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Role of Building Automation Technology in Creating a Smart and Sustainable Built Environment

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Abstract: In today's modern society, people are getting more conscious of the built environment's energy efficiency and sustainability. Sustainable architectural design reduces negative environmental effect by improving energy efficiency, health, comfort, safety, livability for inhabitants, and the ecosystem at large. Other considerations include effective maintenance and optimization of the resources. All of this is achieved by incorporating appropriate technology within the building. Recent developments in the field of IoT, cloud computing, machine learning, artificial intelligence, and other smart wireless technologies could support solutions for building automation systems. Therefore, it is utmost important to determine the potential of these cutting-edge and smart wireless technologies for building automation and management. In this research work, the role of building technologies in creating a smart and sustainable built environment is identified and discussed. To emphasize the importance, a survey is being conducted to identify the current demand for building management systems, as well as their awareness and present scenario.

Keywords: Access control; artificial intelligence; integrated building management systems; internet of things; machine learning.

1. Introduction

In the design of the built environment, sustainable architecture takes a conscious approach to energy and environmental conservation. Green Building Technology, alias 'Sustainable Building Technology,' describes how a building is designed to consume less energy, more design flexibility, a low maintenance cost, and improved air quality.By incorporating creative techniques into the built environment, sustainable design avoids significant adverse repercussions.The proper implementation of a building management system (BMS) is critical for achieving sustainability in the built environment. This is accomplished by completely managing all aspects of the facility, including lighting, elevator, access control, video surveillance, fire security system, heating, ventilation, and air conditioning. The most basic types of BMS are application software, a server with a database, a control device, and smart sensors connected in an internet-capable network. Whereas, most advanced BMS can monitor and control a wide range of building-oriented services across a variety of platforms and protocols, providing facility managers with a unified, shared view of the facility's operations.

To tackle the various challenges in our modern lives, it is essentially important to alter the operation mechanics, management, and control of industries for the years to come. Such as, COVID-19 pandemic related limitations have had a severe impact on many enterprises, markets, economy, society, and our lives[1-8]. This pandemic has generated instant demand to embrace innovative wireless technologies particularly in the field of building management system (BMS)[9-14]. Such latest technologies are not only required to help in remote monitoring and operation but to reduce operational expenditures especially for commercial buildings[15-17].

In recent time, tremendous advancements have been recorded in the in the field of internet and wireless communication, it appears that innovative applications are constructing the underlying foundation and basic framework infrastructure. This provides a solid ground for human life's day-to-day necessities[18-22]. Buildings are being created in such a way that they provide maximum comfort and ease to the inhabitants while using the least amount of energy possible in this period, where energy management is a major issue for everyone[23-27]. However, despite a significant amount of study on building automation, the management and efficient energy use of buildings and facilities have remained unsolved[28-30]. With the advancement in the field of cloud computing

combined with the internet of things (IoT), artificial intelligence and machine language (AI/ML), blockchain, real time monitoring, big data, building information modelling (BIM), and digital twin brings a new paradigm shift in automation, interoperability, energy data management, utilization, and smart analysis of buildings[31-40].

A building should offer safety, security, comfort, and a healthy and ideal place to live. Nowadays this has been adversely impacted with the anxiety of novel coronavirus. Therefore, there is a state-of-the-art obligation to protect people and reduce the spreading of disease. This is achievable with the help of advanced technologies to support, care, and create a healthy and suitable environment for the buildings. Therefore, the next-gen technologies are one of the imperative and smart key tools to minimize the risk of virus transmission.

In this research work, a model using next generation smart technologies for BMS has been presented in Section 2. We have elaborated and conducted an online survey for the next generation building automation technologies that can be incorporated with IoT, cloud computing, and other advanced technologies in section 3. This could help communicate, share resources, and work effectively with the help of various sensing and control unit networks. Finally, concluding remarks and future direction are given in section 4.

2. A model using next generation smart technologies for iBMS solution

The upheaval that began in 2020 has altered our approach to physical security in 2021 and beyond. Low cost and wireless technology have attracted more attention from automation researchers' perspective in the building automation industry. Among other building technologies touchless technology, blockchain, artificial intelligence and machine learning, real-time monitoring and big data, IoT and cloud computing, building Information modelling (BIM), and digital twin technology have attracted more attention and are found most suitable for building automation and management. Current generation BMS are built on open communication protocols which can be easily integrated with other systems and can be accessed from anywhere on the globe.

Building management systems assist building managers and operators in gaining a better understanding of how their facilities operate and allowing them to control and alter system configuration to improve their performance. BMS solution can help visualize data, generate reports automatically, and give alarms when parameters are exceeded. Based on study, research, industry expertise, reviews, with future prediction, the next gen integrated BMS smart technology (iBMS) for the upcoming year and elaborate with the help of Fig. 1.

Touchless technology developments are centered on analyzing the commands issued by human gestures, motion, speech, emotions, retina, holographic imaging, and other means, where each activity may be mapped to a specific set of activities which then execute the required

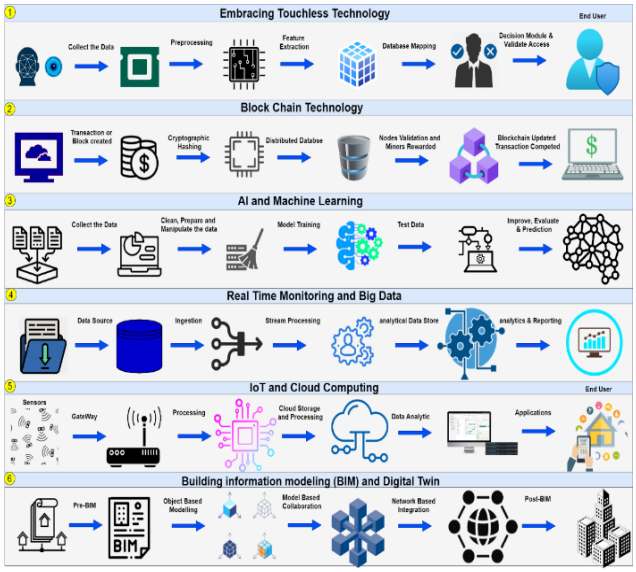

Fig.1: Smart technologies model for iBMS system

action for the user based on pre-programmed algorithms[41-43].

This technology is quite convenient and easy to use. Touchless technology has a simple user interface and saves a lot of time thus helps to prevent the spread of viruses. Most of the public and private enterprises all around the world have stopped using contact-based biometric systems to avoid spreading infectious COVID-19 disease[44-48]. Infrared thermometers, facial and iris recognition systems, and other touchless systems are currently in demand and are rapidly being used as the most ideal contactless monitoring tools. Constructional firms are now focusing more towards touchless, quick, and scalable features to adopt to the 'new normal'. With the use of touchless systems, organizations can take advantage of mobile enabled multi-technology assistance and control. Smart voice-enabled assistants, such as Siri on the iPhone, Alexa on Amazon, and assistant on Google, interpret voice commands to perform the desired activity, such as making a call, searching, fixing a schedule, snapping a photograph, and so on[49-51].

Blockchain is developing as a critical technology in the current context of pandemic control in order to give a reliable, efficient, and low-cost means of allowing better decision-making. As a result, this might lead to a faster response during this crisis. Blockchain is a secure distributed database that contains a chronologically ordered collection of encrypted signatures as well as unchangeable transactional data that is shared among all network participants. All that is required to conduct transactions is a possession of a blockchain wallet. A wallet is nothing more than a software that lets you spend cryptocurrency and make use of public or private

keys so that users can manage their data[52]. Blockchain is safe because it enables users to track funds all the way back to their source in any logistics network, as well as reliable interaction between two or more sides in a digital medium with simple monetary exchange. It has the potential to become the primary record-keeping system for all transactions.

Artificial intelligence has a wide range of applications in buildings, because of its ease of integration with sensors, devices, and other sophisticated modules. Research and experiments related to further development of artificial intelligence and machine learning are going on to combat this pandemic. AI is being employed in the field of medicine to detect, trace, and predict outbreaks as well as aid in viral diagnosis. AI is assisting in the development of medicines using large-scale systems modeling and 3D modeling. By integrating large volumes of data with quick processing and sophisticated algorithms, software can learn automatically from patterns. Whereas machine learning, which is sometimes misunderstood as a synonym for AI, is really a method for achieving AI. It is a contemporary AI application that provides computers access to data and allows them to learn how to do certain jobs on their own. It explores, identifies and automates analytical patterns without human intervention[53-58].

As the lockdown continue and curfews imposed in many regions as a precautionary measure, it brought communities to a halt. It compels individuals to shop, work or even communicate online. Thus, augmented reality and virtual reality play an important role here by allowing consumers and companies to interact in a virtual world. Virtual reality (VR) applications are gaining traction as a strong tool for distant socializing, demonstrating virtual purchasing, conferences, and holding corporate meetings. It does not only meet customers' expectations for a practical experience without exposing them to the outside world, but it also provides day-to-day, person interactions with minimum touch[59-60]. VR immerses people in an experience by imitating many senses like touch, video, audio and so on. Augmented reality overlays real-world objects with computer-generated virtual components. It uses a variety of technologies like 2D, 3D, real time monitoring, sensing and media and augmentations are projected in people's fields which can be viewed using smartphones, tablets or smart glasses. Thus, AR makes interaction between the physical world and virtual world easy[61-62]. AR is ideal for monitoring, remodeling and refitting projects in buildings. Consumers can inspect building sites more closely using real time monitoring through AR.

Cloud computing and the Internet of Things has evolved intertwined emerging internet technologies, with one providing as a basis for the development of the other. IoT systems allow for real-time data gathering as well as automatic and remote-control methods, which may be used to replace traditional monitoring and control systems in a variety of sectors including building automation[63-68]. IoT seeks to link smart devices, gather and analyses data from various settings, and deliver services to end users[69-74]. IoT encompasses four layers such as physical, cloud, communication, and service layer, which serves as an interface for controlling, monitoring, and managing things in a building[75-79]. IoT systems deployed in a commercial building accumulates data related to weather forecasting, quality of air, overall electricity consumption and use, and comfort-related environmental conditioning.

Building information modeling and digital twin technology of buildings has advanced at a breakneck pace in recent years. BIM is a smart 3D model-based technique for recording and displaying a facility's physical and functional attributes. An advanced building based on BIM and Twin technologies helps in reducing energy consumption with increased economic benefits. This can be combined easily with other technologies and helps in improving the life quality of users. BIM is a comprehensive method to planning, constructing, operating, and maintaining a building project as a collaborative process utilizing a single cohesive digital modelling system. It plays a critical role in order to manage the building's life cycle.

3. Result analysis of an online survey on next-gen BMS

An online survey has been conducted on a cluster of 407 people to know about the mindset of participants regarding the need of building management systems, its awareness and its current status through their preferences. Moreover, this survey tried to understand the role of BMS from the mindset of participants in countering pandemic situations. This survey was conducted on respondents of different age groups, gender, qualifications, and working groups. This consists of salaried employees, students, entrepreneurs, etc. The obtained results from the responses have been presented in the following subsections with its observation and complete analysis.

3.1 Awareness about BMS

It has been observed from survey that approximately 81.8% of the respondents are well aware about BMS. Among various types of buildings, the respondents are dealing with, residential buildings are highest, then educational institutes and offices come into the picture. Whereas healthcare buildings, hotels, transport buildings, and commercial infrastructure are lesser in number due to the current widespread pandemic situations and imposed lockdown. From Table 1, it is observed that most of the respondents want to have complete control over all the installed systems available in the building. However, most of the respondents are very concerned about security

issues and energy usage. This indicated their willingness to have access control, intrusion detection, and monitoring system installed in their buildings. And if our energy consumption grows, it will have an economic, societal, and environmental impact on our lives. Respondents too have expressed interest in being able to control practically everything in a smart building, including air quality, temperature, lighting, locks, energy usage, and entertainment.

Table 1. Result analysis of current scenario vs next gen demands of BMS.

Smart Technologies	Need of installation	Preference of having control	Demand % Next gen BMS
Security/Smart access/Locks	✓	✓	75.9%
Surveillance & monitoring	✓	✓	63.3%
Fire safety infrastructure	✓	✓	72.9%
Climate/ Lighting Cont.	✓	✓	65.5%
Energy Monitoring	✓	✓	67.2%
HVAC	✓	✓	66.5%
Smart automation	✓	✓	69.5%

3.2Significance of BMS in our daily lives and its current state

This survey laid emphasis on knowing the basic purpose for the need of a BMS with elaborating the responses obtained from this survey. However, out of all aspect's safety, security, and comfort remained fundamental keys and dominated others smart technologies. Whereas most of the respondents agreed and want to have smart automation with emphasis on safety, security and comfort. Respondents agree and want to have a healthy and safe place to live in with reduced energy consumption together with less impact on the environment. There are numerous challenges while deploying a smart building as shown in Figure 1, but cost of installation and maintenance may be a prominent factor. However, resistance to new technology, lack of knowledge about the different smart technologies available for BMS, and cybersecurity threats are the other factors which are contributing significantly. In Fig. 2, a scenario is discussed where respondents were asked for their awareness about smart building and how they rate their own building with this respect. It is found that most of the respondents are aware about smart buildings and do not consider their buildings as smart ones.

Fig. 3, illustrates that 18.4% of participants believe their facility is smart to a significant extent. Although 35.4% of respondents claim to have smarter building to some extent. 44% consider their structures are still insufficiently smart. Only 2.2% of those polled believe that smart buildings are unnecessary. According to the poll, 17.4% of participants claimed to have installed more than ten smart devices in their facilities, as seen in Fig.4.

While 46.2% of those polled stated their building has less than ten smart devices. According to 36.4% of those respondents, their building lacks any smart technology. This poll question indicates that there would be a demand for smart building systems in the upcoming years.

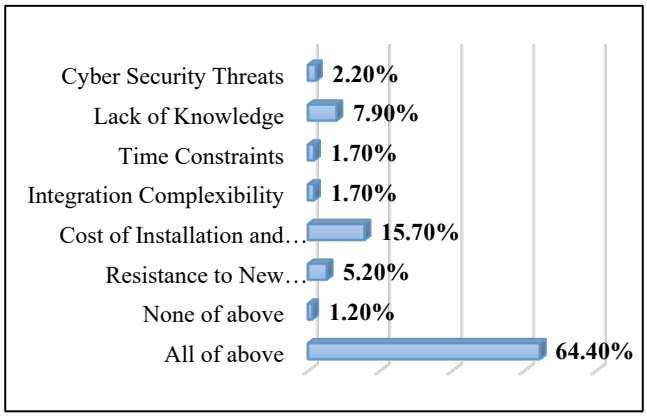

Fig. 2: Challenges in deployment of a smart building

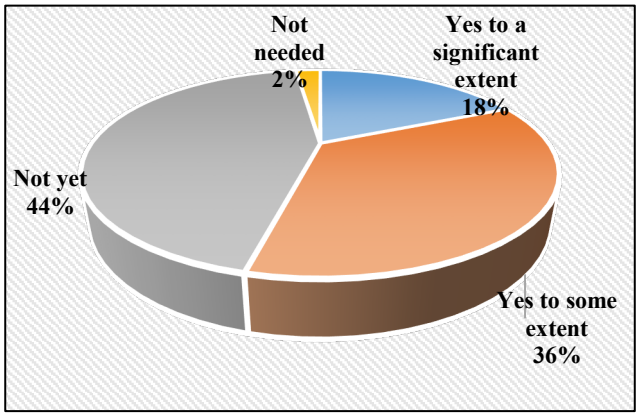

Fig. 3: Current scenario of smart building

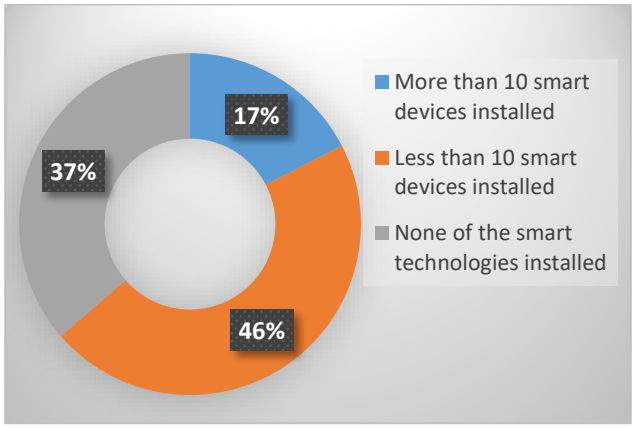

Fig. 4: Intelligence level of current building

3.3 Role of BMS amid pandemic

Our lifestyles have been adversely affected by the ongoing pandemic threat. The majority of respondents agree that the situation would have been different if BMS had been installed beforehand because the chances of spreading infection may have been significantly reduced.

While asking about the kind of technologies that would help in preventing the spread of pandemic and as illustrated in Fig. 5. It is found that 19.9% of participants had a firm faith in contactless technologies such as proximity cards, smart cards, RFID tags, and other similar

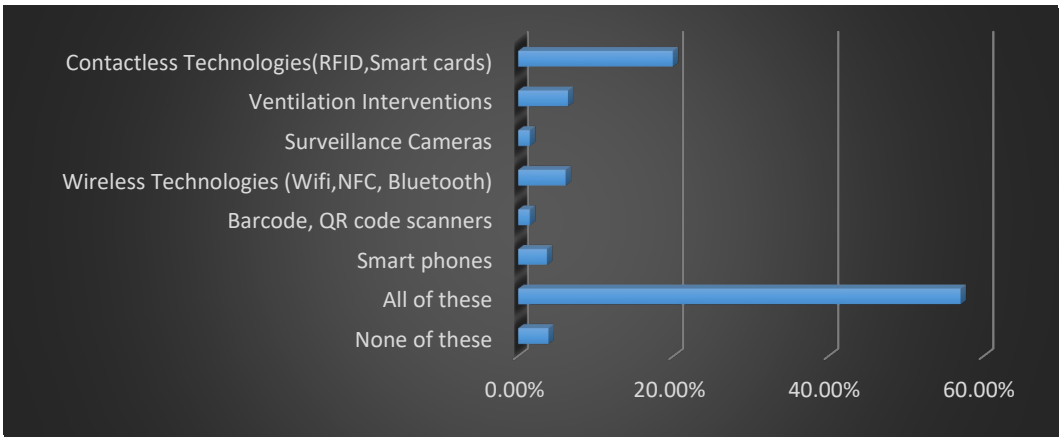

Fig.5: Role of BMS technologies in prevention of virus spread

technologies to mitigate pandemic spread. The technology to prevent infection transmission has grabbed the curiosity of 57% of the participants. Smartphones, barcode scanners, and QR code scanners are all effective in preventing outbreaks. Respondents believe that wireless technology such as Bluetooth, Wi-Fi, NFC, and others, as well as effective detection and monitoring CCTV surveillance systems and optimal ventilation interventions in buildings, will play a key role.

3.4 Future prospects of BMS

Considering our lifestyle, pandemic situation and changing preferences of respondents, BMS can become a good and cost-effective long-term solution. Table 1 outlines the function of various smart technologies in BMS, as well as future aspirations for next-generation BMS. It depicts respondent' expectations for next-generation building technologies, with the majority wishing to have numerous technologies in their facility. The Table 1 also talks about their preference of buildings that are needed to be converted to smart buildings at earliest. Hotels are at the bottom of the list, with 49.3%, while educational institutions are at the top, with 77.3%, followed by healthcare and residential structures. This survey reveals how many respondents want their facility to be converted into a smart building in the near future.

Table 1 demonstrates the importance of smart technologies in BMS, as well as respondent need for control and rising demand for such technologies. This survey illustrate that everyone expects the most control over any smart technology employed in BMS. The future demand % of next BMS technologies has been analyzed and summarized based on the responses collected from survey. Several methodologies have been proposed as potential contenders for next-generation BMS solutions in

Fig. 6, and respondents believe that artificial intelligence and machine learning will be the future of building automation systems. In the survey, artificial intelligence and machine learning operations accounted for 72.4%. Touchless technology-based operations were positioned second on the list with 71.2% due to safety concerns raised

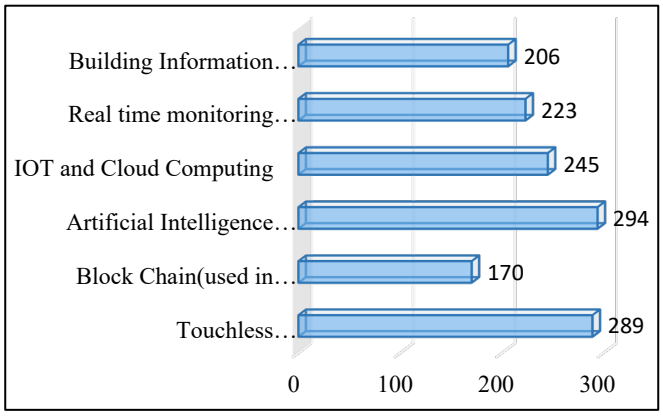

Fig. 6: Designing the next generation buildings

Table 2. Result analysis of current scenario vs next gen demands of BMS.

Building	Present usage status	Next-Gen expected smart buildings
Residential	70%	69 %
Offices	37.1%	63.8%
Education Inst.	64.4%	77.3%
Hotels	21.4%	49.3%
Healthcare Infrastructure	26.5%	69%
Transport/ Comm. Infrastructure/Others	38.1%	70.9%

during the pandemic emergency. Following the remaining advanced technologies, IoT and cloud computing have been recognized as the third option for establishing an efficient BMS Solution. Other novel solutions which respondents indicated confidence in included 54.9% embracing real-time monitoring and big data, 50.7% favouring building information modelling and digital twin, and 41.9 % deliberately supporting block chain, in that order.

Based on the survey responses, Table 2 summarizes the analysis of present associated buildings and future anticipated smart buildings out of various buildings. From this table, it is quite clear that the most common buildings with which the respondents are mostly dealing with are residential buildings comprises of 70%, educational institutions of 64.4%, and Transport/ Commercial Infrastructure/ Others buildings are of 21.4%. According to the data, the survey is conducted on participants having access to various facilities, with each facility contributing to a minimum of 21.4%. Hotels are the least used buildings where respondents have access during the lockdown. Educational institutions are predicted to account for 77.3% of future intelligent building transformations, followed by transportation/commercial infrastructure/others at 70.9%, and residential and healthcare facilities at 69%. Office buildings are the next entity, while hotels are the last. True, the epidemic has had the greatest impact on education, with students being compelled to study from home for the second year now. As a result, everyone wants to see intelligent buildings in the education sector. According to the survey responses, the outbreak has harmed the tourism and hotel industries due to the country's lockdowns and strict restrictions.

4. Conclusion and future recommendations

The purpose of this research article is to provide information on the importance of modern technologies in the field of BMS. This shows how technologies would revolutionize the next generation building automation industry with minimal human intervention. This will be incredibly beneficial in suppressing the pandemic while consuming the least amount of energy possible. An online survey is conducted to better understand the function of BMS in pandemic conditions from the perspective of the individuals. Result analysis of the user preferences were carried out to better understand the need and awareness of BMS system among users. Then current scenario of smart buildings were examined. We tried to find out the expected smart building from the users' perspective. Then they were asked about their expectation from the smart buildings using BMS technology. This research concluded that emerging wireless technologies for building automation have a promising future, as they strengthen wireless connectivity and operation, diminishing the need for manual intervention. Thus, it is high time and moment to embrace smart building technologies to shape and define the future of building management.

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