased safety and logistics and safety in work environments. Although intelligent apps have as other industrial sectors have previously shown, there is a widespread perception that the building industry is falling behind. A preliminary analysis of the literature revealed a persistent deficiency in research that combines IoT and ML technologies. Therefore, this study present a comprehensive review that covered an adequate number of articles on smart building construction technologies published in different venues between 2013- 2023. The major objectives of this study is to review the current research in smart construction technological solutions and infrastructure with goal to identify the current research trends, potentials, and limitations associated with creating and utilizing smart apps in the construction industry. Additionally the work present thorough summary of research areas application demonstrate efficacy for these technologies. Section 2 present material and methods. Section 2 covers various aspect of smart technologies enable in construction. While Section 3 highlights some new research directions for smart construction applications that are quite interesting when developing smart applications. The article is concluded in Section 4, which addresses the problems and difficulties encountered.

II. Material and Methods

A systematic review is a type of research methodology created to collect, assess, and analyze all the data relevant to a given research issue or area of interest. The study chose a systematic review as an approach to carry out the analysis since its goal is to provide an unbiased evaluation of a research issue in a trustworthy, rigorous, and methodical manner. It is important to note that, the strategy recommended by Kitchenham[1] is employed. The process involved several phases and activities (see Figure 1).

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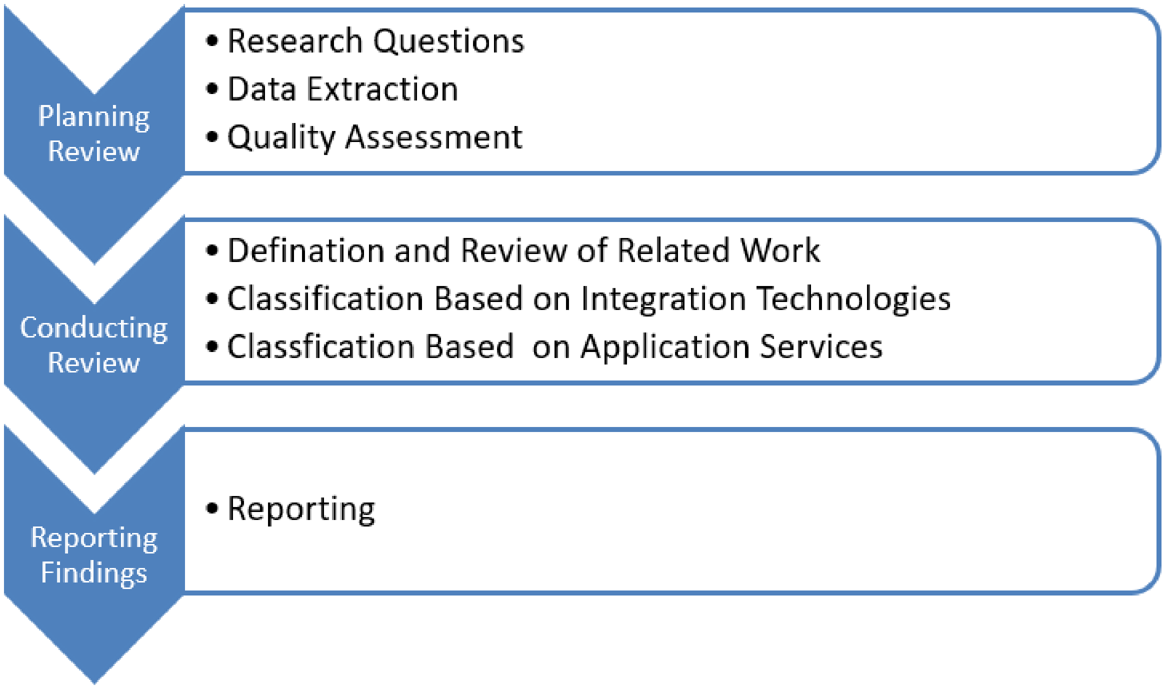

Figure 1. Processes and activity diagram of the literature review

III. Planning Phase

In order to establish the review's scope and determine its main objective, the planning procedure for the review begins with the preliminary inquiry phase. A preliminary review of the literature identifies a number of gaps that spur the investigation into the application and reach of smart building structure.

3.1 Research Questions

Most of the existing review in smart building construction does not have well defined research question (RQ). However, this study presents three main RQ to achieve the goal of the study as follows:

RQ1: What are the quality levels of smart building construction technologies research?

The goal is to identify possible assess the research quality in area of smart building construction technologies.

RQ2: What are the existing technologies for smart building construction?

The goal is to identify possible technologies involved in smart building construction.

RQ3: What are the existing smart building construction applications?

The goal is to identify application of existing smart building construction technologies

3.2. Data Extraction

The review process starts by conducting systematic searches on five different electronic databases based on designed search terms. The study considered "smart building construction technologies". Only journals, conferences are considered from 2013 to 2023. In the search process, three primary keywords, "smart construction", "smart technologies in construction," " and "smart construction application".

3.2.1 The search process

The research search process starts with using "smart construction", which results in 34related literatures. As can be seen in Figure 2, there are more papers related "Internet of Things" followed by "human", "air conditioning" and so forth. This indicates researchers are putting more emphasis on IoT to enable smart construction design in built environments to ensure building sustainability, which also plays a major role in reducing carbon emissions.

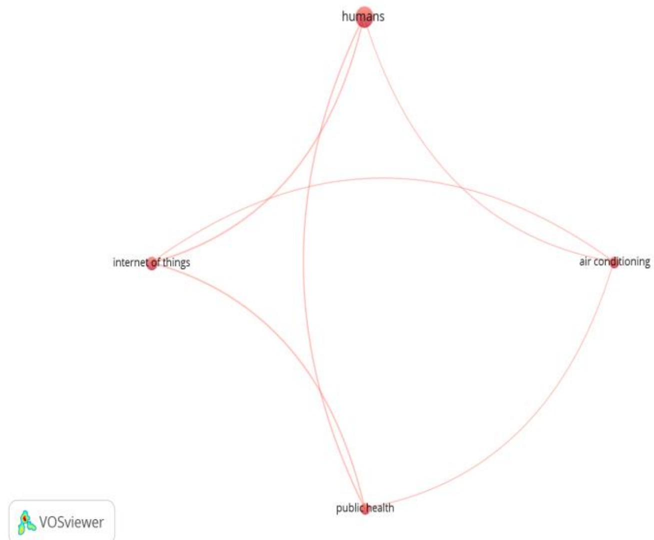

Figure 2. smart construction

The research also used “smart technologies in construction” as a major keyword for searching related literature across five different databases, which resulted in the retrieval of 88 related literatures. It is shown in Figure 3 that papers related to “temperature control”, wearable sensor”, “machine learning”, Internet of Things”, “nano structure” and “bio sensing technologies” have a higher percentage among the literature discovered in this search.

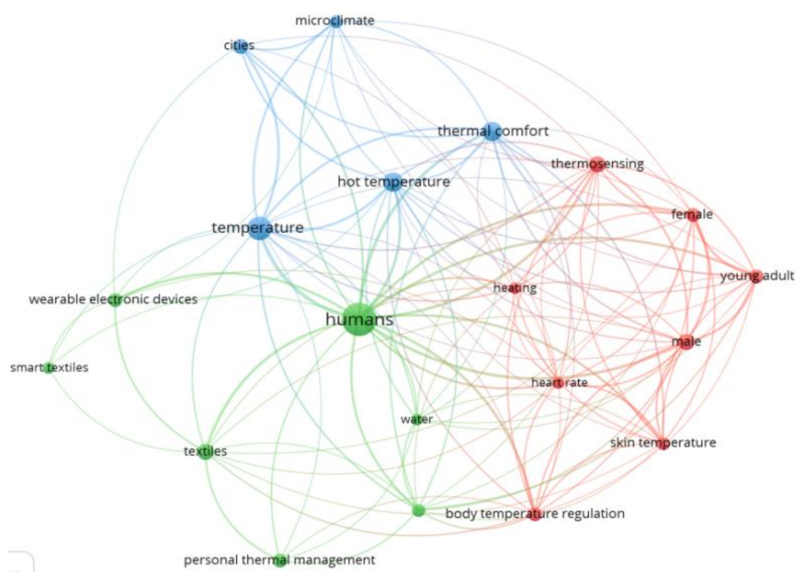

Fig 3. smart technologies in construction

The search moved to “smart construction application” as the main keyword. The search was done across five different databases, which resulted in 87 existing literature. A large portion of the literature discovered on this search is related to “smart home” followed by “internet of things”, “machine learning and so forth, as seen in Figure 4. This shows that research in building energy sectors is utilizing the Internet of Things technology alongside machine learning to transform buildings into energy-aware environments.

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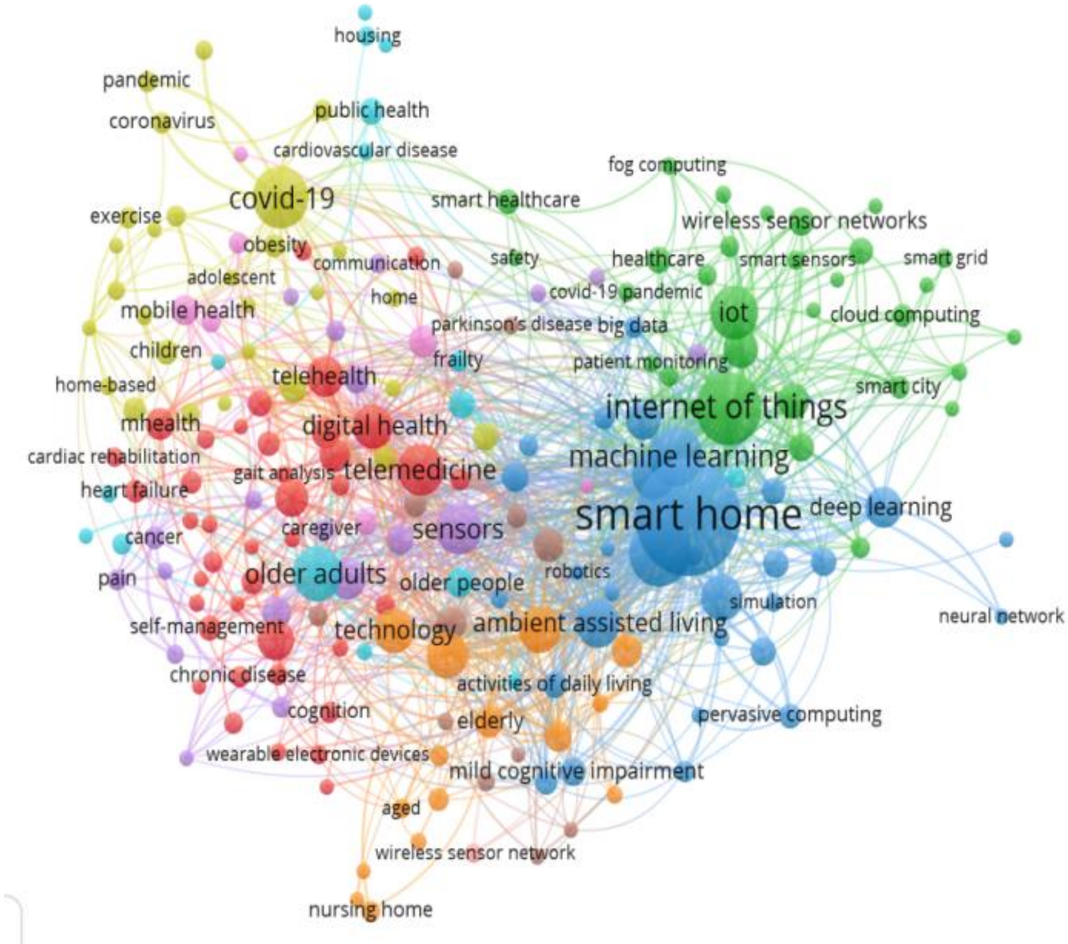

Figure 4. smart construction application

3.2.2. Sorting of the related literature

After the search was done, the entire literature during the search process resulted in 209 literatures. The research team removed similar publications that appeared in several queries by using a Google document page coupled with an Excel spreadsheet. This procedure helps track and remove 76 identical publications and a reduction in the total number of publications from 209 to 133 researches. Substantial duplicates were discovered across the search outcomes received during the second, third, and fifth stages of the query, with only a few duplicates discovered during the fourth phase of the query.

3.3 Quality assessment

The goal of a quality rating examination is to determine the input and degree of research quality for the field of study of smart building constructions.After assessing research using quality assessment requirements, the finding shows that 35 out of 24 studies received a 6/6 grade, 18 studies received a 5.5 out of 6. Similarly, 8 studies out of 54 receive 5 out of 6 and 4 studies receive 4 out of 6. The research with a score of 6 corresponds to the two topics the smart building construction technologies offer an innovative Such with a score of 5.5 are those who do not have enough technique of assessment.

The research with a score of 6 to 5.5 is journal articles. Similarly, those with 4 scores simply presented proof of theory or concept and presented in the form of conferences.

3.3.1 Trend of publication

Figure 5 displays the overall amount of publications, comprising research papers and reviews, according to the publication year, ranging from 2013 to 2023.

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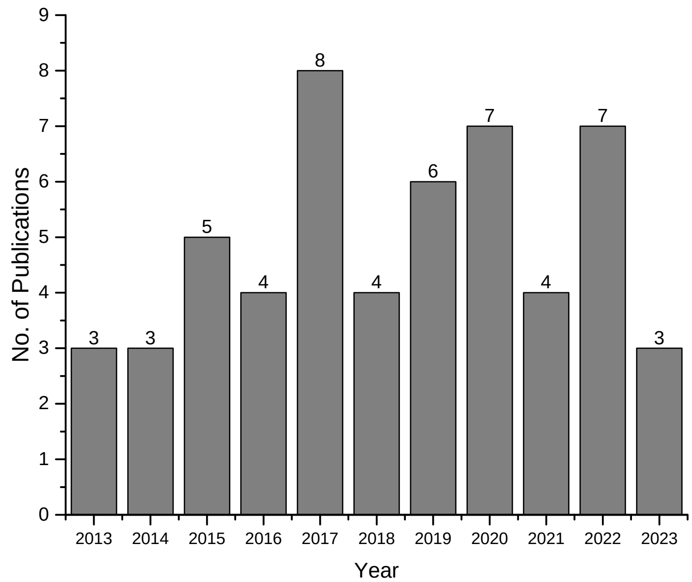

Figure 5.Literature publication trend

Figure 5 demonstrates that the years with the fewest research papers were 2013 and 2014, whereas the years with the most publications were 2017 through 2022. It also demonstrates that a relatively small percentage of scholars (16.4%) suggested survey and comparative review analysis-based review activity. Most of these evaluation works tend to ignore the research constraints that enhance the algorithm platform, architectural design, or model for smart technologies, instead concentrating on identifying shortcomings in the way smart detectors or devices operate. This demonstrates the eagerness of smart home research to seek out scholarly and industry suggestions to improve the efficiency and utility of smart building construction technology.

IV. Definition and related work

Smart has been conceptualized and defined using a variety of meanings. Among the various methods, the definitions by [2] and [3] provided a comprehensive overview of the characteristics of smart houses. According to the study, a smart home is "a dwelling outfitted with information and computer technology, which anticipates and reacts to the requirements of the residents, striving to enhance their ease, security, and amusement by controlling the technology inside the house and establishing links with the outside world." They defined smart homes by taking into account the technological side of the phenomenon, its features and services, and the various user needs they aim to meet. Similarly, a study in [5] defines smart homes as "the coordination of various services within a house through the use of a shared communication infrastructure." It delivers cost-effective, safe, and pleasant home operation along with a high level of clever flexibility and usefulness. An overview of the most recent smart home techniques and strategies can be found in the section that follows.

The suggested smart home system that uses occupant data or variable indoor climate conditions simplifies HVAC operating management[2]. The study satisfies demand-driven design guidelines by utilizing a transparent system of regulation modeled with various parameters. The smart home approach developed by the authors depends on pre-existing external signals to initiate request control[3]. Reactive control has the benefit of not allowing occupant period or change in schedule to impact microcontroller operation. In order to meet demand as inexpensively as feasible, research has devised an algorithm that requires control factors such as expenses, heat request, or photovoltaics production. This suggests that in order to identify the best time to consume energy, processors need to be awake to the appropriate input and analyze it. In [2], a design plan for a smart house is presented that makes use of a more sophisticated control that decides when to use electrical devices throughout optimal usage hours by applying rules for inference and algorithms.

Research in [3-6] employ a variety of installed sensors placed inside the area of interest to detect and forecast occupancy in real-time. By using these methodologies, the past literature's misleading findings about occupant forecasting are minimized, and appliance energy usage is improved. These methods, however, have difficulty anticipating real human occupation in order to prevent false negatives caused by immobile items like pets such as cats and dogs and various other things. Forecasting a construction's current overall occupancy to modify thermal comfort in accordance with the number of occupants creates a further challenge.

According to a research in [7], an HVAC regulator was created that employs passive infrared sensor technology and atmospheric carbon dioxide (CO2) to identify occupants and transmit an indication to an operator that controls climate turning based on the variety of inhabitants in the construction. Despite the fact that these sensors have been extensively employed in earlier research, [8] suggests that their commercial implementation is not feasible. Similar methodology used ML algorithms with CO2-based methods. The assessment of the results shows excellent results even in the face of an abrupt temperature shift inside the area of interest, similar to what happens when a place is occupied.

In a work published in [2-4], an algorithm for occupation identification using audio was suggested. This controller successfully identified human beings and estimated the overall amount of occupants in area using a Gauss Random Theory. The suggested approach produced a certain degree of precision however there were a lot of false positives due to ambient noise in the area. Similarly, in order to estimate occupancy for HVAC flow management, the method necessitates ongoing interaction from all indoor spaces.

A noise cancelation process is introduced in [3] to improve the precision efficiency of the device in [2]. It ignores the resonance degree of the preferred time limit identified. The concept is based on the quantity of the noise the rate obtained by the ambient revoked algorithm, lowering the occurrence of false alarms of use forecasting by 11–12% and saves 3.54% the energy used by HVAC units. However, the study still experiences false residence forecast.

In [2], a control system is described that combines, with the use of computational vision (CV) libraries, camera-based video and image processing with the ability to determine overall occupant counts using interior object detection or enumeration. A comparable technique is employed in [3], which regulates the air flow in the lecture hall by using an estimated population calculation process and single-camera occupants verification. The study of the results of experimentation demonstrates excellent occupancy predictions. Nevertheless, the report's erroneous result stems from the camera's inadequate coverage during pupils' haphazard entry or departure from the area of attention. Poor awareness of occupancy around residence merging throughout the time of an arrival and departure from an area of interest presents the study's main obstacle.

In [2–5], an adaptive regulator is shown that detects human beings in space by combining both thermal and visual cameras. The goal is to use only one camera to minimize false alarms and guarantee identification accuracy, which will boost HVAC expenditures and enhance thermal comfort.

In [6], a non-predictive regulator that mostly depends on occupancy set timelines is developed. It makes use of these kinds of data to establish a model that forecasts a building's occupancy rate and use that knowledge to control HVAC systems. This kind of control method might be helpful in a situation where job activities are strictly followed on a daily basis by a set scheduling policy. Offices, laboratories, and workplaces are excellent examples of businesses that make full use of literature [7–11]. Conversely, this tactic would not work in an environment when usage is flexible or exceeds a predetermined schedule.

The majority of non-predictive controls, such those found in [2, 3], used boolean methods to show how frequently turning gadgets on and off tends to degrade over time. Fuzzy logic as well as more sophisticated decision-control methods employed by [4] were created as enhancements to basic methods that dealt with data in addition to one or zero by providing background and enabling control to choose from a wider range of options. A controller that regulates HVAC consumption of energy based on request was put forth by study in [5]. When the cost for power reaches its peak, the regulator has the ability to react and delay demand. A planning scheme is used in a related method in [6] to identify the signal of regulation that activates the requirement for usage of energy.

The schedule-based regulator that was earlier in use [6–10] to save energy expenses and stop devices from being used when usage is high. One way to make advantage of the energy stored in a machine is to program it to run on reserve when energy prices are lower. This way, other equipment in your residence can use the energy stored in that gadget. This control can be given by either a static mechanism or a dynamically.

4.1 Smart Home Integration Technologies

Comparable duties in a home with a smart system may be accomplished with various system interfaces. For instance, a number of investigations have successfully shown how to manage smart lights via web-based and mobile applications. In an effort to address RQ2, prior survey research did not look at smart home systems in order to evaluate sensible home integrative innovations, which is crucial to spot movements and issues with quality features including efficacy, safety, and security.

4.1.1Mobile application

It has been noted that as sophisticated control techniques have evolved over time, ambient circumstances and human energy profiles have become an essential component of modern HVAC systems, leading to a progressive improvement in efficiency. Many the first-generation approaches, on the other hand, are unable to accurately capture temperature sensations, leading to increased discomfort and consumption of power. The remaining two groups appear in the progression of the initial one in order to determine the amount of indoor occupants, regulate cleaning levels under a desirable discomfort level, and prevent circulation of vacant spaces. Furthermore, a few items, such the ones listed in [2–7], offer the ability to significantly help customers centralize the use of all their gadgets and plan how they use energy. On the other hand, a few number of research permit visually impaired users to utilize screen readers found in most smartphones and tablets to access the layout of various devices, items, and gadgets at home through a more user-friendly virtual interface..

4.1.2 Web application

Most of the time, a website or internet browser may be used by the user to connect to intelligent home appliances with any specific platform dependencies. On the other hand, effective interaction requires a link to the web. Compared to cell phone software, web application evaluation is becoming more and more widespread. The main objective is to use automated and wireless control to make managing household appliances easier. The most advantageous aspect of this online application for managing the device from a laptop or cellphone is that it helps individuals with limitations or challenges..

According to recent studies [2-4], conventional a website tactics are shifting in favor of a more straightforward approach to website and API creation and exposure. Present-day Web APIs transport data payloads immediately as part with the HTTP protocol, instead of using the conventional stack, and totally depend on the collaboration basics provided by the HTTP protocol[5].Furthermore, solutions enforced a new emerging idea of web service creation that allows for an modular the system building by discovering a number small, extremely separated support that have a focus on completing a particular smaller task. These solutions also made use of a client and a server exchange in a more confined and established manner. Thus, a multitude of small, self-contained, replaceable subdomains can be assembled to create intricate applications.

4.1.3 Wearable devices

The term "wearables" refers to a range of gadgets that can be embedded into the flesh, worn as gadgets, or perhaps inked on a person's body. These gadgets serve uses that eliminate the need for hands-on manipulation, and are fueled by chips via the extra benefit of communicating with and receiving details through the network. The adoption of gadget research is comparable to that of web-based and mobile apps. Studies [6–9] used smartwatches to connect with intelligent hub regulators inside the house that assisted residents plan electricity consumption and make suggestions for optimal times when to use energy at lower prices. Studies [10–13] addressed important issues with wearable technologies in multi-residential buildings.

4.1.4 Smart home appliance

Utilizing cameras, a central electronic controller, sometimes referred to as an intelligent home hub, regulates refrigerators, CCTV cameras, lighting, and various other home appliances. The hub was an actual part that functions as the communication, perception, and analysis center for the connected house system. It combines all of the various smart home apps into an integrated app that customers may control remotely. A few instances for digital home hubs are Bulb Hub, Google Assistant, and the Echo from Amazon. Some intelligent home appliances rely on wireless connectivity standards like Z-Wave or Zigbee, whereas many connected home appliances link to the smart family network through Wi-Fi and Bluetooth. By interacting with providers to obtain power costs to lower or time household usage, home automation systems equipped with micro controllers, as recommended in[2–6,] dynamically control household use of energy or control trends in device power use from the grid. Academic and commercial studies in this field is more popular than ever. Over 42% of the entire body of research taken into account for this study concentrated on the design and creation of smart home goods, mostly focusing on kitchen items, dryers, air conditioning, and lighting.

4.1.5 Tactile interfaces

The term "tangible connection" describes the portion of the contact sense that includes shifts in temperature, sonic emotions, and force sensitivity. A number of study teams have developed prototypes in order to better understand touch perception. However, because it become laborious and practically unattainable to assemble different components at each stage associated with these mini sensors, which vary in scale in the centimeter range, the layouts and operator systems used are not capable of mass manufacture. Five primary senses were suggested by the study in[7] to engage with the real and virtual worlds. The suggested method made use of capabilities that only allow for vision, touch, and speech detection. The second type is the more common paradigm utilized when it involves touching. According to study [8], mutual tactile signaling from the touched site to the regulating unit is essential for any connection to be successful [10, 22]. Sensation response alone is therefore unsuitable for any good interface. As a result, the research in [9]offered a multimedia platform that enables users to transmit information via fingertips and receive information via a range of methods, including haptic, visual, auditory, and more.

4.2 Smart home application and service

The research investigated a smart living space, which included the ensuing innovative software and service that increased energy efficiency in buildings, in an effort to address RQ3. Using the Internet of Things, a smart house can transform conventional structures into energy-conscious spaces with planned building systems and procedures that have the ability to save a significant amount of energy and raise tenant comfort levels indoors.

4.2.1 Smart HVAC System

A variety of sensors are used by smart HVAC systems to monitor and regulate the airflow inside. Fanger developed the projected amount displeasure (PPD) and predictive mean vote (PMV) models in the 1970s to measure occupant temperature sensation [6]. Conversely, the PMV model was developed using a real number of occupant surveys. The model is useless for personalized control since it ignores variations and factors[10]. Because of this, numerous scholars have developed specialized models of thermal comfort [11], which may be used to regulate the indoor environment [12] and get higher precision using more precise variables. A number of physiology have been associated with a person's level of thermal relief, as demonstrated by these specific models [11]; the factors that were most frequently used to evaluate temperature sensation were body temperature [13], pulse [14], respiration [15], appearance. Temperature [16], and humidity [13]. These modified warmth models possess an impressive level of correctness for forecasting thermal comfort.

Several studies also found that when people were dissatisfied in a temporary heat surroundings, their skin humidity, pulse, and heart rate showed a substantially distinct trend. Consequently, a relationship exists among physiological variables and people's sense and action of heat. Air Conditioning units can be adjusted based on this association to provide thermal comfort. The result demonstrates that a model developed with machine learning can precisely predict room utilization as a parameter for input to an HVAC control that modifies the interior temperature of the room by using medical data that is entered, such as temperatures of the skin. The wearable controller can improve ultimate thermal convenience in multi-occupant homes.

4.2.2 Smart lighting

Intelligent illumination uses sophisticated controls that integrate employment with lighting and advanced lowering capabilities to avoid illumination of spaces and reduce exaggeration. These controls are achieved by wireless oversight, scheduling software, and demand-response algorithms. Increased energy efficiency are the primary obvious advantage of smart illumination, however, there are numerous other possible benefits as well. Because of this, most research in this relatively new field of study is currently focused on optimizing energy savings when combined with LEDs that have high operating efficiency [17]. In reality, systems with integrated electricity-saving lighting control frequently provide savings in energy costs of 17–60% over conventional lighting control, according to user usage [18].

Cost-effective LED lighting is commonly seen in businesses due to its significant possibility of power reduction and simple retrofitting [5]. In addition, people-centered lighting can be implemented and the brightness of light can be enhanced using intelligent lighting. Thus, it can be said that academic studies in the areas of gardening, design, construction management, visibility administration, and human health as well as business reasons will profit from the introduction of smart lighting networks. The creation of high-brightness LEDs for broad use is of special importance to smart lighting study and application.

Due to their low peak frequencies and powerful lowering skills, LEDs have a great deal of influence over the light's spectrum distribution. In addition, because of their quick switching times, low use of electricity, and long lifespan, they make ideal principal transmitters for multiple channels lighting systems. With the introduction of the LED lighting change, a new age in lighting technology for controlling lights has begun[19].

4.2.3 Smart plugs

This covers a wide range of supplemental and transportable home and office equipment that uses smart plug loads in buildings[20]. Most industrial buildings' smart outlet charges are managed by non-predictive auto control that relies on precise timing. On the other hand, load monitoring or motion-detecting equipment is used in residences for anticipatory device control, which selectively stops the energy supply to an inactive device. A system that turns off plug-in gadgets while not in use was

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offered by the study in [21]. Intelligent outlets, which enable developers and managers of buildings to track, observe, and manage connect devices using whether independent cloud-based providers or particular building control systems, have largely supplanted previous ways of household gadget surveillance, despite being unusual. The authors of [20, 22] suggest that whereas occupation routines and contemporary technologies lead to needless energy waste, the energy data suppliers are blind to this fact. Therefore, in every area that consumes energy, it is imperative to track, investigate, and pinpoint the particular kinds of pollution at the product level. In response, the concept of hybrid gadget load monitoring which ensures appropriate energy usage by connecting intelligent meters and a power grid was put forth.

While they can't control certain gadgets, the plugs in [23]'s research resemble intelligent meters utilized for energy tracking. Unlike smart outlets, which offer more precise real-time data at the gadget level, most current electronic meters analyze the intelligent meter's reading through division methods in order to quantify use at the gadget levels. Smart appliances can offer additional features to control energy usage on a regular basis, although smart metered' views are mainly inactive and require a more prolonged period of tracking and evaluating.

4.2.4 Smart window

Intelligent glazing systems allow you to regulate how much light and heat from the sun reaches the structure. The structures that regulate Smart windows come with continuous shade control that controls light levels through daylight hours, in addition to active as well as passive window tinting that reacts to variations in temperature or sunshine[24]. With more research focusing on its application in adaptable substrates for higher efficiencies at lower costs and more durable devices, a method used in [25] shows an acceptable rate of 22.3% produced in goods made of cheap building materials. A technique uses state-of-the-art thin-film manufacturing for effective windows which function similarly to effective meters to respond to ambient airflow.

Prior calculations have shown that, in comparison to stationary doors, intelligent glass can reduce a building's energy demand by as much as 40%. According to research in [26], there are three main groups into which the underlying concepts of smart screens can be classified. Electrochromic windows alter the degree to which they transmit in response to applied voltages, whereas photochromic and thermochromic doors changed their absorbance in response to variations in light and temperature exertion, respectively [27]. A study proposed a smart window that may be used to autonomously regulate the amount of solar radiation that enters buildings by reversibly switching between an open and a closed state [28]. One of the greatest and most intriguing breakthroughs in technology, it can reduce HVAC energy use in homes and increase natural daylighting, reduce shine, and obscure views [29].

V.Reporting and Potential Research Area

Today smart building construction is equipped with technological innovations and smart devices to achieve several tasks in the building to promote building sustainability. Such innovations and devices are featured with intelligent control techniques with strong design into practice to react or respond to environmental events. Several technologies are available to seamlessly and constantly minimize house energy usage while keeping an acceptable degree of indoor comfort. A survey of the most relevant literature is given in this work. It determines publishing trends based on the quantity of research that is published each year, taking into account both articles from journals and conference papers. The research also uses the set procedure for review to assess the quality of literature and classify the literature based on integration technology and its application.

VI. Reporting Finding

According to the research, the majority of the published work in the SBEMS field focuses on systems that make utilize of an implicit microcontroller that asks for responses from an individual or construction administrator in the event that the grid offers a benefit to program request or reduce building electricity usage. Sophisticated algorithms for learning must be included into intelligent construction equipment in order for individuals to act upon incentives in the event that they are preoccupied or fail to notice them[4,7,9]. The research highlights the demand for intelligent energy control options in all types of buildings by demonstrating whether energy use in commercial buildings is often managed differently than in residential ones.

Achieving adequate thermal comfort is one of the main objectives of HVAC systems. Unfortunately, a preset temperature point is used by a large number of HVAC systems installed in workplaces, which can result in unfavorable interior thermal conditions whenever there is an unforeseen change in occupant or meteorological circumstances. Thus, it is recommended that demand control ventilation should be put in place which can modify the system's threshold temperature according various indoor and outdoor parameters [9,2].

Energy cost reactive controllers are necessary to regulate HVAC systems utilizing a 5-minute period and the price of power from the electricity supply. When electric bills spike, the self-response mechanism can stop an occupant from running the HVAC system more frequently. In order to give tenants the ability to plan ahead for utilizing power-intensive equipment, it is imperative to incorporate a standard pricing scheme that provides tenants with a predicted electricity price estimate per day. An occupier could precisely plan energy-intensive equipment to take advantage of the low-tariff periods by turning on this option [7].

Enhance the occupant sensing and estimation algorithms used in smart buildings today. In order to optimize energy usage, CO2, surveillance, and movement sensors are widely employed in smart building structure to detect and anticipate occupant. At the moment, these innovations are unable to distinguish between human and non-human occupancy. Thus, in order to prevent HVAC load in empty spaces, a presence detection system that can differentiate among human and non-human occupancy is crucial [18].

Enhance the methodology are used to measure thermal comfort in the building to preserve an occupant's prefers comfort. The majority of the research that has been done on thermal comfort evaluation involves third-party equipment, such as a device that is worn to measure skin temperature. Numerous devices from third parties are able to exchange data and interact with online services or suppliers. Thus, in order to ensure the privacy of individuals, researchers must focus on greater responsive thermal comfort investigation, which will lead to a broader adoption of smart building construction technologies.

The advancement of smart building construction solutions requires a significant contribution from academia and industry on smart indoor lighting technologies. Modern lumens, dimmers, and LEDs are used in smart buildings today. Unfortunately, due to inadequate lighting management methods and problems with architectural layout, current lighting systems generate a large portion of building energy usage. To enhance lighting management, lights can be synchronized with partner software and controlled via a remote. Activity and illumination detectors greatly contribute to lowering lighting energy consumption. Dimmers, proper skylight placement, and well-insulated windows can reduce illumination energy use by about 40% [1].

The smart plug that is currently in use is necessary to turn off an appliance. It is possible to enhance the intelligence of smart plug technology to enable scheduling capabilities for the use of moveable appliances. Additionally, interoperability capabilities can improve communication across various SBEM products and allow voice-controlled AI, intelligent thermostats, and AI assistants to impart knowledge [12].

Deep learning integration enables smart plugs to acquire knowledge from and adjust to the patterns of users in response to requests on the gadget. For instance, if the residents schedule an activity at the fitness center, the smart plug-connected dishwasher ought to activate the cycle for cleaning clothing as soon as the resident gets home. This is a crucial method of energy conservation, particularly for a common device such as virtual assistant[12].

Including resident habits in smart window systems can improve the overall energy usage of buildings. This can be accomplished by teaching occupant habits methods for opening windows [6–8]. In order to get daily data, research must thus concentrate on comprehending and modeling tenant window-opening activity using AI approaches.

In order for other intelligent power optimisation technologies to work in advance of an occupant's arrival and drastically cut the use of energy, portable or outside devices have to monitor the occupant's present position. The privacy of the occupants is threatened by these methods. Consequently, a self-learning and reactive smart energy savings system that can forecast occupant locations with greater accuracy and reliability is required [8]. In comparison to setting the HVAC system at a harsh thermostat setpoint, this can assist with start HVAC system at lower temperatures either heating or cooling operations before arriving inside the house to maintain the indoor temperature to the ideal level, saving more energy. Better demand response technologies that enable residents to produce their own energy locally using renewable sources can help reduce the electricity mismatch in the smart grid [19].

Since the beginning of smart buildings, security has proved a significant concern, becoming even more crucial when it comes to data exchange and transfer. Because of an absence of facilities and safety measures, intelligent CCTV systems, digital voice assistants, and thermostats are increasingly becoming popular targets for attacks that cause problems including denial of service and invasion of privacy. Only few research that use security techniques are generally limited to secure certain communication or applications domains and require generality. Research in the field of smart building construction does not presently focus on safety standards. To reduce attacks and create a system for quickly identifying and reporting security breaches, further research on this topic is required in the future [12].

Privacy presents another difficulty. For instance, a smart meter and a sophisticated appliance that monitors occupant routines and vital signs including arterial pressure, pulse, temperatures, drug use, endurance, bedtime schedule, and medicinal products are likely to compromise privacy. This data must be constantly obtained and shared with energy suppliers, other pertinent suppliers,

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or cloud-based data analytics platforms. Existing procedures immediately revealed sensitive resident data without protecting privacy [21].

VII. Conclusion

In an effort to shed light on present developments, issues, and prospects as well as potential future research to enhance smart building construction environmental sustainability, this research examined the selected literature that consist of various types of innovative technologies, and applications. The study search was conducted across five main databases narrowing from the years 2013 and 2023.Of the 54 people analyzed, 65% received a 6/6 score when assess using QAE grade. The finding also revealed that large number of the literature addressed technological integration using a particular degree of automation as a way to control building equipment and appliances. The findings indicate that the majority of the literature concentrated on employing user calendars to integrate smart control in commercial buildings. The results indicate that the literature currently in publication places a greater emphasis on the energy consumption of HVAC systems and places a smaller focus on smart lighting solutions. The majority of smart building technologies work with sensors and actuators to carry out operations, frequently in instantaneously, to complete a task. Typically, this kind of approach is highly critical. Rather than concentrating on the capabilities of sensors and automation alone, scholars ought to investigate how technology like machine learning can be integrated to improve collaboration between smart buildings and residents via efficient communications, in order to increase the efficiency of smart buildings. Data security and privacy is an issue that requires more attention. The results also show that digitalization of smart building technology is increasing, from protocol design to connection. Scalability and interoperability concerns must thus be addressed immediately because they have not been sufficiently addressed in the body of current work.

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